Research Note

A Field Demonstration of the Effect on Streamflow of Clearing Invasive Pine and Wattle Trees from a Riparian Zone

P.J. Dye and **A.G. Poulter**

Division of Forest Science and Technology, CSIR,
P.Bag X 11227, Nelspruit 1200.

SYNOPSIS

Two portable weirs were used to quantify changes in streamflow following clearfelling of a dense stand of self-sown *Pinus patula* and *Acacia mearnsii* along a riparian zone on Kalmoesfontein, a SAPPI forest plantation south-east of Lydenburg, Eastern Transvaal. The weirs were set up at positions 500 m apart on the same stream, and used to monitor streamflow levels before and after the clearing of all trees between the weirs to an average distance of 25 m from the stream. Analysis of streamflow data revealed that the clearing operation resulted in a 120 % increase in streamflow at the lower weir, equivalent to 30,5 m^3 of water per day. Streamflow at the lower weir was less than at the upper weir before clearfelling, but equalled that at the upper weir after clearfelling. This demonstrates that the intervening trees were responsible for the initial difference in streamflow. Two further lines of evidence point to the adjacent trees exerting a strong influence on streamflow. Firstly, a clear daily fluctuation in streamflow was evident at both weirs. This is a consequence of transpiration by trees taking place only during hours of daylight. Secondly, the occurrence of cloudy, rain-free weather led to an increase in streamflow. Such weather reduces the evaporative demand of the air, causing transpiration rates to decline as well.

We conclude that invasive exotic trees should be removed from riparian zones to promote significant streamflow increases from afforested catchments. There is a need for a broader body of information to assess the effects of species, density and age distribution, as well as catchment characteristics, on streamflow responses to clearing invasive trees. This study has demonstrated the suitability of the portable weir technique in capturing such information.

Keywords: Streamflow, riparian zone, *Pinus patula, Acacia mearnsii,* portable weirs.

INTRODUCTION

It is standard practice in South Africa for plantation managers to avoid planting trees in the riparian zones of afforested catchments. The purpose is to reduce the risk of soil erosion close to the stream channel, and to avoid any increase in water use by riparian vegetation. It is suspected that plantation trees growing in riparian zones use proportionately more water than those further away from the stream, in view of the ready availability of soil water close to streams.

The management of riparian zones, however, is often a problem. Exotic, invasive tree species such as *Pinus patula, Acacia mearnsii, Eucalyptus grandis* and *Solanum mauritianum* may rapidly spread into these areas, eventually forming dense thickets which are expensive to eradicate. This colonisation is often promoted by disturbance of the soil and by damage to the existing indigenous vegetation caused during the harvesting of adjacent plantation trees. The use of fire to maintain a stable indigenous riparian community is often risky in view of the close proximity of forest plantations. Manual clearing of invasive trees is costly, and managers need to carefully justify the expense of such operations. An obvious justification would be an increase in streamflow available for use downstream. The importance of increasing streamflows is widely accepted in view of recent droughts and the urgent need to improve water supply to downstream rural communities. Very little information is available on the likely magnitude of streamflow increases following removal of invasive trees in riparian zones. Streamflow increases have been shown to occur after clearing indigenous riparian plants at Jonkershoek (Rycroft, 1955) and Cathedral Peak (Nanni, 1972), but exotic trees were either not present or were left untouched in these studies.

An opportunity to measure streamflow response to the clearing of a dense thicket of pine and wattle trees arose on the SAPPI property Kalmoesfontein in September 1994. The Kalmoesfonteinspruit, a tributary of the Houtbosloop and Crocodile rivers, was heavily infested with self-established trees, but was progressively being cleared to encourage the development of indigenous riparian vegetation. The aim of this study was to assess the magnitude of changes in streamflow resulting from the clearing operation. A further aim was to assess whether portable low-cost measuring tanks, as described by Nanni (1972), can be used to reliably monitor streamflows during such clearing operations.

MATERIALS AND METHODS

Two portable streamflow-measuring tanks were positioned at either end of a 500 m stretch of stream due to be cleared of invasive riparian trees. Streamflows at each site were recorded over a 13-day-period before clearing operations commenced, and measurements continued during and after the clearing operation. Changes in the relation between flows at the two weirs were than attributed to the treatment.

Portable weir tanks

Two portable weir tanks were constructed along similar lines to a design reported by Nanni (1972). Each tank was 1 840 mm long by 910 mm wide by 610 mm deep, and constructed of 3 mm gauge flat iron. A 300 mm deep 30 ° brass V-notch was fitted into one end of each tank. Nylon netting was arranged on the tank side of the notch to trap debris likely to block the flow of water.

A modified Belfort water level recorder was mounted on two cross members towards the notch end of each tank. The recorder float moved within a stilling well which dampened oscillations in water level. An apron of galvanised flat-iron on the opposite end of the tank spread the incoming water before it flowed into the tank. The water entered a hessian bag attached to the apron edge which further reduced water turbulence and trapped any incoming debris. These measures were judged to be effective in ensuring a static head of water in the V-notch. The Belfort recorders were fitted with an MCS250 stream level encoder and an MCS120 data logger. Loggers were programmed to record water levels every 10 minutes.

The tanks were fitted with handles and carried from the nearest vehicle access point to the site. They were placed on a wooden frame positioned in the stream bed and then carefully levelled with a spirit level. A temporary weir was constructed above each tank to channel water to an inlet pipe leading to the tank. The wall of the weir was constructed on a rocky outcrop to minimise the chance of significant seepage around or underneath the inlet pipe. The wall consisted of sand bags encased in plastic sheeting. Leaks were plugged using small bags filled with betonite. A hook gauge placed close to the V-notch was used to periodically check water levels recorded by the logger. Streamflow height at the V-notch was converted to volume flow rates using the Barnes empirical formula (Meyburgh *et al.*, 1970).

Catchment description

The Kalmoesfonteinspruit arises in the study catchment on the SAPPI property Kalmoesfontein, and flows into the Houtbosloop and Crocodile rivers. The site of the weirs was 27 km SSE of Lydenburg, at an altitude of 1 480 and 1 510 m above sea level. The catchment of the Kalmoesfonteinspruit consists of a complex mixture of shales, mudstones, quartzite and diabase of the Transvaal system. Mean annual rainfall is 1 030 mm. The catchment area above the upper weir was 3,2 km^2. Most of this area was planted to pines (*P. taeda, P. patula* and *P. elliotii*) with small unplanted areas dominated by natural forest and invasive *Acacia mearnsii.*

The entire upper reaches of the stream were heavily infested with self-established *Pinus patula* and *Acacia mearnsii.* The frequency, density and species composition of riparian trees was assessed in eight

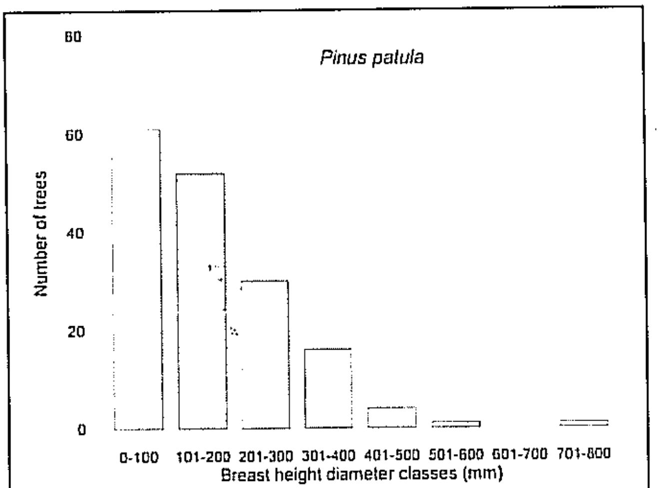

FIGURE 1. A histogram showing the breast height diameter size distribution of P. patula *trees in sample transects.*

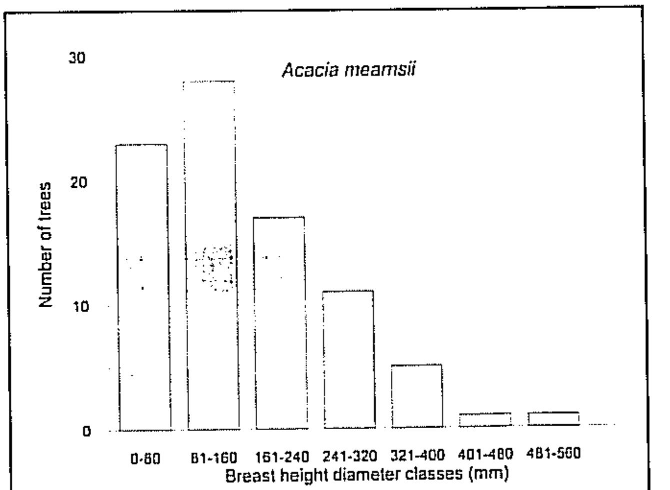

FIGURE 2. A histogram showing the breast height diameter size distribution of A. mearnsii *trees in sample transects.*

transects situated at approximately 60 m intervals along the stream between the two weirs. These transects were aligned at right angles to the stream, were 5 m wide, and covered an average of 30 m on each side of the stream.

Clearfelling commenced on 12 September, and was finally completed on 22 September. However, 90% of the area was cleared between 14 and 16 September. A few small, indigenous trees remained after the clearfelling. However, water loss from the cleared area would have been negligible small after 16 September.

RESULTS

Vegetation transects

The total sample area amounted to 2 545 m^2, in which 165 *P. patula* trees and 86 *A. Mearnsii* trees were recorded. The total of 251 trees suggests an overall density of 10,1 m^2 per tree, or 986 trees per hectare. An indication of the size classes of both pines and wattle is provided by *Figures 1* and *2*, which show the diameter distribution of pines and wattle, respectively.

Streamflow pattern

Figure 3 shows the streamflow recorded at the upper and lower weirs before, during and after the clearfelling operations. Measurements commenced on 1 September 1994, and showed that the stream at the upper weir was flowing more strongly than at the lower weir. This is the reverse of the usual situation where streamflow increases downstream owing to seepage from the stream banks and an increased catchment area. This streamflow decline is attributed to vigorous water use by the riparian trees between the two weirs.

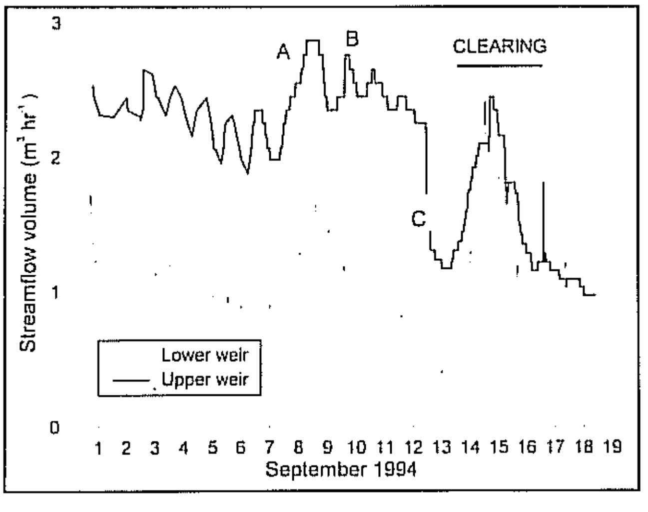

FIGURE 3. Streamflow volume recorded at the upper and lower weirs over the duration of the experiment. Point A marks an increase in streamflow caused by overcast weather. The V-notch at the upper weir was partially blocked at point B, but was cleared at point C.

A distinct circadian fluctuation in streamflow was evident at both weirs. This is ascribed to night-time cessation of transpiration by trees influencing the dynamics of phreatic soils. Water use by *P. patula* and *A. mearnsii* is known to peak around midday or early afternoon, and to cease entirely during the night (Dye, 1994 for *P. patula;* Smith *et al.*, 1992 for *A. mearnsii*). The streamflow fluctuations are clearly lagged in relation to the tree water use. The grid lines in *Figure 3* indicate noon on each day, and show that peak streamflow levels occurred during the late afternoon, while lowest levels occurred in the early morning. This lag is attributed to the fact that the fluctuations being measured are largely generated by areas upstream of the upper weir, and that the lag represents the time the water takes to flow down to the weirs.

An increase in streamflow was recorded at both weirs starting on the 8 September (point A in *Figure 3*). This was caused by cool cloudy weather, and illustrates that reduction of transpiration over a period longer than a single night results in a steady increase over the following day. An equilibrium is not achieved during the day.

A problem arose at the upper weir on 10 September (point B in *Figure 3*), when the netting in front of the V notch came loose and drifted to the notch. This caused artificially high water levels to be recorded and dampened the circadian fluctuations. The problem was rectified on 13 September (point C).

The major period of clearfelling took place from 14 to 16 September, and this period is indicated on *Figure 3*. The convergence of lines on 14 and 15 September indicates that most of the streamflow response took place over this time. After 15 September, the weirs recorded very similar flow rates. Subsequent to 19 September, data were lost owing to theft of piping as well as blockages caused by the large quantities of debris following clearfelling.

The water levels recorded at the V notches were converted to volume flow rates using the Barnes empirical formula (Meyburgh *et al.*, 1970). The mean water level at both weirs was calculated for the period 3 to 7 September, a period of warm, stable weather conditions typical of early spring. Mean water level at the upper weir over this period was 75,5 mm, corresponding to 2,33 m^3/h. Mean water level at the lower weir was 55 mm, corresponding to 1,06 m^3/h. On the basis of the clear convergence in stream levels after clearing, it was assumed that this difference was reduced to zero by the clearing operation. Thus the treatment resulted in a streamflow increase of 1,27 m^3/h, or 30,5 m^3/day.

This difference was divided by the area cleared of trees, to estimate the water use of the trees in units of mm equivalent depth. The approximate area cleared was 25 000 m^2 (500 by 50 m), and so the daily difference of 30 500 ℓ is equivalent to 1,22 mm. This figure is lower than the 3 to 4 mm/day expected of coniferous plantation forest on a clear day (Whitehead, 1981, pp 55). A number of possible hypotheses can be put forward to explain this difference. For example, it is possible that only the trees nearest to stream channel can access phreatic groundwater, while those trees further away have poorer access to soil moisture and therefore transpire at a slower rate. Another transpiration-related hypothesis is that poor canopy ventilation of trees at the bottom of steeply incised valleys leads to relatively high air humidity and low transpiration rates. Alternatively, the phreatic soils releasing water to the stream may still be recharging, and approaching a new equilibrium point with streamflow. Further data on spatial differences in water use and riparian soil hydraulics are required to understand why streamflow increase was not greater than 1,2 mm.

It is important to remember that the largely herbaceous indigenous vegetation which will be allowed to replace the felled trees will transpire and therefore have some influence on streamflow. However, this is likely to be small during winter and early spring when many of the species lose their leaves or become dormant.

CONCLUSION

We conclude that streamflow in afforested catchments is sensitive to the presence or absence of invasive, exotic trees in riparian zones, and that significant increases in streamflow may be expected where dense thickets of such trees are removed. There is a need for a broader body of information to assess the effects of species, density and age distribution, as well as catchment characteristics, on streamflow responses to clearing invasive trees. This study has demonstrated the suitability of the portable weir technique in capturing this information.

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