

Preliminary empirical models to predict reductions in total and low flows resulting from afforestation

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Abstract

Mathematical models to predict runoff reductions due to afforestation are presented. The models are intended to aid decision-makers and planners who need to evaluate the water requirements of competing land uses at a district or regional scale.

Five afforestation catchment experiments were analysed by the paired catchment method to determine the reductions in both total (annual) and low flows. The percentage reduction in flow after afforestation with both eucalypts and pines was determined for each post-treatment year relative to the expected flow based on a calibration relationship with an untreated (control) catchment. We fitted curves to these data points to predict the effects of afforestation under optimal and sub-optimal growing conditions. Eucalypt plantations were found to deplete both total and low flows sooner and in larger quantities than pine stands.

Introduction

Since 1972 the Forest Act has required timber growers to apply for permits to establish commercial plantations on new land or sections of land which, after harvest, have not been planted to trees for a period exceeding five years (Van der Zel, 1990). Such applications may be rejected on the grounds that afforestation would use an unacceptably high proportion of water in the catchment. In considering the permit applications the affect of afforestation has been estimated by means of the so-called Van der Zel curves (Van der Zel, 1995) which are a generalisation, using additional data, of an original curve developed from a single catchment experiment at Cathedral Peak by Nänni (1970). Although very useful, this model is based on limited local data and only accounts for total streamflow reductions, while the reductions in low flow might be of more relevance to decision-makers.

Bosch and Hewlett (1982), in their review of 94 catchment experiments, estimated that mature pine and eucalypt forest types cause 30 to 40 mm change in water yield per 10% of the catchment subjected to change in cover. For example, the clearfelling of a mature pine forest occupying 20% of a humid grassland catchment could be expected to increase streamflow by 60 to 80 mm-a'. Another important consideration is the effect of afforestation on low flows, as it is during the dry period immediately prior to the rainy season that a reliable water supply is most critical for downstream or run-of-river water users. Although afforestation is known to cause significant reductions in both total flows (Nanni, 1970; Van Lill et al., 1980; Bosch and Hewlett, 1982; Van Wyk, 1987; Bosch and Smith, 1989; Smith, 1991) and low flows (Banks and Kromhout, 1963; Bosch, 1979; Keppeler and Ziemer, 1990; Smith and Scott, 1992b), the impact of afforestation on low flows may differ both in relative amount and timing (within the rotation) from that on total flows. Should the impact of afforestation be relatively greater on low flows than on total flows, then it would make more sense to consider reductions in low flow rather than total flow as a guideline for afforestation permit allocations.

Results from earlier forest hydrology studies in South Africa indicate that the water use characteristics of eucalypts and pines may be quite different. Eucalypts appeared to have an earlier

influence on water yield than afforestation with pines, and streamflow reductions due to the eucalypt plantings were apparently larger than those caused by the pines (Van Lill et al., 1980; Bosch and Smith, 1989). This would indicate that different afforestation guidelines may be required for different commercial tree types.

There is, therefore, a need for an improved model that may be used as a guideline for decision-making and planning regarding afforestation effects. The model should provide an estimate of reductions in both low flow and total flow which will occur with varying degrees of afforestation, and should differentiate between pine and eucalypt plantings should differences in streamflow response to these tree types be significant. This paper reports on the analyses of five experiments measuring the effects of afforestation on water yield, and on our efforts to produce generalised models of the observed effects that will fill the needs described above.

Methods

The effects of afforestation on streamflow for five South African research catchments were determined by the paired catchment approach. The catchments were selected to cover, as far as possible, the geographical range of South African forestry (Fig. 1), and to include both species groups for which there are experimental catchments.

One pair of catchments is located on the Westfalia estate (catchment D afforested, catchment B control) near Tzaneen in the Northern Province (23°43'S, 30°04'E); two at Mokobulaan (catchments A and B afforested, catchment C control) situated SE of Lydenberg on the Mpumalanga escarpment (25° 17'S; 30°34'E); a fourth at Cathedral Peak (catchment III afforested, catchment IV control) near Winterton in the KwaZulu-Natal Drakensberg (29°00'S; 29°15'E), and the final pair within the Jonkershoek Valley (Lambrechtsbos-B afforested, Bosboukloof control) near Stellenbosch (33°57'S; 18°15'E), in the Western Cape Province. Some catchment characteristics are summarised in Table 1.

In the case of the Cathedral Peak and Mokobulaan experiments the control catchments are grasslands, burned on a regular two-year cycle. In the case of Westfalia the control catchment is scrub forest, over 50 years old at the time of the experiment, slow-growing and with a stable relationship between rainfall and runoff. At Jonkershoek, the 57% afforested Bosboukloof provided the best of several possible controls. The period (1960 to 1980)

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