TECHNIQUES FOR ASSESSING THE EFFECTS OF AFFORESTATION ON CATCHMENT HYDROLOGY: THE SOUTH AFRICAN EXPERIENCE

Dr Peter Dye

Natural Resources and the Environment, CSIR
C/O School of Applied Environmental Sciences
University of KwaZulu-Natal
P. Bag X01, Scottsville, South Africa
Tel: +27 33 260 5782; Fax: +27 33 260 5266; e-mail: pdye@csir.co.za

Introduction

South Africa is a largely semi-arid country, where areas of high rainfall are limited to relatively small regions in the east and south of the country that benefit from coastal rain-bearing weather systems, or from the orographic effect associated with mountains and escarpments. These areas are of great significance in maintaining river flows which support a great diversity of downstream economic activity. The original vegetation in these areas was mainly seasonally–dormant natural grassland (summer rainfall region) or Machia-type shrubland (winter-rainfall region). Much of this vegetation has now been replaced by plantations of eucalypts, pines and acacias, which are relatively deep-rooted, evergreen, and characterised by higher rates of total annual evapotranspiration. These forest plantations now cover nearly 1.5 million ha. Catchment water yields have consistently declined in areas of new afforestation, causing widespread concern amongst other water users. This problem led to the early initiation of intensive research into the effects of forest plantations on catchment hydrology. This paper provides a brief overview of some of the techniques employed by South African hydrological researchers to understand the link between afforestation and catchment water yields.

Research methodologies

A series of paired catchment experiments was established from 1935 onwards that cover a range of different forestry regions of South Africa. These experiments have been very useful in broadly describing the effects of tree species and degree of afforestation on catchment annual water balances (Scott et al., 1998). They have also provided valuable information on within-rotation variation in evapotranspiration and streamflow due to changes in canopy development over time (van Lill et al., 1980). Lags in streamflow response to forest management have revealed significant storage of water in the permeable sub-soils of some sites (Scott and Lesch, 1997). The disproportionate influence of riparian vegetation on catchment water yield has also been clearly demonstrated (Scott and Lesch, 1995).

The measurement and modelling of hydrological processes in catchments has assumed more importance in recent years, reflecting great strides in the development of instrumentation, and driven by the need to further improve predictions of catchment responses to land use change in a wider variety of catchments. Thus, rainfall interception by forest canopies has been investigated through the use of throughfall interception plots (Schulze et al., 1978). Sap flow rates in a representative sample of trees have been used to estimate transpiration rates in eucalypts (Dye and Olbrich, 1992) and wattle (Dye et al., 2001) plantations. Techniques based on energy balance and micrometeorological conditions (Bowen Ratio, Eddy Covariance) have provided estimates of overall evapotranspiration rates from forests (Burger, 1999; Everson et al., 2000). Scintillometry, a relatively new technique that permits measurement of mean evapotranspiration rates along distances ranging from 100 m to 5 km, has been tested and validated for short crops (Savage et al, 2004), and is currently being evaluated for use over tall forest canopies. Permanent measurement weirs are expensive structures, and consequently the number of gauged catchments in South Africa is low and insufficient to describe the complete range of catchment conditions. Short-term streamflow measurements have been made using portable weirs (Dye and Poulter, 1995), and also by deploying pre-cast weirs in association with pressure transducers for measuring water levels. This wide range of techniques can provide much information on the partitioning of rainfall into “green water” (evapotranspiration) and “blue water” (streamflow) within catchments, illustrating the link between a change of land use and consequent changes in catchment water yield (and the pattern of flow over time).

Modelling is an essential tool in integrating all available information, providing insights into catchment functioning, and allowing extrapolation of streamflow predictions over extended periods of time to describe inter-annual variation in water availability. Models used in South Africa range from the complex (SWAT, Govender and Everson, 2005) to the simple (IHACRES; Dye and Croke, 2003). The latter is a model with few parameters that are estimated from a time series analysis of rainfall and streamflow data. It is particularly useful in highlighting changes in streamflow generating processes brought about by land use change.

Conclusions

The opportunities for research into catchment hydrology have expanded greatly in recent years, and opened up opportunities for understanding and quantifying the links between changing land use and streamflow responses. The use of forests in rehabilitating catchments holds much promise. However, great care must also be taken to minimize reductions in catchment water yield. A variety of powerful research techniques is available to quantify this impact, and assist in optimising the use of land for economic benefits and water yields.

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