

Comment on: 'Plantations, river flows and river salinity'
(R.A. Vertessy, L. Zhang and W.R. Dawes, *Australian Forestry* 66, 55–61, 2003)

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The paper 'Plantations, river flows and river salinity' (R.A. Vertessy, L. Zhang and W.R. Dawes, *Australian Forestry* 66, 55–61, 2003), prepared by members of staff of the CRC for Catchment Hydrology, contains information that can help to clarify certain aspects of water use by trees. However, the views reported and the assumptions made cannot support an application of the research beyond the limited criteria tested. While there is no doubt that, like any other dryland agricultural crop, trees use water, the volume of water they use needs to be considered in context and as part of a wide range of economic, social and environmental variables influencing plantation forestry investment and management decisions.

It is unfortunate that some members of the scientific community are extrapolating the results presented in Vertessy *et al.* (2003) as average outcomes for all plantation forestry. In this article, the National Association of Forest Industries (NAFI) points to the limitations of the research described by Vertessy *et al.*, and the need for an improved and refined assessment of the use of water by trees, together with a better appreciation of the implications of integrating plantation forestry into the farming landscape. Comments are provided on the various sections of the paper.

The paper's abstract

The abstract of Vertessy *et al.* over-generalises the results presented in the paper. Importantly though, the paper's Discussion contains four dot points that are not referred to in the abstract but which highlight the key issues to come out of the paper. The forest industry agrees that its future growth will be driven by planting:

- predominantly in areas with less than 800 mm annual rainfall, and where salinity may be a problem
- in a mosaic across the farming landscape
- uneven-aged stands, and
- away from drainage lines.

It is quite disappointing that the paper does not recognise that most plantations established since 1997 meet these criteria, with the planting around drainage lines regulated by State legislation and the States' codes of forest practice. Nearly all plantations studied in the Australian and overseas catchment modelling research have not been managed according to the requirements of these codes of forest practice.

Most statements in the first part of the abstract represent worse-case scenarios and are not consistent with the content of the paper. Can the current catchment models predict most of the hydrological impacts of afforestation if they do not take into account all of the variables? Is it necessary to ask whether we have the capacity to take account of all the variables affecting water use and indeed, whether the questions have yet been asked? For example, the models should recognise that water use is a function of total rainfall and timing of that rainfall, species, thinning/spacing/pruning management regimes, age classes, site productivity, fertiliser application, soil type and underlying geology, slope, period to canopy closure, location in the catchment (upland versus lowlands), humidity and evapotranspiration patterns, groundwater recharge/discharge locations, the proportion of catchment planted, and the treatment of riparian zones and drainage lines.

The second part of the abstract considers the need for a regulatory framework to control the expansion of the plantation estate. This is despite the lack of mechanisms to account for all water users and for incorporating the positive effects of plantations, the over-allocation of water resources in some catchments, the use of water for other purposes (such as irrigated agriculture) or the requirements of the environment.

A re-capitulation of the state of knowledge

The Holmes–Sinclair and Zhang *et al.* curves (Fig. 1 in Vertessy *et al.* 2003) describe a relationship between annual rainfall and mean annual evapotranspiration, with the difference being runoff or recharge. However, the work of Nick Potter published by the CRC for Catchment Hydrology (Potter 2003) shows that these relationships are not always constant because evapotranspiration depends on when the rain falls — in summer or in winter.

Vertessy *et al.* (2003) claim that the two curves are robust estimators of what is happening, but how many catchments, with varying degrees of plantation cover, have been calibrated and tested with field data against their models? Do the curves take into account varying age-classes of stands, thinning regimes, unplanted areas (roads, log dumps), areas of remnant vegetation, fallow periods or periods prior to canopy closure? Do the models apply equally to all age classes or are they the average across a rotation? Do they pick up in-field variations and species differences in water use?

When discussing Figure 1, Vertessy *et al.* fail to recognise that the major portion (probably around 75–80%) of the plantation estate is in the 600–1000 mm annual rainfall zone. In the future, most new plantings are likely to be in the 550–850 mm annual rainfall zone, and in that range there are relatively small differences in grass and forest evapotranspiration (according to Fig. 1). When the effects of other variables on water use are considered, there may be little difference in water yields between grazed and afforested land. Work in South Africa, for example, has demonstrated that removing trees from creek and drainage lines led to a restoration of permanent water flow.

Similarly, with Figure 2, most existing plantations are in the less than 1000 mm annual rainfall zone. Figure 2 is based on complete afforestation, but what would be the effect on water if the modelling reflected what is happening in the field, by taking account of the codes of practice, the variations in age classes, unplanted areas, and the period to canopy closure?

NAFI does not challenge the validity of the figures and modelling. Rather, industry is concerned that the information presented applies to only a portion of the current forest industry operations. For example, there is limited value in determining the reduction in annual run-off for plantations in the 1200 mm annual rainfall zone (as described in the text). On the basis of land cost alone, very few new plantations will be located in areas receiving that rainfall.

Latest developments

One of the key variables to be considered when determining the effect of afforestation on water yield is the regional hydrology. For example, areas such as the Greater Green Triangle region rely on groundwater, while other areas such as Launceston obtain most of their water from the upper reaches of the catchments.

Figure 3 in Vertessy *et al.* is quite important, as plantation position within the catchments appears to have a strong impact on run-off. Unfortunately, there is almost no further discussion of this theme. When looking at plantation position, there should also be some recognition that areas adjacent to creeks, streams and drainage lines are the most productive forest areas.

From Figure 3, if planting starts at the top of the catchment and only 20% of the catchment is planted, run-off falls from 72 mm to 64 mm (0.72 to 0.64 ML) per annum in the 700 mm-average modelled catchment. If the same trees are planted in the lower parts of the catchment first, mean annual run-off falls from 72 to 31 mm per annum (these may be the low rainfall parts of the catchment as well).

TOPOG and MACAQUE are process models that can help to determine the impact on catchment flows and run-off from different plantation management regimes. It is apparent that while the modelling work covered in Vertessy *et al.* provides individual estimates of potential water use, it will be necessary to use more advanced forest production models, integrated with the hydrological models, to gain a better understanding of the water used by trees. This would allow age-class modelling and an improved distribution of modelled plantations within catchments.

An important statement from Vertessy *et al.* is that ‘the full hydrological effect of plantations is not attained until the stand has reached about 8–15 y of age’. Three other important pieces of information contained in this section of the paper are:

- any catchment containing a significant proportion of young stands will not exhibit the maximum hydrological effects of afforestation
- evapotranspiration rates in mature forest stands are lower than in vigorously growing ones, with decreases becoming apparent after 30–35 years
- variations in productivity also affect the magnitude of hydrological change ensuing from afforestation.

For this last point, the paper briefly discusses how lower growth rates lead to lower evapotranspiration and increased run-off. It is claimed that the use of fertilisers will lead to increased productivity and evapotranspiration with a subsequent decline in run-off. However, in recent work, CSIRO suggests that this may not always be the case, at least in terms of late-age fertiliser application and on a per-cubic-metre-of-timber-produced basis (Benyon 2002). This has important implications for overall water use and, in such cases, it will be important to check and calibrate models against empirical data.

These are key issues that non-forestry people need to understand, as the full hydrological effect of a plantation does not occur until the trees reach their peak in stand volume production. This can range from as little as 8 y in a highly productive flooded gum plantation, to 15 y for blue gums growing on high quality sites, and 20 y in mountain ash and blackbutt stands. The hydrological effect will be expressed at a later time in species that do not have an inherent rapid early growth phase. These hydrological effects then decrease, for any species, beyond the point of maximum volume production and will continue to decrease, as demonstrated by falling evapotranspiration rates in maturing and mature stands.

Vertessy *et al.* make the interesting assumption that plantations are most likely to be established on the more productive sites within catchments, leading to the greatest hydrological effects. However, the reality is that the timber companies generally cannot compete, on the basis of price, for the most productive farmland.

Changes to low-flow hydrology

Vertessy *et al.* (2003) consider the effects of plantation forestry on low flows. There is a need to view these generalised results against the empirical data of Bren from eastern Victoria (L. Bren, Forest Science Centre, *pers. comm.* 2003) and Bren and O’Shaughnessy (2001) for Tasmania. Although Vertessy *et al.* consider the number of low-flow days in ten catchments, their paper does not say whether the catchments are even-aged, fully afforested or planted through drainage lines.

While there is no disagreement that afforestation affects the magnitude of flows or possibly the number of zero-flow days, it is again necessary to question whether all the relevant factors been taken into account. Are the models sensitive enough to confidently predict the number of zero-flow days with relevant precision? How does the number of zero-flow days compare to the case before

land clearing in those regions? The size of the catchments has an impact on the number of zero-flow days. As Vertessy *et al.* state, 'impacts of this magnitude [a large increase in zero-flow days] are far less likely in large catchments'. This is one of the variables that require greater clarification when describing what the modelled results mean.

Implications for the allocation of river flows

The section of Vertessy *et al.* (2003) headed 'Implications for the allocation of river flows' highlights the need for realistic modelling assumptions, and the need to start by determining the area of plantations that would most effectively service the forest products sector. Similarly, there is a need to consider the historical growth of the industry.

Two scenarios are used to assess the effects on water yield of blue gum plantations above the Goulburn Weir, in north-eastern Victoria. Under the maximum afforestation scenario, some 21% of the land above the weir would undergo afforestation. The catchment covers 1.06 M ha of which 600 000–700 000 ha have been cleared for agriculture. This means that forestry would have to replace around 200 000 ha of farming on what is quite productive, and therefore expensive, farmland. It is a highly unlikely scenario.

Currently this region has a plantation estate of around 60 000 ha. Most of it is pine, planted early last century by the former Forestry Commission. It is now owned by the private sector and used to supply mills around Albury. The region also has 3500 ha of eucalypt plantations. The area of new plantations is quite limited.

The key factors limiting expansion of the resource to the level considered by Vertessy *et al.* (2003) are the distance to ports, the slope of the land, the availability and price of the land, the risk of frosts and an understanding of scale. A 200 000 ha resource is large enough to feed a world-scale pulp and paper mill. If such an area of plantations were to be established, as outlined, it would become the most concentrated area of plantation forestry in Australia.

It is interesting that the 21% afforestation model leads to a 14% reduction in mean annual flow in the catchment. It is important to know the assumptions underpinning this modelling work — perhaps trees do not use all of the rain that falls on the land they occupy.

The second scenario is based on a much smaller area of blue gum plantations, leading to a 4% reduction in water yield. Are the models sensitive enough to pick up a 4% reduction in water yield with reasonable certainty? Is this modelling based on the assumption that the most productive land in the catchment would be used?

Again, are the models sensitive enough (and reflecting plantation ages, locations within catchments, open spaces, etc.) to say that 21% afforestation (or planting of over 200 000 ha) would result in an increase of 3–7% in the periods when water entitlements could not be met? Are these results statistically significant?

The modelled results focus on the need to deliver the full 200% allocation (that is, allocations against water rights and against the water sales). How often does the system actually deliver, or need to deliver, the full 200% of entitlements, given that the average is 130%? Two factors that make this part of the analysis difficult to understand are (i) the reliance on full afforestation, and (ii) delivery of the full 200% allocation. These seem to be extreme rather than average or normal circumstances, although it is important to know what happens in extreme conditions.

Impacts on river salinity

The section of Vertessy *et al.* (2003) dealing with impacts on river salinity is one of the key parts of the paper where regional variation in hydrology and geology needs to be part of the explanation. Instead, Vertessy *et al.* use a single set of results to explain many circumstances. There is some discussion that afforestation would lead to a decline in surface water reaching the rivers. However, salty groundwater would continue to flow into the rivers. But what impact do trees have on lowering the groundwater tables and altering the base flow into rivers? In Western Australia, for example, where the rates of lateral water transmission in the soil are low, blue gums can drain the underlying watertables within 6 y. In the face of marked regional differences, what are the forest modelling assumptions underpinning the finding that it will take 35 y for the groundwater to re-adjust so that its salinity level declines to that of surface water?

Relative impacts of afforestation and farm dams

When comparing the effects of farm dams with those of forestry, it would be most appropriate to look at the positive and negative effects of all water use in economic, social and environmental terms. As Table 1 indicates, farm dams lead to a reduction in water run-off of 2–6 ML per annum for each ML of dam capacity. Eucalypts have a lesser impact on run-off than do farm dams in the 600–900 mm annual rainfall zone; for pines this zone is 600–800 mm (Fig. 8). This is a crucial point, given that most trees planted, and to be planted, will be located in these rainfall zones.

It is interesting that in the Yass River catchment, with a land area of 38 800 ha, there is some 6650 ML of farm dam capacity, where each megalitre of farm dam capacity could reduce mean annual flow by 4 ML. This is equivalent to planting around 20 000 ha of pines in the catchment or at least 50% of the land area! If there needs to be balance in water use between various land-uses, it is important to consider the interception in farm dams of 32% of the mean annual flow in the catchment.

Vertessy *et al.* (2003) discussion

The four dot points in the discussion cover the key issues raised in the paper and are fully consistent with current industry objectives. Unfortunately, these same points are not reflected in the abstract. There is no basis for introducing a regulatory regime that applies to plantation forestry alone and which is based on limited results that do not fully reflect industry effort or the overall benefits of plantation forestry.

The forest and timber industry focuses on growing plantations in the most effective locations for a range of outcomes. NAFI has been able to secure \$550 000 in Commonwealth funds for CSIRO to build an investment framework for commercial–environmental forestry. The project aims to consider all available research on tree impacts (both positive and negative), to determine where plantations might be located within catchments in order to deliver the best outcomes and to determine the likely products.

Under this approach, the analysis should start by asking what sort of forest industry is suited to particular catchments in order to derive the area to be planted, together with the environmental implications of those plantations. To close the potential gap between plantation costs and returns, it should be possible to identify the environmental services provided by the plantations and to assign a value to those services. The process should include an assessment of the amount of water used in relation to broad social, economic and environmental outcomes. The challenge is to identify and implement a strategy for planting trees which will deliver the best combination of outcomes.

In their discussion, Vertessy *et al.* refer to the need for legislated solutions to regulate water use and the potential locations of plantations. It is interesting that the case for South Australia and its 26-point plan is raised in Vertessy *et al.*'s discussion. The 26-point plan would seek to regulate water use by plantation forestry in an area where there are un-metered bores and, over the last 10 y, there has been a substantial increase in irrigated agriculture.

The figures on land-use for this region indicate that the water use by trees is far below that of any irrigated crops. There is a 23% recharge allowance for blue gums and 17% for pines, meaning that the trees use, on average, just three-quarters and five-sixths of the available rainfall, respectively. Further work on water use by the trees indicates that they may be accessing groundwater, but only where the water tables are close to the soil surface. In this area the land is criss-crossed with drains to prevent inundation during winter; plantations may be able to use water which otherwise would be drained to the sea.

In the same region, other industries have a vision of increasing their output by the end of the decade. Given that most of any increase will come from irrigation, has the associated water use been challenged? Regional planning should consider geology, hydrology, all land-uses and the outcomes of water use (jobs, income, regional development, etc.), rather than focusing on the land and water used by a single industry.

It is essential that water use is described and analysed in a framework that is consistent across all dryland activities. In South Africa, plantations are recognised as a 'stream flow reduction activity' under the Water Resources Act. However, two considerations are recognised. Research in that country shows that by keeping trees between 10–20 m from the streams, permanent stream flow can be returned. Secondly, new plantation developments can occur if the balance of social, economic and environmental outcomes is favourable. These same rules are also to be applied to other major dryland water uses in that country, such as sugar production.

A formal policy approach requires good science and a comprehensive understanding of the issues being dealt with. There

is some information available on water use by plantations at the moment, but the extreme outcomes constantly referred to are not an accurate indication of what is actually happening in Australia's forest regions.

What the forest industry really requires out of this type of research and analysis

The cap on diversions in the Murray-Darling Basin and the farm dam legislation are just two major components of the water allocation problem that have been dealt with in isolation. An effective property rights and water management regime needs to consider all uses and the positive and negative effects of using that water. Past decisions have taken water away from tree growing and provided it to other dryland activities. Now the problem is giving back the right amount of water to trees that are grown in the most appropriate locations.

A mechanism is needed to allocate water between all the different land uses on the basis of the economic, social and environmental outcomes, as occurs in South Africa. In that country, the assessment process can support the further planting of trees if the overall economic, social and environmental effects are positive.

Vertessy *et al.* might present the catchment modelling results in association with other regional information (covering income, employment, infrastructure, regional development) so that key economic, social and environmental drivers can be used to identify and assess effective plantation development scenarios. This approach is being developed through CSIRO's Commercial–Environment Forestry (CEF) project.

It is anticipated that the CEF project will determine the most appropriate species to plant, the most effective locations for plantations within catchments, the areas to be planted for commercial reasons, timber products, options for regional processing, the scale of environmental benefits, and the economic and employment benefits to a region.

This is a more appropriate process than one which determines the planting area first and then assesses the consequences in terms of the changes in water flow, without accounting for all relevant effects. Another example of an unsatisfactory assessment was Zhang *et al.* (2003), a study of the effects of possible blue gum plantings above Goulburn Weir in Victoria (CRC for Catchment Hydrology Technical Report 03/5).

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