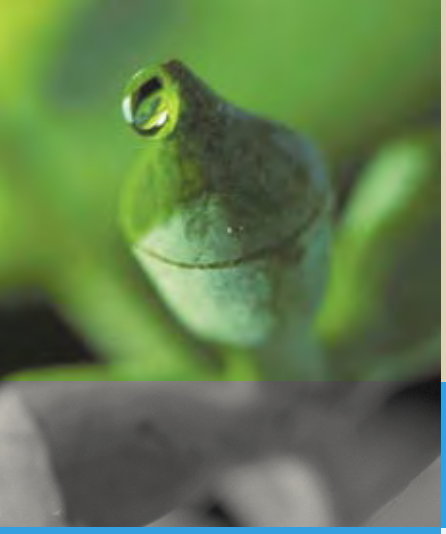

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Plantations and Water

PLANTATION IMPACTS ON STREAM FLOW

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Science for Decision Makers is a series published by the Bureau of Rural Sciences. It describes the latest developments in scientific advice, assessments or tools relating to agricultural, fisheries and forestry industries, including their supporting communities.

Its purpose is to make rural science more accessible to those needing to quickly understand the benefits and implications of the most recent research as a basis for decision-making.

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Key Points

1. Trees have a longer growing season, more foliage and deeper roots than pasture or crops. Runoff from forested catchments is therefore generally lower than from those other land uses.

2. Run-off reduction increases with increasing rainfall. It is estimated to be less than 80–100 mm where rainfall is 500 mm/year and increases to more than 300 mm where rainfall is 1500 mm/year. Stream flow from small catchments may become more intermittent after reforestation.

3. The effect on stream flow of converting agricultural land to plantation is related to the catchment area affected. In smaller catchments, it is difficult to detect an impact when less than 20% of the catchment is planted.

4. In the major plantation regions, plantations occupy between one and six percent of the area of large catchments.

5. Water use is less in younger plantations and when plantations have been thinned. These effects should be considered in estimating plantation impacts on stream flow.

6. Effects on stream flow can be reduced by concentrating plantings in elevated parts of catchments, planting in lower rainfall zones and distributing planting in smaller blocks across a catchment.

7. Research is required to reduce uncertainty in estimating impacts of plantations on stream flow and to translate the results of research on sub-catchments to larger areas.

8. When properly planned and managed, plantation development can contribute to more sustainable land use in rural areas by providing substantial environmental, social and economic benefits with little impact on water availability.

DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

Introduction

Plantations have been a part of the landscape in Australia for well over a century. They now occupy 1.7 million hectares, about 0.2% of the total country or 0.3% of the area used for agriculture. Australia's plantation area has expanded by about 700,000 hectares since 1990. Government and industry share a notional target of 3 million hectares of plantations by 2020 to meet regional industry development and environmental objectives. An average of 66,000 hectares/year of new plantations were established between 1995 and 2004.

The rate of recent plantation expansion on agricultural land is causing community concern in some parts of rural Australia. One area of concern is water. Recent government initiatives to reform water allocation arrangements and increase environmental flows in regulated river systems have highlighted the potential for conflict between the benefits of plantations and their potential to reduce stream flow and groundwater.

The quantity and quality of streamflow depends on rainfall, climate, soils, geology and land cover (Figure 1). In general, mature plantations use more water than mature native vegetation, pasture or crops. Runoff is generally lower in forested catchments than those under pasture or other crops. Greater water use by trees means that plantation development in a predominantly cleared catchment could reduce river flows and groundwater recharge.

This paper presents results of recent analysis of plantation areas and other types of land cover in major plantation regions and a brief review of scientific literature relating to water use by forest plantations.

How Much Plantation?

Five major regions with significant plantation areas were analysed: south-west Western Australia, the 'Green Triangle' (south-east South Australia and south-west Victoria), south-east Queensland, northern Tasmania and the Murray-Murrumbidgee region (Keenan *et al.* 2004). These regions include over 1 million hectares of plantations, about two-thirds of Australia's total plantation area.

Plantations occupy relatively small areas in these regions (1 to 6%, Table 1). Other vegetation cover and land use varies between regions. For example, annual crops, pastures and native grassland are the major land cover in drier catchments (for example, 73% in the Green Triangle and 57% in south-west Western Australia). Native forest and woodland are the major cover in wetter regions in Tasmania (47%) and Queensland (48%).

Most of Australia's existing plantations (about 90%) are in areas with 700–1,500 mm annual rainfall. These were mostly established in large, consolidated areas on public land. Plantations on new sites in the last 10 years have generally been in smaller scattered blocks that occupy small proportions of catchments

FIGURE 1 The Hydrological Cycle of Water Through the Environment.

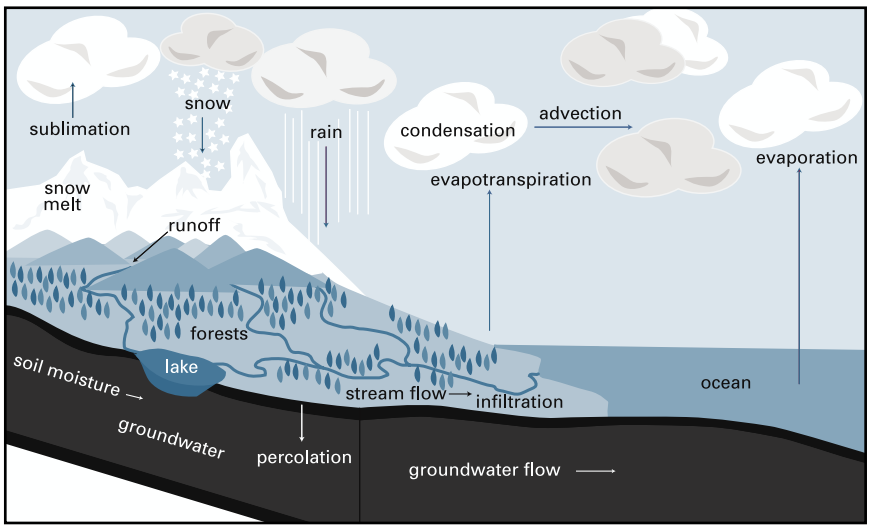


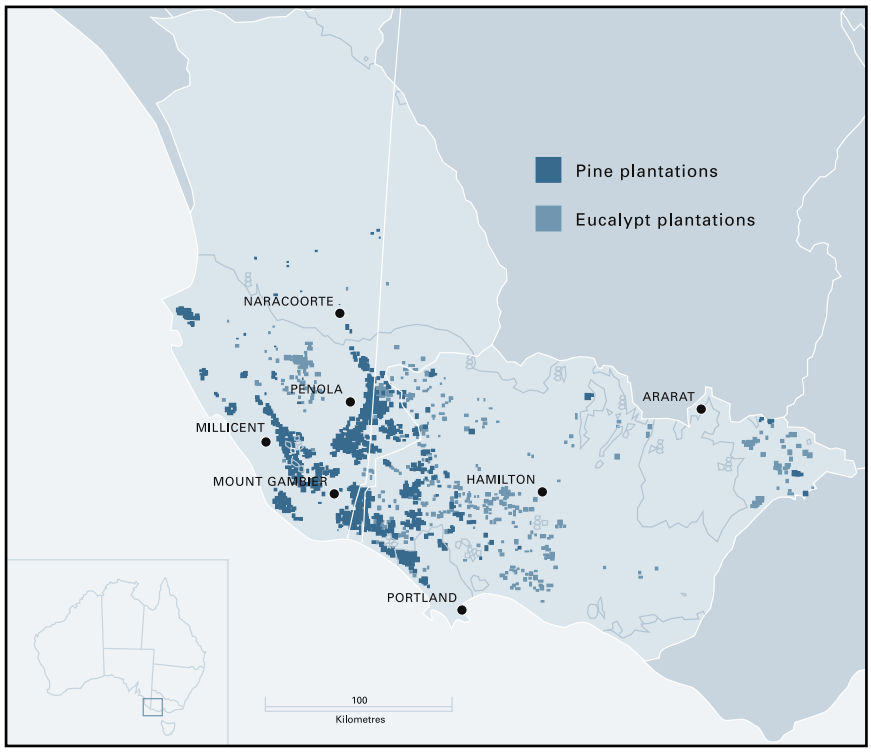
TABLE 1 **Vegetation Cover for Five Regions.**

Vegetation Type	Region by % Area Occupied by Plantation*				
	South-East Queensland	Murray Valley	Green Triangle	South-West WA	Northern Tasmania
Annual crop, pastures, native grasslands	39	66	73	57	32
Native forest or woodland	48	26	15	29	47
Other	10	7	8	12	15
PLANTATIONS					
(% of catchment)	2	1	4	3	6
(ha)	166,000	202,000	240,000	269,000	157,000
Total area of catchments (ha)	8,158,000	16,647,000	6,047,000	10,117,000	2,807,000

* Plantation areas are as at December 2000 Source: Wood *et al.* 2001

or sub-catchments (Figure 2). In future, this trend is likely to continue with most plantations established in smaller blocks on private land purchased or leased from landowners or in joint venture arrangements. As well, due to land availability and cost, they are likely to be established in areas with 600 to 800 mm average annual rainfall.

FIGURE 2 **The 'Green Triangle' Region of South Australia and Victoria Showing Larger Consolidated Blocks of Older Pine Plantations and More Recently Established, Scattered Areas of Eucalypt Plantations.**



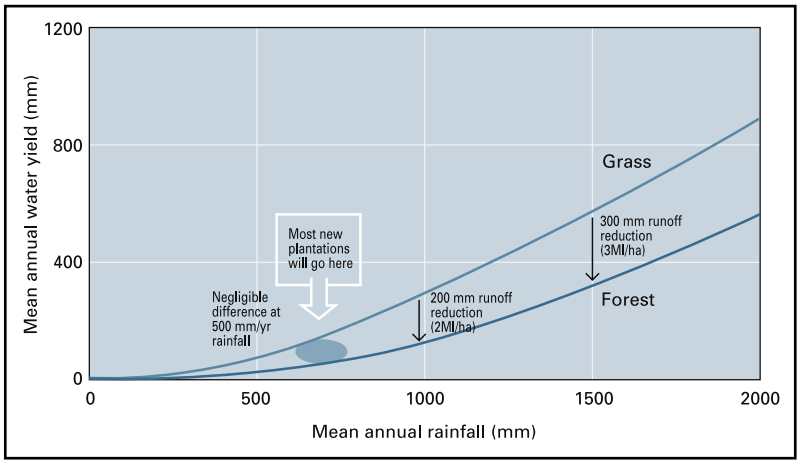
Water Use by Agricultural Crops and Forests

The proportion of rainfall used by plants depends on soil type and depth, plant type, condition and stage of plant growth and crop management. Annual crops and pasture use less water than perennial vegetation, including trees, primarily because of their shorter growing seasons and shallower root systems. The canopies of native and plantation forests intercept more rainfall than pastures or other crops, which adds to their higher evapotranspiration[1].

A model based on many published studies indicates that run off reduction from forested catchments is lower (<80 mm) where the annual rainfall is less than 500 mm/year and increases with increasing rainfall (Figure 3). Actual difference in run off for a particular location will depend on soil type, topography and position of the forest area in the landscape.

[1] Evapotranspiration is the sum of water vapour that diffuses into the atmosphere from vegetation, soil and water surfaces.

FIGURE 3 Water Yield is Higher from Grassed Catchments than Forests.



Source: Zhang *et al.* 2003

Impacts of Plantations on Streamflow and Groundwater

When agricultural land is reforested, streamflow impacts will at first be minor and will increase until canopy closure[2]. Stream flow reductions tend to peak within 10–20 years of establishment, possibly later in drier environments.

Thinning can temporarily increase streamflow. The effect can last for four years but is undetectable unless more than 20% of the trees are removed. A radiata pine plantation, for example, is typically thinned three times during a growing cycle of 30 years. Due to the thinning and harvesting cycle, only a proportion of a plantation estate will be at canopy closure at any given time. This can reduce run-off impacts below those indicated in Figure 3.

Change in stream flow after reforestation or clearing of forest is related to the catchment area affected. It is difficult to detect a significant effect on stream flow in catchments smaller than 1,000 ha where less than 20% is affected and where rainfall is uniform across the catchment. In larger catchments, this relationship breaks down due to variation in rainfall across the catchment. Impacts on run off in larger catchments will depend on the location of planted areas in relation to rainfall and other land uses across the catchment.

Reforestation and clearing also affect the pattern of stream flows. Reforestation can moderate flood peaks and increase the number of low or zero flow days. Changes to flow patterns are likely to be more significant for streams that are not regulated by large water storages.

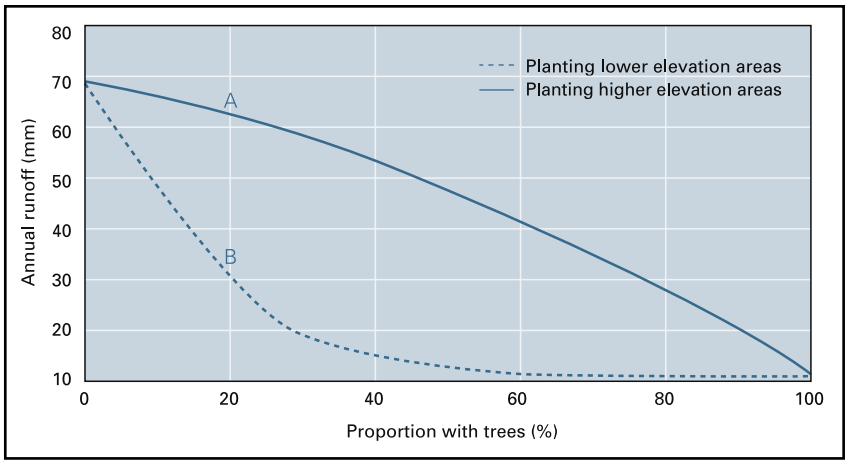
Trees can take up water from shallow groundwater. In lower rainfall regions, this can result in water use being much higher than annual rainfall and a reduction in total aquifer storage. The impact on groundwater storage will be related to the area of plantation, the depth of the water table and plantation management. This is a source of concern in some regions (such as south-east South Australia) where domestic, industrial and irrigation water is drawn from shallow aquifers.

Position in the landscape and planting design can affect the impact of plantations on stream flow. Plantations established close to drainage lines intercept more water than those established further away (Figure 4). Planting further away from streams could therefore help minimise impacts on streamflow. However, there could be a trade-off with tree growth as the trees higher up the slopes may have less available water and grow more slowly.

Plantations established in strips across the contour may use more water than the same area of plantations established in blocks or perpendicular to the contour (Stirzaker *et al.* 2002).

2 Canopy closure is where young tree crowns grow to touch each other and the trees fully occupy the site.

FIGURE 4 Position in the Landscape Affects Runoff.
In this modelled example, planting the highest 20% of the catchment could reduce runoff by about 5 mm/year (A) while planting the lowest 20% could reduce runoff by about 40 mm/year (B).



Source: Vertessy *et al.* 2003

Management Options to Reduce the Impact of Plantations on Stream Flow

It is likely to be easier to target parts of the landscape for reforestation under a 'farm forestry' approach, rather than broad area or whole-farm planting. Under this approach, the owner can choose specific sites within a farm for trees and keep other areas for pasture or cropping. Farm forestry can also provide shade, shelter and land protection benefits that enhance agricultural production and can produce an additional source of farm income.

The effect of plantations on water yield can potentially also be minimised by:

- targeting new plantation establishment in lower rainfall areas (<800 mm/year) where reductions in water yields are smaller;
- dispersing plantations across the landscape and keeping them to less than 20% of a catchment;
- phasing plantings to give a spread of age classes;
- maintaining the plantation at a lower stocking through thinning;
- choosing species that are well adapted to the site and, where practical, species that use less water.

Variation Between Regions

There is significant regional variation in the impacts of plantations on stream flow (O'Loughlin and Nambiar 2001). In some regions, such as parts of Western Australia, vegetation is generally lower. River systems in Tasmania are short and most do not supply large populations or major irrigation areas. Many plantations have replaced native forest and therefore the net impact on streamflow will be low.

Plantation Benefits

Reforestation with plantations provides substantial environmental, social and economic benefits. Targeted plantations can help control erosion, reduce salinity and improve water quality.

Plantations provide the majority of timber used in Australia to manufacture products for home building, paper and other products. Much of this is processed locally and timber industries are major employers in some regional communities. For example, plantation forestry uses about 13% of all the land used by primary industries in the Green Triangle region. However, the plantation sector in that region generates 30% of the gross value of primary industries and 23% of the employment generated by primary industries.

Plantations can be located to stop the movement of water through salt stores. For example, reforestation with blue gums is reducing salinity in the Collie and Denmark Rivers, Western Australia.

Policy Implications

State governments control the use of water flow in Australia. Governments allocate water resources by issuing 'rights' (licences, allocations or entitlements to control water use). Water rights vary greatly, within and between jurisdictions, in their duration, security, flexibility, divisibility and transferability. Water rights arrangements are complex, with many inter-relationships and dependencies in their provisions. It is important that care be taken in seeking to adjust any one component of a system, as there would usually be ramifications for the integrity of the system as a whole (Productivity Commission 2003).

Significant regional variation in the impacts and benefits of plantations requires flexible policies that can be adapted to suit different biophysical, legal and institutional circumstances. This could include a mix of regulatory or market based approaches.

A water rights system that includes plantations would require:

- efficient and practical methods for measurement, monitoring and attribution of the hydrological effects of plantations and other land uses;
- analysis of economic and environmental benefits of plantations compared with alternative land uses;
- consideration of other land use or management effects such as changing agricultural management practices, other types of revegetation, weed incursions, fire and the changing structure of native forests and woodlands;
- consideration of water property rights for existing forest owners;
- analysis of the role of plantations in sustainable development objectives.

Agricultural land management practices are changing. Minimum tillage, reduced fallows and use of perennial pastures and key line ploughing aim to reduce erosion and nutrient loss and retain more run-off on farms. Farm dams are also increasing. These changes need to be considered when assessing potential effects of land use changes on stream flow.

Limitations of Current Research

Rainfall is the most important spatial variable in hydrological studies. However, data for a catchment is often only available for one or a few measurement stations that may not accurately reflect the variability across the catchment. This potential error is more significant in larger catchments (100s to 1,000s of km^2) and where rainfall is low and highly variable from year to year.

Models developed to analyse impacts of plantations on streamflow are based on studies of catchments with relatively stable vegetation cover. They may not accurately reflect 'transitional' effects, where a proportion of the new forest area is in younger age classes or where streamflow is still responding to past events. Some models also assume a relatively simple separation into forest or non-forest vegetation cover. Forest structure varies greatly between catchments and regions.

Thus, models may not represent actual impacts on water use accurately in those catchments where forests differ significantly from situations used to develop the model. Hydrological data shows that models can overestimate reduction in water yield in some circumstances. Uncertainty related to modelled estimates is greater in lower rainfall areas (600–750 mm/year).

Most hydrological studies have been carried out in small catchments (<50-100 ha). Extrapolating results to larger catchments (thousands of hectares) may introduce bias. In larger catchments there are areas that do not contribute to stream flow and this will vary with the size, topography or geology of the catchment. Results derived from small experimental catchments may therefore overestimate impacts at larger scales.

Plantation management regimes are changing, with lower initial stocking and heavier thinning and changing rotation lengths. Research based on historical studies may not apply to current circumstances.

Research Needs

A number of topics warrant further research, including:

- Long-term monitoring of stream flows at catchment and regional scales.
- Development of methods for low cost assessment of water use of different types of land cover.
- Comparative studies of water use (interception, evapotranspiration and use of groundwater) and impact on run-off and stream flow of different land uses and land cover.
- Comparative studies of water use and plantation management practices and species in different climates and soil types.
- Analysis of potential impacts of climate change on water use by different vegetation types and resulting catchment water balance.
- Development of catchment models to assess potential water use impacts of plantation establishment that integrate stand level models of water use. These should focus on lower rainfall regions, explicitly model 'transitional effects' and use realistic scenarios of plantation development and management. Model validation should account for the effect of scaling up results from small experimental catchments to larger scale catchments.

CONCLUSIONS

Conversion of agricultural land to plantations may reduce run-off and streamflows. If this occurs across a large part of a catchment the consequences may be significant for water supply. In most places, plantations make up only small proportions of catchments. They also contribute positively to regional economies and can provide environmental benefits. With appropriate catchment selection and plantation planning and management, plantations can be a viable and positive part of the rural economy with minimal impacts on stream flow.

The challenge is to apply scientific knowledge to develop policies and institutional arrangements that provide for plantation development in those parts of selected catchments where they have the most commercial and environmental benefits with little impact on water flow.

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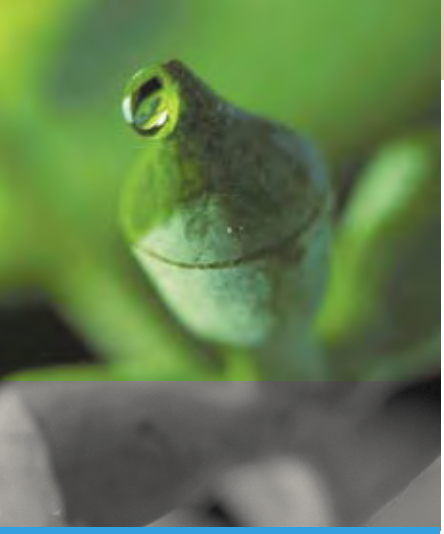

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