Forests, grassland, and water catchments

Australia has a fair amount of hardwood, but very little natural softwood. In 1965 the Australian Forestry Council recommended that the country should aim at producing all its softwood needs by the year 2000. To achieve this would require an increase in the rate of expansion of softwood timber plantings from 16 000 hectares per year to 30 000.

In fact, during the past few years, the Australian and State governments and private companies between them seem to have been planting additional areas, mostly with pine, at a rate of about 36 000 ha each year.

This planting program has involved clearing native eucalypt forest, mainly in southern Australia, and it has brought foresters into collision with two other interested groups in the community—city water supply authorities, and conservationists.

Foresters and water supply authorities have similar requirements. Both need areas of land with reasonably high rainfalls, which are located fairly close to centres of population yet on which very little urban development has taken place.

Only relatively small areas of native eucalypt forest remain on the not-very-extensive high-rainfall areas of southern Australia, so conservationists tend to see clearing large areas of such forests for pine planting as a threat to the nation's heritage. Water supply authorities fear that clearing a catchment and planting it with pine trees could both reduce the quality of the water it produces in the short term and lessen the amount of water that the catchment will yield in the long term.

Clearing land and replanting it nearly always reduces to some extent the quality of the water that a catchment will produce in the short term. Topsoil washes off, making streams that feed the reservoirs muddy. However, once the newly planted forest has become established, the muddy-water problem tends to go away—at least until the forest is harvested and replanted once more.

Conservationists tend to see clearing large areas of such forests for pine planting as a threat to the nation's heritage.

Discoloured water coming out of household taps caused Canberra citizens to complain for many years from 1930 onwards. Many people pointed the finger at pine-planting operations on the city's water catchment. An investigation during the early 1960s by Professor L. J. H. Teakle of the University of Queensland revealed that soil washing off the newly cleared and planted areas was in fact only a minor cause of the problem. By the end of the first year after replanting, enough vegetation had usually grown up to prevent mud from entering nearby streams anyway. It turned out that most of the mud was coming from other works that left the soil bare, such as roads and firebreaks, and from erosion of stream banks caused by earlier use of the area for grazing.

In fact, with planning and careful supervision of contractors, foresters can (but often don't) minimize the amount of soil washing away from newly cleared areas if not completely prevent it. To achieve this requires employing measures that don't disturb the topsoil more than

Churned-up soil means muddy water in the reservoirs.

Do eucalypt forests yield more water than pines? Evidence is conflicting.

necessary. For example, they can use rubber-tyred tractors rather than crawlers, lift out logs rather than drag them across the ground, and avoid clearing along water-courses. Siting roads properly, keeping their numbers as few as possible, and keeping them well drained also help to minimize the amount of mud washing into streams. Planting grass, clover, or other vegetation on bare areas (including access roads and firebreaks) helps too. The Canberra study suggested that the water running off any piece of ground would be clean—provided it was managed to carry the equivalent of about 7½ tonnes of dry vegetation of any sort per hectare.

So forest plantations need not necessarily greatly reduce the quality of water coming off a catchment. But what of the question of whether plantations of pines, or any other trees, reduce water yields? Information is scarce, and the situation confused.

Pines *v.* grassland

Over the years evidence has built up that grasslands yield more water than pine plantations—and the difference can be substantial. The water becomes available either as run-off over the land surface or as groundwater.

A few years ago, a research team from the CSIRO Division of Soils in Adelaide studied recharge to the groundwater under grassland and pine plantations on the plain that surrounds Mount Gambier in south-eastern South Australia. This plain is unusual in that it is very flat, and its limestone surface is very permeable. Rain-water does not run off it as surface streams, instead it percolates through the surface until it reaches an impermeable layer of silty clay. It then flows over this layer as groundwater, finally to reach the sea. Probably any recharge to this groundwater can be regarded as comparable with run-off elsewhere.

A 4-year hydrological study carried out by the then Mr John Holmes and Mr John Colville at a grassland site about 40 km inland from the coast revealed that about 63 mm of the annual rainfall of 632 mm reached the underground aquifers. The rest evaporated away. (Mr Holmes is now Professor of Earth Sciences at Flinders University.)

A similar experiment in two pine plantations suggested that during winter and spring (when most of the rain falls in that area) evaporation from the pine forest was more than twice as high as that from grassland. In addition, evaporation balanced the rainfall, so no recharge at all could be going on beneath the pines. At Canberra, Dr Tom Denmead of the CSIRO Division of Environmental Mechanics has come to a similar conclusion. He compared evaporation from a local wheat field with that from a nearby pine forest. He too concluded that evaporation was faster from the pine forest.

Two further experiments on the plain surrounding Mount Gambier—one carried out by Professor Holmes and Mr Colville, and the other by Dr Graham Allison and Mr Murray Hughes, also of the Division of Soils—confirmed that recharge beneath pine forests was less than that beneath grassland. Incidentally, Dr Allison and Mr Hughes used the tritium fall-out from the large nuclear tests in the Northern Hemisphere during the 1950s as an indicator of the age of various samples of groundwater. To test the accuracy of their estimates of the age of their groundwater samples, they predicted the ages of wines of known vintages by checking the levels of tritium they contained.

. . . and *v.* eucalypts

It may now be possible to say that plantations of pine trees use more water than grassland, but we don't know whether a pine plantation uses more water than a stand of eucalypts. So we can't yet say whether one tree type is a more suitable cover for a catchment than the other if a maximum yield of high-quality water is required.

Of interest in this regard is a joint study, carried out by the University of New South Wales and the State Forestry Commission, of a pair of very similar catchments at Lidsdale State Forest, about 130 km north-west of Sydney. One

We don't know whether a stand of pines uses more water than a stand of eucalypts.

Sparkling clean water falls over one of the gauging weirs in the Cotter catchment near Canberra.

catchment was covered with thinned 35-year-old pines, and the other with mature native dry sclerophyll forest. The proportion of the ground covered by the forest canopies was comparable in both catchments, although no doubt the pine cover was somewhat denser. Run-off under the eucalypt forest was quite substantially greater than under the pine forest—being about 14% of the rainfall under the eucalypt forest compared with about 8% under the pines.

This study also pointed to a reason for these differences—pine canopies let less rain fall through than eucalypts. The pines intercepted 18·8% of the total rainfall during the 31 months of the experiment, and the eucalypts 10·6%.

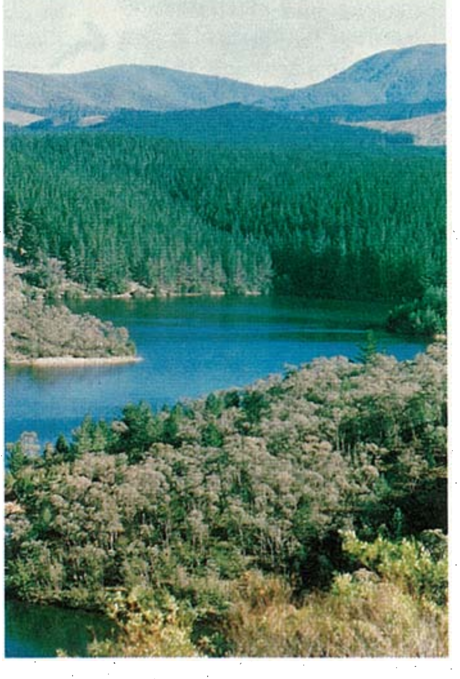
Where the rain went at Lidsdale

	pine	eucalypt
	(percentage of total rainfall)	
interception	18·8	10·6
throughfall	81·2	89·4
run-off	8·3	14·2

Near Canberra, Mr Ross Morland and his colleagues in the Watershed Management group of the CSIRO Division of Forest Research (formerly the Forest Research Institute) have for the past few years been studying run-off from under pine plantations and eucalypt forests, and from cleared land in catchments at altitudes varying between 700 and 1500 metres.

This group's early results have indicated that various types of mature eucalypt forest yielded greatly different proportions of the available rainfall as run-off. For example, dry sclerophyll forest yielded only 5% of the rainfall, and wet sclerophyll forest about 15%.

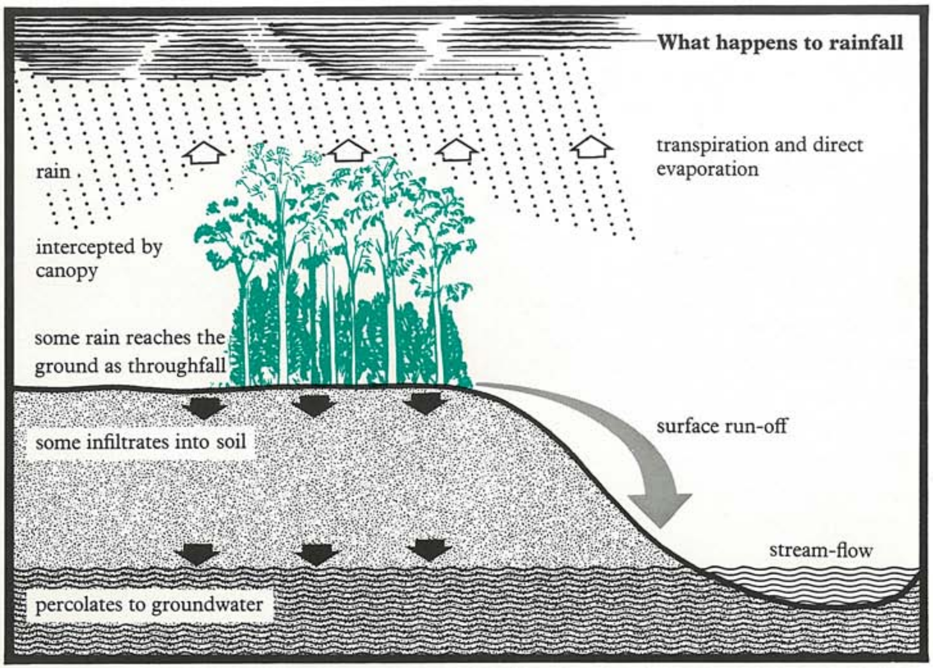
By comparison, catchments at similar altitudes covered with vigorous, dense, and unthinned stands of pine yielded only 3·5% of the rainfall as run-off, mainly because 50–70% of the rainfall was intercepted, and evaporated by the forest canopy, and so never reached the ground. However, an older thinned plantation yielded 12% of the rainfall—appreciably more than the yield from mature dry sclerophyll eucalypt forest at a comparable altitude.

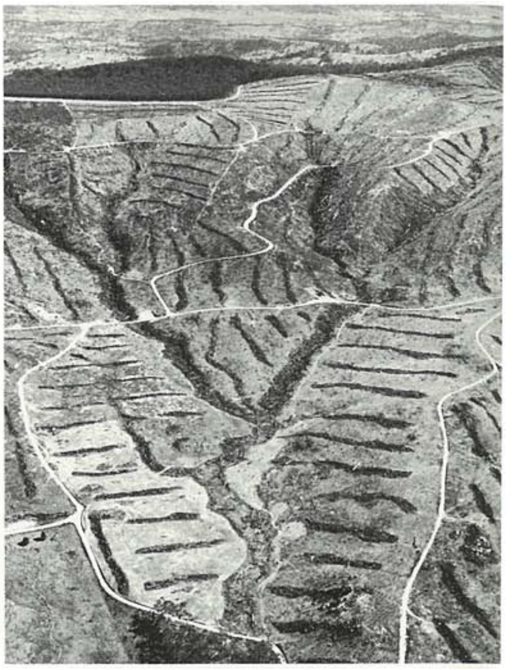


Pines and eucalypts on the Cotter catchment. Water yields are lower under young fast-growing trees than beneath mature ones.

As might have been expected, clearing a catchment covered with mature pine gave a dramatic increase in water yield. After clearing, the catchment vegetation became light- to medium-density grass, and the water yield rose to 30% of the rainfall. As the pine forest regenerated, the water yield declined once more.

So water yields from catchments planted with pines can probably be expected to be cyclical, being high during the establishment phase, low for the 15–20 years when the stand is dense and growing vigorously, and then increasing as the forest matures and thinning is carried out.





Eucalypt forest cleared for pine planting in New South Wales. Clearing along the creek beds often causes erosion.

Comparisons with eucalypt forests managed in the same way (in other words clear-felled and then allowed to regenerate) have not been carried out. Nevertheless, studies by the Melbourne and Metropolitan Board of Works of a somewhat comparable situation in the Melbourne city water catchments following the 1939 bushfires do suggest that the water yield during the period of vigorous regrowth would be lower than if the catchment were covered by mature eucalypt forest.

Melbourne's water catchments are closed. Neither timber-cutting nor agriculture is permitted. Mountain ash covers large areas of these catchments. Much of the mature mountain ash forest was burnt out during the disastrous 1939 bushfires. Such fires kill mountain ash and the shrubs beneath it, but at the same time they prepare a suitable seed-bed for mountain ash on the forest floor. A dense forest of regrowth results, and so the sequence of events after the bushfires was not unlike clear-felling and replanting.

The Melbourne and Metropolitan Board of Works has records of stream flows in the city's catchments dating back to the early 1900s. Stream flows declined rapidly about 5 years after the fire. By this time the forest of regrowth was well established. The flows stabilized after a further 10 years at levels well below those before 1939. For example, the stream flow from the Maroondah system of catchments between 1944 and 1970 was almost 25% lower than pre-1939—a quantity representing about 10% of Melbourne's annual water consumption. Even now, flows from these catchments are below levels before the fires, although there are some indications that they are increasing.

To summarize, the information available so far about water yields from different types of vegetation suggests the following:

- pine plantations, and probably eucalypt forests, use more water than grassland
- mature, thinned pine forests may or may not use more water than mature eucalypt forests
- vigorously growing pine forests use more water than mature ones
- vigorously growing young eucalypt forests use more water than mature ones

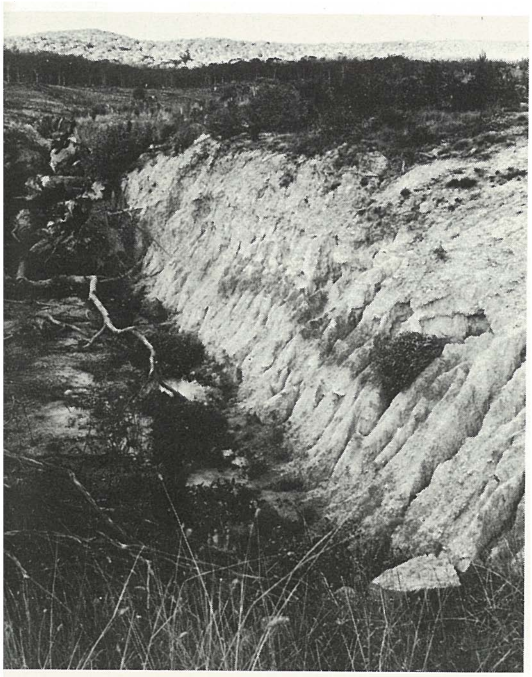
This evidence seems to suggest that on a forested catchment a cover of mature forest will yield the most water. Use of the catchment for timber production, which involves stimulating the growth of young trees, must reduce the water yields. Maintaining a cover of thick grassland would be expected to yield more clean water than mature forest, but this would rarely be feasible. (Covering the catchment with concrete would give even more!)

Evaporation and radiation

Why do some types of vegetation yield more water than others? At Flinders University, Professor Holmes was puzzled by his earlier observation while at the CSIRO Division of Soils that near Mount Gambier the amount of evaporation from pines was nearly twice as high as that from grassland during winter and spring.

For evaporation to occur, energy must be available, and this energy must ultimately come from the sun. Pine forests look darker than even the greenest grassland, which means that they reflect less of the sun's energy. They therefore absorb more, and get rid of most of this extra energy by retransmitting it as infrared radiation. Additional energy required by pines to evaporate more water than grassland must come from the extra energy that they absorb. In addition, faster evaporation may occur from pine trees because, being rougher, they create more turbulence. Professor Holmes's calculations suggested that the extra energy absorbed directly from the sun wasn't enough. At Flinders University Dr Chris Moore has now sorted this problem out. Dr Moore carried out this research under Professor Holmes's direction to gain his Ph.D. He has since moved to the United Kingdom.

Dr Moore's approach was to divide into their separate parts the processes of absorbing energy from the sun, reradiating it, or using it to allow evaporation, and to measure each one. Now it is relatively easy to measure the incoming and outgoing radiation, and the temperature and humidity, above a pasture. But to do this over a forest is another matter. Dr Moore used what's



The same cleared area. Eroded creek beds give dirty water.

known as an 'eddy correlation' technique. He mounted his instruments on a tower above the canopy of a vigorously growing 10-year-old plantation.

He used a number of instruments newly developed by the CSIRO Division of Atmospheric Physics, and at Professor Holmes's invitation Mr Bruce Hicks and Mr Peter Hyson, from the Division, cooperated with Dr Moore to test whether the technique could be accurate enough to give meaningful results.

The results of two experiments in May and October 1972 were very encouraging, so Dr Moore continued to take measurements the following year.

He pieced together this story. Autumn, winter, and spring are the seasons in South Australia when most of the rain falls, so at that time of year the soil is relatively moist, and the process of transpiration in the growing trees and pasture plants can go ahead without the hindrance of water stress. When the vegetation is not wet from rain, the only water loss from either forest or pasture would be through transpiration and evaporation direct from the soil.

Being darker green, forests absorb more energy than pastures. It might be expected that this absorbed energy would increase the rate of water loss of the forests as compared with grassland, but Dr Moore's measurements showed that for a dry forest this was not so. In fact the water loss through evaporation from a dry forest was less than that from grassland. Heating of the trees and foliage of the forest itself accounted for the extra absorbed energy, and this extra heating mostly went on during the first few hours after sunrise, to the exclusion of evaporation.

Lost at night

In a wet forest the situation was very different. The evaporation from a wet forest canopy appeared to be much faster that that from neighbouring wet grassland. By day the incoming energy absorbed by the dark green foliage provided all the energy for evaporation, but it also warmed the forest canopy. This meant that evaporation from the wet canopy could continue at night as the forest cooled down.

By day, energy from the sun also powered evaporation from wet grassland, but the evaporation rate tended to be a little slower since, being paler, the grassland reflected more of the sun's energy. The greater roughness of the pines would have also added to this difference. But by night very little evaporation could occur from the wet grassland, since this type of vegetation could not store heat like the forest canopy so it cooled down immediately the sun set.

But there is another factor too. The thick pine canopy intercepted and stored about five times as much rainfall as pasture. In winter near Mount Gambier, rain usually comes as a fairly fine mist every 4–5 days. After rain the forest canopy has a great deal more rain stored within it than the grassland vegetation, and this stored rain-water is evaporated at a rapid rate. Not only is the evaporation rate from the forest canopy higher than from the pasture, evaporation lasts much longer because of the larger amount of water stored. So over 24 hours forest can lose considerably more water than grassland.

Dr Moore's calculations show that during the winter months the evaporation from his pine stand equalled the precipitation—thus bearing out Professor Holmes's and Dr Colville's earlier suggestion that no rain actually gets through the canopy to be available for recharging the underground aquifers.

Do these results apply only to the particular climatic conditions found near Mount Gambier, or do they apply elsewhere too? Obviously the situation would be completely different in regions whose rain falls mainly in summer—in the warm conditions the evaporation rates would be different. However, Professor Holmes considers that over most of southern Australia, where most of the rain falls during the cooler months, conditions are similar to those around Mount Gambier up to an altitude of about 1000 metres. Above that height, low temperatures greatly reduce evaporation, and trees may actually accumulate water from low cloud—a process known as fog drip.

The next, even more difficult, step will be to apply similar techniques to the much more variable trees in eucalypt forests. Professor Holmes does not intend to do this, since no suitable areas are available within a reasonable distance of Adelaide. However, researchers from the CSIRO Division of Plant Industry's Ecology Section are already collecting information for a comparison of evaporation rates from pine and eucalypt forests.

More about the topic

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