Don't overfeed the trees!

What they learned about effluent-irrigated plantations at Wagga Wagga

Brian Myers wouldn't mind a dollar for every time he's sung the praises of sewage effluent. He's been doing it for years, and probably won't kick the habit until we all regard sewage effluent as a resource, not a waste-disposal problem.

As leader of CSIRO's Wagga Wagga Effluent Plantation Project, Myers and his team have studied in detail the pitfalls and possibilities associated with re-using sewage effluent. Their mission now is to translate the project's findings into technical guidelines for designing and operating effluent-irrigated plantations. These will help managers across Australia to guard against the environmental risks of this rapidly-expanding industry.

Myers says the economic and ecological sustainability of effluent-irrigated plantations depends on the motivation behind their establishment. 'Many people put a plantation in as a delaying tactic, a camouflage for disposal,' he says. 'They're not seriously trying to end up with a useful product.

'The Wagga Wagga trial has shown that if sewage effluent is not treated as a water and nutrient resource, and the plantation managed accordingly, tree quality will be poor and the system will become overloaded with water and nutrients.'

Myers says the industry is 'at the crossroads' in terms of adopting a sustainable approach to effluent irrigation. 'There is a real danger of the wrong path being taken,' he says.

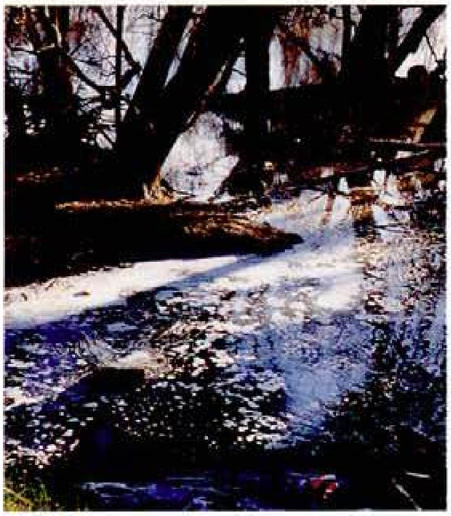
'People must do market research and understand the water and nutrient dynamics to ensure the plantation enterprise is sustainable and productive.

'No one would dump a truck-load of expensive fertiliser on a small paddock and watch the rain wash it away to contaminate a river or water table, so why do we do it with effluent?'

The appeal of tree plantations as a means of re-using sewage effluent is evident in the industry's expansion in recent years. Since the Wagga Wagga trial began in 1991, the area of tree plantations in Australia dedicated to effluent re-use has trebled from 500 to more than 1500 hectares. From the perspective of those responsible for the treatment of sewage effluent, it's easy to see why the idea of an irrigated plantation would be tempting.

Sewage effluent, generated in Australia at a rate of about 250 litres per person per day, is pretty potent stuff. After undergoing primary and secondary treatments, it typically contains high levels of nitrogen (10-30 mg/litre) and phosphorus (4-10 mg/litre), and is slightly salty and alkaline. Traditionally this brew has been discharged to waterways and oceans, contributing to the eutrophication of rivers which in turn causes blooms of toxic blue-green algae.

Trees grow quickly when fed on a nourishing diet of sewage effluent. These eucalypts at the Flushing Meadows trial site near Wagga Wagga are pictured at eight months (above) and four years of age (top).



As an extension of the Wagga Wagga Effluent Plantation Project, the Australian Bureau of Agricultural and Resource Economics and CSIRO are undertaking a cost-benefit analysis of effluent re-use schemes. One of the most difficult issues to be tackled during this analysis will be the long-term costs, which re-use should eliminate, of environmental degradation due to river discharge of effluent. Brian Myers says that cost-cutting in attempt to make plantations economically sustainable is likely to threaten their environmental sustainability.

In response to increasing public concerns, and to tighter regulation regarding such discharge, alternative effluent-management practices are being sought. The pleasantly 'green' vision of creating a vigorous forest holds tremendous appeal, but is it as simple as finding a site, diverting the pipes, sitting back and watching trees grow?

Of course the answer is no, but given the circumstances, it's understandable that plantations might be established purely for 'waste' disposal. The trap is that unless plantations are properly managed, the environmental problem will merely be shifted underground.

'Many plantations are established with the aim of protecting rivers and watertables from nutrient contamination,' Myers says. 'But the processes of water use, nutrient cycling and salt management in effluent-irrigated plantations are often not well enough understood for this objective to be met, or to prevent soil and groundwater degradation.'

The guidelines that evolve from the Wagga Wagga project will help plantation managers improve their understanding of these factors, thus steering them along the path toward ecological sustainability and productivity.

Watertight solutions

In helping people to visualise the potential hazards of effluent irrigation, Myers often describes the soil beneath a plantation as a giant sponge. Adding trees to the system has the effect of increasing the sponge's capacity for water uptake, enabling higher rates of irrigation. As the trees grow, expanding their leaf area and consequently their water requirements, greater volumes of water can be added.

As with any irrigation system, however, adding more water to the soil than it is capable of absorbing will result in leakage to the groundwater system. In addition to contributing to rising water table levels, overloading can cause run-off into watercourses and erosion, reduce soil productivity, threaten tree health through waterlogging and root decay, and increase the risk of tree loss in high winds by encouraging shallow root growth. Too little irrigation can also cause problems, such as reduced growth rates, poor tree health due to water and salt stress, and increased susceptibility to insect attack and disease.

Methods for calculating how much water can safely be applied to effluent-irrigated plantations have been refined during the Wagga Wagga project. These are based on estimates of the plantation's

Effluent research outstanding in the field

For the past five years, CSIRO scientists and technicians from Canberra have trekked regularly down the Hume Highway to a place called Forest Hill, 15 kilometres east of Wagga Wagga. Their mission has been to establish and monitor the growth, water and nutrients of a tree plantation irrigated with sewage effluent from the Forest Hill township and the Royal Australian Air Force base nearby.

In October 1995, the researchers were recognised for their efforts when the Wagga Wagga Effluent Plantation Project won the BHP State Landcare Research Award for New South Wales. This is awarded annually to an individual or organisation for outstanding achievements in either land conservation research, or the development of landcare technology.

A team of up to 17 staff from CSIRO Forestry and Forest Products and the Division of Soils is involved in the Wagga Wagga project. Its major sponsors are the Land and Water Resources Research and Development Corporation, Murray Darling Basin Commission, New South Wales Department of Land and Water Conservation and Wagga Wagga City Council. Tahara Pastoral Pty Ltd has provided the 4.6-hectare trial site, christened 'Flushing Meadows'.Scientists contributing to the project are: Richard Benyon (tree water use), Warren Bond (soil physics), Randall Falkiner (soil chemistry), Phillip Polglase and Christopher Smith (nutrient cycling), Val Snow (model development), Tivi Theiveyanathan (water balance) and PhD student, Nick O'Brien (biomass and nutrient accumulation).

The aim of the trial has been to determine the effectiveness, environmental limitations and sustainability of plantations as a means of land-treatment of effluent. Six inter-connected sub-projects have examined different aspects of the plantation system including: tree growth and quality, tree water use and site water balance, nitrogen dynamics in soil and vegetation, phosphorus dynamics, groundwater impact and tree species, and provenance and clone response to effluent irrigation.

Although the six-year trial is nearing completion, Wagga Wagga City Council will continue to manage the plantation as a land-treatment for effluent. This will give the research team the opportunity to monitor the plantation, paying particular attention to changes in the soil chemistry and groundwater beneath it. Wood produced by the plantation is likely to be marketed to local industries for heat-energy production, and the manufacture of medium-density fibre board.

Tahara Pastoral recognises the plantation's commercial potential and is keen to expand its size to 20 or 30 ha. The prospect of exporting CSIRO's effluent irrigation 'know how' to Asia is also being considered.

ability to utilise added water and nutrients and involve striking a balance that minimises the risks of both over-irrigation (or the need for river discharge of excess effluent) and severe under-irrigation.

To prevent water loss from the system, the rainfall plus the reclaimed water must not exceed the water transpired and evaporated from the whole plantation (trees, understorey and soil). The Wagga Wagga Effluent Plantation Project has demonstrated that under-irrigation by up to 50% of the plantation's water use capacity increases sustainability and improves tree quality while only moderately reducing growth rate.

Major factors influencing potential plantation water use include monthly and annual balances between evaporation and rainfall at the site, the leaf area of the chosen species at various stages of stand development, and the proportion of rainfall and irrigation lost by interception and evaporation.

Fast-growing plantations can use water at rates of up to eight millimetres a day, the equivalent of 80 000 litres per hectare per day during peak summer periods. Water use is strongly seasonal, however, and during winter (in southern Australia) it may be as low as 0.5 mm/day. During this time, rainfall is likely to exceed the water-use capacity of the plantation, and there are usually some months of the year in which irrigation is not possible without overloading the soil. Storage facilities are therefore needed to match the relatively constant flow of effluent from the sewage works with the plantation's varying needs.

Balancing nutrient and salt loads

Another important factor affecting the rate at which effluent can be applied to tree plantations is the need to balance the application and removal of nutrients. When effluent is discharged to rivers, the nutrient of greatest concern for its affect on algal growth is phosphorus. In the soil, however, the mobility of phosphorus is low compared with that of nitrogen. Thus nitrogen is easily leached from the system if applied at a greater rate than the plantation's capacity to accumulate it.

'Losing nitrogen to the water table may not be harmful in small amounts,' Myers says. 'But in large amounts the damage caused to the water table may persist for much longer than the harmful effects of effluent discharge to rivers.

'High nitrate levels in groundwater make it unsuitable for human consumption and most state regulations prohibit leaching of nitrate from effluent-irrigation sites.'

Treatment ponds full of sewage effluent awaiting its fate. Will it be treated as a resource or a waste disposal problem?

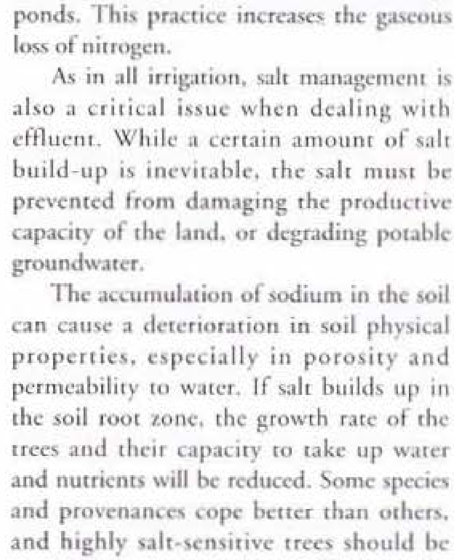
Up to a certain age, tree plantations provide a wonderful repository for nitrogen, most of which is stored in the leaves. But after two to five years, when the branches of adjacent trees are touching and the foliage intercepts most of the sunlight, the story changes. From this point on, the nitrogen returned to the soil by fallen leaves provides most of the canopy's requirements. Continued wood growth requires some additional nitrogen, but the quantities are small. The implication for plantation management is that after the canopy has closed, the amount of nutrients applied to the system must be reduced, or the trees must be harvested and replanted to return the system to the rapid-uptake stage.

One way to meet this requirement is to grow trees that can be harvested at short intervals. A short-rotation plantation can retain a relatively constant annual demand for nitrogen (and water) if stands are at different stages in the production cycle. Some will be newly established, with their small trees accumulating little nitrogen. Others will have reached their maximum uptake levels. Still others will be at their reduced accumulation levels following canopy closure. Irrigation requirements across the plantation will vary according to the stage of development.

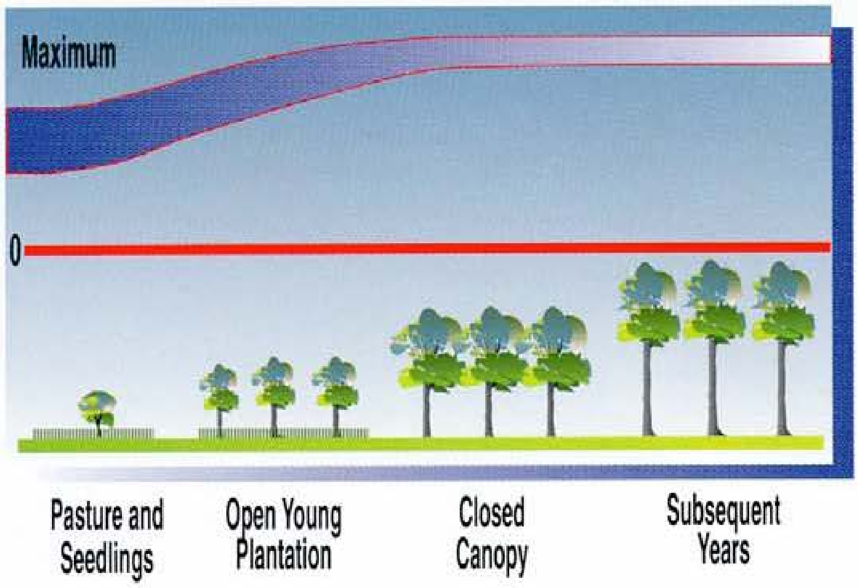
One way of increasing the nitrogen uptake of a plantation in the first year or two is to sow a high-yielding cereal or forage crop, or to allow weeds to grow, between the rows of trees. Other options are to apply less effluent to larger areas, or to reduce the nitrogen concentration of the effluent through longer retention in storage ponds. This practice increases the gaseous loss of nitrogen.

As in all irrigation, salt management is also a critical issue when dealing with effluent. While a certain amount of salt build-up is inevitable, the salt must be prevented from damaging the productive capacity of the land, or degrading potable groundwater.

The accumulation of sodium in the soil can cause a deterioration in soil physical properties, especially in porosity and permeability to water. If salt builds up in the soil root zone, the growth rate of the trees and their capacity to take up water and nutrients will be reduced. Some species and provenances cope better than others, and highly salt-sensitive trees should be avoided in plantations. Unless the accumulated salt is washed out of the root zone regularly, however, damage will occur.



Peter Crapper calibrates a Peizometer for monitoring a shallow perched water table. Applying too much effluent to tree plantations can overload the groundwater system.



Total water use by the plantation increases as the amount of foilage in the stand increases. Water use is minimum (equivalent to that of pasture) at time of planting and maximum after canopy closure at age two to four years.

The amount of leaching required to achieve this 'washing' of the root zone can be estimated from the salt content of the effluent, the quality of effluent applied and the plantation's water-use rate. In many locations, rainfall will provide enough leaching in most years to protect the root zone. When this is not the case, extra irrigation is needed, a requirement that conflicts with the aim of avoiding nitrate leaching. Careful management is therefore essential to minimise the risk of damage by both salt and nitrate.

Name your product

In view of the considerable investment required to establish and operate a sustainable effluent irrigated plantation, it makes sense to grow trees that will bring the greatest possible financial return. This means that as well as being suited to the particular site conditions, the trees must yield a product that is marketable and can be harvested regularly (to combat nutrient build-up).

Market demand may be influenced by tree form and wood quality, including density, strength and fibre length. Often the choice may be between Pinus radiata and a range of eucalypt species. Eucalypts grow more quickly than pines initially, reaching their peak water use and nutrient accumulation rates sooner, but pines ultimately store more nitrogen in their foliage. The marketability of trees at the age of canopy closure (two to five years) may influence the choice of species.

The potential return from trees will depend largely on the availability of suitable markets (such as a sawmill or pulp mill (in the region. Common products from effluent-irrigated plantations are likely to be domestic firewood and eucalypt or pine chips for reconstituted products such as chipboard or fibre board. Another option is short-rotation production of wood for industrial heat energy which has the advantage of removing all the above-ground biomass at frequent intervals and regeneration can be achieved by coppicing.

In some locations, economics may favour the growth of melaleucas or eucalypts for their leaf oils, or fast-growing acacias for bark tannins.

Myers says that future work at the Wagga Wagga trial site is likely to concentrate on energy plantations with a two to three year growth cycle. The timber would be used by local industries for heat-energy production. The reason for this end-use is that once the tree canopy at Wagga Wagga closes, under-irrigation is necessary to prevent the leaching of nitrogen. Therefore to fulfil the original aim of providing a sustainable alternative treatment for sewage effluent, and a marketable product, the 'crop' must be regularly removed.

Reclaiming and re-using water is a responsible alternative to sending it to an ocean outfall or draining it into watercourses and effluent-irrigated plantations have the potential to make a contribution to Australia's wood production.

Myers and his colleagues estimate that the amount of effluent produced in the Murray Darling Basin is sufficient to irrigate up to 25 000 hectares of fast-growing plantations. In view of this potential growth, the lessons learned at Wagga Wagga are invaluable. They will go a long way towards ensuring that effluent-irrigated plantations are environmentally sustainable.

Woodchips or fuel wood? Decisions about what to produce are important to the overall sustainability of effluent-irrigated plantations. Factors such as proximity to markets and processing facilities, and the crop's capacity to convert nitrogen, must be considered.

More about effluent irrigation

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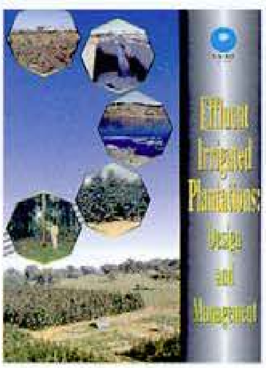

Is there anything you really wanted to know about effluent irrigation, but were too afraid to ask? Well you need not worry, because the answer is bound to exist in a glossy new publication by CSIRO Forestry and Forest Products and the Division of Soils. The booklet, *Effluent Irrigated Plantations: Design and Management*, draws on the findings of the Wagga Wagga Plantation Project, and other trials conducted elsewhere in Australia. Written by former *Ecos* editor, Robert Lehane, it uses non-technical language to explain the production and environmental issues related to irrigating trees with sewage effluent. Much of the information in this article is extracted from it. The booklet costs $14.95 plus postage and is available from CSIRO Publishing, PO Box 1139, Collingwood, Vic. 3066, (03) 9662 7666, toll-free 1800 645 051, fax (03) 9662 7555, email: marie.ricotta@publish.csiro.au.

Where is the industry growing?

Sewage effluent is being used to speed the growth of trees at many locations throughout Australia. Here are brief descriptions of three of such enterprises, two in Victoria and one in Queensland.

Research and development on effluent-irrigated plantations is being conducted at several sites by the Centre for Forest Tree Technology, a business unit of Victoria's Department of Conservation and Natural Resources. These include Shepparton, Werribee, Orbost and Mallacoota. The Shepparton work, begun in collaboration with the Goulburn Valley Region Water Authority in 1993, is a major focus and includes studies of species growth and the variation between provenances, silvicultural management including thinning and pruning for quality sawlogs, nutrient and salt balances, tree water use and changes in soil properties under various coppice rotations.

Richard Stokes

Thinned six-year-old effluent-irrigated *Eucalyptus grandis* at Shepparton showing six-month-old coppice regrowth between the retained trees.

The centre's Tom Baker says the sustainability of effluent-irrigated plantations can be limited by the trees' declining capacity to sequester nitrogen once they reach closed-canopy stage (see main story). Short crop rotations of three to six years are being used at Shepparton as a means of maximising nitrogen sequestration and removal from the site at harvest. The impact of such short rotations on water use by the plantation and the value of the product is being studied.

At Orbost in eastern Victoria, a 30-hectare irrigated plantation consisting of 36 000 trees was established in 1992/93 by the Victorian Department of Conservation and Natural Resources and the Orbost Water Board (now East Gippsland Water).

The plantation was set up to handle an increase in waste water generated by the townships of Orbost and Marlo whose combined population is 4000. Trees were chosen in favour of extending an existing pasture-irrigation system because of the greater potential for economic return, and the opportunity it offered to test a range of eucalypt species under these conditions. Some 270 megalitres of effluent can be disposed of annually in the plantation which is irrigated for four months of the year. The effluent is stored in a winter lagoon between irrigation periods.

Superintendent of Works at East Gippsland Water, Russell Bates, says the plantation is proving to be an effective means of land-based waste disposal, the alternative to which may have been ocean discharge. He says the trees will be harvested at 10 to 15 years of age and processed locally for pulp.

In Queensland, the WC Fields Effluent Re-use Project involves waste water from the Cleveland Sewage Treatment Plant on the edge of Moreton Bay being applied at different rates to grass and eucalypt trees. The project is led by Ted Gardner of the Queensland Department of Primary Industries Resource Management Institute, and Dr Peter Dart from the Centre for Integrated Resource Management at University of Southern Queensland. It is supported by the Redland Shire Council and the National Landcare Program.

Gardner says the project is addressing the issue of how various effluent nitrogen levels affect the rate of leaf biomass production (required for nutrient storage) compared with the leaf area development, required for transpiration. It is also examining the water use, biomass production and nutrient storage of eucalypts versus grass pasture.

Over yearly time steps, trees will use up to 50% as much water as grass for similar biomass production. For a given yearly volume of sewage effluent, this has substantial practical implications to the irrigation area and wet weather storage volumes required for environmentally sustainable effluent re-use. The crop with greater water use would require smaller and less expensive irrigation areas.