Restoring Nature's Balance

The Potential for Major Reforestation of South Western Australia

by Syd Shea and John Bartle

The coincidence of a number of factors has provided the opportunity for the establishment of extensive plantations of Eucalyptus globulus (Tasmanian Bluegum) on cleared agricultural land in the south-west. If the full potential of this opportunity is realised, a new industry could be created which, by 10 years, could generate up to $400 million in export income, provide a new source of income for farmers and make a significant contribution to the reduction of salination and phosporus pollution at no cost to the community.

Marie Lochman

In the last 150 years, vast tracts of southern Australian native eucalypt woodland and forest have been converted to agricultural use. This has involved nearly complete removal of the tall, perennial native species and their replacement with low, annual crops and pastures. These changes in vegetation density and type have caused major changes in the water balance which in turn profoundly affects soils, streams, rivers and estuaries.

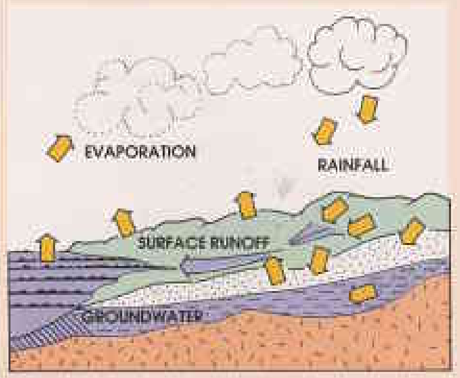
The result, in south-west Australia, was the salination of half the freshwater streams and the pollution of most coastal wetlands and estuaries.

Farmers are not to be blamed. To remain viable, a farmer had to clear native vegetation and fertilise crops. Successive governments provided numerous inducements for farmers to clear land and State departments encouraged the use of fertilisers. All Western Australians benefited from agricultural development in the south-west, so individual farmers cannot be expected to bear the cost of remedying a community problem. But solutions must be found.

A typical salt seepage area in the 600 - 900mm rainfall zone. Reduced water use under agriculture provides surplus water to flush out salt stored in the subsoil, which causes valley waterlogging, salt damaged soils and salinised streams (left).

A MATTER OF BALANCE

Water moves in a cycle through complex pathways between and within the continents and oceans. Solar energy powers evaporation over free water surfaces. In the atmosphere, water vapour is distributed in global wind systems to eventually be precipitated as rain, hail or snow. Over land, precipitation may be directly re-evaporated from wetted surfaces, or extracted from soil water storage by plant roots to be evaporated from leaves in a process called transpiration. These two types of evaporation are together called evapotranspiration. Precipitation can also be stored in the soil or infiltrate more deeply to recharge ground water systems.



Direct surface run-off and discharge from ground water systems forms streamflow which returns water to the ocean to complete the cycle. The principle of the conservation of mass applies in the water cycle, i.e. no water can be lost from the system, though it may change state (solid, liquid, gas) and travel along some very slowly moving pathways (deep regional ground water systems, glaciers). Thus the flow of water through an ecosystem is in equilibrium.

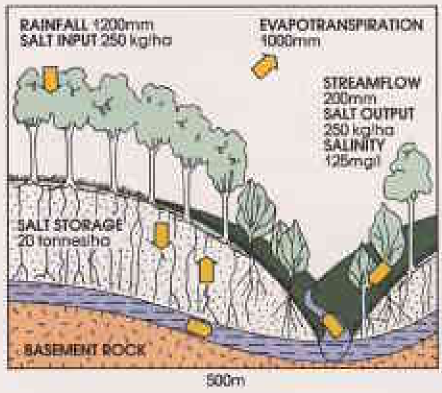
The characteristics of the water cycle of a particular area is studied by constructing a budget. This is a simple accounting of inputs (rainfall), change in storages (soil water, ground water), and outputs (evaporation, transpiration, streamflow, deep leakage loss), where inputs equal outputs, corrected for any change in storages. Water budgets are usually calculated for natural drainage basins or catchments because it is relatively easy to measure output with stream gauging stations.

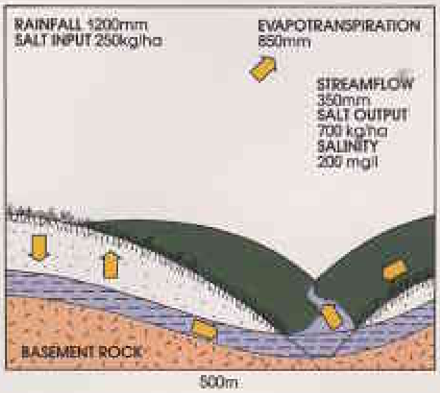
The Water cycle (Left).

Any changes in the components of the water cycle will cause the existing **balance** between inputs, outputs and storage to change. The most readily changed component of the water cycle is evapotranspiration. Any change in the density and type of vegetative cover on an area of land will change the water use characteristics of land and its water balance.

Where evapotranspiration is reduced, either storage or other output components must increase to maintain the balance. This might be expressed as an accumulation of ground water, an increase in the area of moist or waterlogged land and an increase in streamflow. Where transpiration is increased, moist areas and wetlands may contract and streamflow diminish.

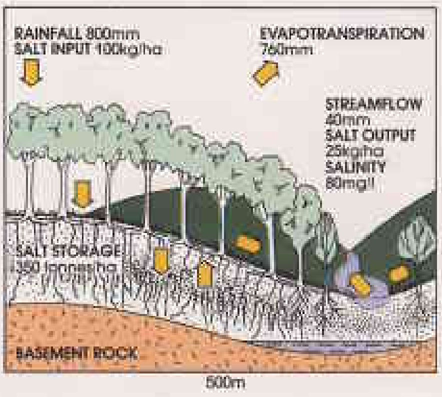
Changes in land use which have altered vegetative cover and thus changed the water balance are the cause of major environmental problems in southern Australia.

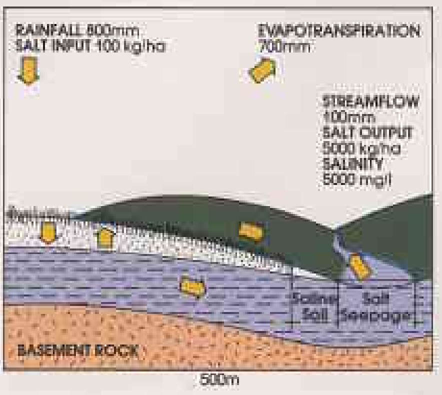




In the high rainfall areas sufficient rainfall passes through the soil to prevent salt accumulation, even though the natural vegetation consumes a large proportion of the rainfall. (far left).

The removal of native vegetation causes marked increases in streamflow, but stream salinity does not increase significantly because there is little salt stored in the soil (left).





In low rainfall areas the vegetation uses almost all of the rainfall. Even though large quantities of salt accumulate in the soil the system is in equilibrium and stream salinity is low (far left).

When the high water-consuming native vegetation is removed, evapotranspiration decreases and the water table rises mobilising the salt stored in the profile (left).

SALINATION

The concepts of 'cycles' and 'balances' can be applied to the movement of salt through an ecosystem. In the south-west of W. A. large inputs of salt in rainfall, deep soils with a large capacity to store water, a generally moderate terrain which results in sluggish drainage and a native vegetation which is highly adapted to consume water, combine to make salt a uniquely important factor in the water cycles of south-west ecosystems.

As the winds which bring rain to the south-west of Western Australia sweep across the Indian Ocean they absorb salt, so that on average between 60 and 260 kg of salt are deposited each year on each hectare of forest.

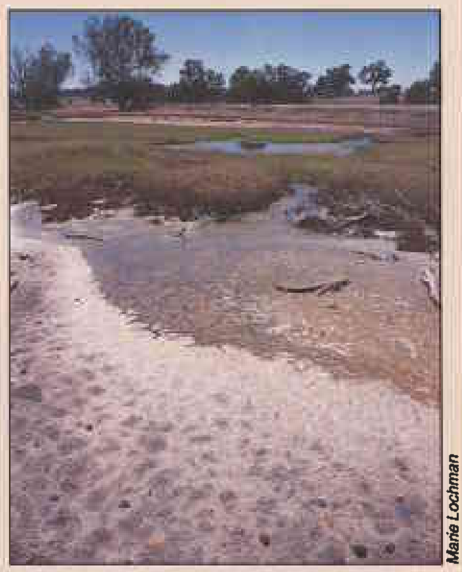
Where the soil is either porous or shallow, permitting rapid movement of water through the profile, or where rainfall is high, most of this salt is flushed from the soil and accumulation does not occur. However, in lower rainfall areas or where the soils are such that only slow movement of water occurs, the deep-rooted native vegetation consumes nearly all of the rainfall. The roots absorb the water but not the salt. Over thousands of years large quantities of salt have accumulated in the soil over large areas of the Darling Plateau. The distribution of salt broadly follows the rainfall gradient across the Darling Plateau. In the high rainfall zone on the western edge of the plateau salt storage is low but it increases progressively as annual rainfall falls below 1 100 mm.

While the vegetation is undisturbed, the system remains in equilibrium and stream salinity is low - even when there are large quantities of salt stored in the soil.

When the native vegetation is replaced by agricultural crops or pastures, there is a reduction in evapotranspiration. The response in water and salt balances varies across the rainfall gradient, such that three distinct zones can be identified. In the High Rainfall Zone (greater than 1 100 mm rainfall per annum), the extra water passing into ground water and out in streamflow never results in a significant loss of water quality.
In the Intermediate Rainfall Zone (900-1 100 mm rainfall per annum) a moderate stream salinity effect may be observed. However, in the Low Rainfall Zone (less than 900 mm rainfall per annum) the accumulation of ground water mobilises the stored salt to create salt seepage areas on the valley floors which damage agricultural soils and greatly reduce stream water quality.

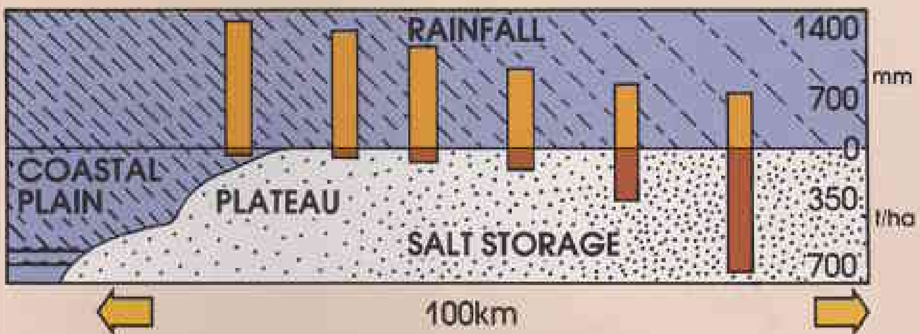
Most of the State's agricultural land lies in the low rainfall zone : more than 300 000 ha of previously fertile farmland is salt damaged and about half of the total water resource of the south-west region has been degraded.

The 600-900 mm rainfall portion of the low rainfall zone is the major target for reforestation. The 600mm isohyet marks the rainfall limit for commercial forestry and also encompasses all of the water catchments with potential for rehabilitation, in particular the Wellington, Warren, Kent and Denmark catchments.



Salt seepage areas in the 600-900mm rainfall zone (above).

Evaporation from the salt seepage areas can cause a surface crust of salt to develop (below).



As rainfall decreases, salt accumulation increases (above).

WHAT IS EUTROPHICATION?

Agricultural crops need a high level of nutrients, which is usually supplied by fertiliser. Any excess of nutrients can move into streams and drainage lines and end up enriching lakes, wetlands and estuaries. Too many nutrients leads to abundant aquatic plant growth, especially of algae. This process, called eutrophication, has profoundly detrimental effects on the ecology of a water body. Large masses of algae can accumulate on the shoreline, generating obnoxious odours as they rot, and preventing beach access.

The Peel-Harvey Estuary's major conservation and recreation values are severely threatened by eutrophication. But almost every estuary and wetland in the south-west is suffering to some degree.

Phosphorus inflow to the Peel-Harvey Estuary has increased six-fold in the last three decades; it is the major nutrient causing eutrophication. The phosphorus inflow is greater than the rate of discharge into the ocean. The surplus has accumulated in sediments. The phosphorus stored in the sediments is now so large that it will sustain algal growth even in years of low streamflow and low phosphorus input.

About 60% of the phosphorus input originates as superphosphate fertiliser applied to infertile sandy coastal plain farmland, which makes up less than 9% of the whole catchment area draining into the estuary. These sandy soils have little capacity to bind phosphorus, and are very porous. Winter rainfall readily leaches phosphorus from the soil into surface drainage. The efficiency of leaching is greatly enhanced by the water balance under agriculture: with the trees gone, there is less evapotranspiration of water, causing an increase in the seasonal duration of surface (and shallow sub-surface) water movement and the doubling of streamflow. The construction of drains in some areas has further increased the efficiency of the leaching process.

Algae deposited on the shoreline at Falcon Beach (above).

Aerial view of floating algae in Austin Bay in the Peel Inlet (left).

Delta of the Harvey River which delivers phosphorus enriched water into the inlet (bottom left).

Drains constructed to reduce water logging in low-lying areas of the Peel/Harvey catchment also increase the amount of phosphorus in the estuary (below).

LOOKING FOR SOLUTIONS

Salinity and phosphorus pollution (eutrophication) involve complex social, economic and technical problems.It is now recognized that no single measure will produce a solution. This has given rise to the concept of 'integrated catchment management' where a range of measures, tailored to the particular locality, will combine to produce a satisfactory solution.

A major step in developing a solution was compulsory bans on the clearing of native vegetation in selected salt-prone catchments. Introduced in 1976, these bans did halt rapid deterioration in water quality. Even if no further clearing of native vegetation occurs, however, stream salinity will continue to increase in areas where native forest has given way to agriculture. Also, the compensation and social costs of the bans were high. Compulsory measures to achieve change in land use can only be a last resort.

The Department of Agriculture has conducted research on systems of agriculture which are less prone to cause salination. The water use of conventional crops and pastures has been determined; there has been better definition of the capability of soil and land to sustain particular water use regimes; salt-tolerant species and management practices have been identified to utilise salt-damaged soils in seepage areas; and perennial grazing shrubs such as tree lucerne have been evaluated. Drainage systems which increase the outflow of surface (or shallow sub-surface) water to reduce water logging and the infiltration to saline ground water systems, have also been developed.

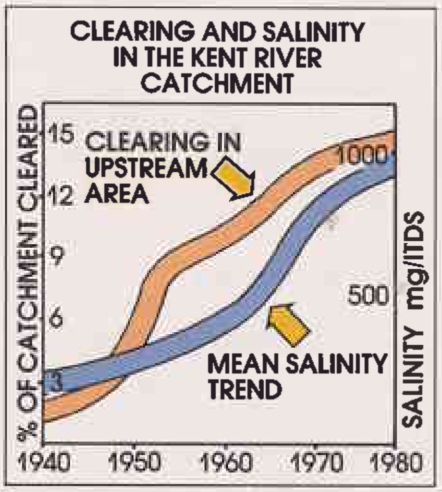
On the coastal plain a variety of strategies are being employed, or have been proposed, to reduce phosphorus pollution of the Peel-Harvey Estuary. These include fertilisation modification programs, the regulation of point sources of phosphorus pollution (e.g. piggeries) and the construction of a channel to the ocean to improve water exchange.

The role of trees

Since salination results from the conversion of forest to agricultural crops, an obvious strategy was to reverse the process by planting trees. However, it was considered that it would be unwise to use native species (for example, jarrah) because of their susceptibility to jarrah dieback. There were doubts that tree species could be identified that would be able to grow on the harsh soils of the Darling Plateau and duplicate the high water consumption capacity of native forest. Consequently research was undertaken to identify tree species with high water consumption capacity and an ability to withstand harsh soil conditions. Several outstanding high water-consuming tree species have been identified.

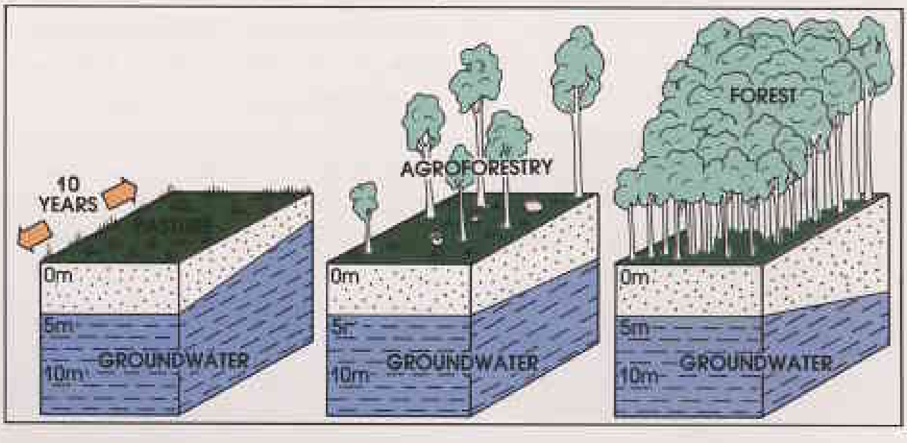
Attempts were also directed at identifying tree species which combined high water consumption, tolerance of adverse soil conditions and high commercial productivity. Trials have also been conducted to evaluate the potential for tree growing at densities which permit agricultural production, i.e., agroforestry.
Unfortunately, most of the tree species which have a high water consumption capacity are not commercially viable.

More recent research indicates, however, that high water consumption requirement is not as important as had been assumed. Dramatic reductions in water table levels have been observed under forest stands of several different tree species, including species with commercial potential. In some areas, the re-establishment of a forest on agricultural land has caused watertables to be reduced by four metres.



The stream salinity trend closely follows the trend in agricultural clearing (left).

Field trials have shown that the re-establishment of forest on cleared land will rapidly cause the water table to fall, which reduces the discharge of salt into streams and the area of water-logged, salt-affected soil in the valley bottoms (below).



Marie Lochman

Jiri Lochman

Seven-year-old *E. globulus*, east Wellington catchment. This stand produced 20m^3 per ha per annum (far left).

E. globulus can resprout from the stump (coppice) to produce a new crop, doing away with the need to replant (left).

Ten-year-old *E.microcarpa*, east Wellington catchment. This species has high water use but little commercial value (below).

Cliff Winfield

Trees and the reduction of phosphorus pollution

It is estimated that a reforestation program of 55 000 hectares on soils of the coastal plain which are most susceptible to phosphorus leaching will reduce the total phosphorus input into the Peel-Harvey system by 25%.

Trees are more efficient users of fertiliser because their roots fully explore the soil profile and tap the water table. Thus they are also able to absorb nutrients over a longer period of the year than agricultural crops. Less phosphatic fertiliser is required to grow trees and the application can be timed to minimise direct runoff into streams.

A tree crop's capacity to lower the ground water table will also contribute to a reduction in fertiliser pollution. A reduction in the water table would reduce lateral surface and sub-surface flows of water which are the principle pathways of phosphorus entry into drains and streams.

Why Bluegum?

The Western Australian Water Authority has undertaken a major reforestation program in the Wellington Catchment involving the planting of 5 000 hectares of re-purchased farmland. This programme has cost 10 million dollars. The tree species being planted in the Wellington Catchment have primarily been selected for their high water consumption and salt tolerance. Most have little potential for wood production. It will be possible, and in some situations necessary, to establish non-commercial trees. But the cost incurred by the community to compensate for income foregone by farmers makes the large-scale establishment of non-commercial trees impractical.

The major eucalyptus species which have been planted for wood fibre around the world are *Eucalyptus grandis*, *Eucalyptus saligna* and *Eucalyptus globulus* (Tasmanian Bluegum). In W.A. over a number of decades, trial plots of tree species have been established on different site types. Of the paper producing species, bluegum is the superior performer.

Bluegum has wood quality characteristics which are ideal for high quality paper production. It also has the capacity to grow on a wide variety of soils although its growth rate varies according to soil type and rainfall. The average growth rate in the target area for planting is estimated to be 20 cubic metres per hectare per annum, but on high quality sites it may exceed 40 cubic metres per hectare per annum.

Growth rates and fibre quality could be significantly increased by tree breeding and more intensive site management.

Bluegum can be grown on a rotation between 7 and 13 years depending on soil type and rainfall. Two further rotations could be obtained after the initial planting at minimal costs because bluegum, like many other eucalypt species, resprouts from the cut stumps.

The economics of bluegum plantations are such that farmers entering into an annuity scheme could receive annual net payments between $50 and $250 per hectare depending on site quality. These payments compare favourably with that obtained from traditional agricultural crops.

The projected rates of return for an investor in the scheme - between 10 per cent and 18 per cent real - are highly competitive. The investment is further enhanced because it would qualify as a legitimate primary industry tax deduction.

THE ECONOMICS OF BLUEGUM PLANTATIONS

The current price for marri and karri woodchips is $10.29 per cubic metre. But this type of woodchip material is less suitable for paper production than bluegum. For example, on average the yield of pulp from marri and karri chips is 42 per cent, compared with 58 per cent from bluegum. This and other factors mean that bluegum would be priced between $15 and $25 per cubic metre. It is likely because of the projected deficit in wood supply that the price will increase over time at rates greater than inflation.

One of the most simple analyses of the commercial viability of bluegum is to compare cost and returns over the rotation. On an average site, it is expected that it would cost approximately $1 300 per ha to grow a plantation of bluegum to maturity at age 10 for a return of (assuming wood price at the stump is $20 per cubic metre) $4 000 per ha.

But when computing the economic return from tree crops, allowance must be made for the time delay between expenditure and returns. The most simple way of assessing the profitability of bluegum plantations is to compute the rate of return (interest rate) on the investment over the 10 year period of the plantation. Economic models have been developed by CALM which allow a range of costs and price inputs to calculate the rate of return. If a price of $20 per cubic metre is assumed, on sites producing 20 cubic metres per annum the rate of return would be approximately 14 per cent real. This means (assuming an inflation rate of 6 per cent) the nominal return on an investment in bluegum would be 20%.

Another way of assessing the commercial viability of bluegum is to calculate the annuity which could be paid for a farmer using the softwood sharefarming model. On farms which produced average growth rates (assuming a $20 per cubic metre price for wood) the annuity rates would vary between approximately $50 - $120 per ha. On sites where productivity is higher, the annuity could increase to $250 per ha.

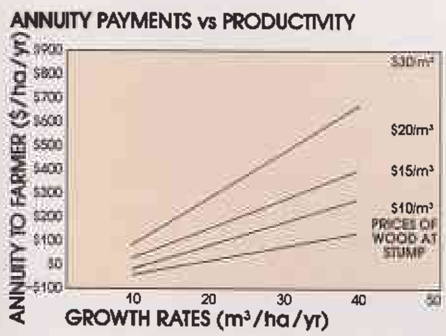
Some indication of the overall benefit of a major reforestation program based on bluegum to the State can be obtained by showing the total costs and returns over a period of years.

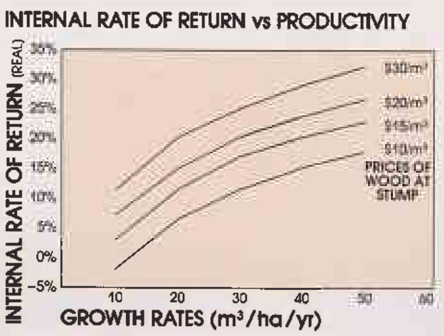
If, for example, a 10 000 ha program of plantation establishment was initiated and maintained for a period of 10 years and then two further rotations of bluegum were grown from coppice from these plantations, the gross return per annum in year 10 would be approximately $120 million. This gross return could be sustained indefinitely at an annual growing cost of approximately $15 million.

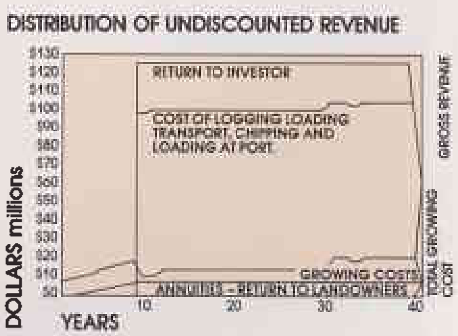
Annuity payment to landowners in an *E. globulus* sharefarming scheme, for various growth rates and log prices (below).

Profitability of *E. globulus* forestry, for various growth rates and log prices (centre).

Distribution of export revenue in WA from *E. globulus* sharefarming. (Based on a planting rate of 10 000 ha/yr for 10 years (right).







THE DEMAND FOR PAPER

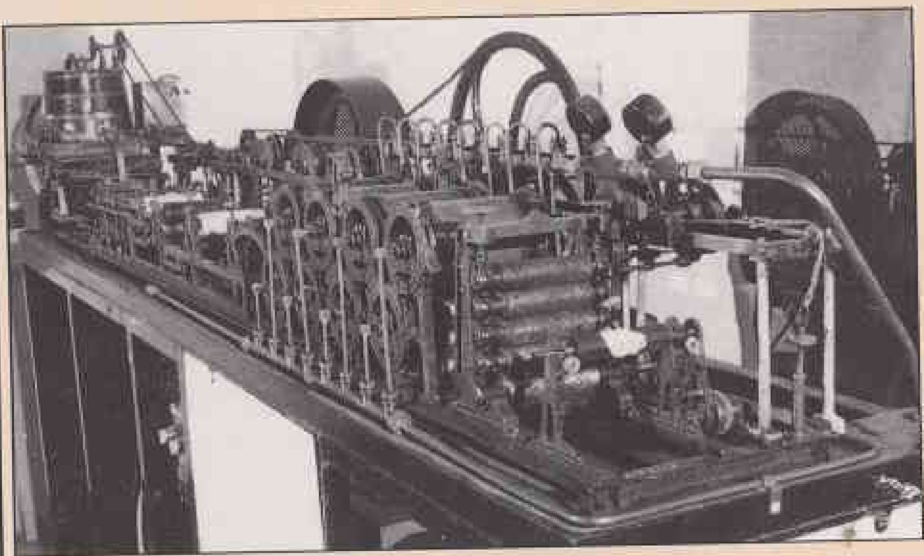
There has been a significant increase in the demand for high quality printing and writing paper, despite predictions of the development of the 'paperless office'. For example, in the United States the growth in demand for printing and writing paper is increasing 4% per annum. If this annual growth rate is applied to current world consumption of paper pulp suitable for high quality paper - 40 million tonnes per annum - there will be an increase in demand of 1.6 million tonnes per annum.

The suitability of eucalyptus fibre for fine paper production was first demonstrated by I H Boas at the Perth Technical College in the 1920s. Increasingly, pulp producers around the world are using eucalypts to meet demand for high quality paper. Eucalypts have optimum fibre characteristics for the production of printing and writing paper.

Large quantities of eucalyptus wood fibre are being produced from plantation growing eucalypts around the world. Ironically, Australia, home of the eucalypt, has only 40 000 ha of eucalypt plantations. Brazil has established 2.2 million hectares and Spain, South Africa and Portugal each have more than 400 000 ha of eucalyptus plantations.

Several countries are proposing to or have increased their plantation establishment rate. But despite this, it is conservatively estimated that by 1997 the demand for eucalypt wood fibre for Japan alone, will exceed supply by 5.5 million cubic metres per annum. This represents a doubling of the current Japanese hardwood fibre imports.

Between 250 000 - 500 000 ha of eucalyptus plantations would need to be established within three years to make up this deficit.



Courtesy C.S.I.R.O.

Some of the early work which established the large world eucalypt pulp/paper industry was done in Western Australia. This machine was used by I. H. Boas at the Perth Technical College in 1918-21 to make paper for comparison of the value of various species and processes for paper making.

Tasmanian Bluegum

John Bartle

Tasmanian bluegum (*Eucalyptus globulus*) occurs naturally in S E Tasmania, the Bass Strait Islands and S. E. Victoria. Its low level of frost tolerance restricts its distribution to low altitudes and near coastal locations.

Its common name refers to the blue-green foliage of the seedling plant. The juvenile foliage is quite different from the mature foliage.

A twenty-year-old stand of *E. globulus*, near Manjimup (left).

The mature tree is smooth-barked, and looks similar to karri.

Seed collected by British and French explorers in the 18th century were the basis of the first overseas plantings. The species proved very adaptable and productive, and it has become the most important temperate zone eucalypt in world forestry. It is also widely planted at high altitudes in tropical latitudes. Its common uses include fuelwood, poles for roundwood construction, sawn timber, and more recently it has become a major pulpwood species. International plantings now exceed two million hectares.

LEGEND
ISOHYETS
FOREST AREAS
CATCHMENT AREAS
PLANTING ZONES
COASTAL PLAIN
INTERMEDIATE RAINFALL (900-1100mm)
LOW RAINFALL (600-900 mm)
RIVERS
SHORT FORESTED (FRESH)
INTERMEDIATE, PARTLY CLEARED
LONG, LARGELY CLEARED (SALINE)
SCALE
INDIAN
OCEAN
SOUTHERN
OCEAN
Toodyay
Wanneroo
York
PERTH
Mundaring
Jarrahdale
PEEL
HARVEY
Dwellingup
Boddington
Harvey
Bunbury
Collie
WELLINGTON
Busselton
Kirup
Augusta
Manjimup
WARREN
Pemberton
KENT
DENMARK
Windy Harbour
Walpole
Denmark
Albany
Kalgan
N

Area available for planting

Within the 600 mm rainfall isohyet there are approximately 1.5 million hectares of private land within economic haulage distance from the ports of Bunbury and Albany. One-third is located on the coastal plain and two-thirds on the Darling Plateau. Approximately one-third of this land retains native vegetation and under current government policy would not be available for planting. Preliminary surveys indicate that approximately 500 000 ha would either not be suitable for bluegum planting or would be more suitable for agriculture. The remaining, approximately 500 000 ha of cleared agricultural land, could potentially be planted with bluegum.

It is possible to purchase and replant farms, but, apart from the large expenditure which would be required for a land purchase program, land purchase could cause social disruption. Land purchase by government or large companies is perceived by local residents as being detrimental to the community.

In any case, it is unlikely either for environmental reasons or for commercial tree growing that it would be desirable to purchase and replant whole farms. In some situations, whole farms may be suitable for planting. But it is anticipated that on most farms only a proportion of the land will be suitable for bluegum either because the soil conditions are unsuitable, or alternative agricultural crops are more profitable. The environmental benefits of tree planting would also be maximised by strategic rather than whole farm planting. It is possible that a variety of planting strategies could be used. For example, in addition to 'block' plantings, strip planting of various widths could also be employed. Planting locations would be specified as part of an integrated catchment plan based on the particular local attributes of that land.

SOFTWOOD SHAREFARMING

Pinus radiata is a highly productive and profitable species. But it takes between 25 to 30 years to grow to maturity and to realise the income. The softwood sharefarming scheme overcomes this problem by paying farmers an annuity. The scheme also encourages farmers to manage the plantations under contract to CALM thus contributing to on-farm employment. In addition to an annual payment, the farmer receives a percentage of the return from harvesting the final crop. For example, a farmer contributing 100 ha to the scheme on relatively high quality sites would receive $7 000 per year, indexed against inflation and $30 000 at the end of the rotation.

Over 3 000 ha has been planted under the softwood sharefarming scheme and it is expected the majority of the State's annual target of 2 000 ha per year will be planted on farms using the scheme.

Pine trees will help reduce salinity and phosporus runoff, but the State's annual planting program of 2 000 ha per year is not large enough to have a significant effect on regional water balance problems. The 2 000 ha program is designed to meet local demand for timber and any additional plantings could only be justified if there was a significant export market for pine timber. This is unlikely to develop in the foreseeable future. But the 'sharefarming' model can be applied to growing short rotation eucalypts. In addition to overcoming the problem of the delay on return from tree crops, sharefarming makes it easier to integrate the plantations with existing farm activities and maximise their environmental benefits.

Farmer participation

Any scheme involving the establishment of extensive bluegum plantations on private land would be voluntary. Individual farmers may choose to undertake tree cropping with bluegum independently, but the most attractive proposition for farmers is likely to be a scheme based on the already proven softwood sharefarming model. Sharefarming permits advanced payments in the form of annuities, minimises the risks to individual farmers, keeps the farmer on the farm and diversifies his income. It also provides the flexibility to make tree cropping competitive with existing agricultural practices and the opportunity to maximise the environmental benefits.

What's been done so far?

The West Australian Chip and Pulp Company (WACAP) has already embarked on a program in the lower south-west which assists farmers using a variety of incentive schemes to establish bluegum plantations. Under this scheme over 1 000 ha of plantation will have been established on 21 different farms by 1988.

The W. A. Government has approved the initiation by CALM of a pilot operational trial of a bluegum hardwood sharefarming scheme which will result in the establishment of between 1 500 and 2 000 ha of bluegum plantations in the catchment of the Peel-Harvey Estuary and the Wellington Reservoir in 1988.

As canopy cover increases so the volume of streamflow decreases. It is therefore possible to deliberately thin the forest to increase the yield of water (right).

Above a threshold level of stand density no further increase in total forest growth occurs. Thinning can therefore be used to reduce canopy cover and stand density without loss of growth potential, as well as to improve water yield (far right).

Can We Do It?

There is little doubt that W. A. has a significant **comparative** advantage to provide a large proportion of the increasing market for wood that can be used to produce high quality printing and writing paper. Our climate, soils, moderate terrain, technical competence and political stability combine to put Western Australia ahead of most other countries which can grow eucalypts. But this advantage will not persist forever.

The principal factors which will determine whether W. A. can capitalise on this opportunity are the availability of sufficient capital to initiate the scheme and the preparedness of farmers to grow bluegum plantations as an alternative crop.

PROSPECTS FOR A PULP MILL IN W.A.

One of the major criticisms of the current W. A. woodchip industry is that the full potential of the resource to generate export income is not achieved because the woodchips are processed into pulp and paper in Japan. There have been a number of investigations undertaken by WACAP of the potential to establish a pulp mill in W. A. over the period since woodchips were first exported. But up until recently the commercial environment has not been favourable. In the last two years, however, the environment has changed and a new feasibility study is being undertaken by WACAP.

A pulp mill's viability is dependent on size. The minimum size of a viable mill is between 250 000 and 350 000 tonnes per year. A mill of this size would cost $750 million to build.

Before an investment of this magnitude is made, investors need to be assured of the long-term security and quality of the resource.

A bluegum plantation program of 100 000 ha would ensure the continued supply of high quality fibre to a mill and would significantly enhance the prospects for the establishment of a pulp mill in W. A.

In addition to the employment generated during the construction phase, a pulp mill would provide approximately 300 permanent jobs and would generate up to $200 million of export income per year.

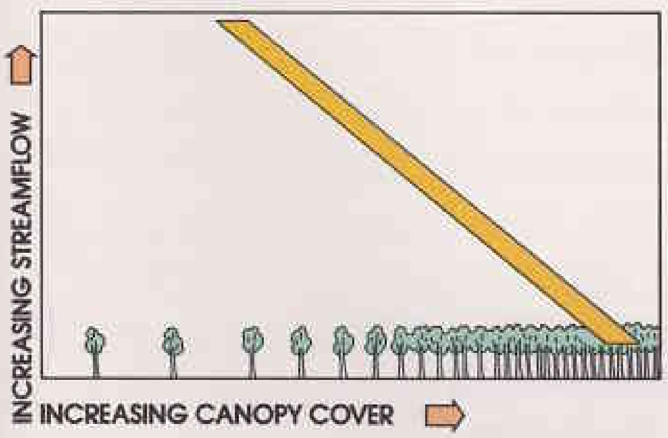
THINNING FORESTS TO INCREASE WATER YIELD

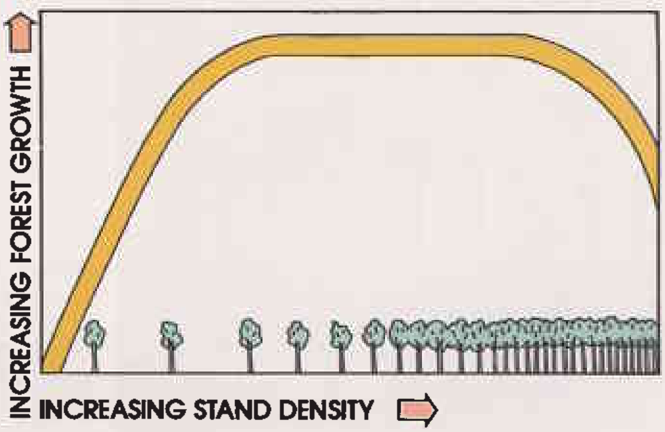
The maintenance or establishment of forest on land which has salt stored in the soil profile is essential to reduce salinity. This is because of the high water consumption by forests. For the same reason, dense tree cover on land where the soils have not accumulated salt reduces the yield of fresh water. It would be detrimental to water production to establish dense forest on cleared land which is not prone to salination. Research carried out over more than 15 years has shown that it is possible to significantly increase the yield of fresh water from metropolitan water catchments by thinning the forest in salt-free areas while at the same time preserving or enhancing other forest values.

Thinning

Most forests thin themselves naturally as they develop - albeit slowly. Thus a hectare of newly regenerated forest may have 100 000 seedlings. But as the stand develops some trees become dominant and rob their neighbours of nutrients, water and light. At maturity the forest may have less than 1 000 trees per hectare.

The jarrah forest is unusual in that volume mortality in dense regrowth stands is very low. Yet virgin stands of jarrah typically consist of relatively few large trees with an almost park-like structure. It is possible that in the past, natural thinning of the jarrah forest was brought about by periodic high intensity wildfire. If the jarrah forest is not thinned it stagnates -





remaining as dense, slow-growing, straggly trees.

The practice of thinning has been carried out by foresters for over 100 years and in W. A. there has been extensive research on techniques and effects of thinning on native and exotic forests. Thinning involves the removal of small and defective trees and essentially duplicates a natural process; thus progressive thinning of native regrowth forest results in it developing a structure, over time, similar to that of the virgin forest.

Thinning and wood production

When scientific management began to be applied to forests in Europe it was assumed that the ideal forest density - that is the one producing the most wood - was one which was abstractly defined as 'normal'. The normal forest was a dense forest and it was assumed that a forest of lesser density was not producing the maximum wood increment. Pioneering work by a European forest scientist, Mar Moller, showed that, in fact, a forest stand produced the same amount of wood over a wide range of stand densities. The so called 'Moller plateau' principle has since been found to apply to many different forests including W.A.'s native and exotic forests.

By thinning a forest stand, the same amount of wood being produced each year is concentrated on fewer trees, thus increasing their growth rate. For example, individual jarrah trees in an unthinned forest stand may take more than 400 years to reach a mature size, whereas in a thinned stand the same tree may take less than 80 years to reach the same size.

Stand density and water yield

Not surprisingly there is a strong relationship between stand density and water yield because the denser the forest the greater the leaf area. Broadly speaking, the greater the leaf area or canopy cover, the greater the consumption of water. For example, in high rainfall catchments in the jarrah forest it was shown that a reduction in canopy cover can nearly double streamflow into reservoirs.

It will be possible to achieve this increase in water yield while at the same time maximising the growth of individual trees and maintaining total forest growth.

There are large areas of regrowth jarrah forest that would benefit from thinning. Since thinning would enhance their development to the same structure as virgin forest, the conservation and recreational values are unlikely to be reduced and tree growth would also be increased.

But the principal benefit would be the impact on water yield of Perth metropolitan catchments. Preliminary estimates indicate that a thinning program on metropolitan water supply catchments would increase the annual water yield by 48 million cubic metres. This extra water could be produced at a cost of between 2 and 8 cents per cubic metre.

The dense *Pinus pinaster* stands which have been established on the Gnangara water mound north of Perth have a negative effect on water production because they use more water than the native woodland they replaced. But the natural water balance can be restored by thinning them to a density which reduces their water use to the same level as the native vegetation.

High quality thinned jarrah forest near Dwellingup. Thinning forest in salt-free areas can increase the yield of fresh water from the forest (left).

Acknowledgements

The information that is presented in this article on salination and eutrophication is a distillation of over two decades of research by many people in State and Federal Government agencies, tertiary institutions, and private companies. The complex nature of these problems is such that a number of disciplines must be employed and integrated before the cause and solution can be found. Western Australia is fortunate in that it has been able to achieve a high degree of cooperation and coordination of research on land and water problems.

Development of the data on the potential of bluegum has been the responsibility of a team of workers in the Department of CALM. We also acknowledge the pioneering work which has been undertaken by WACAP and Mr Gordon McLean of McLean Sawmills (1966) Pty Ltd.

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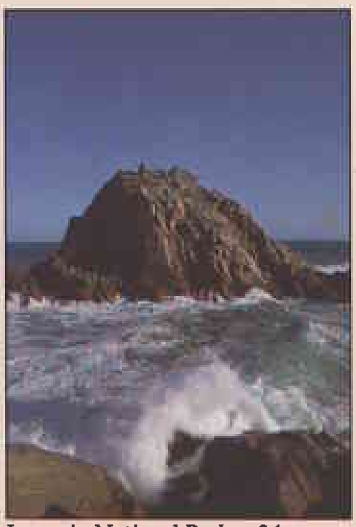

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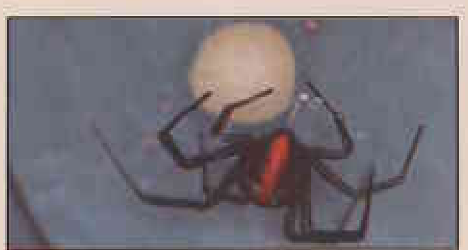

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Managing Editor: Sweton Stewart
Editor: Liana Christensen
Designers: Trish Ryder / Robyn Mundy
All maps by Department of Conservation and Land Management Mapping Section.
Offset plates by The Colour Set
Printed in Western Australia by Kaleidoscope

Published by Dr S Shea, Executive Director,
Department of Conservation and Land Management,
50 Hayman Road, Como, W.A. 6152

Cover Photo
Trees loom out of the mist at Amelup near the Stirling Ranges. Photograph by Robert Karri-Davies.

EDITORIAL

The economic development versus environmental protection debate is a constant feature of our society today. No-one will disagree that our environment needs protection; there is also no doubt that Australia must improve its economic performance if we are to maintain our living standards and enjoy the natural environment which we are blessed with. This *Landscope* describes a project which combines environmental and economic advantages.

Australia's import bill for forest products is $1.7 billion. Of this a considerable portion is paper which is made from eucalypt fibre. A Perth scientist was the first person to demonstrate that eucalypt could be made into paper, yet it is other countries that have capitalised on this discovery. For example, Brazil, Portugal, Chile, South Africa and Spain have established over 3 million hectares of highly productive eucalyptus plantations. Australia, home of the genus Eucalyptus, has only 40 000 hectares of eucalyptus plantations.

Despite our late start, there is no reason why W.A. cannot share some of the rewards which would come from capitalizing on the increasing world demand for high quality paper. We have the land and climate to grow the trees and the skills to do it competitively.

Widespread afforestation of the south-west is also an essential prerequisite to ameliorating salination and eutrophication of our waterways. It is unlikely that afforestation of the magnitude required could be achieved unless it is commercially driven. The production of trees for paper could provide the opportunity to carry out the afforestation program necessary for improving the environment at no cost to the State.

It would be ironic if the world demand for the much maligned woodchip provided the solution for what would arguably be two of the most serious environmental problems in south-western Australia.