QUEENSLAND **AGRICULTURAL JOURNAL**

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Special issue
AGROFORESTRY

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Editor K. N. Robinson

Artwork P. Wellings

Cover R. B. Eggleston's property 'Melrose' at Condamine Plains. Trees provide many benefits to this irrigation property with shelterbelts for crops and farm dams improved for wildlife. In the background retained vegetation along the Condamine River protects the riverbank and forms a corridor for the movement of wildlife in the region.

Photograph National Parks and Wildlife Service

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The Honourable the Ministers of Primary Industries and Forestry, N. J. Turner and W. H. Glasson, are pictured examining a copy of a *Queensland Agricultural Journal* article 'Trees on the Farm'.

Ministers' foreward

It is the policy of the Queensland Government to encourage landholders to plan their land use, and to maintain adequate tree cover on areas which are unstable or unsuited for food production. This policy can be best carried out by landholders through education in the benefits of good land management, supported by cooperative research from the Departments of Primary Industries and Forestry.

The problems caused by overclearing are manifold: secondary salinity on valuable valley floor farmland, weed regrowth following pasture degeneration, land slips, stream bank erosion, and pollution of streams and siltation. The management of existing trees on farms, and the planning and development of new tree plantings can fulfil the six basic objectives of this policy:

- *control of salinity;*
- *stabilisation of erodible areas;*
- *provision of shelter and windbreaks;*
- *maintenance of water quality;*
- *wildlife conservation; and*
- *timber for farm use and commercial production.*

The papers in this edition of the Queensland Agricultural Journal *outline simple and practical ways for landholders to deal with these issues. They provide guidelines on how landholders can maintain a healthy tree cover, and how to go about planting trees to ensure the best results. They represent a large body of information arising from close cooperation between the Departments.*

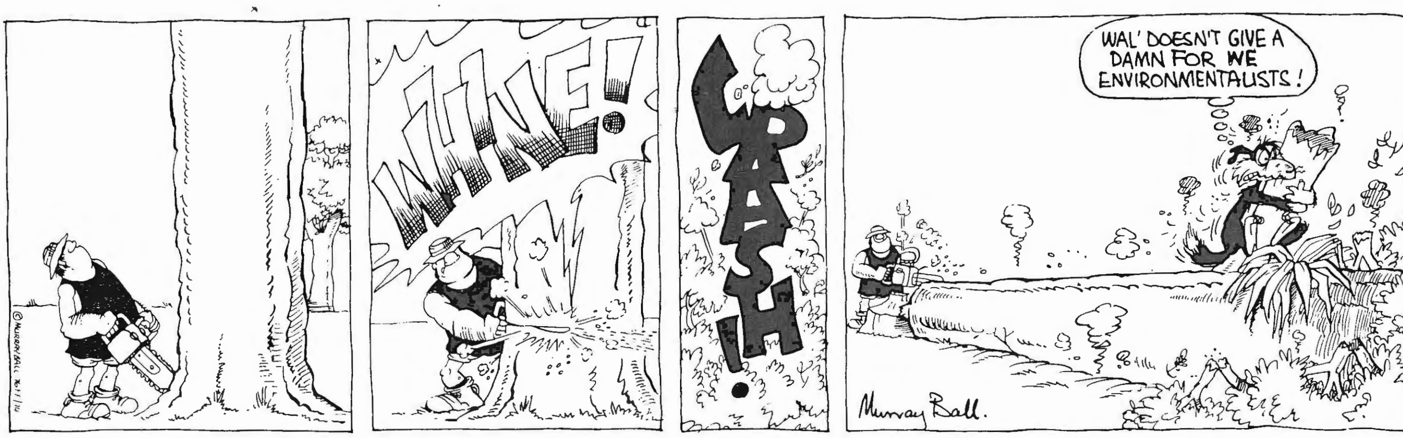
Foresters and agriculturists consider the depletion of Australia's arable land through erosion and salination, largely brought on by overclearing, to be an urgent national conservation problem. It is one which has led to serious environmental and economic losses. These papers provide information for landholders to plan balanced development.

N J Turner

(N. J. Turner)
Minister for Primary Industries

W H Glasson

(W. H. Glasson)
Minister for Lands, Forestry and Police



About this issue

The concept of devoting an entire issue of the Queensland Agricultural Journal *to the topic of agroforestry grew from an idea by Peter Johnston, Senior Land Resources Officer with the Queensland DPI. For this reason, Peter has acted as co-ordinating guest editor of this issue, the largest single issue of the journal so far published.*

Agroforestry may be defined as the integration of agricultural and forestry production systems. Peter prefers to broaden the application of the term to include any use of trees on farms: for control of erosion or salinity, nature conservation, shelter and shade for stock, windbreaks for crops as well as for production forestry for wood, pulp or forest products. The collection of papers within this issue follows that theme, bringing together the ideas of many authors.

Early in 1983 the Departments of Forestry and Primary Industries were becoming closely involved with agroforestry issues and a series of extension articles was seen to be needed to communicate the accumulated knowledge to landholders. Peter was the author of an agroforestry article 'Trees on the farm' and knew that a number of other groups were active in the promotion of tree planting and retention on farmlands. He believed that some of these groups would wish to contribute to the issue.

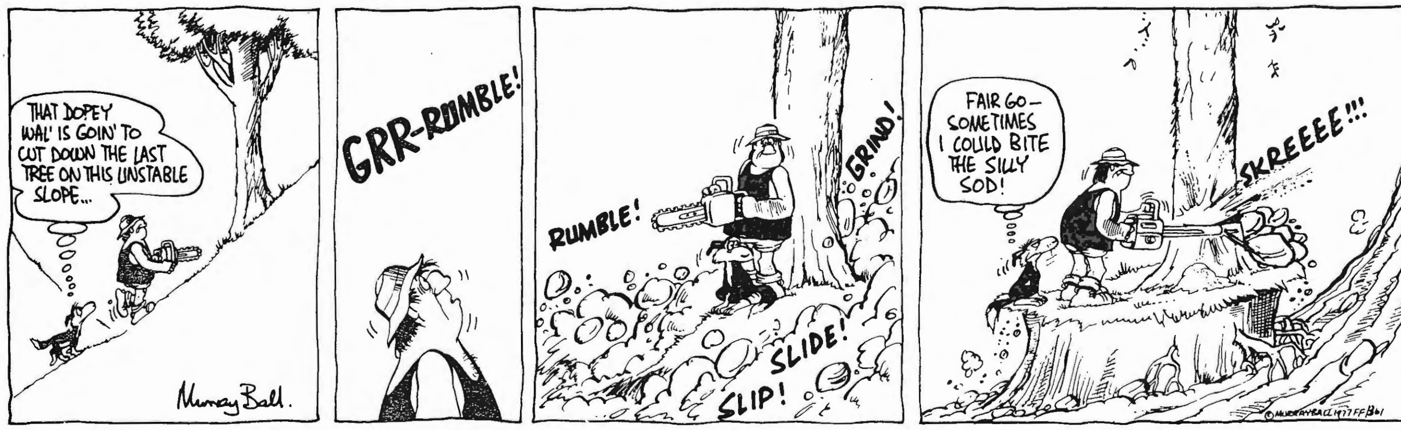
After the Department of Forestry offered to write some articles he approached other branches within the DPI, the CSIRO Division of Forest Research, the Men of the Trees, Greening Australia (Queensland), the National Parks and Wildlife Service, the Urban and Environmental Geology Section of the Mines Department, the Water Research Foundation and the Australian Forest Development Institute. This issue is the result of that action.

Peter Johnston has long been involved with trees and agroforestry in both his private and working life. He is a councillor of the Men of the Trees, sits on the executive of the Northern Chapter of the Australian Forest Development Institute and is a member of the National Parks Association. He is currently researching land management aspects of dieback in native trees having previously worked on the importance of trees in landslip, salinity and erosion control.

Peter is an enthusiastic fan of Murray Ball's Footrot Flats characters. As the reader will soon appreciate, the dog expresses many sentiments close to his own.

In 1985, Peter plans to act again as co-ordinating editor, to help prepare an issue of the Journal *devoted to a study of land degradation in the State. More exactly, the issue will deal with land rehabilitation, since the emphasis is to be on the positive aspects of this huge problem.*

Peter Johnston is pictured in a saline area in south east Queensland, where obviously trees are needed to begin the process of reclamation.



Rural tree dieback

F. R. Wylie, Division of Technical Services (Research and Utilisation), Queensland Department of Forestry, and P. J. M. Johnston, Land Resources Branch

Dead or dying native trees are becoming a common sight in many parts of Queensland. In the last decade, rural tree decline (or dieback) has been recognised as an Australia wide problem. It is attracting considerable community and government attention (for example, New England dieback in New South Wales and jarrah dieback in Western Australia). In Queensland, as a result of this concern, a number of Queensland government departments including DPI, Forestry, the Water Resources Commission, Lands, and National Parks and Wildlife Service are looking at dieback in our State.

Much of the information in this article stems from a dieback survey conducted by the authors during the past 3 years. This survey involved over 200 landholders in an area stretching from the New South Wales border north to Rockhampton and from the coast west to Longreach.

Below are answers to some of the questions most commonly asked about rural tree decline.

Figure 1. Occurrence and severity of dieback in central and southern Queensland, from a 1981–3 survey.

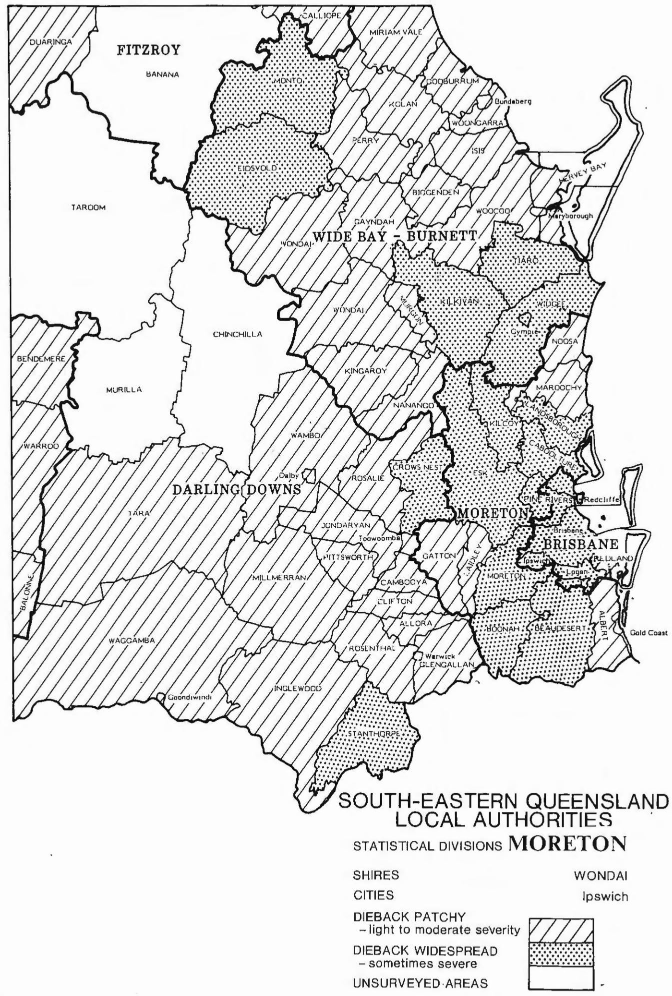
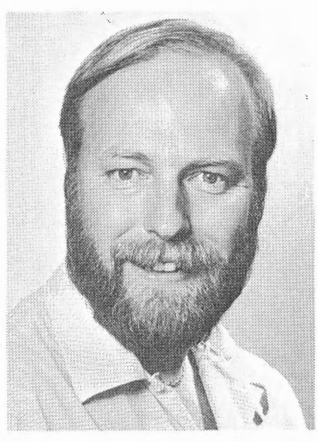


Figure 2. Occurrence and severity of dieback in south eastern Queensland, from the same survey.

Ross Wylie Ross is an entomologist in the Department of Forestry's Forest Research Branch. He has been centrally involved in research on rural tree dieback in southern Queensland.



Peter Johnston Peter, a Senior Land Resources Officer with the DPI, has conducted projects concerned with trees on farms since 1970. At present he is responsible for several Branch programmes on agroforestry, rural tree dieback and local authority land use planning.

What is dieback?

Dieback is the progressive dying back of tips or branches in the crown of a tree which, if unchecked, may lead to tree death. A tree with severe dieback in its crown has most minor or major branches dead and leafless and the remaining crown comprises mainly secondary or sucker regrowth on branches or stems. This stag headed appearance of many trees is often a sign of declining vigour and premature death. However, the tree may not die for many years after the first appearance of dieback symptoms. It is important to understand that dieback is better described as a 'condition' rather than a 'disease' (although disease may be involved).

What causes dieback?

There are many factors, acting individually and together, which contribute to the present widespread decline of rural trees. These factors may vary from place to place, and our knowledge of all the reasons for tree decline is far from complete. Many trees have died as a direct or indirect result of human activities on the land, but other factors such as drought, flood, fire, frost, wind, insect attack or pathogens also affect the health of large numbers of trees over broad areas at any one time.

In some cases of dieback, it is possible to identify a single major causal factor. For example, in Western Australia, jarrah dieback is largely caused by the root rot fungus *Phytophthora cinnamomi.* The single causal agent is the exception rather than the rule and, normally, complex interactions of factors are involved, often over a long time span. For example, selective clearing of native forests for cultivation or grazing causes a drastic change to the environment of the remaining trees. These trees either adapt to their new conditions or remain permanently stressed and prone to insect injury or disease. For old, well established trees, such a change may be sufficient to cause decline or death. Often, one tree may die while its immediate neighbours can appear to be healthy because of individual differences in their vigour, species, degree of disturbance or position.

Excessive tree clearing in susceptible catchments may result in the development of water table salinity which in turn causes stress or death of trees. This may not be apparent for several decades after the initial clearing.

Some further examples of factors which are known to cause tree disorder in Queensland are:

- overclearing of native vegetation—increased exposure;
- increased soil and water salinity;
- defoliation by insects—leaf-eaters, leaf miners, skeletonisers, sap suckers;
- pathogens of roots and leaves (for instance root rot fungus, *Phytophthora cinnamomi);*
- drought;
- flood, waterlogging;
- fire—wildfire, pasture and stubble burning;
- lightning strikes;
- hail;
- wind;
- frost;
- excessive or careless application of herbicides;
- stock damage—rubbing, soil compaction;
- nutrient changes favouring populations of pasture-tree feeding insects—improved pastures, fertilising;
- reduction in populations of insectivorous birds—loss of nesting sites;
- reduction in populations of parasites of leaf-feeding insects—loss of nectar sources for some adult parasitic insects;
- mistletoe; and
- old age.

Where has dieback occurred in Queensland?

The accompanying map was prepared following the native tree dieback survey conducted in southern Queensland between 1980 and 1982. Dieback of native trees was reported in all of the 70 shires covered by the questionnaire and field studies. The severity ratings shown on the map combine:

- the number of recorded occurrences or distribution of dieback in the shire;
- the range of tree species affected; and
- the severity of individual occurrences.

In 50 shires, dieback was patchy, generally of light to moderate severity and involved only a few tree species. Widespread dieback, sometimes severe and involving a wide range of tree species, occurred in 20 shires. Dieback is most severe in the Fitzroy, Wide Bay-Burnett, Moreton and Brisbane regions and on parts of the Darling Downs. It is significant that dieback is generally more severe in areas of population concentration and intensive land management.

What tree species are affected

Almost 70 species, including some commercially important timber species, are affected by dieback. The most commonly and widely affected are river sheoak *(Casuarina cunninghamiana),* narrow leaved ironbark *(Eucalyptus crebra),* grey ironbark *(E. drepanophylla),* pink bloodwood *(E. intermedia),* spotted gum *(E. maculata),* silver leaved ironbark *(E. melanophloia),* yellow box *(E. melliodora)* and Queensland blue gum *(E. tereticornis).*

Trees of all ages are affected, from seedlings to mature and overmature trees.

Is dieback a new phenomenon?

In Europe, the effect on tree health of such practices as excessive tree clearing, overgrazing, fire and urbanisation was recognised as early as the 4th century BC by Greek and Roman writers. So too were the consequences of large scale tree loss—erosion, siltation, soil salinity and flooding. In Australia, reports of periodic decline of native vegetation date back to at least the 1850s although, in Queensland, the problem has previously been less severe than at present.

Is dieback on the increase in Queensland?

The answer is 'Yes'. Response from landholders to the questionnaire survey indicates a sharp increase in the numbers and species of trees showing decline over the past decade. The problem is not yet as severe as in other states, although localised severe dieback has occurred in some parts of Queensland. This increase may be related to the accumulation of land management and environmental stress factors acting on a remnant tree population over a long period, combined

Plate 1. Dead and dying trees are becoming a common sight in parts of rural Queensland.

Plate 2. A tree with severe dieback in its crown has most minor or major branches dead or leafless. The remaining area of crown is composed mainly of secondary or sucker regrowth on branches or stem.

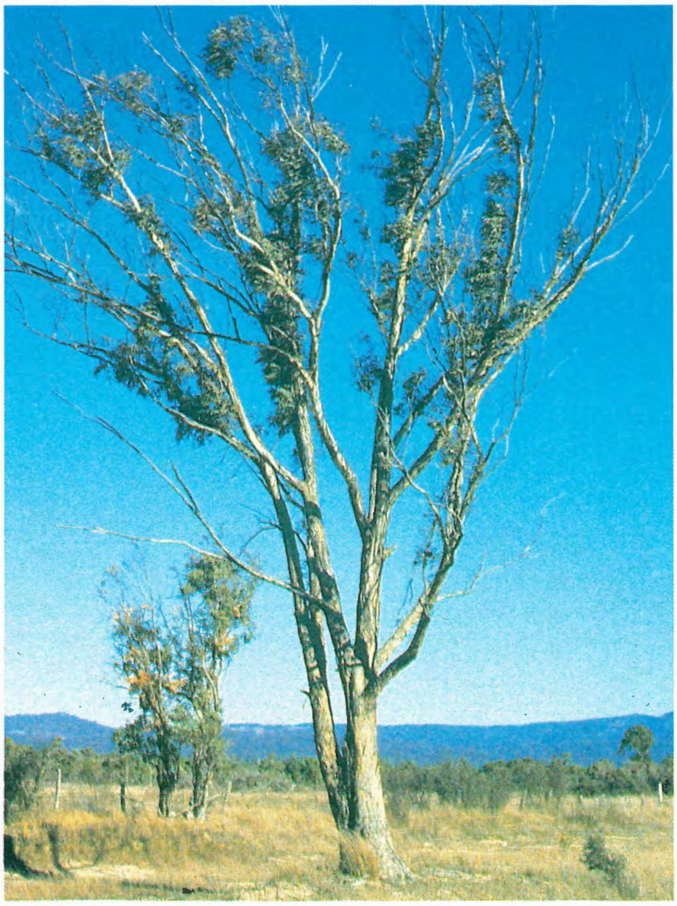


Plate 3. Leaf eating beetles such as Christmas beetles can rapidly strip a tree of its foliage.

Plate 4. Following loss of trees through clearing and dieback these cattle have been forced to seek shelter where they can find it.

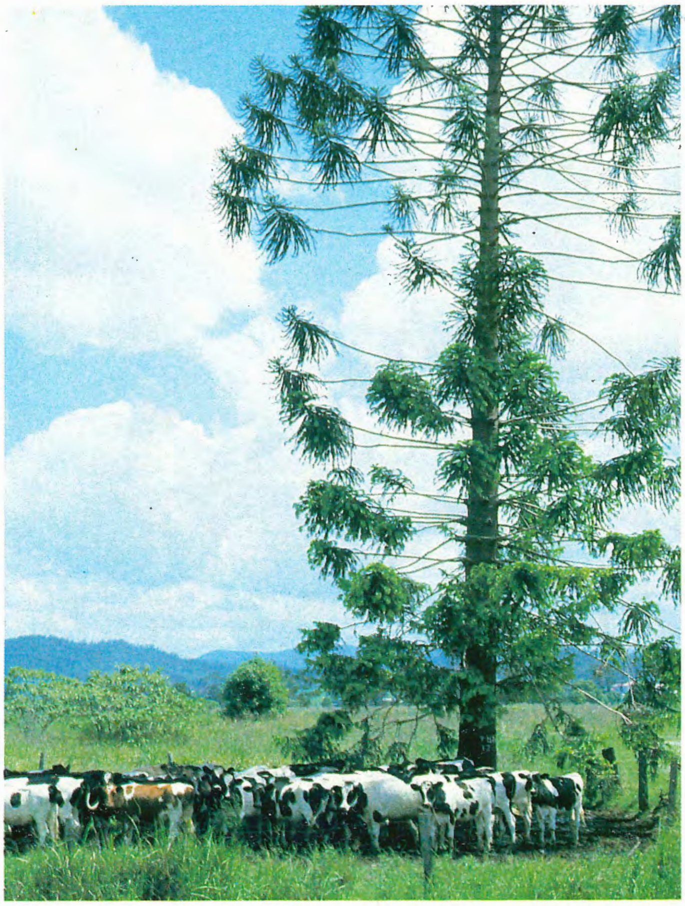


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Plate 5. Isolated trees and small clumps left following clearing are more liable to be affected by dieback than larger blocks.

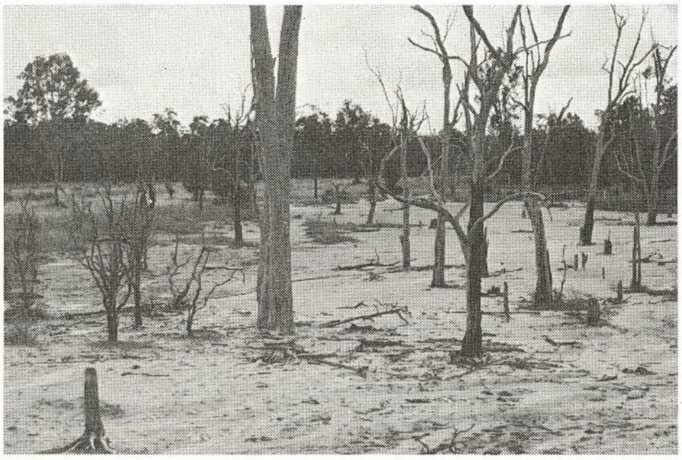

Plate 6. Clearing of some susceptible catchments has led to water table salinity as has occurred here in the Lockyer Valley.

Plate 7. Excessive clearing or tree death can lead to landslip problems and erosion.

with the climatic extremes experienced in the past few years. For example, 1974 was one of the wettest years on record for most of Queensland, while south east Queensland experienced its driest summer for 50 years, 3 years later. In 1982 and 1983, widespread areas of the State were declared drought stricken.

Why should we be concerned about dieback?

Until recently, the main impact of dieback was regarded as one of aesthetics. However, studies in areas where considerable tree loss has occurred have revealed serious economic implications for both rural and urban communities. Excessive clearing of the Bremer and Lockyer catchments of south east Queensland has led to landslip, salinity and serious soil erosion. Over 1 200 landslips which cause damage to roads and property have been identified in the catchments and are affecting productivity on about 6 000 ha.

In Queensland, water table salinity affects more than 7 300 ha of land valued at over $2 million and the annual productivity loss exceeds $1 million. The areas affected are growing both in size and number.

Other examples are:

- water and wind erosion leading to soil loss;
- silting up of streams and reservoirs;
- stream bank erosion and blockage of waterways by fallen trees;
- loss of stock shade and shelter;
- loss of fodder tree species;
- loss of pasture shelter windbreaks;
- loss of valuable timber resources (for instance commercial timber species, farm fencing and building materials);
- loss of wildlife habitat (in particular habitat for insect-eating birds); and
- loss of honey production.

What can be done about dieback?

Because of the many factors which contribute to the decline and death of trees, it is unlikely there will be a single cure for the problem. First of all we must understand the dieback mechanisms operating, so that the causes and not just the symptoms are treated. With knowledge of how to keep trees healthy in various rural situations, we can act to arrest the decline and to re-establish tree cover on denuded and degraded lands.

Achieving these goals is the responsibility of the whole community and requires a cooperative effort by government, scientists and landholders. In Queensland, the State Committee on Tree Decline in Rural Areas has already undertaken a number of field surveys and studies aimed at identifying problem areas, tree species affected, factors contributing to tree disorder and community attitudes to trees and tree decline. Landholders have been asked to help in devising practicable solutions to the problem. Community groups and individuals are also involved in tree planting programmes and efforts are being made through the media and publications to promote awareness of the problem.

There is no doubt that any solutions will include radical changes in attitudes towards the role of trees on rural lands and in some land management practices. To prevent further land degradation and loss of long term productivity and to maintain an ecological balance require careful planning of development. Acceptance of this concept offers hope of a solution.

Murray Ball and 'Footrot Flats'

Murray Ball, the creator of the comic strip 'Footrot Flats', kindly gave permission for the inclusion of a number of his cartoons in this issue of the *Queensland Agricultural Journal.* Murray lives in Gisborne, New Zealand, on what he describes as 'the remains of his four acre ranch after the floods and landslides'.

He is often seen 'wandering morosely from landslide to landslide wringing his hands and throwing futile pieces of clay at marauding cattle which are eating his young trees'. Obviously, Murray's sentiments, as expressed through the dog, are in accord with the editors' and we appreciate his generosity in amusingly reinforcing our message.

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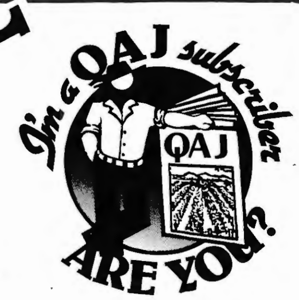

The *Queensland Agricultural Journal* is published primarily for the man on the land. It is issued six times a year and has an annual total of more than 300 pages.

The *QAJ* is illustrated in colour and black and white. Articles deal with: agricultural extension advice and recommendations; legal and regulatory information; and the practical application of the DPI's research for Queensland agriculture.

Proven practices and trial results are published in an easy-to-read form. Often, a *QAJ* article gives enough detail for the primary producer to need no further guidance or information. However, personal and specific advice can always be obtained from DPI extension staff. The *QAJ*'s ultimate aim — in line with all DPI activities — is to help the primary producer achieve greater productivity.

Primary producers can recoup the low subscription price of the *QAJ* many times over through the successful implementation of its recommendations.

Apart from primary producers, the *QAJ* appeals to other important audiences, including agribusinessmen, hobby farmers, home gardeners, and school and tertiary students.

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Trees and erosion control

D. Houghton, Soil Conservation Services Branch

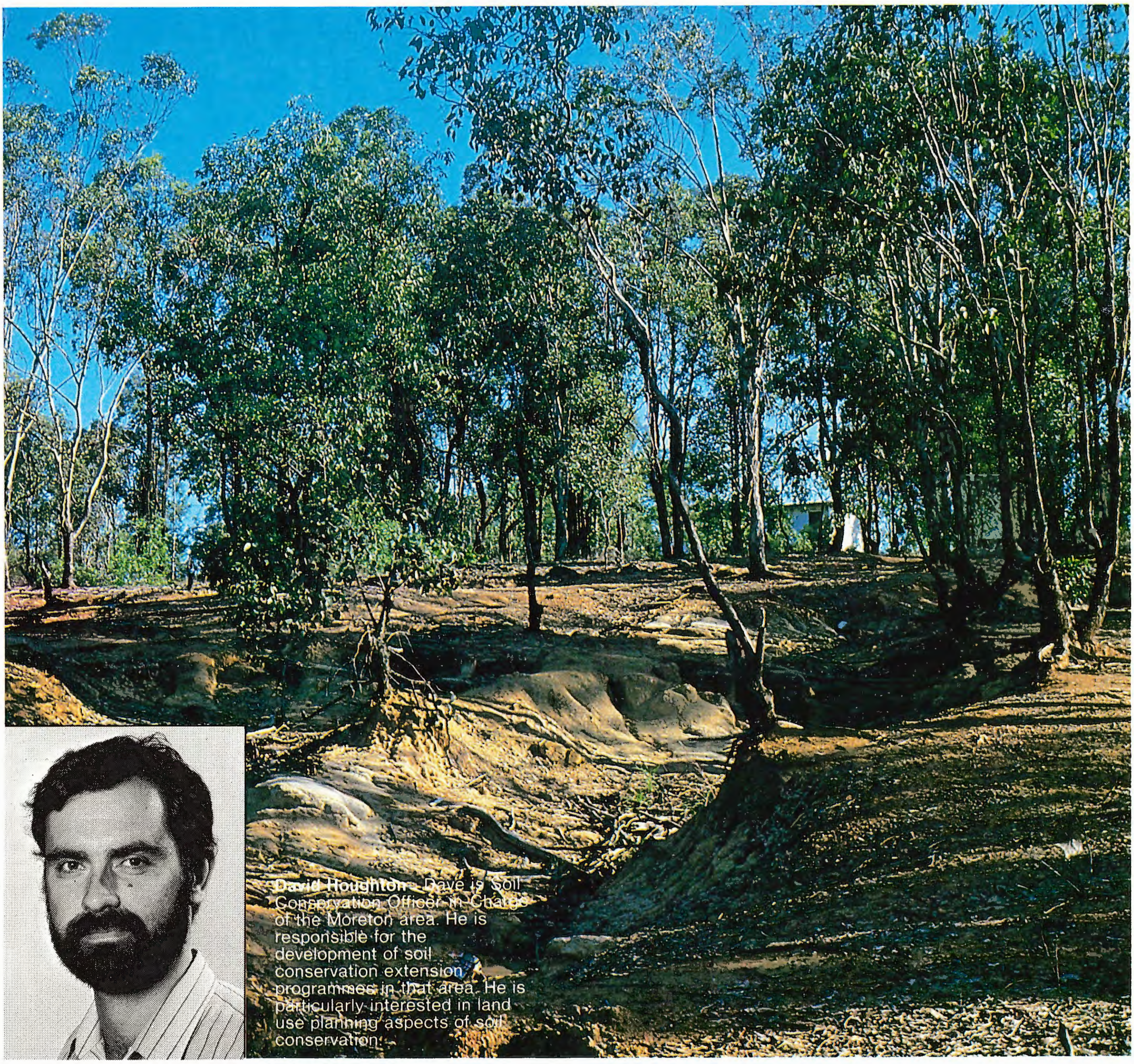
The tree has long been regarded as vital for the prevention of soil erosion.

As a generalisation, the steeper the land slope, the greater the need for trees. However, slope is not the only factor that determines the need for trees. The relative position of trees on the landscape, the land type and the management of the land all determine how effective trees are in erosion control.

Also, the inherent characteristics of some tree species make them more efficient than others in combating soil loss. The canopy type and density, branching pattern, root structure and growth pattern of a tree influence the tree's effectiveness as an erosion control agent. Some tree types and trees in the wrong position can actually aggravate an erosion problem.

This article deals with the role trees play and where trees are needed to control erosion.

Increased runoff from cleared upland areas can cause severe gullying of natural drainage lines.



David Houghton—Dave is Soil Conservation Officer in Charge of the Moreton area. He is responsible for the development of soil conservation extension programmes in that area. He is particularly interested in land use planning aspects of soil conservation.

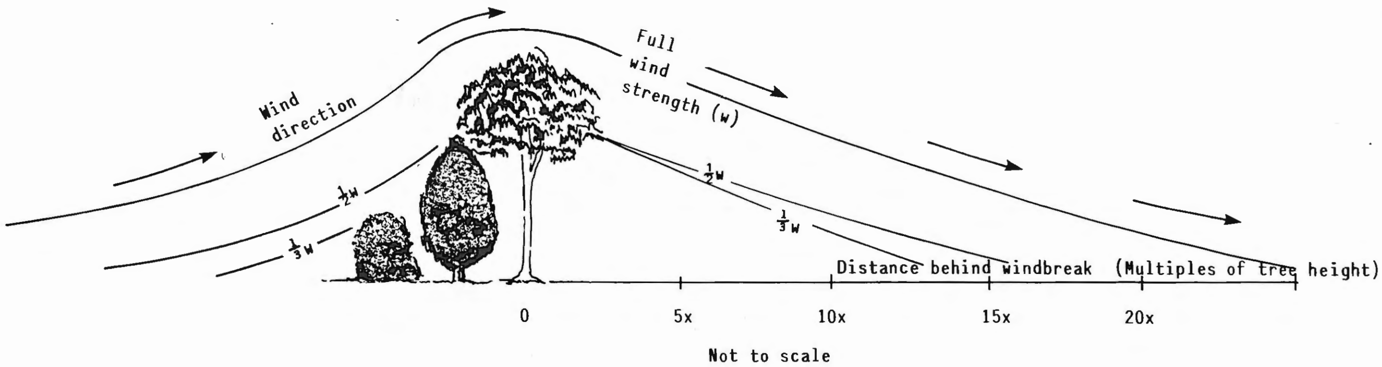


Figure 1. Effect of shelter belt on wind velocity.

Trees and wind erosion

Wind erosion is not a great problem in cropping areas in Queensland at present. Most cultivation is on clay soils where soil particles are sufficiently cohesive to resist removal by wind. The gradual expansion of cropping onto the lighter textured soils in the Western Darling Downs may markedly increase the extent of wind erosion. The problem is greater in the western arid grazing lands where grazing pressure and the removal of browse shrubs have increased the possibility of desertification.

Wind erosion occurs when wind velocity is great enough (usually greater than 18 km/h) to lift soil particles into the air and carry them away or to make the particles jump along the ground. These jumping particles then dislodge and break up other particles which are in turn moved by the wind.

The most effective way of reducing wind velocities to non-erosive levels is by preserving or planting windbreaks of trees or shrubs and maintaining ground cover. The effect of trees and shrubs in reducing wind velocity is shown in Figure 1.

A reduction in wind velocity also reduces evaporation of moisture from the soil. Soil moisture acts as a binding agent on soil particles making them less easily eroded.

The roots of trees and shrubs also help to bind the soil together.

Trees and water erosion

The effect of a tree in preventing erosion by water is shown in Figure 2. The four ways in which trees help reduce soil loss can be discussed in detail.

It reduces raindrop intensity

The primary cause of soil erosion by water is the explosive effect of raindrops on a bare soil surface and the subsequent removal of the disturbed soil by runoff water. The greater the intensity of the raindrop, the greater the disturbance of the soil.

The canopy, branches and trunk of a tree act as interceptors of raindrops, greatly reducing the force of the drops, but often increasing the drop size. A significant amount of rainfall may find its way to the ground via the branches and trunk. Some tree species, by virtue of their shape, are particularly efficient at channelling water towards their roots. Also the leaf and bark characteristics of some species provide a large capacity for water to be held on the tree surface.

The raindrops that are not intercepted by the tree may land on leaf litter around the base, which further protects the soil surface from raindrop action.

It increases infiltration

Following dislodgement of soil particles, an effect of raindrop impact can be the sealing of the soil surface. This subsequently reduces the rate of infiltration of water into the soil.

Some soil types are particularly prone to this problem, notably those with a high clay content at the soil surface. Only a fraction of the total amount of rain that falls on some soil types is absorbed and becomes available for plant growth. The greater proportion may be lost through runoff, which aggravates the erosion problem. By reducing the raindrop intensity, trees help to prevent surface sealing. Surface litter dropped by the tree also reduces surface sealing and keeps soil pores open for rapid infiltration of rainfall.

Trees generally have a deeper rooting habit than grasses or crops that replace them on farms. As such, they are able to use more water and dry the subsoils to a greater depth than grasses or annual crops. When trees are removed, the moisture content of the soil increases, resulting in runoff occurring sooner than otherwise during rainfall periods.

It maintains soil nutrient levels

An important factor in the prevention of soil erosion is the maintenance of organic matter, particularly in the surface layer of the soil. The presence of high levels of fresh organic matter supplied as leaf and bark litter promotes soil aggregation which, in turn, decreases the susceptibility of the soil to erosion. The continual cycling of nutrients through their absorption by roots and subsequent deposition on the soil surface by litter decomposition maintains organic matter levels and soil fertility. Numerous native tree species such as acacias and, to a lesser extent, casuarinas, fix atmospheric nitrogen in the soil. Removal of such trees combined with poor management can reduce soil fertility rapidly.

It binds the soil

Where the soil surface has been exposed and eroded to some extent, the roots of trees can help prevent further losses by binding the soil together, strengthening and consolidating the immediate area and resisting the flow of water. In addition, the trunks of dense timber stands slow runoff water and prevent it from concentrating and causing gully erosion.

Trees as erosion control agents

The effectiveness of trees in reducing soil loss on a particular area of land depends on:

- the land types present within the area;
- the position of trees on each land type;
- tree type and density;

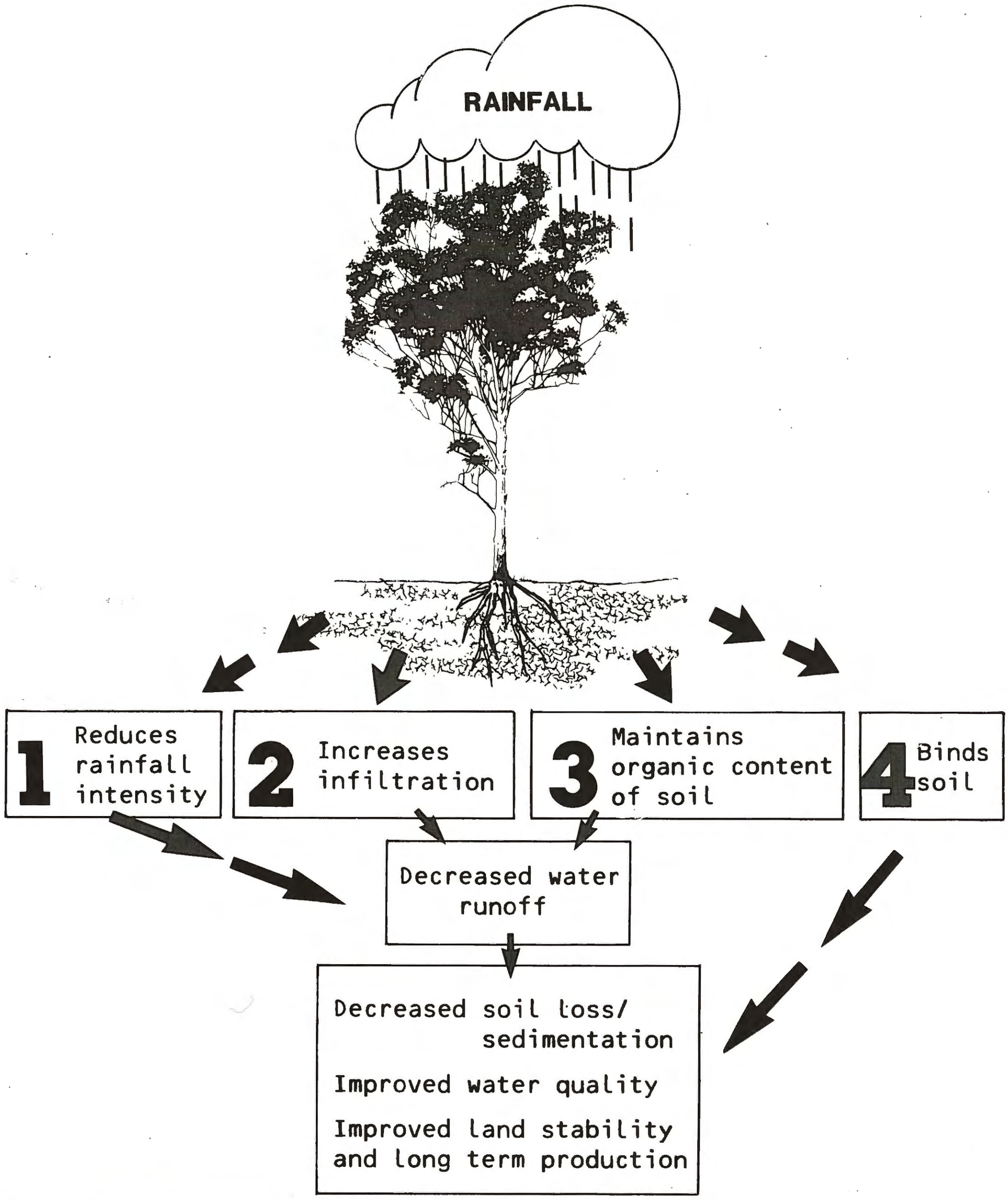


Figure 2. The effect of trees on erosion.

- the understorey type and density;
- the use and management of the land.

Trees may not always be the best single answer for erosion control. Considerable erosion can occur in certain forested areas, particularly where a combination of shallow infertile soils and heavy stocking occurs. This is especially evident if the tree species have a sparse canopy cover and a shallow rooting system which restricts the growth of a protective grass cover. Erosion may be further aggravated if such trees are positioned on the lower portion of a slope and the area above is cleared. Runoff from the upland area flows through the timbered land eroding exposed areas of soil. Cattle camps require careful positioning for this reason.

On some land types, other forms of vegetative cover can be at least as efficient as trees in providing protection against erosion. For example, in areas of moderate slopes and fertile soils, a dense ground cover such as couch grass or kikuyu would be effective in preventing soil loss. Although greater runoff may occur with a complete grass cover when compared to a tree cover, the amount of soil loss may be insignificant. If a grassland area is poorly managed by overgrazing or indiscriminate burning, or the pasture growth is inherently poor, the protection offered against erosion may be limited. Some soil types are unsuitable for healthy grass or pasture development, in which case tree protection is necessary.

On steeper areas of land, the possibility of landslips occurring is greater where only a dense ground cover exists. Minor but extensive landslips (terracettes or solifluction) and major landslips may develop to the extent that considerable areas of bare soil are exposed to erosive agents. Trees provide the best form of protection against landslip on slopes greater than 25% and, in some cases, on slopes as low as 18% depending on geology and soil type.

Trees are probably even more important in the prevention of gully erosion of slopes, natural watercourses and alluvial areas. When trees have been removed from a catchment, frequency and volume of water flow in gullies and watercourses increase for reasons mentioned earlier. When there is a permanent change in the size and frequency of flows, the waterways adjust their shape to compensate for these

Plate 1. Where a combination of poor soils, overgrazing and unsuitable tree species occurs, severe erosion may result.

flows. Active erosion of the bed and banks of the waterway occurs until a new equilibrium can be obtained. However, if flows are continually increasing or the soil types are highly erodible, then active erosion continues to produce increasingly worse effects throughout the length of the watercourse. During periods of high rainfall the intensity of floods and flood erosion in low lying areas increases.

Widespread clearing of trees from river banks is often undertaken with the intention of speeding up the movement of flood water. Extensive streambank erosion and sedimentation have occurred in many areas as a result. While trees within the bed of a stream may aggravate the flooding problem, the preservation of trees over the full bank area is vital for erosion control and has little effect on flood intensities.

Extensive clearing of timber can be the initial step in the process of tunnel erosion. Where trees and tree stumps have been removed, water can infiltrate otherwise impermeable subsoil layers very rapidly. If the subsoil is dry and easily dispersible, tunnels may form. These tunnels can develop year by year to the extent that they finally collapse and form gullies.

Conclusion

Trees are vital for the prevention of erosion in most parts of the landscape. However, their effectiveness largely depends on the land type on which the trees are situated and the type of enterprise and management of that piece of land.

The consequences of clearing or planting trees should be considered not only for possible on-farm advantages and disadvantages but also in relation to the effect on the whole catchment. For this reason, there is a need for catchment planning to determine areas in need of tree retention or planting, and areas where the removal of trees would have little detrimental effect on long term stability.

Trees and salinity

K. K. Hughes, Land Resources Branch

Introduction

A survey of salting in non-irrigated lands in Queensland has identified a marked association between clearing of trees and later outbreaks of seepage salting. About 8 000 ha are seriously affected by seepage salting as a direct consequence of land clearing since settlement. The resulting loss in land value is estimated at $2.0 million, and the productivity loss at $1.0 million per annum. In addition to land degradation, clearing can result in water quality deterioration through salinity. Where urban water supplies are threatened, as has occurred in Western Australia, water quality can become a bigger issue than land degradation.

Indicated trends for secondary salinisation are for expansion of existing outbreaks of seepage salting, and for new outbreaks as additional areas are cleared.

The total area affected as a consequence of clearing is small compared with the total area cleared since settlement. However, the saline seepages are scattered throughout eastern Queensland in many productive valleys, and the current estimate of area affected does not include large areas of incipient salting not readily detected or estimated.

Consequently, secondary salinisation is regarded as a serious problem requiring immediate preventative action. When the seepage stage is reached, it is very difficult to reverse the process.

As Queensland still has large uncleared areas there is an opportunity in this State to ensure that further seepage salting does not develop. Techniques for the identification of lands susceptible to seepage salting on clearing are required so that action can be directed against specific vulnerable areas. A blanket coverage against salting by means of clearing restrictions on all land types is impractical and unjustified, since many lands do not contribute to seepage salting and do not require preventative measures.

Process of seepage salting

The association between clearing of trees and salting stems from a decrease in water usage when trees are removed. Trees can use large quantities of water by evapotranspiration. When trees are removed from the

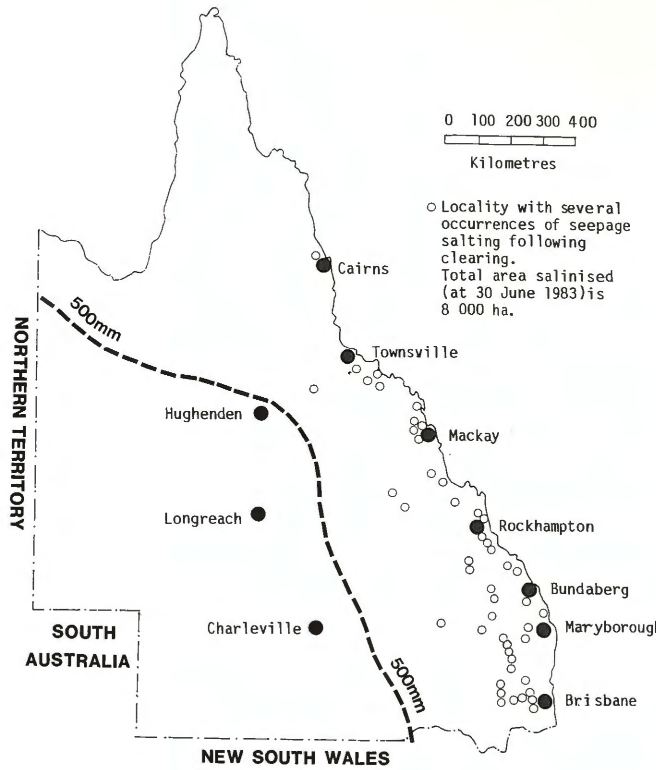
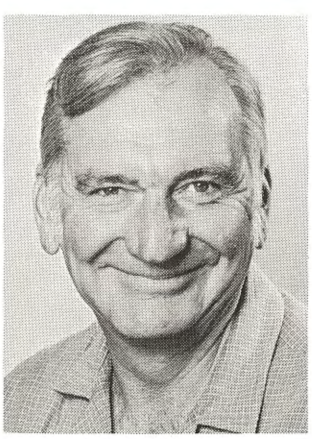


Figure 1. Distribution of dryland seepage salting in Queensland.

Plate 1. This seepage salting outbreak in the Lockyer Valley has been caused through clearing of trees from critical areas of the valley floor and hills. The removal of trees has allowed groundwater to accumulate and cause salting when it reaches the surface. Saline water seeping from this bare sterile area drains eventually into Brisbane City water supply.



Keith Hughes Keith, a geologist with 30 years' experience in applied geology, has worked on land resource surveys and land degradation problems since joining the DPI in 1974. More recently he has specialised in the identification of lands susceptible to salting and has researched controlling factors.

landscape, the resulting excess water may percolate through soils and the bedrock to the watertable. Where lateral drainage is poor, water levels rise. Groundwater normally contains dissolved salts from rainwater, soils and rocks. Additional salts may be dissolved from weathered rocks and soils invaded by the rising watertable.

When groundwater levels are less than 1 m from the surface soil capillary rise draws groundwater to the soil surface, where salts can be concentrated by evaporation of the water. Conditions which favour salt concentration include bare soil surface, high temperature, low humidity and strong winds. Salt pans, salt marshes and salt flats develop naturally by this process over long periods of time.

Seepage salting following clearing is a recent development associated with land use changes since European settlement, and is classed as induced salinity. A typical seepage salting occurrence comprises a bare, sterile, salt encrusted surface fringed by salt tolerant vegetation with highly saline groundwater underlying or seeping from the area. Where a deep creek or gully intercepts the watertable and prevents groundwater rising to cause salting, a flow of poor quality water results causing deterioration of surface water quality.

Susceptible lands

Lands susceptible to seepage salting on clearing have the following characteristics:

- Groundwater at shallow depth (usually less then 6 m) under native vegetation.
- Indicator vegetation.
- Salt sources in the groundwater, and/or the soil, and/or the bedrock.
- Rainfall in the range 500 to 1 500 mm annually, with high seasonal evaporation following wet seasons.
- Intake areas (permeable soils and rocks) in higher landscape positions, with runoff areas (impermeable soils and rocks) in lower landscape positions.
- Poor drainage, with seasonal waterlogging in low lying areas.

These characteristics may be present to varying degrees, providing a range of salinity hazards.

Lands not susceptible to seepage salting on clearing, even when the climatic factor favours salting, have impermeable soils preventing deep percolation of water under normal rainfall conditions.

Vegetation as indicators

The use of vegetation to identify water intake areas, runoff areas and areas susceptible to seepage salting is currently under investigation. Some general associations from work in progress are:

- **Areas susceptible to seepage salting:** indicator vegetation is black tea tree *(Melaleuca bracteata)*.
- **Intake areas:** indicator vegetation is softwood scrub, *Angophora* spp., cypress pine *(Callitris columellaris)*, silver-leaved ironbark *(Eucalyptus melanophloia)*, some areas of lancewood *(Acacia shirleyi)* and some areas of bendee *(Acacia catenulata)*.
- **Runoff areas:** indicator vegetation is brigalow *(Acacia harpophylla)*, gidgee *(Acacia cambagei)*, belah *(Casuarina cristata)*, and some areas of poplar box *(Eucalptus populnea)*.
- **Waterlogged areas:** indicator vegetation is tea tree. A tea tree understorey below species other than tea tree indicates a perched watertable. In general, perched watertables have good quality groundwater.

A knowledge of the vegetation, soils, geomorphology, groundwater data and climate is currently needed for detailed assessment of secondary salting.

Seepage salting under native vegetation has been recognised under *Melaleuca bracteata* in the Clermont area, and under *Melaleuca nodosa* in the Maryborough area. These occurrences are not associated with clearing. They are natural events caused by extremely wet seasons bringing shallow watertables and salts to the soil surface for short periods. They are characterised by soil salting only, without prolonged watertable rises or dead vegetation. In general, these occurrences seem fairly restricted and related to long term seasonal effects.

Preventative measures

Preventative measures vary depending on the severity of the salting hazard, on whether intake or runoff areas are being treated and on landholder expectations. Ideally, because the cause and effect are separated, a catchment approach is required, but in practice various compromises are likely using a range of measures. In general, preventative measures should aim to:

- Manage intake areas to prevent excessive water intake. This may range from careful irrigation practices to avoid adding excess water, to maintaining deep rooted vegetation (native or commercial) over the intake areas. More water should be available for trees to utilise in the lower landscape positions in the intake areas.
- Prevent water build-up on toe slopes in runoff areas by maintaining deep rooted vegetation at this location. Trees should also be maintained in lower landscape positions as an insurance against water build-up. Selected clearing should not cause any problems on runoff areas because of the inherent impermeability of these areas.
- Intercept or harvest runoff water to keep this good quality water out of potential seepage areas.
- Ensure drainage from susceptible areas is not impeded, for example by siltation of creeks, building of water storages or roads.
- Maintain deep rooted vegetation along intake/runoff contact zones to utilise water and prevent seepages from these contacts.
- Maintain good vegetation cover (salt tolerant grasses, trees or crops such as lucerne) in valley floor discharge areas, to prevent subsurface water reaching the soil surface. Avoid land uses which bare the surface, for example unrestricted cultivation or overgrazing.

Conclusions

- There is a very large potential for induced salinity following clearing of trees in Queensland. Preventative measures must be implemented to ensure this potential is never realised. These measures must be directed at the lands susceptible to salting.
- If nothing is done about induced salinity, the consequences are a slow inexorable deterioration of our land and water resources, with eventual crippling costs from losses in land value and productivity. There is often a long lag time of about 20 years between clearing and salinity outbreak, which diminishes responsibility and incentive to take preventative action. Also, there is increasing pressure to develop land indiscriminately for quick returns.
- We need then to rehabilitate those areas already affected by salting, and to prevent further outbreaks by restricting clearing on those lands susceptible to salting. There are landscape positions (for instance toe slopes) where trees are more effective in utilising water, and emphasis should be placed on the planting of trees and retention of trees in strategic landscape positions.
- Stepped up research is urgently required to identify potential problem areas more accurately, and to determine practical preventative measures. These data are required for landholders, industry and Government for multilevel coordinated action against salinity, ranging from land use policies down to on-farm preventative measures.

Forest clearing and landslides on the basalt plateaux of south east Queensland

W. F. Willmott, Geological Survey of Queensland, Department of Mines

Landslides are particularly common on the cleared slopes of the basalt plateaux and ranges of south east Queensland. They are more prevalent in these areas than in similar steep terrain formed on most other rock types, and they may occur on quite gentle slopes. It is clear that the basalt terrain forms a sensitive geological situation which is in delicate balance under natural conditions. Disturbance of those conditions, by clearing of the original forest, has altered the balance and led to failure of the slopes in landslides. Enough is now known of the processes involved to advise in general terms the types of slopes where further clearing should be avoided, and where revegetation would be desirable to minimise future landslide activity.

The plateaux

Basalt plateaux and ranges occur in an arc around the southern and western margins of the Moreton Region, and in the Sunshine Coast hinterland. They include the Springbrook, Beechmont, Tamborine and Lamington plateaux, the ranges between the Lamington plateau and Rathdowney, the Great Dividing Range and the Toowoomba escarpment as far north as Ravensbourne, and the Mapleton-Maleny, Buderim and Mount Mee plateaux.

Small outliers, such as Mount Marrow north of Rosewood and Mount Glorious are also present. Some of the valleys between the plateaux, such as the upper parts of the Nerang, Coomera and Albert valleys, are also underlain by basalt and have similar landslide problems.

Basalt is a rock which breaks down readily to deep fertile soils. In the eastern areas, these soils have combined with high rainfall to allow the growth of dense rainforest. In the early decades of this century, the fertile soils encouraged clearing for dairying, bananas and intensive grazing. Unfortunately, farm sizes were often small, which necessitated the clearing of even the steepest slopes. On some plateaux, such as Beechmont and Maleny, very little of the original forest remains.

The basalts

The basalts are volcanic lavas that were poured out during the Tertiary period about 20 million years ago. They were originally much more extensive, but have been reduced in area by the gradual erosion of streams. The plateaux of the southern border ranges originally formed the northern flanks of a large volcano centred over Mount Warning in New South Wales, but the origins of the other lavas of the region are not so clear. In places, bands of soft sediments such as mudstone and sandstone are interbedded with the lavas; these were deposited in small transient lakes on the flanks of the volcanoes.

The basalt occurs as numerous individual lava flows that are roughly horizontal. While the thick, harder flows resist erosion and form scarps and cliff lines, the softer or more fractured lavas, or bands of sediments, form gently sloping benches or shelves on the flanks of the plateaux.

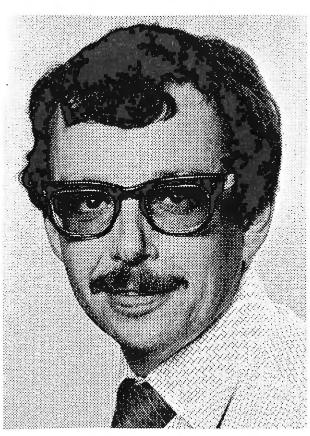
Following erosion of the edges of the plateaux over long periods of time, large volumes of rock and soil debris (colluvium) derived from disintegration of the scarps have accumulated on the scarps, on the benches and on extensive aprons covering the older rocks beneath the base of the basalt.

Red krasnozem soils are common on the plateaux surfaces, and dark grey to black, clayey prairie soils, chocolate soils and black earths are usual on their benched flanks. Such black soils are typical of areas mantled by colluvium. Many of these contain large quantities of swelling clay minerals (for example, montmorillonite) which cause the soils to crack on drying and to swell on wetting. The swelling is accompanied by a marked decrease in strength. The presence of sodium cations in some of these clays tends to accentuate the loss of strength that accompanies the wetting.

The landslides

Most of the landslides occur on slopes and benches on the flanks of the plateaux and ranges, and few occur on the actual surfaces of the plateaux. Several types of slides can be recognised in various topographical and geological situations (see Figure 1). However, in nature many slides exhibit characteristics of more than one type. Landslides on a typical benched slope on the flanks of a plateaux are shown in Figure 2.

Debris slides (or flows) have occurred on the scarps and very steep slopes (over 35%). These are narrow failures of colluvial debris and soil which move rapidly downslope, often as a viscous fluid, leaving behind a small semicircular head scarp. Once initiated they can retreat upslope by further failure of the head scarp in subsequent periods of movement. They commonly occur beside gullies, or on concave-shaped slopes, where the colluvial debris is thicker and seepage of groundwater is greater than elsewhere. Such slides are very common on the major scarp lines, where together they can disrupt a large proportion of the slope. They are particularly common on slopes that formerly supported rainforest, as it seems that a greater thickness of colluvium is present there than under eucalypt forests.



Warwick Willmott Warwick is a Senior Geologist of the Geological Survey of Queensland within the Department of Mines. He has worked in various fields of geology, in recent years chiefly on geological factors affecting urban and near urban areas.

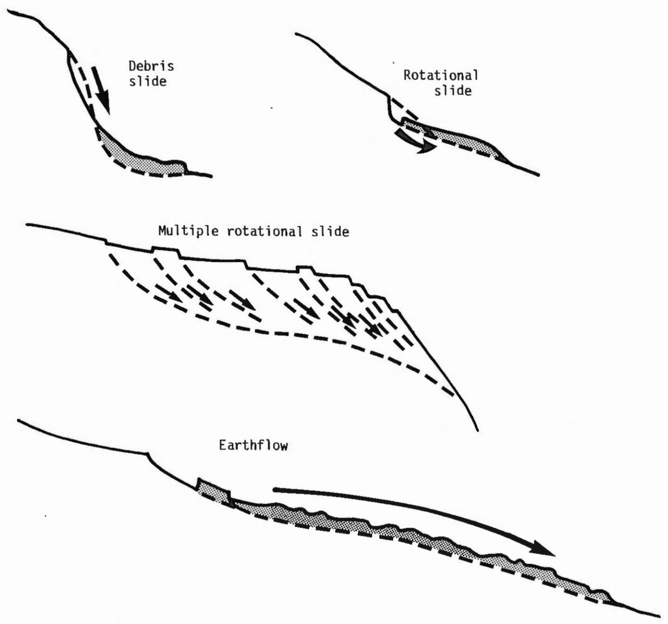


Figure 1. Common types of landslides on basalt plateaux.

Rotational slides or slumps develop on moderate to steep slopes (25 to 35%) where sufficient soil and colluvium have accumulated around concave slopes and adjacent to gullies. They also develop on local steep slopes beside gullies cutting across benches, and on hummocky topography on the colluvial aprons beneath the basalt. They occur relatively suddenly, and exhibit a semicircular head scarp, a back-tilted upper section and a disrupted toe section that grades into an earth flow. They merge into debris slides with increasing steepness of slope, and into multiple rotational slides on flatter ground.

Complex multiple rotational slides disrupt large areas on the benches and colluvial aprons. They are broad, deep, slow moving slides which occur in colluvium on the outer edges of benches, or above changes in slope ('drop-offs') on the aprons. Where beds of soft sediments occur beneath the bench or apron, failure may also occur within this material. They almost always occur around gully mouths, that is, where the gully drops over the edge of a bench, or on other low concave areas which tend to be spring zones.

The slopes of the upper sections of the slides are quite low (in places almost horizontal) and the semicircular head scarps may be subdued to less than 1 m high. However, further down the slide several subsidiary scarps of increasing height usually separate back-tilted blocks and, towards the edge of the bench where slope angles steepen to 25%, the slide mass may be quite disrupted. On the colluvial aprons where a pronounced bench edge is usually absent, the lower sections of such slides deteriorate into earth flows.

Virtually all cleared benches and aprons show examples of these large slides, which in places are very numerous. Some of the largest extend down the whole bench or apron, and may be up to several hundred metres from one side to the other. Several slides together may disrupt benches for a length of up to 2 km. Once started, movement can be expected to be reactivated intermittently during major wet seasons.

Earthflows are shallow failures where most of the movement is by a form of flowage. They occur mainly on the colluvial aprons below the base of the basalt where they are gradational from the complex multiple rotational slides.

Damage to land productivity

Landslides on the basalt plateaux are far more widespread than is commonly realised, and damage to rural land can be quite devastating. Overall, significant areas have been degraded, and some slopes have been rendered virtually unusable.

Adverse effects include the following:

- a break up of the soil profile, bringing infertile subsoil or rock to the surface, with a consequent reduction in pasture productivity;
- erosion of this disrupted soil by run-off water;
- germination of seeds of noxious weeds, such as groundsel bush, in the disrupted soil;
- the irregular slide mass prohibits access for machinery to control weeds by slashing or spraying;
- wet swampy areas develop in the back-tilted upper sections of major slides, degrading pasture and making a bogging hazard for cattle;
- loss of stock in deep crevices in the disrupted slide mass (particularly in freshly failed slides);
- choking of streams with slide debris, affecting irrigation potential;
- damage to fences;
- loss of accessibility to some parts of properties, disrupting management and stock movement; and
- damage to roads, dams and buildings.

The slides also present hazards for building and closer settlement, which is now increasing on the plateaux because of the attractive scenery and panoramic views.

Causes of the landslides

Compared to mountainous areas in other parts of the world, the ranges of south east Queensland are relatively subdued and mature. In such areas, slopes reach a balance between the progressive weathering of the rocks and the removal of the weathering debris by water erosion; landslides then occur only rarely and usually only on the steepest scarps. Such a balance exists even in geologically sensitive situations, such as basalt country, although it may be relatively more delicate.

Where extensive landsliding has occurred in such a mature district over a short period of time, say within the last 100 years, some change must have occurred to alter the balance.

Landslides occur when the strength of the material involved is reduced to below what is required to support its weight. There are only limited ways this can happen:

- Firstly, the internal properties of the material may change by gradual weathering, but this is unlikely to happen on a wide scale over a time span as short as 100 years.
- Secondly, the bulk strength of surface material may be reduced by the loss of tree root support following clearing.
- Thirdly, and probably most importantly, a loss of effective strength may be caused by groundwater pressures developing within the material.

Although fluctuating groundwater pressures have occurred periodically in wet seasons for thousands of years, and are part of the natural balance, evidence has become available in recent years that groundwater levels and pressures rise significantly when the natural forest cover is removed. This is mainly due to the loss of transpiration of water by the trees. In the Canungra

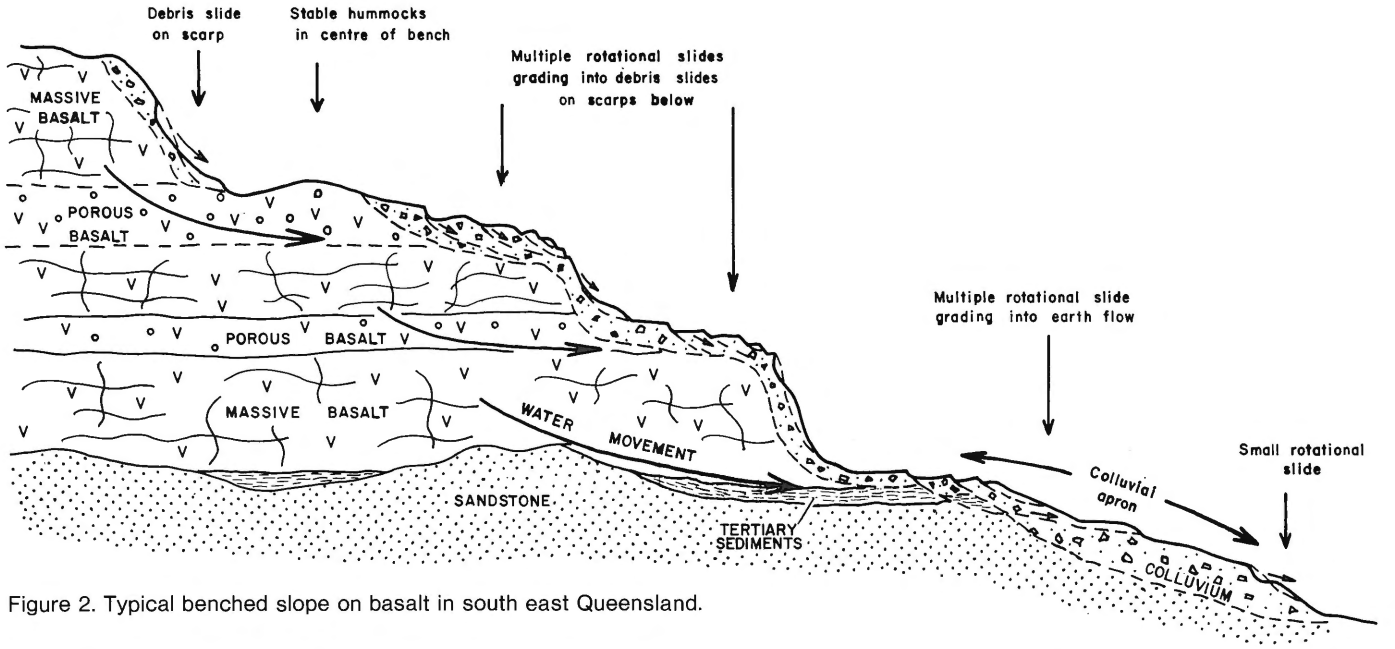


Figure 2. Typical benched slope on basalt in south east Queensland.

district there are reports of new springs developing on a benched slope a few years after clearing, and these have remained permanently active. Such general background rises allow higher peak pressures to develop during intense rainfall than was previously the case, and in susceptible locations these may cause a sufficient loss in strength to cause sliding. This effect is particularly important on the benched slopes, where groundwater is fed laterally outwards onto the hillside. On steep slopes and scarps the effect is combined with an increased rapidity of soil saturation following loss of the tree canopy, and a reduction of strength caused by loss of the tree root systems.

On Tamborine Mountain it is possible to compare similar slopes, some of which are cleared, and some of which are maintained as forest in National Parks. Despite close inspection there is little evidence of sliding in the timbered areas except on the steepest scarps, although undoubtedly occasional landslides have occurred in the past. In contrast, the similar cleared land has failed dramatically over large areas.

In summary, **the extensive recent landsliding has occurred because clearing of the forest has disrupted a delicate balance in a geologically sensitive situation.**

The geological sensitivity results from:

- the horizontal strata directing groundwater flows, through fractured or porous layers above tighter bands, laterally outwards onto the slopes;
- thick accumulations of unconsolidated colluvial debris on the slopes that can move relatively easily;
- the presence of swelling clays in the soil and colluvium which lose strength on saturation; and
- the presence in places of beds of soft sediments in the basalt sequence which themselves may fail.

The clearing has caused:

- a rise in groundwater levels and pressures through reduced transpiration, resulting in a reduction in strength of soil and colluvial debris, especially on benched slopes;
- increased rate of absorption of rainfall by the soil, reducing time taken to reach high groundwater pressures;
- decreased release of groundwater pressures on lower slopes because of changes in soil texture and compaction; and
- a direct reduction in strength of surface material through the loss of the binding support of roots, especially on scarps and steep slopes.

The combination of these factors has led to failures in susceptible locations when triggered by heavy rainfall.

Locations at risk

Obviously not all cleared basalt areas are unstable, and landslides are mainly restricted to certain susceptible locations. These are as follows (see Figure 3):

On the scarps and very steep slopes (over 35%)

- Virtually all areas formerly supporting rainforest. Because of the thick cover of colluvial debris these are susceptible to numerous large debris slides, which are particularly common close to gullies and on concave slopes, where they may disrupt a large proportion of the hillside. Only the crests of the most prominent side spurs are likely to be unaffected.
- In areas formerly covered by eucalypt forest, all gully heads, sides of gullies and pronounced concave slopes are susceptible to small debris slides. Only the crests of side spurs are likely to be unaffected.

On moderate to steep slopes (25 to 35%)

- Gully heads and local concave slopes are susceptible to small rotational slides and debris slides. The crests of prominent side spurs and most broader convex side spurs are generally stable.

On the benches (slopes 0 to 25%)

- All gully mouths and other depressed concave areas on the bench edge are susceptible to large multiple rotational slides. Where such depressed areas are large, the slides may extend across almost the whole width of the bench.
- Sides of gullies cutting across the benches are susceptible to small rotational slides.
- Only prominent knobs or rises in the centre or rear parts of benches (underlain by basalt bedrock or colluvium) can be considered stable with any confidence. Intermediate areas that are neither knobs nor concave depressions are difficult to assess.

Plate 1. Multiple rotational slides grading into earthflows in the concave section of a slope.

On the aprons of colluvial debris beneath the basalt (slopes 0 to 25%)

- Broad, gentle concave depressions are susceptible to large earthflows and multiple rotational slides.
- The edges of any changes of slope (drop-offs) are susceptible to multiple rotational slides.
- Sides of gullies cutting the aprons are susceptible to small rotational slides.
- Only the crests of prominent ridges separating the broad concave depressions and pronounced knobs or rises on the rear parts of the aprons can be considered stable with any confidence.

On the undulating surfaces of the plateaux

- Few slides are known in the well drained kraznozemic soils. Only in more hilly, dissected parts do small rotational slides develop on local steep slopes immediately beside gullies.

Prevention

Prevention of landslides is far preferable to subsequent rehabilitation, which is expensive, long term and possibly only partially effective.

The primary preventative measure that can be applied is to avoid forest clearing in susceptible areas. Unfortunately, it is almost too late for this on some plateaux such as Beechmont and Maleny, where forest remains only in patches on the steepest scarps. Nevertheless, some forest does remain to varying extents on most of the plateaux and ranges, and it is important that this is not cleared further in susceptible locations.

That is, **no further clearing should occur on the 'locations at risk' described above.** A desirable pattern of clearing and retention of forest for a benched slope is shown diagrammatically in Figure 3.

On cleared land, prevention of new landslides and renewed movement of existing slides can be helped by surface drainage of susceptible areas, thus helping to reduce peak groundwater pressures that may develop in wet periods:

- Springs, seeps and wet spots should not be trampled by stock, as this could seal the soil and increase pressures in the hillside behind. If the water is required for stock, it should be piped to safe locations.
- Dams should not be constructed in susceptible locations.

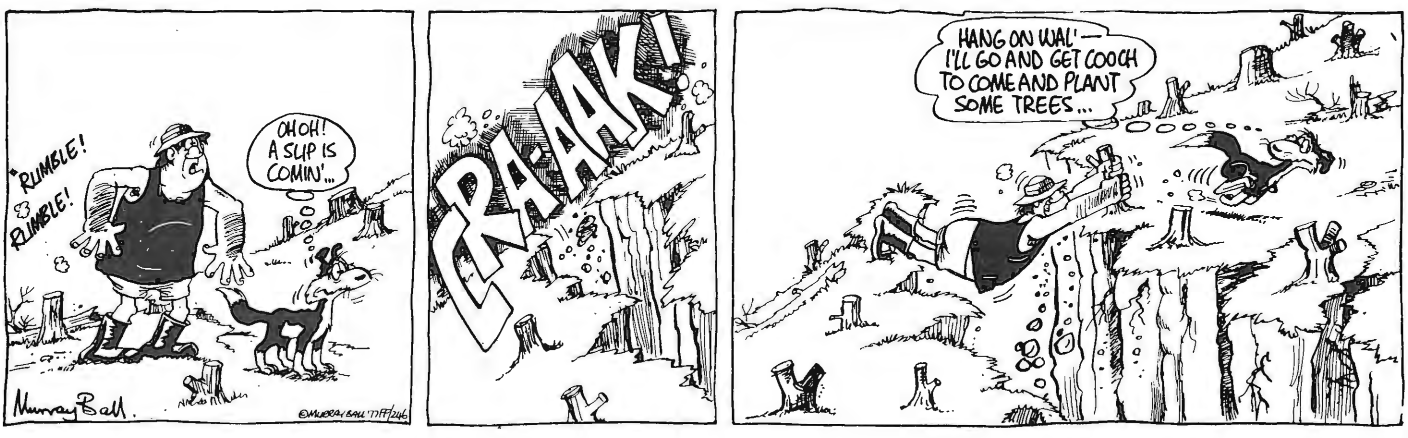


Plate 2. Clearing of a scarp taken to extremes.

Plate 3. A multiple rotational slide on the edge of the lower concave section of a bench.

Plate 4. A typical concave section of a bench edge. Sliding occurs in major wet seasons.

Plate 5. A stable section of a bench with few wet concave depressions.

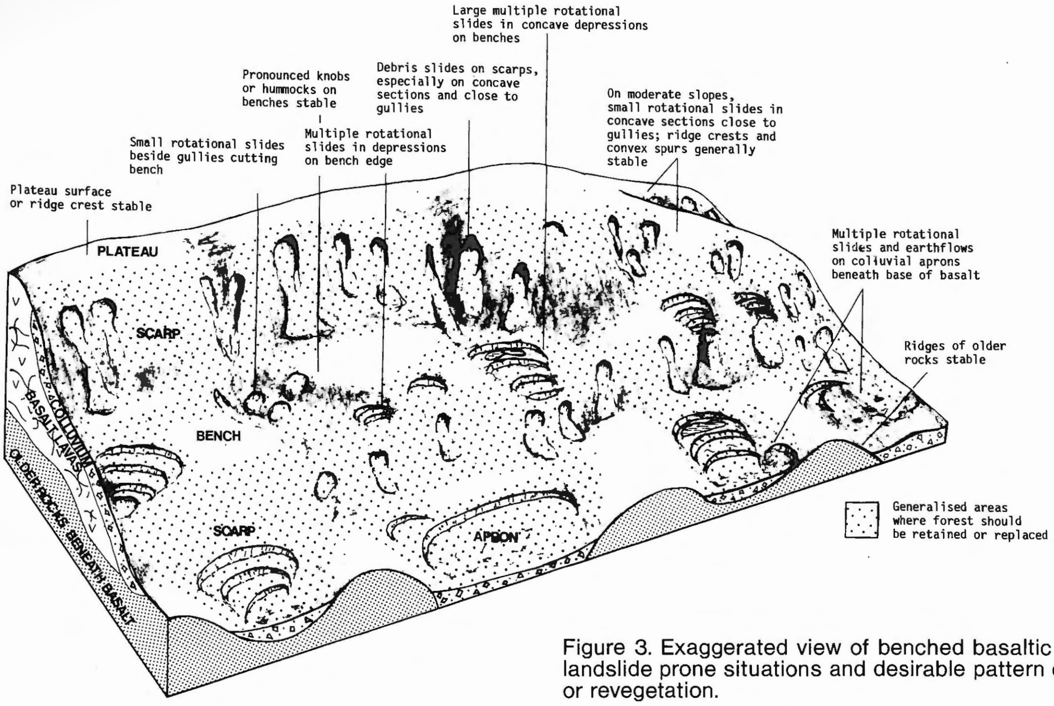


Figure 3. Exaggerated view of benched basaltic hillslide, showing landslide prone situations and desirable pattern of forest retention or revegetation.

- The temptation to use the swamps and ponds that develop in the back-tilted upper sections of multiple rotational slides on the benches for stock dams should be avoided. Instead, all means possible to drain such areas should be taken.
- Any drains should remove the water to safe locations as directly as possible. Lateral drains should preferably be sealed to avoid expanding the saturated area.

Rehabilitation

Rehabilitation of existing landslides or susceptible areas, particularly those on benches, primarily involves reducing groundwater pressures. Attention to surface drainage as described above helps but, as much of the water has a deep seated source (groundwater percolating through the rocks from the plateaux above), this alone is unlikely to be adequate.

Installation of subsurface drains can be effective, but this is a high cost solution appropriate only for the protection of capital structures, such as main roads and buildings. The possibility of blockages also gives uncertainty as to their long term effectiveness. Investment in such schemes is unlikely to be justified for farming.

A less costly although longer term approach is to promote water uptake through transpiration of a replanted tree cover. There is increasing interest in this approach, as it has potential for restoring some form of productivity to the land (although long term), as well as controlling some of the main effects of landslides, such as soil erosion and noxious weeds.

There is little information available at present as to what density of tree cover is required to achieve this satisfactorily. It is suspected that full forest cover will be necessary, as the residual strength of failed materials is commonly less than it was in the unfailed state. Consequently, there is probably a need to reduce groundwater pressures to less than original levels if possible. Fruit tree orchards are unlikely to be sufficient, apart from their unsuitability for wet ground.

There are some grounds for optimism in that the extent of reforestation needed is probably restricted to the locations at risk, and their immediate surrounds, rather than large subregional areas. Such locations are where groundwater flows are concentrated and hence amenable to increased transpiration.

In support of this assessment, evidence from Tamborine Mountain suggests that clearing of the plateau surface has had little effect on the stability of the benches below where forest still remains, but that local small areas of clearing within the forest on the benches have caused sliding. Thus, the desirable clearing and retention pattern shown in Figure 3 can also be used as a desirable reforestation pattern.

Reforestation on the basalt plateaux presents certain problems, and normal plantation forestry techniques could commonly be inadequate. The main problems are likely to be:

- choking effect of the dense kikuyu grass if reforestation areas are fenced off, the cost of chemicals and labour to control it, or the loss of seedlings to stock if the areas are not fenced;
- wet swampy areas in the centres of landslides or spring zones;
- possibility of further movement in landslides disrupting roots of growing trees; and
- choice of species for planting, preferably with the aim of some eventual economic return.

On the wettest and most mobile areas the priority should be to establish any form of tree cover that is possible, and thoughts of commercial return should be secondary. Tree species not normally used in forestry may be necessary, and loss of trees through root disturbance in the early part of the programme will have to be accepted (and replaced). However, in better drained peripheral areas, greater emphasis could be placed on commercial timber species.

There is a need for further investigation and experimentation with revegetation techniques appropriate to varying local situations, if efficient rehabilitation programmes are to be undertaken by landowners on these basalt areas.

Cattle need shade trees

J. J. Daly, Beef Cattle Husbandry Branch

Beef production is increased through improving both the animal and the environment. In any given environment, the aim should be to select and breed animals that are best suited to that environment. At the same time, the environment should be modified so that production is increased to an optimum level compatible with the need to conserve scarce soil resources and native plant and animal communities.

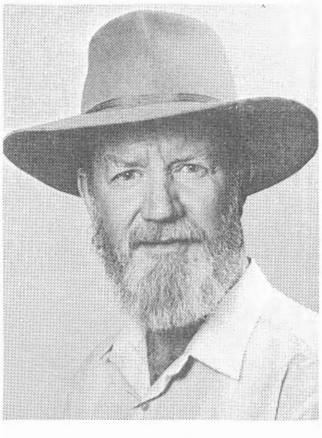
For beef production, the environment is improved through providing greater access to water, better feed, and shelter from the heat and cold. In the early development of the beef industry, cattle were first introduced into areas where native pasture existed but permanent water was limiting. As there is a limit to how far cattle can graze from a watering point, the first priority was to provide more watering points to increase access to existing pasture.

As water shortages were overcome and fences were built to control movements of stock, the next priority was to expand feed resources. With large areas of scrub and forest, timber was cleared and replaced with pasture. With problems with regrowth control, the clearing of land became an obsession in a lot of cases and little thought was given to providing nature strips to give shade and shelter for stock and wildlife.

The main consideration influencing whether trees were cleared or left was if their removal would increase grazing. Trees left were generally an afterthought and could be used for shade. In a hot environment where cattle seek shade, it was generally conceded that cattle need shade but the importance of it was difficult to assess. Without water cattle soon die and they do not live very long without feed, but how important is shade? In naturally treeless country, cattle do reasonably well without shade and the absence of any attempt to provide shade in these areas testifies to the low priority given to the need for shade in a heat stressed environment.

Shade seeking

The activities of an animal during any day are concerned with maintenance of life and survival of the species. Observation of the behaviour of animals provides an insight into the relative importance of different activities in varying environments.



Dan Daly Dan is a Senior Extension Officer with the Beef Cattle Husbandry Branch in Brisbane with special interests in breeding and general industry statistics and trends. Dan has experience in beef production systems varying from the most intensive to the most extensive.

Vital activities for cattle in any environment are walking, grazing, drinking, ruminating and resting. In the more extreme hot and cold environments, shade and shelter seeking are also vital to survival. There are distinct patterns for some of these activities. Some vary with paddock size, terrain, the weather and the needs of particular classes of stock.

In the more extensive areas of Queensland, there are three major grazing periods. The first is an early morning peak followed by a rest/ruminating period generally on water as the day heats up. In the cool of the afternoon, a more extensive grazing period begins. This is followed by a rest/ruminating period and a smaller grazing peak starting about midnight, which is followed by another rest/ruminating period. Hot conditions reduce daylight grazing and extend midnight grazing while cool conditions tend to encourage some midday grazing.

During the heat of the day most cattle seek shade. The extent of this activity depends on the needs of particular animals. Young calves are more susceptible to heat than older animals, and heavy in calf and lactating cows are more stressed than dry empty cows and steers. There are also breed differences; Tropical breeds graze later in the morning and recommence grazing earlier in the afternoon and so use shade for a shorter period than British breeds.

Young calves are stressed because it takes them some time to develop their heat regulatory mechanism. Pregnant and lactating cows are more stressed because the processes involved in growing the foetus and producing milk generate heat and so they have a higher heat load. Among the breeds, British and European breeds have higher energy requirements and produce more body heat when resting than Tropical breeds. They also have less effective heat dissipating mechanisms than Tropical breeds.

Relatively little research has been done on animal behaviour in the northern Australia environment. Work done highlights the importance of shade. Some of the earliest work on animal behaviour was done at the South Johnston Research Station in the wet tropics using Shorthorn steers on tropical pasture. Shade seeking in small paddocks was influenced by high temperatures and humidity. Time spent in the shade varied from 9 to 11 h/day during the summer. This fell to 7 h/day in the autumn and declined to a situation where no shade was used in June.

In a hot dry climate at Hamilton Downs near Alice Springs, the behaviour of a herd of Shorthorn cows was observed under extensive grazing conditions during a 2 year period. Unfortunately records were not collected on shade seeking so the importance of this cannot be determined from the records. However, it is reported that cattle sought shelter, and on a number of occasions suddenly headed south towards ranges and shrubby areas to shelter from cold south east winds and rain. Also summer behaviour was quite different to behaviour in other seasons, and this was assumed to be due to the influence of high temperatures and solar radiation.

An interesting observation was that cattle in shade in the middle of hot days continued to chew their cud but cows resting in the sun abstained. Ruminating increases the heat load and this activity is regulated to reduce the heat stress. Ruminating increases energy needs by 5% above that used when resting. This increases body temperature and reduces the energy available for maintenance and body condition. Tropical breeds tend to ruminate slightly less than British breeds.

Chewing the cud is the second most important activity of cattle, taking from 5 to 9 h of an animal's time each day. Time spent ruminating depends on the quality and quantity of feed and the amount of grinding required. At Hamilton Downs cows spent 8 h/day ruminating in summer when on poor feed and 5 h/day ruminating in winter when feed was good. As a proportion of grazing time, ruminating was equal to 84% of grazing in summer and 48% in winter. On average, the cows grazed for 42% of the day, ruminated for 27%, rested for 23% and walked for 8%.

During the hot dry seasons with high temperature, poor feed and weak cattle, an additional burden is a need for increased rumination. To accommodate this need and reduce heat stress, there is a very large increase in night time ruminating and a reduction in resting time. A reduction in day ruminating could slow the rate of digestion and reduce food intake. A reduction in resting time probably increases fatigue during grazing and could affect both selectivity and intake. The provision of shade provides for a more appropriate distribution of rumination during the day and allows for more rest. This is probably important to animals at this time of the year.

A notable observation at Hamilton Downs was that the daybreak grazing period was the most regular activity in the cow's day. The area grazed at daybreak was the most preferred location and the area most grazed in the next 24 h period.

The behaviour of Shorthorn cows was also studied at Alroy Downs on the Barkley Tableland. Observations were made in the heat of summer (October–November) in shadeless open plains and in situations where ample and limited shade existed. With no shade, cattle came in to water as the morning warmed up and camped on the water until the cool of the afternoon. They came in to water in groups of fewer than 30 head and ran the last 100 m to water and avidly drank the cooler water near the float valve. Usually, the temperature around denuded watering points varied from 36° to 43°C and on occasions went to 48°C. Ground temperatures were about 66°C and visibly stressed calves.

Calves born in shadeless country had high mortalities during the first week of life. A calf born in the early part of the day was immediately subject to extreme heat particularly if it was not shaded by its mother. Until the calves were old enough to travel to water with their mothers, the cows stayed close to their calves and made quick trips to water after planting their calves. During the hottest part of the day in these first few days, the cow often stood close enough to shade the calf.

A calf usually accompanied its dam to water when 1 to 4 days of age depending on how far it was born from water. On hot days with ground temperatures about 66°C these animals were visibly stressed and sought any shade provided by other animals, posts, troughing or dead cows. Stressed animals had high respiration rates, often were 'tonguing' and, if standing in the sun, lifted each foot in turn in an attempt to escape the intense ground heat. Calves seldom lived if their rectal temperatures were over 42°C.

When resting on water there was a tendency for cattle to lie down as conditions got hotter. This probably reduced the amount of radiation from the ground and the energy expended in standing. This has been shown to be about 9% higher than when lying down. Drooling of saliva is a sign of heat stress and was a common sight around exposed watering points.

In shadeless country, cattle left the water to graze at 4 to 6 p.m. depending on how hot it was. The herd split into two groups of walkers and non-walkers. Walkers walked 6 km out from water and spread out to graze. The non-walkers spread out to graze as soon as they left the water and grazed up to 4 km from water. The non-walkers remained relatively close to water and grazed longer on sparse feed. Walkers moved to abundant feed and did not have to move much while grazing. There appeared to be little to distinguish the two groups other than a higher number of calves among the non-walkers (39% as against 19%). Calves were reluctant to leave the water and were the last to move away. Small calves less than 3 weeks old mostly accompanied non-walkers.

In areas with ample shade throughout the paddock and close to water, some cattle camped on the water during the heat of the day and a proportion camped in shade away from water. Those camping away from water came in to water in the late afternoon or during the night.

In limited shade areas, with shade areas some 3 km from water, the herd split into three groups. Two groups, the walkers and non-walkers behaved similarly to walkers and non-walkers in the treeless country and grazed treeless areas. The third group of shade seekers camped in shade during the heat of the day and came in to water at night. There was a notable difference between the shade seekers and the rest. Shade seekers were heavier, in better condition, had sleek coats and were more alert than the poorer conditioned, rough coated walkers and non-walkers.

It would appear that in areas with limited shade and no shade at watering points, water access acts as a substitute for shade. When camped on water, cattle would return for occasional small drinks during the resting period. However, water access appears to be less effective in reducing the heat load than use of shade. In areas with ample shade, cattle grazed later in the morning before the midday rest and they recommenced grazing earlier in the afternoon than those not using shade. On very hot days some animals in the area with ample shade would graze in the hottest part of the day. This was very rarely seen in the shadeless areas.

In the areas with limited shade some 3 km from water, it is difficult to understand why all the cattle did not use shade. Perhaps a habitat learning experience gained in one environment persists for some time when animals are moved to another environment. So cattle born and raised in a treeless environment remain non-shade seeking walkers and non-walkers when moved to an area with limited shade.

How long this behaviour persists is not known. Experiences, particularly those gained in early life, may alter the later behaviour of an animal for a considerable time. In sheep it has been shown that grazing behaviour learnt early in life under extensive conditions persists for up to 2 years when moved to intensive conditions.

It could also be explained by home range behaviour. When stock are moved frequently from paddock to paddock, as in the more intensive areas, they do not adopt a home range. In extensive areas with large

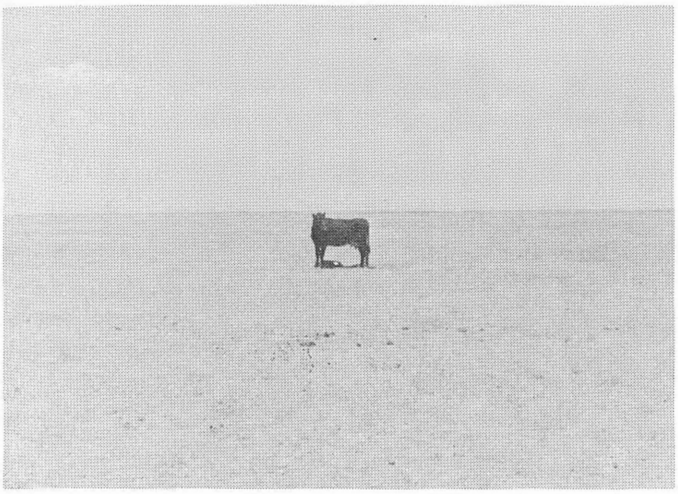


Plate 1. Calves born in shadeless country have high mortality rates. Cows often stand close enough to shade new-born calves.

paddocks, they tend to split into groups and graze particular areas and this behaviour is passed from mother to progeny. It has been suggested that the areas different groups graze have been developed by social competition whereby some animals are forced to graze less favourable areas and develop a herd identity.

Observations made at Alroy Downs indicate that shade has to be very close to water before the walkers and non-walkers use it. If shade was more than 300 to 400 m away from water it was not used.

The importance of shade for calf survival in north west Queensland has been observed in Shorthorn herds at Kamilaroi and Granda. On average, about 20% of calves born are lost before weaning. Half of these (about 10% of births) are lost before branding and most die from heat stress in the first week of life during the hot dry and humid periods extending from October to March.

In a less stressful environment at Belmont Tropical Cattle Research Centre near Rockhampton, 5% of all calves born in the various Tropical and British breed herds die during the first week of life. This is about half the mortalities expected in the north west during a comparable period.

In the north west with some shade available, the most critical factor affecting calf mortalities from heat stress was whether a calf was born during the day or night. If a calf was born during the resting period extending from mid morning to mid afternoon, there was a good chance that the cow calved in the shade, particularly if it was a hot day. On the other hand, if a calf was born during the night, early morning or late afternoon, there was a good chance of its being born some distance from shade. For these calves it could be some days before they were moved to shade, and mortalities from heat stress were high, particularly among undersized calves from heifers.

High mortality rates in young calves are not peculiar to British breeds. In fact, Belmont research has shown that mortalities in the first few days of life are greater in high grade Brahmans and Africander calves than in British breed calves. High mortalities in the first week of life are associated with high or low birth weights. Brahman calves in particular are smaller and weaker at birth and are more easily stressed, but subsequent survival is excellent. Zebu crossbreds, especially Africander crosses, had higher survival rates than British breeds at every stage.

Heat stress and fertility

The previous section was concerned with animal behaviour and the more observable effects of exposure to high temperatures. The effects of heat stress on fertility and calf birth weights are less obvious but crucial.

Research at Belmont has shown that fertility levels, measured as the ability to produce a live calf, declined as heat stress increased. The degree of heat stress was indicated by the rectal temperature of the cows a few weeks after the completion of mating.

Rectal temperatures averaged 39.8°C and were 0.5°C higher in British breeds than in zebu cross cows. The depression in calving rates for given increases in rectal temperature was the same in different breeds. Adapted breeds had higher fertility levels at any given rectal temperature.

The reduction in calving rates increased as rectal temperature increased. For every 0.1°C increase in rectal temperature above 39°C, calving rates were reduced by 0.9%. This incremental reduction rose to 2% and 3.5% as rectal temperatures rose to 40°C and 41°C, respectively. Overall, the average depression in calving due to heat stress was 15 to 25% in the British breeds and about 10% in zebu cross herds. Stressed cows also gave birth to lighter calves.

Heat stress can significantly increase the length of the oestrous cycle, reduce the intensity of oestrus and cause cows to come into oestrus at night. These influences combine to reduce the chance of cows getting in calf and extend the intercalving interval. If a stressable cow does get into calf, heat stress can terminate the pregnancy. If the embryo survives, stressed cows give birth to undersized calves that have a high mortality when born into a stressful environment.

Research with sheep highlights the importance of a relief from heat stress on embryo losses. Ewes under continuous heat stress during the first 15 days of pregnancy lost 83% of their embryos. Similar ewes stressed for 8 h of the day had an embryonic loss of only 35%. There probably is no phase of reproduction that is not vulnerable to heat stress. In hot weather, mustering and yard work should be organised to reduce heat stress on cows.

Zebu cross cattle are regarded as quite heat tolerant and it is surprising that, even in a relatively mild environment, they display a susceptibility to heat stress that significantly affected productivity. Obviously, there is a need to select for heat tolerance and the culling of cows failing to calve helps. There also is a need to modify the extremes in the environment and provide greater access to shade.

Provision of shade

Except in very small paddocks where cattle graze over the whole area each day, the area grazed is influenced by the palatability of the grass species, location of water and shade, the topography, weather and other unidentified factors.

In moderate size paddocks and normal weather conditions, the area grazed each day is almost randomly determined and initiated by various individuals. There is no overt leadership when grazing and the termination of a rest period is usually initiated by less gregarious individuals who move away from their neighbours; others follow. These initiators are unlikely to be dominant animals. In fact, when walking it has been found that mid dominant animals are in the

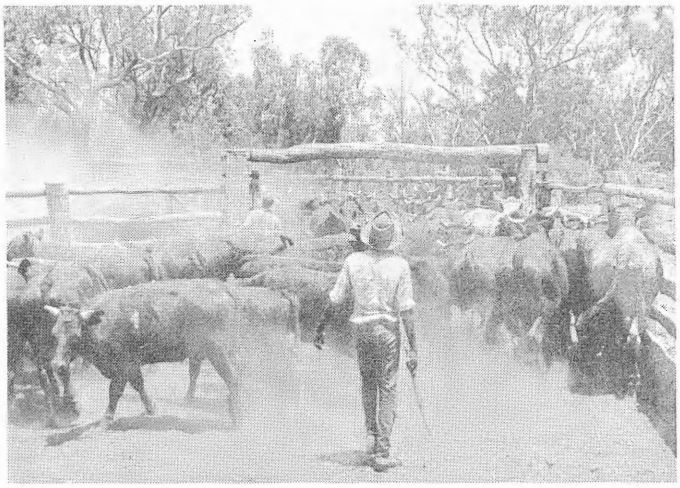


Plate 2. There probably is no phase of reproduction that is not vulnerable to heat stress. In hot weather mustering and yard work should be organised to reduce heat stress on cows. Yards should also have shade.

Plate 3. As the mercury rises high, all breeds of cattle seek shade. Tropical breeds use it for a shorter period of time than the more heat susceptible breeds.

lead. These are followed by dominant animals, with low dominant animals bringing up the rear. This is sometimes called leadership by pushing rather than pulling.

In larger paddocks in extensive areas, cattle have the opportunity to become very selective in their grazing habits. This, plus the adoption of home range grazing areas by different groups, contributes to non-random use of country with tendencies to overgraze some areas and undergraze others. In these areas a major influence on where cattle graze is the location of water.

For the majority of cattle the area grazed around a watering point (the piosphere) extends 4 km from water. Only when pasture deteriorates do they go out beyond 8 km.

Pasture usage around a watering point decreases as the distance from water increases. Areas close to water are overgrazed and country within 0.5 to 2 km radius can be completely bare. Where pasture still persists, overgrazing changes the composition of the pasture with annuals replacing perennials in overgrazed areas.

At greater distances from water, the pockets or spots grazed are determined by the palatability of the pasture species and the ability of cattle to walk to that location. This selective grazing behaviour results in overgrazing and denudation of some areas, an uneven distribution of nutrients from faeces and a change in the composition of pasture. At the other extreme, large areas of less palatable pasture are left ungrazed.

Selective grazing is one of the most important factors limiting beef production in extensive areas—particularly where there are different soil types and pasture species. In the USA it has been shown that this behaviour depressed steer growth during the summer by 36 kg/head—worth $32 per head at 90c/kg liveweight.

Paddock size is one of the main determinants leading to overuse and underuse of pasture. Cattle walk more in larger paddocks, particularly during the cool months of the year. In large paddocks in the Northern Territory, some cattle walked 24 km to feed and returned to water every 2 or more days. Smaller paddocks reduce both walking and the degree of selective grazing.

Within any paddock, water, licks and shade can be used to manipulate the distribution of cattle. Water is the single most effective attractant directing where cattle congregate and graze. Palatable licks and supplements are the second most effective attractant and, if placed away from water, can be used to direct where cattle move once they leave water. Shade closely follows licks as an attractant. Combinations of two or more attractants are more effective than any one in determining where cattle congregate.

Conclusion

To reduce heat stress in the Queensland environment shade is needed where cattle congregate. This means shade should be available at watering points, which should be distributed to disperse the herd to reduce over and undergrazing. Belts of shade trees are needed so cattle can maintain normal social distance from each other and to provide some shelter from cold winds that can be experienced at times.

The real value of shade trees in reducing heat stress and improving productivity has generally been overlooked and large areas of valuable shade have been destroyed. Tree planting programmes should be developed in shadeless areas so that shade is provided for the most stressed animals—breeding cows and their calves. Shade should also be available at cattle yards.

Artificial shade can be provided in those situations where trees are difficult to grow. In these cases it may not be possible to provide a structure that can shade both cows and calves. However, as calves require a relatively small shade area, they can be provided shade at watering points using a creep to exclude older animals.

Cattle handling techniques should also be devised to reduce heat stress when mustering and working cattle in yards. Cattle should be worked quietly and in hot weather midday stress can be avoided if cattle are mustered in the cool of the afternoon, yarded overnight and worked in the yards in the early morning. Cattle are easier to work when not stressed and with this approach they are returned to their paddock before the heat of the day.

Plotting a better future for lambs

A practical guide to providing shade

G. Roberts, Sheep and Wool Branch

Plots of shade trees planted in joining and lambing paddocks have proved a simple and effective means of increasing lamb-marking percentages at 'Toorak' Research Station in north west Queensland. In these semi-arid sheep lands, the average daily maximum shade temperature exceeds 35°C for 6 months of the year. During this period temperatures above 40°C are common. The Mitchell grass plains are generally devoid of shade, and large heat loads are placed on sheep. Dry Merinos that have become adapted to the environment suffer no obvious ill effects from heat stress, but the effect on pregnant ewes and their lambs can be catastrophic. Since most lambings in the north west are timed for late summer/early autumn when pastures are normally at their best after summer rains, pregnant ewes and newborn lambs are exposed to extreme environmental temperatures.

Effects of heat stress

Heat stress has an adverse effect on breeding ewes at two periods in the reproductive cycle. At joining it can cause suppression of oestrus, conception failure and early embryonic mortality during the first 7 days after ovulation. Ewes stressed by heat in the last 6 weeks of pregnancy suffer an increase in body temperature which they are unable to reduce. This sustained high temperature has the effect of reducing the birth weight of their lambs (Figure 1).

Since birth weight is related to survival, light lambs born to heat stressed ewes are more likely to die soon after birth than their heavier counterparts. Figure 2 shows the effect of birth weight and ambient temperature on lamb survival. Lambs which survive the extreme temperatures often pay a penalty due to heat stress which results in slow growth rate, reduced ultimate body size and reduced wool production at first shearing.

These effects of high environmental temperatures on sheep have been documented for the open Mitchell grasslands of north west Queensland by officers of the Department of Primary Industries 'Toorak' Research Station.

Shade trees

An obvious and simple solution to the problem is to provide shade in joining and lambing paddocks. This solution is not new. Many derelict frames of sheds that were once roofed with hay or grass can be seen in paddocks throughout the north west of Queensland. Attempts have also been made over the years to grow trees along drainage lines and bore drains. Both these

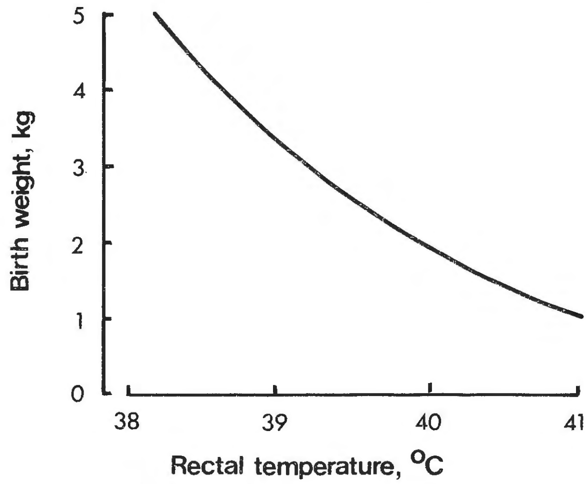


Figure 1. Effect of high ewe body temperature on lamb birth weight.

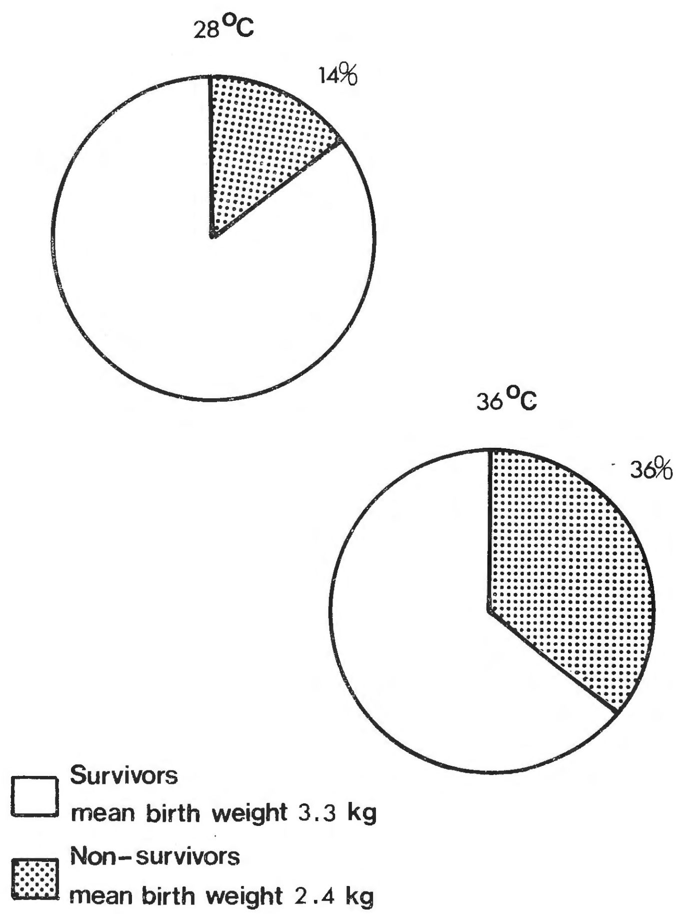


Figure 2. Effect of birth weight and ambient temperature on lamb survival.

Gerry Roberts Gerry is the Officer-in-Charge of 'Toorak' Sheep Field research Station at Julia Creek. He has developed an extension service based on 'Toorak' research findings, such as the subject of this article.

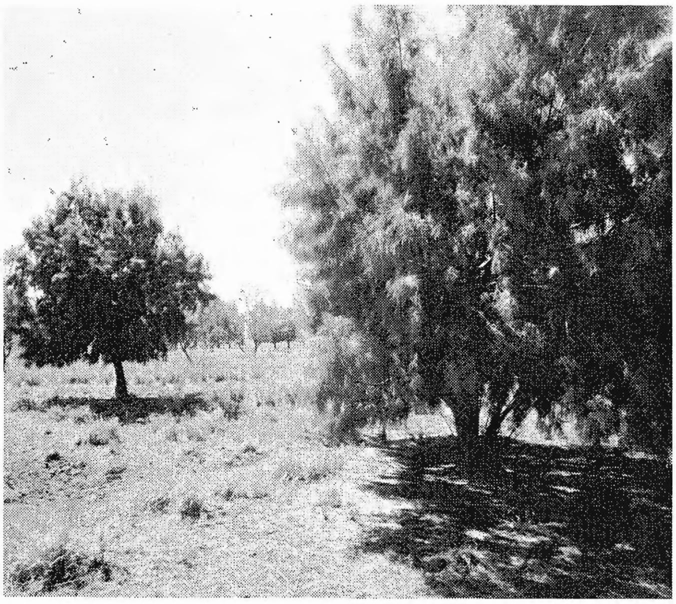


Plate 1. A plot of Athel pines at 'Toorak' Research Station.

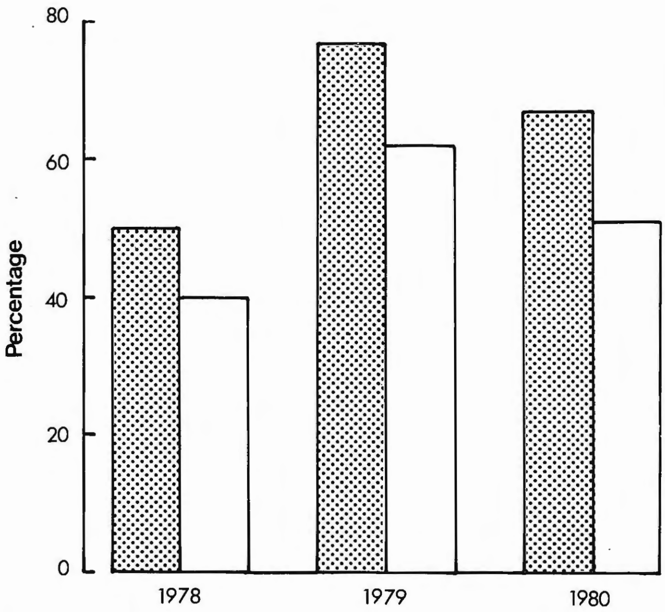


Figure 3. Lamb-marking percentage of ewes lambing in a paddock planted with Athel pines ▩ and in an unshaded paddock □.

techniques provide the much needed shade but they have significant limitations. Sheds require renewing and are expensive to build and maintain. Trees are restricted to areas where there is an open water surface.

To overcome these limitations, Sheep and Wool Branch officers planted a plot of Athel pine *(Tamarix articulata)* trees at 'Toorak' in 1975. The plot was designed so that the trees could be established, watered and maintained with a minimum of effort. By 1978, the trees were sufficiently well grown to provide shade and not be destroyed by grazing. To test the benefit of shade in lambing paddocks, a group of pregnant ewes was allowed into the plot and at the same time a comparable group was placed in a similar but unshaded paddock. In the following 3 years ewes in the shaded paddock produced significantly more lambs than ewes in the unshaded paddock (Figure 3).

Since that time the technique for establishing the Athel pines has been altered to improve strike rates, reduce maintenance problems, hasten growth and promote tree survival.

Planting techniques

The trees are planted 10 m apart as in the original plot design. Water is provided in a polythene pipe system, and the area is fenced to prevent damage to the trees while they become established. Any number of trees can be planted; normally one is provided for every 50 ewes.

Planting involves the following steps:

- Select a site close to where sheep water.
- Have water with a head of 1.5 to 2 m for adequate pressure. (Because of the piping system little water is needed.)
- Dig holes with a post hole digger, 40 to 60 cm deep.
- Mix three shovels of sand plus one handful of gypsum with the soil from the hole.
- Lay 25 mm polythene pipe along each row, and 25 mm or 38 mm delivery pipe as supply lines.
- Drill a hole of less than 1 mm in the pipe at each tree hole.
- Fill the tree holes with water and leave overnight.
- Take fresh cuttings from existing Athel pines, each 40 to 50 cm long and from 2 to 6 cm in thickness. Allow two cuttings per hole.
- Drop a handful of general fertiliser into a water-filled hole.
- Place two fresh cuttings and the sand/soil mixture in the hole leaving 8 cm of each cutting above the ground.
- A mound of earth around the trees at a distance of half a metre prevents waste of water.
- Erect the fence.
- Keep the ground around the cuttings soaking wet until they strike (usually at about 6 weeks).
- Soak recently struck plants every 2 weeks for the next 4 months and at 2-monthly intervals for the following 12 months. After that one soaking every 4 months should be adequate.
- Ideal planting time is October. This allows trees to strike and establish in warm weather then grow quickly during the wet season.
- When new plants are about 40 to 60 cm high pull out the weaker one from each hole.

Two men can establish a plot of 40 trees in one day, including erection of the fence. The equipment required is:

- 25 mm polythene pipe;
- 38 mm delivery polythene pipe;
- electric fence energiser;
- 1 000 m of 12.5 mm plain wire;
- 12V battery; and
- polythene pipe fittings.

Conclusion

On the Mitchell grass downs in northern Queensland a plot of Athel pine trees reduces the heat load at joining and lambing. This results in 10 to 16% more lambs at marking, as well as a faster growth rate and more wool from the lambs over the first 16 months of their life. Athel pine plots are easy and cheap to establish and maintain, and they are self-renewing.

The establishment of shade plots allows a sheepman to select his best paddocks for lambing.

Tree clearing and the community

N. M. Dawson, Land Resources Branch

Trees are one of our greatest resources, providing a cheap and effective means of stabilising land that is susceptible to serious land degradation. They can also positively contribute to farm income as other articles in this issue show.

Land degradation in Queensland is causing loss of productivity, erosion, sedimentation, flooding and pollution. It is recognised that 690 000 km² of this State are susceptible to either wind and water erosion, river bank erosion, salinity or landslip.

Worse still, these problems not only affect individual landholders but they can affect the whole community and the future productivity of our country. On well over 70% of this area, simple land use practices such as the retention of trees in key areas could be the answer. The planned retention of trees prevents these problems from occurring.

Overseas experience, and experience here, prove that the costs of replanting degraded areas with trees is not only terribly high but essential.

Queenslanders have the opportunity to prevent these problems occurring by consulting land use specialists in the Department and planning before they clear any forested area. The advice is cheap; the costs in not planning can be high.

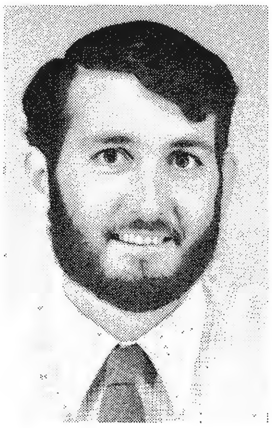
Potential problems

Every Queenslander sees or is being exposed to problems which have resulted from the overclearing of trees on hazardous or critical areas. These include:

- water and soil salinity,
- landslip causing damage to infrastructure,
- river bank collapse causing productivity loss and siltation,
- flooding,
- wind erosion,
- soil erosion, and
- water pollution.

These problems, unfortunately, have not been restricted to property boundaries but are now having a substantial effect on the general community or adjoining farmers.

For example, landslip along the coastal hills has caused losses in some years approximating $2.0 million worth of damage to roads and infrastructure as well as polluting creeks. There are estimated to be over 250 000 ha of land in Queensland that are very susceptible to landslip. The broad distribution of these areas can be identified on maps.



Noel Dawson Noel is the Director of Land Resources Branch of the DPI. He is involved in programmes of land resource assessment and State planning issues. Noel has recently returned from a 3 month interchange in New Zealand.

Dryland salting mainly caused by overclearing has led to extreme loss of productivity on over 8 000 ha of land at a cost in land value terms alone of $2.0 million. It is estimated that annual losses in production are $1.0 million. How would you feel if you suffered losses from salting and you had not even cleared the country causing the problem? In some cases, the more valuable lands may be reclaimable by drainage but generally there is a permanent loss of production.

River bank collapse and erosive flooding associated with the clearing of vegetation on river banks is no respecter of fencelines. Stream breakthroughs occur in these areas and cause serious erosion on adjacent properties. Deposition and bank breakdown also cause local flooding.

Overclearing and poor management in catchments can lead to increased runoff in periods of high rainfall, aggravating flooding and erosion of river banks. They can also reduce flows in dry periods. A well forested catchment usually spreads runoff over a longer period

Plate 1. Land degradation in Queensland is causing loss of productivity, erosion, sedimentation, flooding and pollution.

Plate 2. Clearing of roadsides without approval can lead to fines. Trees on roads can be a valuable means of controlling salinity and wind erosion.

and provides cleaner water. It is particularly important to keep trees on the steep or more erodible lands.

Queensland has only experienced a small number of severe dust storms in the last decade but when they occur they cause serious inconvenience to farming and urban communities. There are, however, large areas of Queensland (about 30%) where indiscriminate or unplanned clearing of trees and removal of cover could lead to dust storms similar to those experienced in the southern states and the USA.

Clearing of small watercourses and other unstable land types combined with poor management is also causing serious gully erosion throughout the State. Silt from this erosion covers roads and fills dams. The costs of removal are high and are usually paid for by local authorities. Perhaps the biggest effect of clearing of these unstable lands is that on water quality and creeks. We have all noticed the general decline of these in recent years, particularly in those overdeveloped or poorly managed areas of the State.

Planning to prevent community problems

The significant point in regard to these issues affecting the general public is that they could have been prevented. Better, we can still prevent further expansion of the problems by sound planning. Planned development can be much cheaper than repair and in many cases repair may not be economically practical.

Articles elsewhere in this journal detail how trees can be used in farm plans to control land degradation. I will concentrate on how the retention of trees in specific locations can prevent community problems arising.

The first point is that before landholders clear areas of land they should wherever possible consult officers of the Division of Land Utilisation. These officers can advise the suitability of the land for clearing and identify specific management practices that may be needed to prevent land degradation. They are experienced in farm planning principles.

As well, the Development Planning Branch and other Departments prepare maps which identify hazardous areas where clearing of vegetation could cause problems of landslip, salinity and serious erosion. In these areas, it is essential that advice is sought before clearing to prevent irreversible damage to land productivity, water quality or infrastructure. Ideally, this information should be included in Local Authorities' Town Planning Schemes.

General principles which would be followed in any tree clearing programme are:

- Keep trees along the banks of all defined drainage lines (at least 10 m),
- do not clearfell whole paddocks, but keep shade and shelter for future needs,
- on the lighter soils maintain windbreaks perpendicular to the prevailing strong winds,
- definitely do not clearfell on slopes exceeding 20% inclination, without first seeking advice,
- seek advice where hazardous areas have been defined or district problems are known, and
- think of your neighbour before clearing.

Queenslanders are extremely lucky that many of the areas susceptible to severe land degradation have not had their protective cover of tree and shrub vegetation removed. In other parts of the world, countries are busily replanting these degraded areas *at great expense.* In New Zealand, it is common to spend $5 on each tree planted. When you think of this in terms of thousands of trees on a farm it is very expensive. Finally, trees take many years to grow and stabilise these areas. To grow properly they need to be fenced and protected from fire and other dangers. This adds to costs. We can avoid this sort of cost by good planning in any tree clearing programme.

Plate 3. A river bank well stabilised by trees. Clearing out the fallen trees prevents bank scouring.

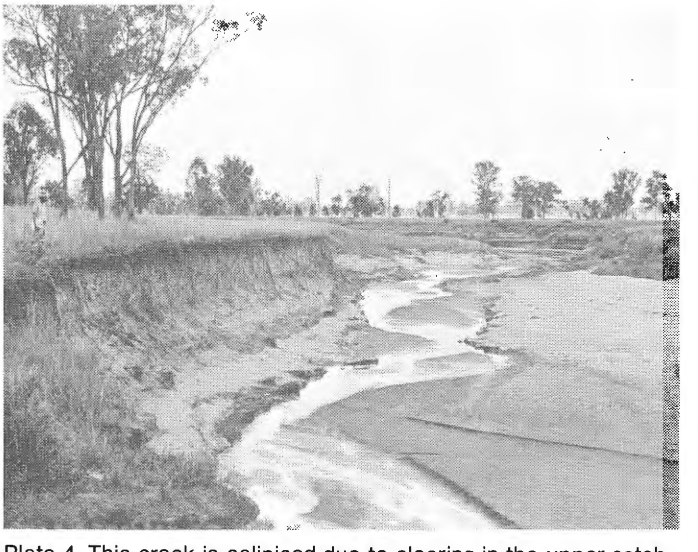


Plate 4. This creek is salinised due to clearing in the upper catchment. Clearing of the banks has also led to erosive flooding and bank collapse.

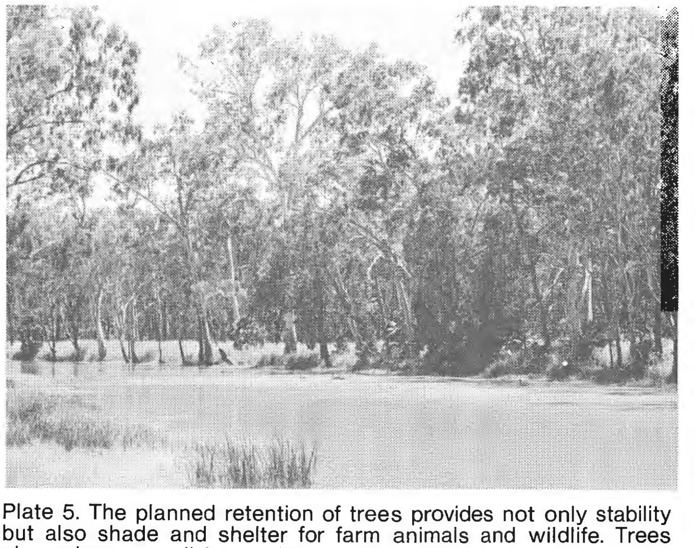


Plate 5. The planned retention of trees provides not only stability but also shade and shelter for farm animals and wildlife. Trees also enhance our living environment.

On-farm nature conservation

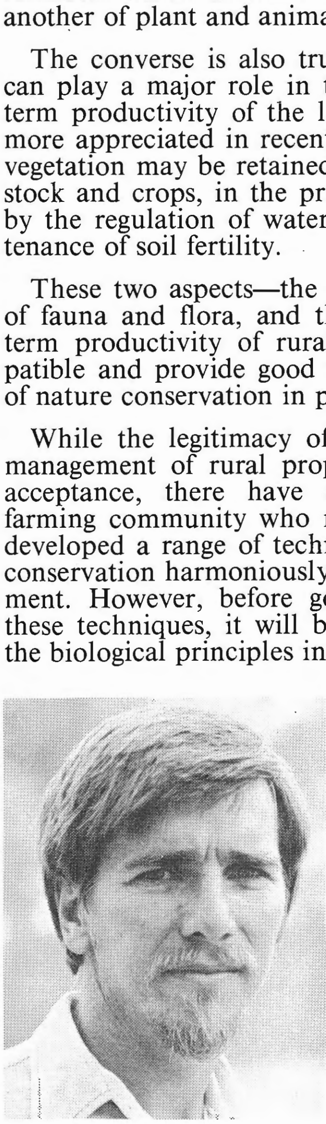
J. James, Queensland National Parks and Wildlife Service

Recently a working committee of producer organisations published the document *An Agricultural Policy for Queensland* which gives the following as one of its recommendations: 'Conservation in rural areas should aim at a balance of achieving a managed ecosystem in which native flora and fauna species are maintained along with the long-term productivity of the land'. It is in this context that the value of on-farm nature conservation can be fully realised. While our national parks and other similar reserves set aside examples of the various fauna and flora communities of Queensland, they alone do not achieve a satisfactory level of conservation of native plants and animals. The real value of these reserves is only realised when they function in conjunction with the surrounding landscape with its remnants and corridors of natural vegetation, its partially cleared grazing lands and its greatly modified agricultural lands. The contribution to nature conservation by non-reserved lands is in fact highly significant, and includes their values as habitat for native plants and animals, and as passageways and corridors which allow the dispersal from one area to another of plant and animal populations.

The converse is also true in that natural vegetation can play a major role in the maintenance of the long term productivity of the land, a fact that has become more appreciated in recent years. Some of the original vegetation may be retained and used as shelterbelts for stock and crops, in the prevention of salting problems by the regulation of water balances, and in the maintenance of soil fertility.

These two aspects—the conservation of our heritage of fauna and flora, and the maintenance of the long term productivity of rural lands—are generally compatible and provide good reason for the consideration of nature conservation in property management.

While the legitimacy of nature conservation in the management of rural properties is now increasing in acceptance, there have always been those in the farming community who recognised it, and who have developed a range of techniques which help fit nature conservation harmoniously into their property management. However, before going on to discuss some of these techniques, it will be helpful to review some of the biological principles involved.



John James John is presently involved in a new initiative of the Queensland National Parks and Wildlife Service, their Rural Nature Conservation Programme. This is a voluntary scheme to encourage wildlife conservation on all rural lands.

Ecological succession

The concept that plant and animal communities on any area of land develop through a series of stages is a basic principle of ecology termed 'ecological succession'. This may be illustrated by reference to a ploughed paddock which is fenced off and left unworked. This paddock will pass through several stages, called 'seral communities', to reach a final or mature community called the 'climax community'. The seral stages might include 'pioneer' annuals, followed by perennial grasses which form a grassland community followed by a shrubland community consisting perhaps largely of wattles, then a forest community of eucalypts and finally in wetter areas a rainforest community. Each stage provides the conditions needed to allow the next to develop. As the plant species and the structure of the habitat change so does the associated fauna, and generally each new stage is more diverse in both fauna and flora than its predecessor.

Obviously the above is simplified. Many factors influence succession and an understanding of these factors is most important. Fire, perhaps the best known example, can greatly modify both the seral stages and the climax community. For example, a sequence of regular, low intensity fires through woodland and forest communities generally maintains a grassland understorey while intermittent, high intensity fires encourage a shrubby understorey.

Fire, to which much of Australia's fauna and flora has become adapted, may also be necessary to trigger the change from one seral stage to the next. Many native shrub species such as the hakeas require fire to allow the germination of their seeds, while the seeds of wattles and the lignotubers (bulbous swellings at the junction of the stem and roots with dormant buds) of many eucalypts are stimulated into growth by fire. Thus, a grassland area fenced off to allow trees to regenerate may need fire to stimulate tree growth if the exclusion of grazing has not been sufficient.

Exotic plants and animals, if present, also influence the cycle of succession. These may be managed species such as introduced pasture grasses and grazing stock, or unwanted species such as introduced weeds and animal pests. Where regeneration of plant communities is attempted, management of these influences is most likely to be necessary.

Size, shape and proximity to other wildlife habitat

For an area to be of greatest possible benefit for nature conservation, the size, shape and proximity to other wildlife habitat should be considered when possible. A larger area of vegetation not only supports more of the same types of species than a smaller area but often supports a greater range of species. This would include some of the larger species of fauna which require significant areas for feeding and shelter to allow them to survive, and which are often less affected by outside disturbances.

The importance of shape lies in the fact that for any given area, that with the least length of perimeter suffers the least disturbance from influences outside it. Thus, the closer the shape of a reserve is to a square (or even a circle) the better the preservation of that particular plant community.

The nearness of a plant community to other areas of natural vegetation is important in the maintenance or development of diversity in both flora and fauna. Many plant and animal species require continuous or near continuous habitat to allow dispersion or repopulation to occur readily. Many of the smaller species of fauna, such as some frogs and lizards, are not capable of crossing large distances of unsuitable habitat and, if they try to do so, are highly vulnerable to predation. Local populations of plants and animals in small remnants of habitat on private lands are susceptible to severe depletion or even total loss as a result of fires, drought or similar influences on the habitat. Thus, populations of those vulnerable species, and those affected by adverse factors, both spread and regenerate most quickly when the area is contiguous to other areas of similar habitat, but less quickly though still effectively if corridors of vegetation such as shelterbelts, roadside verges and watercourse vegetation are available to provide passageways between areas of similar habitat. Corridors are particularly valuable in that they have the dual role of providing useful habitat in themselves as well as allowing quicker and more effective dispersal of wildlife.

Special features and patchiness in the environment

Certain features in some habitats give rise to greater species diversity than otherwise similar areas lacking those features. These include the presence of water, both temporary and permanent, rocky outcrops, caves

Plate 1. Remnants of native vegetation such as shade clumps, vegetation along road reserves, shelterbelts and watercourse vegetation combine to provide useful habitat for wildlife, ensuring that populations of native plants and animals are able to survive alongside agricultural enterprises.

and mature trees with hollow limbs. These, with other like features, allow a greater range of species both plant and animal to utilise the total environment. An example would be the utilisation of an area by rock wallabies because, among other features this species needs, rocky outcrops were present.

Patchiness within the environment also increases the diversity of species for similar reasons. This can result from fundamental differences in the soils (for example cypress on sandy outcrops in brigalow soils), from differences in slope, drainage and soil depth (for example *Melaleuca* clumps in areas of poor drainage), or even from the presence of several 'seral stages' in any one community such as occurs when only part of a community is burnt, or the intensity of the burn varies within the area.

Thus, the presence or absence of 'special features' may often be used in deciding which of several available areas would be most suitable for nature conservation purposes. Management practices which maintain or create patchiness may well be beneficial in increasing wildlife diversity and should be used except where the conservation of a particular species is the primary concern, in which case management must be directed towards its particular needs.

Dispersal of animal populations

Apart from the regular seasonal changes of species that occur from migratory animals (for example such native birds as the rufous fantail, the dollarbird and painted snipe) the species composition of an area also changes in response to irregular, often barely perceptible factors. What is suitable habitat for a species in one year may not be in the next. Thus, an area of vegetation may support an owl in seasons when there is an abundance of rodents but it will not in years

Plate 2. When remnants of native vegetation are linked by corridors their value to wildlife conservation is greatly enhanced. Here remnants of vegetation are linked by retained vegetation along a stock route.

when there are too few rodents available for its food requirements. In such 'poor' years the resident owl would either be forced to hunt over a larger area or, if this was not available, it would starve and disappear from the area. When conditions 'improved' other owls would take up residence from refuge areas if they are nearby.

Understanding this concept of habitat fluctuating in its suitability for some species is important for land-holders with small areas of wildlife habitat who may otherwise think that something is wrong with their management of a reserve. It is one explanation of why a particular species may be resident for a few seasons only to disappear again for several seasons. This is often particularly noticeable with our native birdlife.

Irregular changes in the presence of species on a shorter time scale often involve species that are classed as 'nomadic' animals. Such animals move from one area to the next seeking favourable conditions. Among our native birds many of the honeyeaters fit this category, moving in response to the flowering of their various food plants. Much of Australia's fauna is nomadic, largely in response to an environment whose rainfall is unpredictable. Remnants and corridors of natural vegetation in rural areas are obviously highly beneficial for such species, which need to be able to move over large areas.

Occasionally, an unexpected animal is found in an area away from its usual habitat. This, usually short term, occurrence is most likely the result of an animal traversing inappropriate habitat in search of suitable, unoccupied, habitat in which to live. Often it is a young animal reaching maturity which has been forced to seek out a new place to live as a result of insufficient habitat near its birth place. The presence of the occasional water rat in a fowl run well away from any water or of a koala up a gum tree in a suburban backyard are not unfamiliar examples of this.

Plates 3 and 4. Attitudes to the value of vegetation along roadside verges and around paddock boundaries vary. Such vegetation does, however, provide wildlife habitat and corridors as well as wind protection for adjacent paddocks.

Having dealt with some of the biological principles it is now appropriate to discuss some practical examples. Clearly, on a property, trees may be required or retained for various reasons and probably in most instances for multiple reasons. Thus, nature conservation may not have a high priority but, where it can be considered in management decisions involving farm trees, much can be done for the wildlife conservation of the area.

In considering what can be done on the property, the opportunities are examined under the following categories:

- retention and regeneration of native vegetation;
- maintenance of natural values on productive lands; and
- artificial habitats.

Retention and regeneration of native vegetation

Some property owners have set aside areas of their properties as 'farm reserves' for nature conservation. These areas are valuable for fauna and flora as they are managed specifically for that purpose. While these may be utilised from time to time for secondary purposes such as the harvesting of timber for fence posts, their value to nature conservation is high because they conserve the whole habitat in a relatively unaltered state. This in turn means the greatest diversity of species living in that community is conserved. In those farm reserves located on soils of high productive potential, vegetation types that are poorly represented in our national parks or similar reserves are frequently conserved. In addition, these vegetation types are usually diminishing on private lands by being cleared for primary production. It follows that even small

Periodic deep ripping alongside trees to cut roots entering cropping or pasture areas can reduce moisture stress caused by invasion of tree roots.

reserves of this kind are particularly important. Good examples of this are remnants of brigalow and softwood scrubs.

Farm reserves do not necessarily mean the loss of income. There are parts of many rural properties that have low productive potential: they may be steep, have stony soils, be wet and poorly drained, or be prone to soil erosion. Such areas, if natural vegetation is retained or allowed to revegetate, are often admirably suited to farm reserves for wildlife. The same factors which make them unsuitable for production are often the 'special features' which give rise to increased species diversity and hence increased value for wildlife habitat. Such areas are often regarded as useless, problem segments of a property which could only be developed at great cost with doubtful return. However, the farm reserve option gives them purpose in the overall farm management and in the future may well be seen as an asset to the property.

Plate 5. Clearing of steeper slopes is often unproductive, and may cause problems such as weed invasion of the cleared area or soil salting further down the slope. Such areas left with their native vegetation or allowed to revegetate provide useful wildlife habitat and make excellent 'farm wildlife reserves'.

Plate 6. Native trees retained in a grazing paddock are beneficial for both wildlife and stock. It is important to ensure that younger trees are allowed to grow to replace the mature trees when they die.

Shelterbelts and windbreaks of retained vegetation have as their primary purpose the improvement of production. If nature conservation values are considered in their planning and management they can also be beneficial for wildlife, particularly if they link up other areas of vegetation and serve as wildlife corridors.

If revegetation is desired, whether for the development of shelterbelts, for wildlife areas or for the restoration of degraded areas, the use of native plants, especially local ones rather than exotics greatly enhances its wildlife value. Several factors can influence the success of such operations. Perhaps the most important is the length of time since the area has been cleared. If it is less than 5 years there is a reasonable likelihood that the natural revegetation will reappear if the area is simply fenced off. If replanting is necessary, then use of locally collected seed is advisable where possible. Also, rather than just planting the species that previously occupied the mature or 'climax' community, a look around the district to observe those native species which are first to colonise disturbed areas in similar situations may well identify the 'pioneer' species. These 'pioneer' species, which are often the wattles, may be important in the early stages of the revegetation programme. These can be planted to simulate one of the earlier 'seral' stages of the ecological succession, and may well improve the success of the revegetation effort.

Maintenance of natural values on productive lands

Landscapes must be altered to achieve agricultural and pastoral production, but this does not have to be done with a disregard for the landscape and its natural values. Indeed, research continues to show that there are economic advantages for those who work within the capability of the land and attempt to fit these activities harmoniously in with the landscape. If the

Plate 7. Lake Broadwater Environmental Park seen in the context of surrounding agricultural lands with their remnants and corridors of native vegetation. These are integral parts of the successful functioning of any reserve.

production benefits of retained vegetation are considered in conjunction with their potential for nature conservation, much can be done towards achieving 'a managed ecosystem in which native flora and fauna species are maintained along with the long-term productivity of the land'.

In many pastoral situations where trees have been retained, grazing pressure or incorrect fire management has not allowed any natural regrowth of trees, resulting in an even-aged population of older trees. While this may not present any immediate problems, the long term result is the loss of all trees from old age. Thus, it is important to ensure that a suitable age structure of trees is retained in pastoral areas, which involves correct fire management and reducing grazing pressure to allow some regeneration. In the case of smaller more intensively grazed paddocks, fences can be used to exclude stock from some parts of the paddock until young trees have grown sufficiently to withstand grazing pressure. Such fences may then be rotated to other parts of the paddock, so that there are always young trees being allowed to regenerate.

Other valuable contributions to nature conservation are shelterbelts around cropping and pasture paddocks and retained vegetation along creeks and riverbanks. Again there are good economic reasons for these management options and again they can be made even more useful if wildlife values are considered in their implementation. Such actions as the inclusion or retention of some older trees with hollows suitable for tree dwelling mammals and nesting birds, the linking up with other areas of natural vegetation and the inclusion or retention of shrub layer species in these areas improve their value for wildlife.

Artificial habitat

A significant part of any rural property, especially agricultural enterprises, would come under the classification of a totally altered habitat. Some native fauna are able to use these areas. For example, in a cropping paddock native species such as quail are able to find suitable habitat. Indeed, where it is practicable, the retention of the stubble phase of the crop during summer months often allows quail to nest and rear young successfully. The presence of vegetation near open paddocks or provision of suitable roosting sites permits other, often beneficial, species such as kestrels and owls to utilise these paddocks as foraging grounds. Obviously, some of these options would not be applicable in situations where it would be likely to increase crop losses from species such as cockatoos and galahs.

The improvement of farm dams for wildlife has been well documented elsewhere (for example *Wildlife in the Home Paddock,* R. Breckwoldt 1983) and is not dealt with here. However, it is an excellent example of an altered environment which when constructed with consideration for nature conservation can provide useful wildlife habitat without any loss of function.

Another artificial situation is amenity planting. This involves the use of trees and shrubs to improve the immediate surrounds and microclimate of a homestead by protection from winds and the provision of shade. If native species are included, especially those providing nectar or fruits, the amenity value is increased by the presence of greater numbers of native animals.

Thus, in summary, what is needed in order to achieve the aims of the fauna and flora recommendations of *An Agricultural Policy for Queensland* is not an upheaval of present day farm management but simply the inclusion of an additional consideration, nature conservation. If this can be seen as part of sensible overall farm management for the maintenance of long term productivity then the future of our native flora and fauna is greatly enhanced. Those farmers who already accept this reasoning are serving as both example and incentive to allow greater integration of nature conservation with rural enterprises for the mutual benefit of the countryside and the community.

Trees in the landscape

H. E. Kleinschmidt, Botany Branch

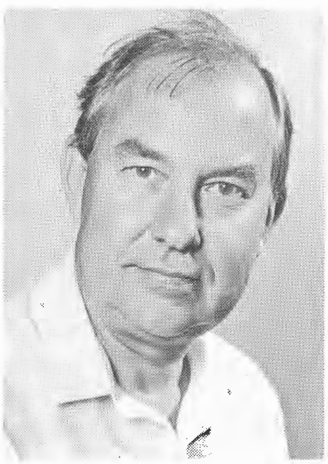
Plate 1. A sterile landscape devoid of live trees.

Plate 2. Trees in harmony.

When planning a landscape, it is essential to envisage the trees at maturity—to know what they will look like some 20 years in the future. It should be remembered that a landscape is not a static but a dynamic entity, which grows and matures with time. It changes with the seasons and presents a different aspect with differing times of day. Although it will be possible to view it from different angles, from near and far, unlike a picture it is possible to step into it and become part of it. All these changing sensations should give pleasure if the design is thoughtful enough.

Before we can start digging the holes and planting the trees there are a number of practical points that we must consider. In the planning process, these practical considerations, apart from the purely economic and utilitarian ones which are dealt with in other articles in this issue, must be given priority.

Summer and winter shade from mature trees should be considered, particularly where the planting is close to dwellings and where areas of cultivation could possibly be shaded. Trees give a different shade pattern in summer and winter. In summer, the sun rises in the south of east and sets in the south of west; it passes almost overhead. In winter, it rises in the north east and sets in the north west and follows a very low arc in the sky. The angle the sun makes with the horizon alters with changing latitude. In Brisbane, the shade area extends in winter about the same distance as the height of the tree but this decreases as one travels north.



Harry Kleinschmidt Harry is a Senior Botanist and has been with the DPI for about 25 years. He has written two books on weeds and has studied landscape architecture at the QIT.

Plate 3. Some plants are poisonous—angel's trumpet is beautifully perfumed but deadly to children.

Plantings should abate the severity of the wind; they should lessen the glare of the setting sun and create oases of shade to offset the blazing summer sun.

Plants should be strategically placed to avoid damage to adjoining property. Since the winter sun can also be a force to consider, we must decide on the balance between deciduous and evergreen trees. Deciduous trees then bring their own problems. Leaf fall and its consequences must be taken into account if the plantings are near buildings.

The use of conifers should be considered. Many of the exotic species are often subject here to disease and have a fairly short life. There are a few native species which could be considered, such as the native cypresses *(Callitris* spp.) and the similar sheoaks *(Casuarina* spp.). Such introduced species as Monterey cypress *(Cupressus macrocarpa),* pencil pine *(Cupressus sempervirens),* bookleaf pine *(Thuja orientalis)* and slash pine *(Pinus elliottii)* seem to do well.

Root systems and their invasive qualities should be considered in relation to drains and sewerage lines. Some trees seem to delight in creeping under driveways, paving and retaining walls which they later lift and crack. Fig trees or rubber trees, umbrella trees, jacaranda, mango trees and willow trees have all been implicated in the blockage of drains and sewerage pipes. If areas of cultivation are nearby, both shade and root invasion should be considered.

Some trees are poisonous or harmful, especially to enquiring young children and wandering stock; some are very bitter and often this is sufficient deterrent. Plants that immediately spring to mind are angel's trumpet, oleander, yellow oleander or Cook trees and white cedar with its enticing berries. It is wise, with a young family, to keep temptation out of reach.

Although, in rural areas particularly, economic considerations leave little room for unnecessary costs, ground modelling should be at least considered. Dams are a feature of all country areas and the cut from such a project could be used to create a more pleasing ground swell. Ground modelling can also be used to create a sound barrier. Where arterial roads are close by, this could be a worthwhile consideration. Sound can travel through trees; there is a widespread misconception that trees stop sound. They do not, to any great extent. A sound barrier needs to be made of a dense material, such as a brick wall or an earth bank.

And while we are discussing dams, the sight and sound of water can create the feeling of coolness. Water in repose, as in a dam, creates a feeling of serenity. A babbling watercourse can create a sense of tranquillity as well as of coolness. So it might be worth considering placing a dam near the house.

Then, of course, there is the suitability of plants to the area. Trees of rainforest origin are unlikely to succeed in the far west, except under an extravagant water regime. It has been said that the more exotic the garden, the more it requires the hand of the gardener, but this is not always so. Many exotic species from a similar climatic region flourish in an alien land. They do not suffer the depredations of the insects and diseases that they were subjected to in their land of origin. But trees planted into a landscape, native or otherwise, must be in harmony with their immediate surroundings and the land beyond the confines of the area under consideration. So it is usually wise to find out what trees grow within the visual area. These are a guide to what trees to plant.

Perhaps the site abuts an urban area with many exotic trees. These then are not out of context. Or, perhaps, a homestead is being planned in an untouched area; a complex of exotic species can then form an oasis of trees different from those in the surrounding area, and by their very contrast add to the brilliance of composition.

Shape of leaves and their size give a plant 'texture'. Harmony and contrast in this as well as in colour of foliage, and shape and height of the mature tree should be considered when the final choice is made. Flowering trees usually have only a short season in flower; for most of the year, they present foliage alone. So foliage

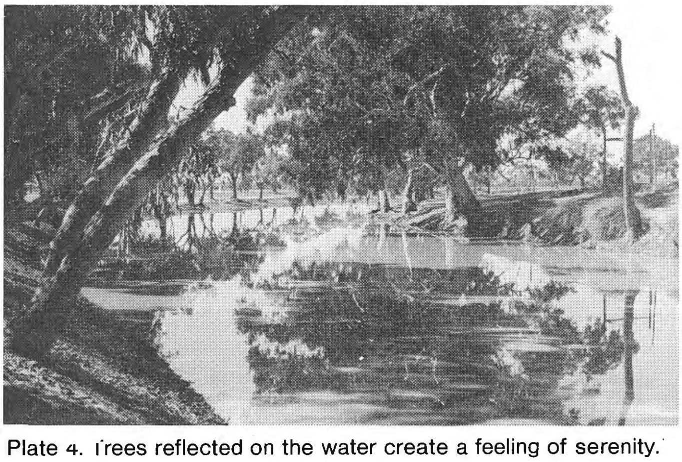
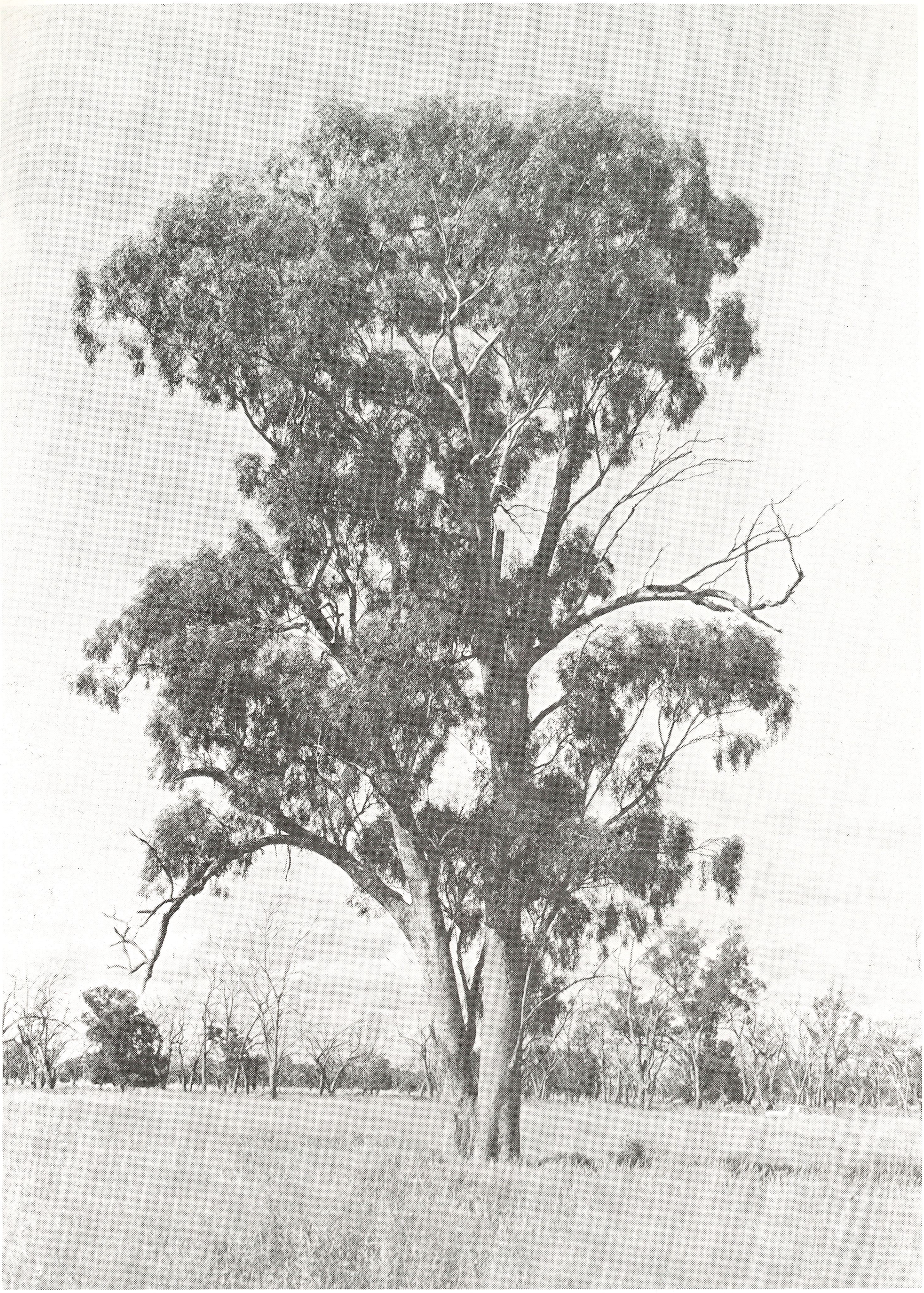
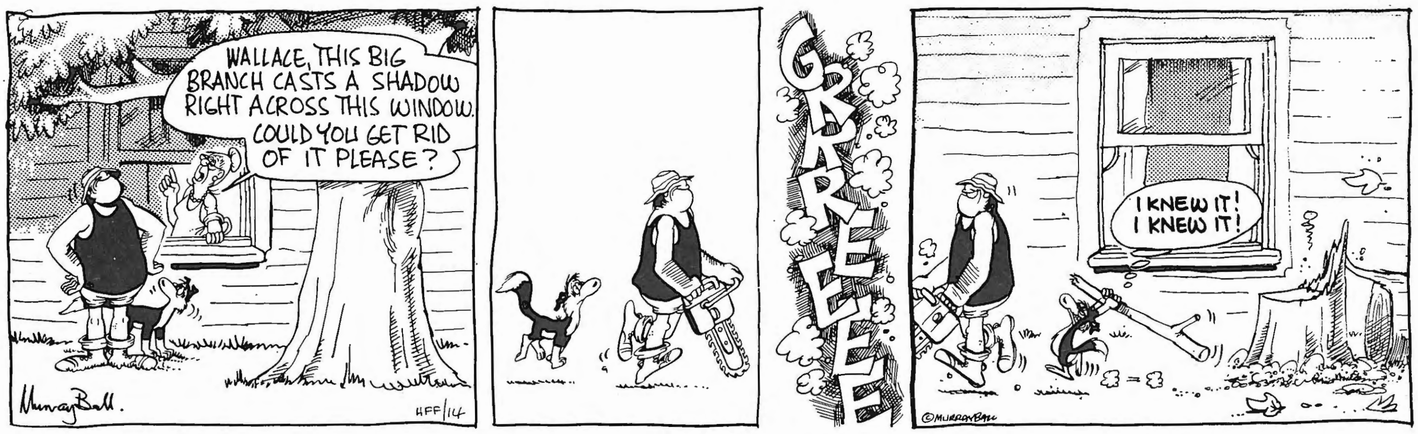


Plate 4. Trees reflected on the water create a feeling of serenity.





is just as important as flower colour. Season of flowering, as well as flower colour, should be taken account of so that the overall picture presented by the landscape has some focal point of colour throughout the four seasons, with one species coming into flower as another fades.

It is difficult to define where practical considerations end and pure aesthetics begin. In the planning process, these considerations merge as the plants are used by the designer as colours from a painter's palette.

Without doubt, the influence of environment can create or disturb peace of mind, which in turn affects judgment and can generate fatigue. This influence is concerned as much with the subconscious as with the conscious mind, so a landscape should not jar if both conscious and subconscious are to be satisfied.

We are the product of the world around us. But, equally, we have inherited the influences of many centuries of art and landscape design which, however much we may deny it, affect our preferences.

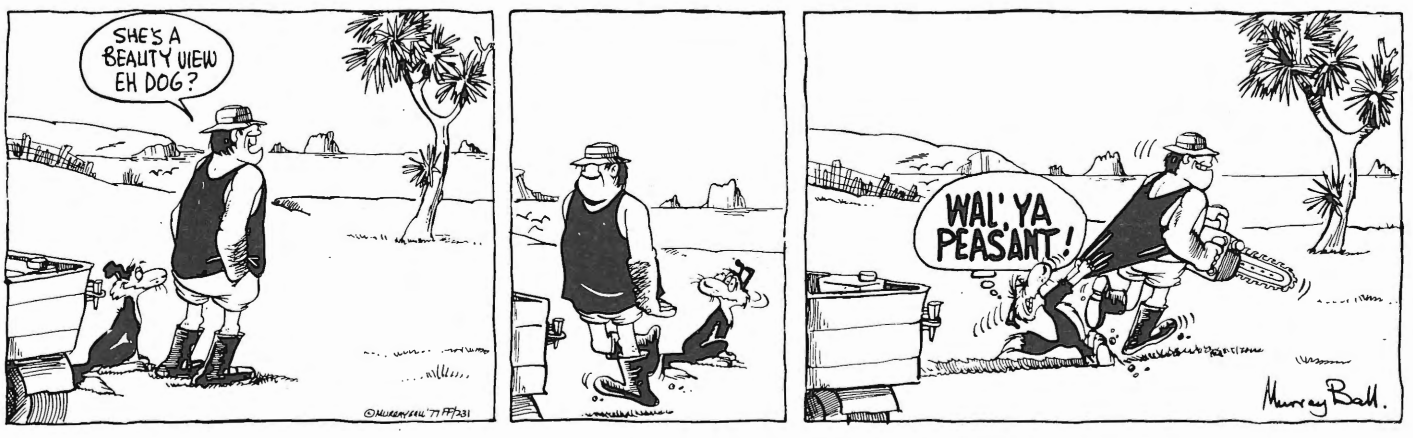
Here, in Australia, we have a unique vegetation. But we are influenced, to some extent, by the landscapes of Europe, England and the ancient cities of Rome, of Greece and of the Middle East. Our interpretation of these influences must necessarily be tempered to a large degree. We are born and bred to the scent and look of gum trees; we appreciate the beauty of vast spaces and of brilliant light. These are our pillars of ancient Greece and our vistas of English country estates bathed, not in subdued European light, but rather in the rich, gleaming contrasts of our summer sun.

Creating a landscape is like creating a work of art. Harmony, balance and proportion must be achieved in line, mass and colour. Lines as in the heights of trees can focus the eye towards a distant view. Similarly, lines in the recurrence of rounded masses or recurrent colour can focus the observer's gaze towards a point perhaps much lower than the horizon.

Harmony and contrast can both accentuate the appeal of a particular landscape. Towering trees accentuate the horizontal rolling downs.

It has been said that the professional, trained in the arts, is the only one ultimately competent to design a landscape. As a painter paints a picture, so a landscape designer calls on his inspiration to plan a landscape which is more than just the trees, shrubs and earth but which evokes a sense of wellbeing in the beholder and of rightness with the world. If perhaps the designer wishes to create a special mood, to convey a sense of serenity or of infinity, or perhaps an abstract idea, then the professional is needed. He is able to comprehend both art and other considerations.

The artists of antiquity, the great masters, have all influenced their descendants and given examples from which the designer of today can learn. And the great landscapers both modern and old have all taught how certain effects can be achieved. But the creation of beauty is not the domain of the professional alone; beauty lies in the eye of the beholder, and in this we are all equal. Each of us has within us sufficient of this mysterious art to devise a landscape which does not offend but rather pleases the senses. All it takes is a conscious and thoughtful effort.



A tree planting project in the Brisbane Valley

D. M. Cameron, CSIRO, Division of Forest Research, and R. D. Patterson, The Australian Forest Development Institute

Introduction

As community interest in tree planting increases there is a corresponding increase in demand for advice on tree planting systems for a wide range of situations throughout the State. In some regions, experience has been accumulated over many years and with a number of species. However, the further one moves away from the coast (the areas most used for tree planting) or away from the species most commonly planted by the Department of Forestry and forestry companies, the more difficult is the task of selection of species and the techniques for planting and maintenance.

The Department and forestry companies have concentrated their efforts in areas where an acceptable rate of growth and/or return on investment can be achieved. Good growth and health of trees are undoubtedly aims of community groups interested in tree planting. But some plantings are required for reasons other than economic return and timber production. Community interest in tree plantings may be for environmental reasons such as improving landscape stability when landslips are a problem, for aesthetic reasons in urban sites where unsightly buildings or industries need a visual screen, or for improving habitat diversity for wildlife.

It is important to accumulate information on tree trials in the non-forest planting zone, so that tree planting systems which are efficient, ensure good survival and growth, and utilise mechanical means, can be developed and used. This article reports on some of the aspects requiring study and describes an example of its implementation when a number of professional and community groups cooperated on a project.

Aspects requiring study

Species selection

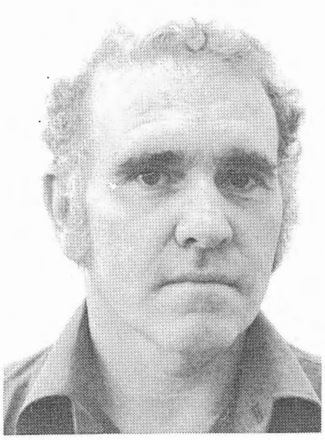
Many different tree species have been planted in Queensland. Information on their performance has in part been compiled by the Department of Forestry (*Trees and shrubs* and assorted brochures) with other information available through the Society for Growing Australian Plants (*Australian Plants*) and in such publications as *The Use of Trees and Shrubs in the Dry Country of Australia* and *Growing Trees on Australian Farms*. However, a complete list of suitable trees and shrubs is not available, nor are detailed comments on performance, special requirements or special features. Care is needed in assessing the purpose of a planting and matching against this the species which may be suitable. It is likely that the list of suitable species for the central and southern coastal regions will be very long compared with that for western regions. Considerable testing of a wide range of species will be necessary in the various climatic zones and within soil types to provide as wide a range as possible for selection.

Site selection

Before establishment, it is important to assess potential sites carefully to ensure that they are available for a long time, can be fenced, surrounded by a fire break and are accessible by vehicle or tractor. These are aspects of good management. It is also probably wise to carry out small plantings of up to several hundred trees on reasonable sites before becoming involved in large plantings or grappling with difficult sites. Such an approach provides scope for developing the skills of tree care and acts as a confidence booster for later plantings.

Site preparation

Cultivation of the planting site is beneficial in most soil types. Besides breaking compacted layers, it improves aeration and can increase the mineralisation of nutrients. Cultivation should always be matched to the soil condition so that the roots are not likely to be impeded in their movement through the soil. At times, rotary hoeing of the surface is adequate while at other times ripping of a compacted layer at some depth may be desirable. Cultivation should not increase the potential for erosion. On erodible sites, row cultivation should be restricted to the contour, leaving uncultivated strips between rows. This results in tree rows which are not straight, and there may be subsequent management problems if tractor maintenance is carried out across the contour.



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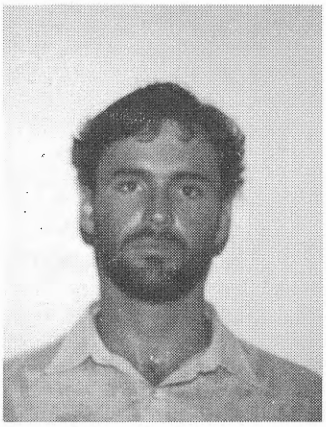


Ross Patterson Ross is the Secretary of the Northern Chapter of the Australian Forest Development Institute. Currently he is studying full-time for his Master of Agricultural Science degree at Queensland University.

Plates 1 and 2. A 9-month old planting of flooded gum near Kin Kin shows the necessity of proper tree nutrition. The tree on the left is 2.2 m having received phosphorus only. The tree on the right at the same site is 4.4 m tall after fertilisation with nitrogen, phosphorus, potassium, sulphur, magnesium, manganese, boron, copper and zinc.

Weed control is another aim of cultivation. It should reduce competition for the trees for as long a time as possible without causing unacceptable erosion. The timing of weed control should be planned to ensure adequate kill as close as possible to the planting date. If it is carried out too early, the seedlings of the next weed crop may become established. If too late, wet weather immediately before planting could result in a transplanting of the weeds rather than a kill.

In some locations, machine cultivation may not be possible. A tractor mounted post-hole digger or a back-pack motorised auger reduces the labour input to the operation but in some cases there is no way but to resort to a planting mattock. In such cases, weed control can be attempted by clearing around each planting site or by using weedicides. There is a wide range of weedicides now available and the development of rope wick applicators allows strict control of the operation with drift dramatically reduced.

Planting method

Forestry authorities carry out a very large percentage of their planting using planting machines on the three point linkage of rubber tyred tractors. Their use increases planting rate per worker about fourfold, ensures better depth control and a firmer planting, and reduces planter fatigue. No small private plantings have been carried out with machines but their use should be investigated for their great benefits. It may be necessary for some modifications to cope with different species, stock type and planting conditions.

In most cases planting is by hand but advantage could be made of an invention by Mr. J. Leggate (A.B.C. Tree Care Awards) of a 'tree keeper' (see *Caring for Young Trees,* an A.B.C. publication) which can be installed at the time of site preparation. The technique has particular application in rocky gravelly sites and in hard setting clays. A length of PVC tubing is placed in the soil immediately after cultivation allowing adequate depth for the plant to be inserted at a later more suitable planting time.

All planting methods require the plant to be well packed into the soil so that air spaces and dry soil are removed from close contact with the roots or the soil core. It is generally desirable to have the plant slightly deeper than its position in the nursery soil. Even though forest authorities in Australia do not water immediately after planting, the practice is followed by large forestry companies in Brazil and South Africa. Improved survival there would suggest that the practice should be followed in this region when the soil is dry or dry conditions are expected for the week or so after planting.

Contrary to common belief, Australian native trees as well as exotics generally respond to the addition of fertiliser, at least in the first year in the field. Fertilising at the time of planting ensures a nutrient supply for the young plant to grow rapidly and compete vigorously with weeds. A pocket about 10 cm from the tree and 10 cm deep containing 50 g of diammonium phosphate should provide most of the nutrient requirements for the first half year.

Post-planting treatments

For fast early growth, it is essential that trees are kept free of weeds and supplied with nutrients and water. Weed control after planting needs to be carried out carefully so that trees are not damaged by cultivation or weedicides. The effect of cultivation on tree roots has not been closely studied but it would be wise to avoid the rooting zone which can be greater than the branch spread of small trees.

Weed control using weedicides must be carried out with great care. Small quantities can be harmful or even toxic to small trees. Arbor guards or tree screens are necessary if a spray technique is used. Alternatively, the rope-wick method reduces drift but care is still necessary to avoid brushing leaves or the fresh bark of small trees.

If dry conditions persist after planting, it may be necessary to apply 3 to 5 L of water once per week until good rains ensure establishment. Information on plant nutrient deficiencies found in similar soils in the region can provide a guide for follow-up fertiliser composition and rate.

Case study: Esk

Some landholders in the Esk region consider that tree clearing since first settlement in the mid 1800s has been so successful that some reforestation is necessary. Remnant trees are often over-mature and frequently have dieback. Through constant grazing and poisoning, replacement regeneration has often been eliminated. An active tree planting programme is needed to ensure that the cover will not decrease further.

One landholder in the region, Mr R. McConnell of Inverstanley, demonstrated his concern by allocating some of his land for a pilot project. The aims of the project were fourfold:

- to assess candidate species for planting in the region;
- to test a system of establishment and maintenance;
- to provide a pilot planting for the region; and
- to provide direct benefit to the property in the form of shelter for stock, timber production and site stabilisation.

A number of different organisations were interested in the project and prepared to have members involved. They were the Department of Primary Industries, Australian Forest Development Institute, Institute of Foresters of Australia and the Men of the Trees. The project was partly funded from the National Tree Program.

Sixteen species were selected for the trial, some with potential on this site for pole and farm timber production *(Eucalyptus cloeziana, E. maculata, E. tereticornis, E. camaldulensis, E. argophloia, E. crebra* and *E. drepanophylla)* while others were primarily for shelter and site stabilisation *(Casuarina cunninghamiana, C. torulosa, Melaleuca leucadendron, E. moluccana, E. tessellaris, E. propinqua, E. sideroxylon, Flindersia australis* and *Leucaena leucocephala.)*

A corner of a paddock was fenced to exclude grazing, contours located and ripping carried out to 20 cm using an agricultural 65 hp tractor with ripper centre mounted on a three point linkage tool bar. Four weeks later (early January 1983) planting was carried out using a mattock to prepare holes in the rip lines. Planting stock varied from 5 cm high eucalypts in polystyrene planter boxes to 25 cm high crows ash in 15 cm pots. Other pot types used were biodegradable 5 cm net pots and 7 cm polythene propagation tubes. *Leucaena* striplings were planted open root. Pots were removed at the time of planting which was to a depth slightly greater than the potting mixture depth in the pot.

As the soil was quite dry at the time, provisions were made for watering within 1 h of planting. Weekly watering was continued for several months, when the delayed wet season arrived.

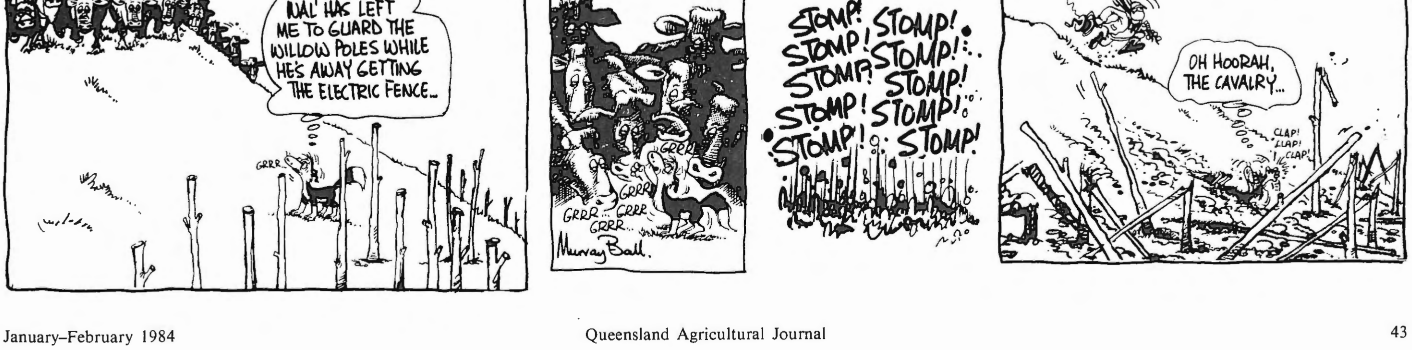
The layout of the planting was in lines of randomised blocks each of 22 single tree plots. Even though this slowed down the planting operation, it was considered valuable to randomise the material as much as possible over the site to provide a better assessment of species performance and to end up with a mixed planting rather than a series of single species plots.

Despite regular watering following planting, the extremely dry conditions from January to April resulted in the loss of about half of the trees. As a rule, plants raised in the larger containers survived better than those in small containers. Refilling was carried out in May following good rain during the previous 2 months. Very favourable soil moisture conditions have persisted since then and good survival maintained until late summer.

Stock have been excluded from the area and will be until the trees are large enough to withstand cattle browsing or rubbing. The exclusion has meant that the grass stand has grown very high—a problem for both fire control and competition for the trees. It was not reduced until late winter as it was considered likely to provide some protection for the trees from frosting and windburn.

Plans for fire breaks and grass and weed control using Roundup® through a rope-wick applicator are being developed. Heights of trees will be measured at the end of the first year and comments made on health and general development to provide guidelines on tree species for planting in the region.

There are a number of lessons which can be learnt from this case study. The first is the difficult task of matching planting stock to present and future weather conditions. It appears to be unwise to use soft plants less than 15 cm in height raised in pots less than 6 cm in diameter and less than 10 cm in depth. Planting should be carried out when the soil is moist rather than in anticipation of wet weather. More intensive cultivation and more frequent slashing and tending would have improved growth and survival.



Greening Australia

P. D. Scott, Greening Australia, Queensland

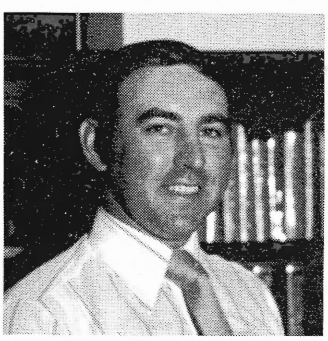
The world conservation strategy points out that failure to achieve the objectives of conservation is often related to failures to achieve the social and economic objectives of development. Unless development is guided by ecological, economic, social, cultural and ethical considerations, it may have undesirable effects in the long term.

Conservation and development are often seen as being incompatible. However, they both aim to meet human needs, with conservation ensuring that the material basis of development is sustained and the environment protected so that society can generally enjoy the benefits of development. The 'Greening Australia' concept aims primarily to integrate consideration for conservation and development with the realisation that we are dealing with a renewable natural resource—trees.

The world conservation strategy aims to blend the needs of conserving resources using proper land management practices that complement and increase food production. However, many major environmental problems which directly affect our agricultural productivity have occurred as a result of the exploitation of trees as a natural resource.

While it is accepted that food production must be maintained and increased to satisfy growing populations, reforestation—the restoration of trees as a renewable resource—can be successfully blended with the demands of land use and land management. In this manner, trees are seen as being largely beneficial in attempts to control those environmental problems which might limit or reduce productivity—such factors as soil erosion, water quality, lack of shade and shelter, and in the fight against salinity build-up.

The problem is, however, much broader than the recognition of environmental problems. It is more than simply trying to reduce a rate of tree decline. There is a requirement for proper planning, replanting, regeneration and conservation to ensure that our needs for trees in social, economic and environmental terms can be sustained in the immediate future and beyond.



Peter Scott Peter is the State Co-ordinator of Greening Australia (Queensland) and is involved in the promotion of the National Tree Programme. He has an appreciation of the economic benefits of trees through practical experience, which has helped in the development of Greening Australia.

Tree planting and tree regeneration are important ingredients of an overall approach to the improvement and expansion of our nation's productivity, as well as providing recognised social and environmental benefits. Quite simply, trees are a renewable resource on which a major sector of our national economy and, ultimately, the social and environmental welfare of all Australians depend. Trees provide a living partnership—the source of economic development and an aid to productivity—as well as being the silent guardians of our environment, atmosphere and privacy.

In the decades leading up to the twenty-first century, it is imperative that those trees needed to sustain a nation's economic and environmental development should be planted in ever increasing numbers. Equally important, correct planning and consideration for the benefits and uses of trees must precede any planting or regeneration project, however large or small.

If trees are to be regarded as a renewable resource, their adaptability and potential in economic and environmental terms must be fully considered. Undesirable or poor results could arise equally from incorrect planting of unsuitable species for specific areas, as from uncontrolled exploitation of this natural resource.

There is a growing recognition within the community that attention must be given to a 'national tree programme' and, in such considerations, the 'Greening Australia' project to arrest tree decline in the nation by the bicentenary in 1988 is of paramount importance.

The economic and environmental benefits of such a project are so great that it could well be regarded as the most important social, environmental and economic project yet undertaken. Its attractiveness is that it is a realistic conservation project which clearly seeks to integrate conservation with the requirements of development for the benefit of the nation. It also seeks to involve all sections of the nation without exception, in a project of massive proportions.

Tropical pastures in eucalypt forest near Gympie

B. G. Cook, Agriculture Branch, and R. J. Garthe and R. F. Grimes, Forestry Department

Many farms in coastal and subcoastal Queensland have areas of standing forest, often considered to have little potential for animal production. Such areas are either left as a source of fence and yard timber or, in the right economic climate, cleared completely for native or improved pasture development. The importance of retaining trees in minimising the development of salt problems and in preserving the rapidly diminishing supply of millable hardwood has often been overlooked. In 1974, the Forestry Department, the DPI and the Wanamara Pastoral Company began an experiment to assess the feasibility of introducing tropical pastures into predominantly spotted gum *(Eucalyptus maculata)*/yellow stringybark *(E. acmenoides)* forest with minimum land preparation. The experiment was established in 145 ha of State Forest at Neerdie, an area of shallow, infertile sand and clay loam soils, with a rainfall of 1 200 mm. Pasture improvement carried out by the holder of the grazing lease was permitted for the purposes of this experiment, and does not represent a change in Forestry Department policy.

Pasture development

By August 1974, all millable logs had been taken from the experimental site yielding 18 m³/ha, which today would be valued at $216/ha. Unwanted trees were killed by injection with a Tordon/2,4,5–T mixture. On average, about 80 trees/ha were retained although this varied from 20 to 160 trees/ha in experimental plots distributed throughout the area. The area was then divided into two similar blocks, one remaining undeveloped and the other being sown to tropical pastures. Native herbage, largely blady grass *(Imperata cylindrica)*, and logging debris were burnt in December 1974. The following seed mixture was aerially broadcast onto the improved pasture block immediately after the burn.

Grasses	**Sowing rate/ha**
Molasses grass *(Melinis minutiflora)*	70 g
Green panic *(Panicum maximum* var. *trichoglume)*	1 120 g
Katambora Rhodes grass *(Chloris gayana)*	280 g
Whittet kikuyu *(Pennisetum clandes tinum)*	210 g
Hamil grass *(Panicum maximum)*	370 g
Narok setaria *(Setaria sphacelata* var. *sericea)*	560 g
Total grass	2.6 kg
Legumes	
Greenleaf desmodium *(Desmodium intortum)*	850 g
Archer axillaris *(Macrotyloma axillare)*	1 120 g
Cooper glycine *(Neonotonia wightii)*	1 120 g
Siratro *(Macroptilium atropurpureum)*	560 g
Cook stylo *(Stylosanthes guianensis)*	280 g
New Zealand white clover *(Trifolium repens)*	560 g
Total legume	4.5 kg

Molybdenum trioxide was applied at 210 g/ha by mixing it with the lime or bauxite dust on the legume seed pellet. Superphosphate at 500 kg/ha was flown on in March 1975. A further 250 kg/ha of molybdenised superphosphate was applied in April 1976 and 125 kg/ha of superphosphate in February 1980.

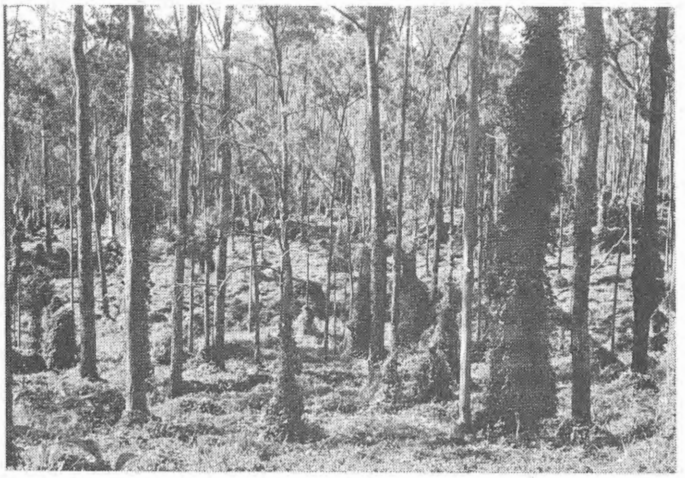
Despite unfavourable weather after sowing, most species established well. White clover did not establish at all, and kikuyu has only ever been noted in ash heaps where fertility was higher. Pasture growth was poor during 1975, but good rain in January, February and March 1976 promoted vigorous growth as shown in Plate 1. Legume, particularly Archer axillaris, grew up trees to 4 or 5 m, and spread over the ground largely smothering blady grass and small shrubs. Initially, the pasture was strongly legume dominant. Today, the pasture is grass dominant, but retains a healthy legume component. The most productive grasses have been Hamil grass, molasses grass and Narok setaria, although Narok is suppressed by trees. Hamil grass is showing signs of dominating the pasture. If this trend continues, long term pasture productivity will suffer through loss of legume. It is, therefore, advisable, if undertaking a similar type of development, to use less aggressive grasses such as molasses grass and green panic.

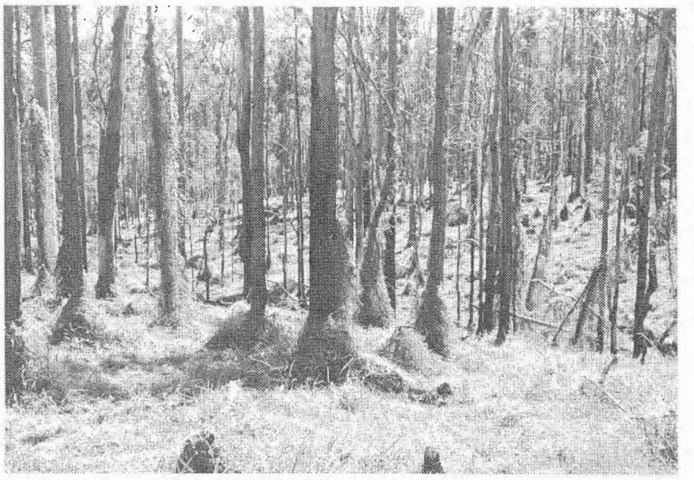
Archer axillaris has been the most productive legume throughout the experiment. Greenleaf desmodium made a major contribution initially, but the proportion in the pasture has declined. Overall, trees have not suppressed total legume yield and only slightly suppressed total grass yield. Yields of sown pasture have been comparable with yields obtained from similar pastures on cleared land. However, animal production has probably been less as a result of the lenient grazing management adopted.

Grazing management

Trees and debris and the broken nature of the terrain prevent the use of cultivation implements. Therefore, if the legume component is lost from the pasture, it cannot be restored by simple cultural methods. Grazing management has been chosen to minimise stress on the twining legumes thus ensuring their persistence in the pasture. It should be noted here that continuously grazed twining legume pastures in south east Queensland are usually productive for only 5 to 7 years due to gradual legume decline.

The aim is to have the pasture unstocked during the period of most active legume growth—January, February and March. This enables the legume to climb over grass and shrubs, and up trees. In the case of Archer, it also permits free seeding. The pasture is lightly stocked during April and May at about 1 beast to 3 ha. At this stocking rate, cattle tend to graze mainly grass. Stock numbers are increased to about 1 beast to 1.5 to 2 ha during the dormant months of June, July, August and early September in an endeavour to remove all edible bulk over this period. When active pasture growth resumes, stock numbers are reduced to about 1 beast to 3 ha so that only lush grass growth is utilised. The system is flexible and must be varied occasionally to accommodate stock movements on the freehold part of the property. This





Plates 1 and 2. Neerdie trial site area, (left) before grazing and (right) after grazing.

flexibility extends to summer grazing should the need arise, provided the pasture is spelled the following summer.

Timber growth

Since 1974, the average diameter increase of trees in the improved pasture block has been 30% greater than for trees in the native pasture block. The current value of standing timber in the improved pasture block is $175/ha. This value will increase as more trees reach millable sizes. Therefore, the retained trees in the pasture can be viewed as a valuable capital fund accruing interest.

There is one major drawback to this being a perpetual system. Eucalypt regrowth has been suppressed by vigorous legume growth. Nine new saplings per hectare have developed in the improved pasture and ninety in the native pasture. While this low replacement rate may be a plus from a grazing viewpoint, it may be inadequate to maintain a sufficient stand of trees with periodic logging. It may be possible to increase the forest stand by grazing heavily in summer for several years thus keeping the pasture more open. Large reserves of legume seed in the soil should ensure no permanent damage to the pasture.

Appraisal

As with any development there are advantages and disadvantages that the landholder must weigh up in his own situation. The balance determines whether such a development is feasible on a particular farm.

Advantages

- Such development can be applied to large areas at relatively low cost. Cost savings arise since the area is neither cleared nor ploughed.
- Salinity problems can develop in low areas where nearby ridges have been cleared of timber. Retention of trees, therefore, minimises the possibility of salt pan development.
- Ploughing steep country often leads to severe soil erosion. Chances of soil loss are reduced if no tillage operations are use before planting. In this project, fire only was used in land preparation.
- The presence of trees reduces the incidence of frost. Mild frost damage has been noted only in low lying areas. In nearby areas of similar altitude, where all trees have been cleared, comparable pastures have been severely frosted. This means quality green standover feed is available throughout winter.
- During the long dry periods experienced between 1976 and 1982, the pasture under trees has appeared less moisture stressed than similar pastures in nearby fully cleared areas.
- Diversification of land use is a buffer against hard times in any one industry. The retained timber resource may be capitalised if beef prices are depressed. Trees also provide the option of diversifying into apiculture.

Disadvantages

- Mustering can be difficult due to the tree stand and scattered logs. This can be partly overcome by using a more tractable class of stock.
- Fence maintenance is often required due to falling branches and dead trees. Clearing a 20 m strip around the fence line eliminates this problem.
- Noxious weed control could be difficult if an aggressive legume were not used. Experience at Neerdie shows that browsing cattle and vigorous pasture have suppressed groundsel, the most troublesome noxious weed in that area.
- Regrowth suppression may be too effective for maintenance of a timber resource.

The success of this development shows that trees are not necessarily a barrier to pasture improvement, as has often been thought in the past. On the contrary, they may well be an advantage. Similar success cannot be guaranteed in other situations. However, such development could mesh into many farm systems, and feasibility should be investigated.

Bruce Cook Bruce has conducted agroforestry research in the Gympie district, involving pasture development among both native hardwood and softwood species. This incorporates his professional interest in pasture agronomy with a recreational concern for native trees.

Russell Garthe Russell is a field researcher based at the Department of Forestry's Gympie Research Centre. He manages the Department's research programme in eucalypt and native hardwood forests.

Richard Grimes Dick is the District Forester at Yarraman. Until recently, he worked in the Land Use and Information Branch of the Department of Forestry.

Gympie messmate reforestation potential in the Wide Bay region

R. J. Garthe, Forest Research Centre, Gympie, Queensland Department of Forestry

Agroforestry: a desirable objective

The decline of pastures in the Wide Bay and other coastal dairylands was recognised in 1960 with the beginning of CSIRO research into methods of restoring pasture productivity. Initially, landholders attributed the pasture decline to lowered rainfall and the invasion of inferior species such as blady and mat grasses. However, research has shown the decline is directly related to lowered soil fertility and that productive pastures can be grown only after remedying the nutrient deficiencies.

Since 1960 the number of dairy farmers has declined greatly and the land has been managed for beef cattle production, small cropping or tree crops. Some has been subdivided for rural residential blocks or allowed to become overgrown with wattle, blady grass and groundsel. Agroforestry offers an opportunity to stabilise steep slopes and return underutilised land to productive use. Farm appearance and value can be improved.

Species selection

The tree selected for agroforestry must be suited to the climate and soil, and achieve a high growth rate and an economic return. Gympie messmate *(Eucalyptus cloeziana* F. Muell.) is such a species and is native to the Wide Bay region.

Gympie messmate occurs in isolated stands between Gympie and the Atherton Tablelands on permeable, free draining and acidic soils. In the Wide Bay region, the species occurs naturally on soils derived from sandstones, shales and phyllites. It has been successfully planted on soils derived from shales near Pomona.

Growth rates

Within any region, growth rates vary with soil type and drainage. Consequently, individual sites can be given a quality rating depending on past Gympie messmate growth on that or similar sites. Sites which are typically poorly drained or shallow are not recommended for planting and are usually below quality rating 32.

Gympie messmate planted on a 32 rated site reached 20 m in 7 years and at age 29 years were greater than 33 m in height. Average diameter measured at 1.3 m above ground level was 44 cm and the total volume produced was 9.3 m^3/ha/year.

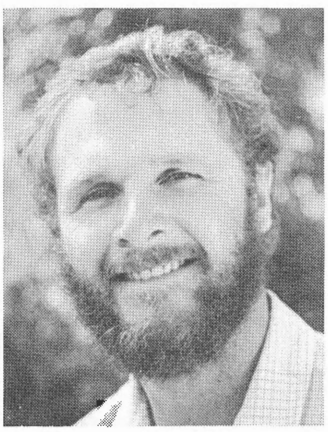
Gympie messmate has a great potential for producing large transmission poles which attract a premium price owing to their scarcity. Current market value for an 18.5 m medium class pole sold from Pomona is $88.80. Five planted stands were assessed for pole yield with results shown in Table 1.

Market

About 35 000 poles are required in Queensland each year. Demand is expected to increase as new mining towns are established and the existing electricity network is extended. Queensland's traditional supplies are dwindling and demand for poles 15.5 m and larger cannot be met from the existing natural forests or planted pine forests. As shown in Table 1, Gympie messmate can be grown to large sizes on rotations of 30 years. The smallest timber produced may be saleable as poles shorter than 15.5 m, or posts or other roundwood.

Table 1. Assessment of Gympie messmate plots for pole potential (1981). Values in the body of the table are numbers of poles per hectare

Experiment	Age	Site index	Pole length (m)									
			9.5	11	12.5	14	15.5	17	18.5	20	21.5	23
1	30	26	10	5	. .	35	40	30	35	. .	. .	. .
2	35	30	10	10	10	. .	10	40	30	49	30	20
3	30	32	. .	10	25	25	. .	44	35	15	. .	. .
4	30	34	. .	15	20	10	5	10	35	25	44	. .
5	35	38	30	. .	10	30	30	30	10	30	. .	. .



Russell Garthe Russell is a field researcher based at the Department of Forestry's Gympie Research Centre. He manages the Department's research programme in eucalypt and native hardwood forests.

Economic analysis

The economics of growing Gympie messmate on a regrowth farm site have been calculated on the basis of the schedule outlined in Table 2. Costs total $573/ha to the fifth year. However, spot herbicide treatments are likely to replace ploughing on steeper slopes. Overheads were assumed to be 20% of the actual expenditure.

Plot 3 (Table 1) yielded $8,568/ha when cut at age 30 years, a return equivalent to $94/ha/year when discounted at 5%. Plot 3 had a quality rating of 32.

Project development

In cooperation with willing landholders, the Forestry Department is in the process of establishing a series of plots covering a range of soils to demonstrate this tree's potential. Demonstration plots on the Atherton Tableland, where climate and soil are also suitable, are also under consideration.

Gympie messmate is available from the Department of Forestry at Gympie for $30 per 100 plants, plus a refundable charge for packaging.

Summary

Gympie messmate has the potential to be grown economically on (underutilised) land within the Wide Bay region. The establishment of Gympie messmate reduces erosion, adds to the value of the properties and supplies a product in high demand.

Further information is available from the Department of Forestry at Gympie.

Table 2. Operations schedules for establishing Gympie messmate on a regrowth farm site

Year of expenditure	Operation	Cost ($/ha)
0	Clearing	105
	Ploughing	126
	Weed control	50
	Cost of plants	50
	Planting	65
	Road construction	30
1	Weed control	100
	Firebreak maintenance	3
3	Weed control	35
	Firebreak maintenance	3
5	Firebreak maintenance	3
Annual	Road maintenance	3

Plate 1 (left) A Gympie messmate plantation at 2.5 years of age.

Plate 2 (below) A Gympie messmate plantation at 29 years of age; the average height is 36.5 m and average diameter 44 cm.

Plate 3 (below left) Degraded farmland near Gympie suitable for eucalypt plantations.

Forest and water: just what is known?

D. S. Cassells, Forest Research Centre, Gympie, Queensland Department of Forestry

Introduction

The relationships between forest and water—both imagined and real—have been debated for quite some time. In fact, in Europe and in North America, the role of forests for watershed production has been one of the more important factors leading to the conservation and scientific management of forest resources.

Forests and water are of particular concern in Australia. We live in a continent that knows well the extremes of drought and flood. We also live in a continent where large areas of native forest have been cleared during the 200 years since European settlement for conversion to pasture, crop or urban and industrial use. Conflicting opinions are often forcefully stated about the environmental impact of these dramatic changes to the Australian landscape. Some people feel that widespread clearing has caused reduced streamflow and the drying up of springs and wells. Others feel just the opposite has happened. However, the question still remains—just what do we actually *know* about the relationships between forests and water resources?

This article aims to summarise what is known about the relationship between forests and water resources based on sound scientific research. It also outlines the limits of our knowledge and suggests the type of research that is required if we are to manage our forests and agricultural land wisely.

The watershed forest as an ecosystem

The hydrological cycle

An ecosystem is a natural area such as a watershed, where plants and animals and their physical and chemical environment interact dynamically. Within any particular watershed ecosystem, water moves in a continuous cycle—from the atmosphere to the earth by precipitation and, ultimately, from the earth back to the atmosphere by evaporation. This continuous water movement is called the *hydrological cycle.* Its principal components and pathways are illustrated in Figure 1.

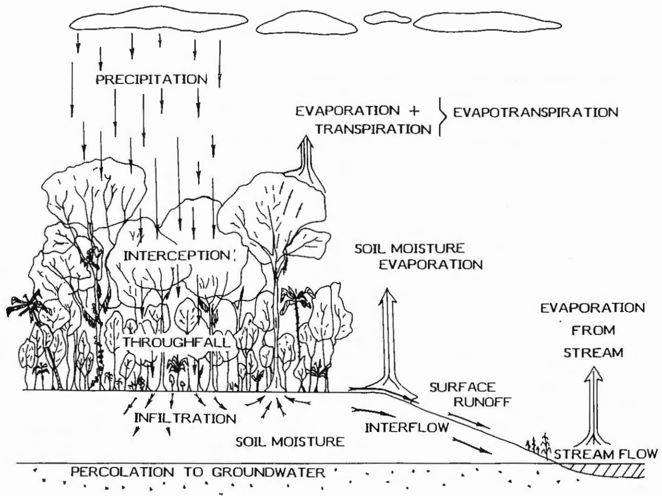


Figure 1. The hydrological cycle in a watershed forest ecosystem.

Within any watershed, the hydrological cycle can be considered to be the flow of water in its various states between water storage compartments such as the atmosphere, the vegetation, the soil, the stream channels and so forth. The individual flow pathways between storage compartments—precipitation, interception, throughfall, infiltration, evapotranspiration, percolation, surface runoff, interflow and streamflow—are called *hydrological processes.*

The response of a watershed to a particular rainfall event is determined by a complex array of interacting factors. Among the more important of these are:

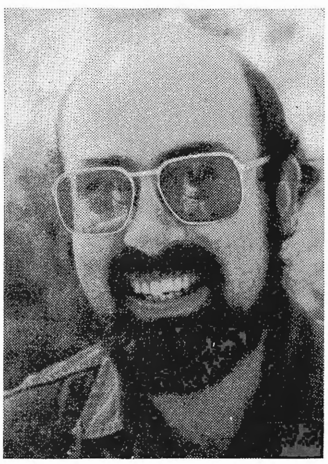
- The timing and the intensity of the particular rainfall event;
- the catchment's geomorphology;
- the nature of the catchment's parent material and its soils;
- the condition of its vegetation and its soil surface; and
- the soil moisture status of the catchment immediately before the rainfall event.

A framework for study

A framework for studying the impact of land use change on the hydrological cycle is described in this section.

The main concern of forest hydrology has been to quantify the impact of changes in forest land use such as timber harvesting or clearing for pasture on the quantity and quality of water yielded from forested catchments. However, with the complex array of factors influencing catchment response to rainfall, this is not a simple task.

Studies monitoring the streamflow from adjacent cleared and uncleared catchments have been undertaken in many regions since the early 1900s. However, the results of these studies have proved inconclusive. Simply monitoring adjacent catchments does not define whether any hydrological differences are in fact due to differences in other catchment characteristics such as geomorphology or soils.



David Cassells Dave manages the hydrological research programme in the Department of Forestry. The main current areas of interest are hydrological processes in exotic pine plantations and tropical rainforest areas.

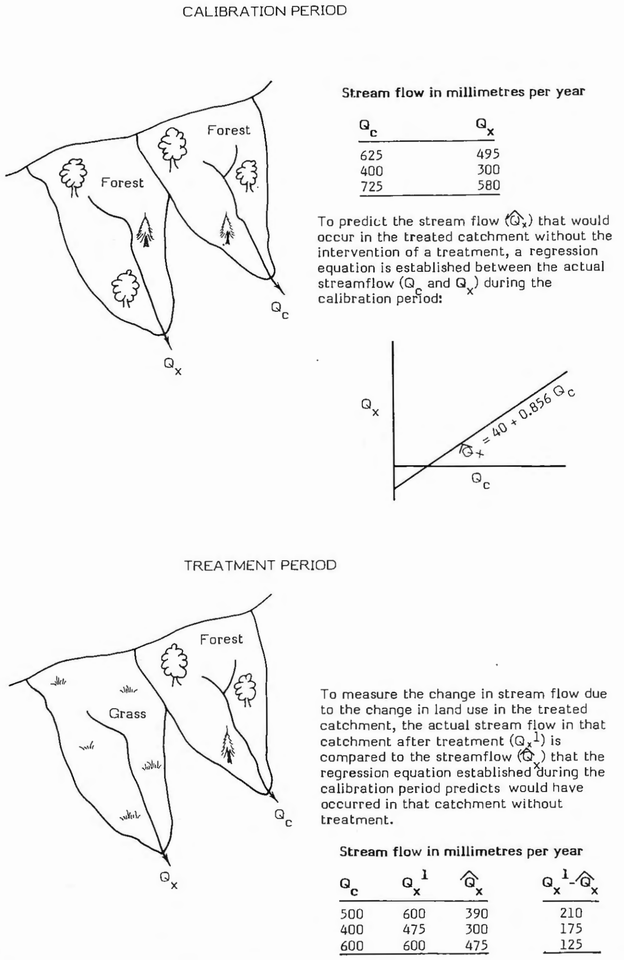


Figure 2. A simplified sample of a paired catchment experiment using regression analysis.

One of the more significant developments in forest hydrology has been the 'paired' or 'controlled' catchment experiment. The essential elements of this technique are illustrated in Figure 2. In essence, the technique involves establishing a statistical relationship between the hydrological output of two or more catchments during a calibration period before any treatments are applied to any of the catchments. This relationship, together with the continued output from the undisturbed control catchment, is then used to provide an objective basis for determining the magnitude of any hydrological changes in the treated catchments that result from the treatment that was applied. For example, in the hypothetical case in Figure 2, we can be confident that the streamflow of the treated catchment increased by an average of 170 mm per annum during the measure period following the conversion of its forest cover to pasture.

The 'control' catchment approach was first used in the Wagon Wheel Gap Study which was started in 1911 in the mountains of Colorado in the United States. Since this pioneering work, it has become the most widely accepted method for evaluating the hydrological impact of land use change in catchment areas. In the past decade or so, much emphasis has also been placed on the investigation of hydrological processes within controlled catchment experiments. This allows researchers to say not only *what* the effects of land use change are, but also *how* and *why* these effects are occurring. This information is essential if the results from specific catchment studies are to be realistically applied to other areas.

In Queensland, controlled catchment experiments studying the impact of forest clearing were established by the Department of Primary Industries at the Brigalow Research Station in 1965, by the Department of Forestry in collaboration with the Department of

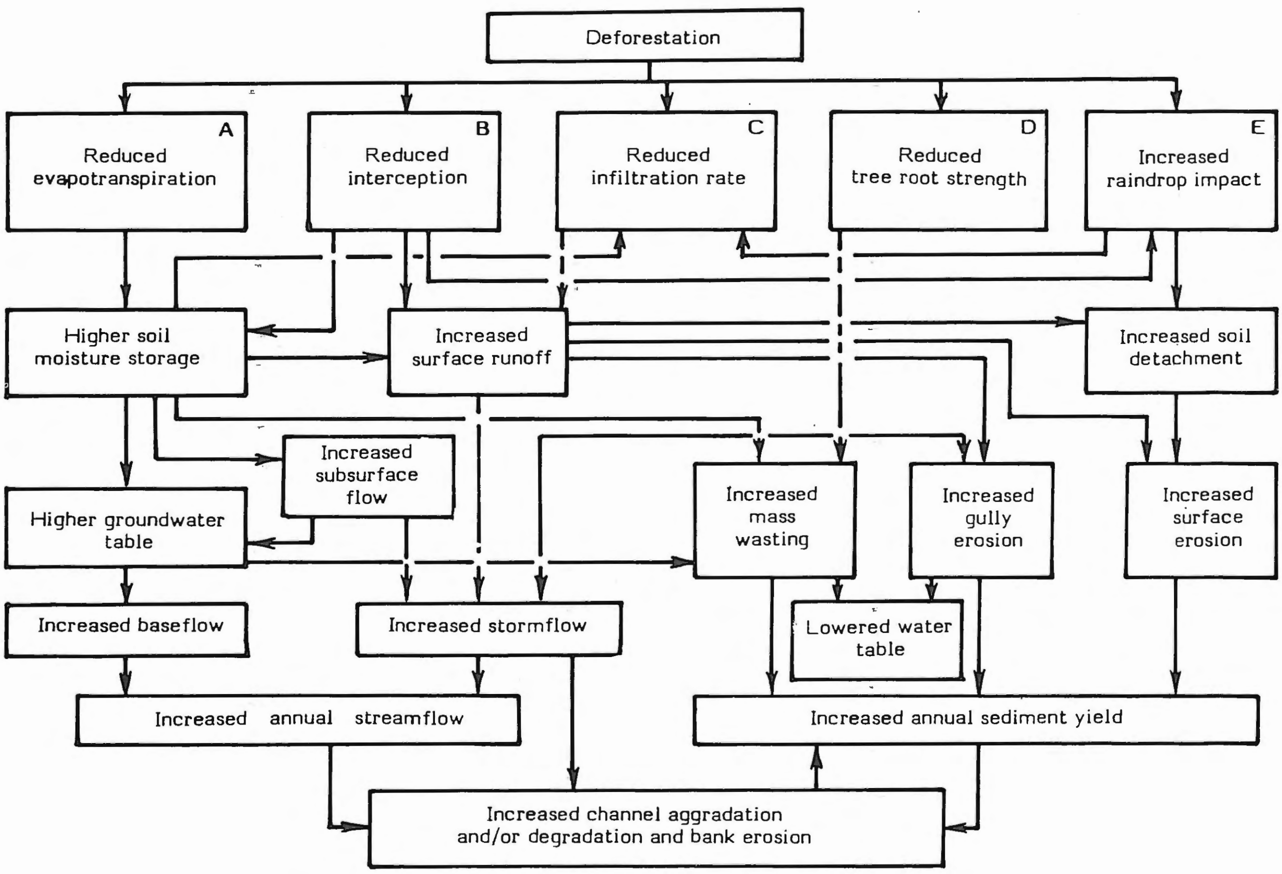


Figure 3. Some likely hydrologic changes following deforestation.

Geography at the James Cook University in the tropical rainforests near Babinda in 1969, and by the CSIRO Division of Soils at Narayen in 1970. Controlled catchment studies are inevitably long term ventures and, so far, only results from Babinda studies have been widely reported.

The hydrological effects of changing forest cover

Figure 3 illustrates some likely changes in the hydrological behaviour of a catchment following partial or complete removal of its forest vegetation (deforestation). The word 'likely' is used because the hydrological response of a catchment is influenced by many factors of which the condition of the vegetation is but one, albeit an important one because man can exercise deliberate control over it.

Research in many regions has indicated that the *primary* effects of deforestation on the hydrological cycle are usually those shown in the upper tier of Figure 3:

- reduced evapotranspiration;
- reduced forest canopy rainfall interception;
- reduced rainfall infiltration into the soil;
- reduced tree root strength; and
- increased raindrop impact on the soil surface.

However, in the context of land use management, planning or evaluation, it is secondary effects on the lower tiers of the diagram that are of greater interest. It is these effects that are discussed in this article.

Effects on total rainfall

The influence of forests on total or gross rainfall is not referred to in Figure 3 because little is known about it with any certainty. In major international reviews of forest influences in the late 1960s and early 1970s, researchers concluded that, in the absence of convincing evidence to the contrary, we must assume that the mere presence of forest cover does not affect gross precipitation.

There are some notable exceptions to this generalisation in climates where condensation or 'fog drip' from forest leaves and stems makes up a large part of annual precipitation. In these situations, forest clearing would significantly reduce the total annual precipitation. However, there are few cases where fog drip precipitation is significant, and they are certainly the exception rather than the norm.

Effects on annual streamflow

In almost every case, controlled catchment experiments have demonstrated *increases* in annual streamflow following partial or full deforestation. A recent international review of 94 of these studies in a wide range of environments showed:

- none of these experiments resulted in reductions of water yield with reductions in forest cover; and
- none resulted in increases in water yield with increases in forest cover.

Furthermore, the review concluded that the size of these changes in water yield could now be predicted. The review suggested:

- in pine and eucalypt type forests, a 10% change in forest cover causes a 40 mm change in streamflow;
- in deciduous hardwood forest, a 10% forest cover change causes a 25 mm streamflow change; and
- in low brush forests, 10% forest cover change causes a 10 mm streamflow change.

None of the experiments evaluated in the review produced any change in annual streamflow when the reduction in forest cover was less than 20%.

While only broad generalisations can be made, it is interesting to note that, in the only Queensland study with available published data, these predictions were close to the actual measured changes in annual streamflow.

In the Babinda studies, the treated catchment had a light salvage logging 2 years before 70% of the catchment was cleared for the establishment of tropical pastures. Based on the predictions, one would not expect any real change in annual streamflow following the light logging operation, but one would expect an increase in annual streamflow of approximately 280 mm after clearing. In fact, no increases in annual streamflow after logging were measured. However, in the 2 years following clearing, an average increase in annual streamflow of 293 mm occurred.

Effects on floods and dry season flows

Any changes in timing of streamflow following changes in forest cover are often as important as or even more important than changes in annual streamflow. Should these be expressed as changes in floodflow during storm events or as changes in the baseflow that stretches streamflow between storms and seasons?

The available research evidence indicates that changes in streamflow following forest alterations occur predominantly as baseflow, though changes to floodflow are also common. In both cases, changes in evapotranspiration appear to be the key controlling influence on catchment response to land use change.

In the United States, controlled catchment experiments have usually, but not always, indicated increases in floodflow following forest clearing. In a number of studies, these increases were seasonal with the largest increases occurring during the summer growing period.

The pattern occurs because evapotranspiration from the forested areas during the summer growing season is usually higher than that from other types of catchment cover such a pasture. This means less soil water is available to percolate through to groundwater to maintain baseflow. It also means that there is greater detention storage potential under the forest. Should flood rains occur, this extra detention storage delays floodflow initiation and reduces flood peaks. During the dormant winter season in the United States, and particularly with deciduous hardwood forests, evapotranspiration differences between forests and other catchment covers are smaller and floodflow behaviour under different covers seems to be quite similar.

The increases in floodflow following forest clearing in some controlled catchment studies have been quite dramatic, with increases in flood peaks as high as 250% being recorded. However, a major review of these studies in 1982 showed that there was no overall cause and effect relationship between forest cutting in the headwaters and floods in the lower basins.

While at first this may appear surprising, it becomes less so when one considers the important factor of scale. While flooding may well be increased close to the area that is cut, this effect appears to be reduced to insignificance as the water is routed down a major river basin. On this larger scale, other factors such as the nature and intensity of the precipitation, the direction it moves across the basin, and the size and geomorphology of the basin itself become of paramount importance.

Indeed, rainfall intensity and catchment geomorphology can dominate the floodflow response of even small catchments in extreme environments. For example, in the Babinda catchments, which often experience high intensity rainfall, clearing the rainforest produced little or no effect on floodflow with the increase in annual streamflow being largely expressed as baseflow. Substantial surface runoff occurred under even the undisturbed rainforest. Process studies have subsequently demonstrated that the catchment's subsoil has a low permeability in relation to the high rainfall intensities of the prevailing monsoonal storms. It is this, rather than the condition of the catchment's vegetation or its soil surface, that is the fundamental influence on its floodflow response.

Effects on groundwater and salinity

With reduced evapotranspiration following forest clearing, more soilwater percolates to groundwater. As a result, there is often a rise in the groundwater table following deforestation.

If the groundwater is saline or the soil profile contains salt, the rising groundwater tables associated with forest clearing may cause severe land management problems. Raised water tables cause saline water to come to the soil surface more often. Subsequent evaporation from the soil surface allows salt to accumulate in the upper soil horizon.

In Australia, more than 160 000 ha of agricultural land have been adversely affected by salinity problems following forest clearing. Water quality problems resulting from salinity induced by forest clearing also occur in many Australian streams, particularly in the south west of Western Australia.

Effects of erosion and stream sedimentation

Many studies have shown the impact of timber harvesting on erosion and stream sedimentation. Reducing forest cover accelerates erosion from catchment areas and increases sediment in streams. For example, an American study in Arizona showed that after logging and road construction, the sediment yield from a small catchment increased from 3.6 t annually to 21 t after just two summer storms, and to 58 t after two winter storms.

However, with well managed timber harvesting operations, any acceleration of erosion is generally only temporary because the regenerating forest gradually begins to provide the soil with similar protection to that given by the original forest. Many studies have also shown that strict control can substantially reduce the impact of the actual logging operation itself, even on quite erodible sites. For example, a study near Cairns has recorded marked reductions in the stream sediment concentrations associated with rainforest logging following the imposition of strict watershed management controls on forest harvesting. Before the implementation of these controls, the highest sediment concentration recorded was 750 mg/L following a single storm that produced 67 mm of rain. After the implementation of these controls, the highest sediment concentration recorded was only 180 mg/L following a storm that produced 259 mm of rain.

Clearing forests for alternative land uses such as grazing or cropping can cause greater changes to rates of soil erosion and stream sedimentation. The Babinda catchment study showed that logging caused a two to threefold increase in peak stream sediment concentrations. However, clearing the treated catchment for pasture development caused a tenfold increase in peak sediment concentrations. These high levels were maintained for more than 3 years after the catchment was cleared. Seven years after the initial clearing, the suspended sediment concentrations, although much reduced, still had not returned to preclearing levels, despite the recolonisation of the watershed by grasses and regrowth.

Another broadscale study in New South Wales has indicated that between the early 1940s and 1967, there was an increase of some 750 000 ha in the total area of that State affected by moderate gully erosion. This increase was apparently almost entirely due to forest clearing and cultivation, with 70% of the increase occurring in the wheat growing areas on the slopes and plains. In this context, it is worth noting the suggestion in Figure 3 that severe gully erosion and mass wastage may physically drain an area to lower the water table. In such extreme cases of land degradation, there is the possibility that the usual research finding that forest clearing increases streamflow could be reversed.

However, in agricultural areas there is also considerable potential to reduce soil losses associated with cultivation and grazing through the adoption of appropriate soil conservation and stock management practices. Effective erosion mitigation is required on all lands, both to protect their productive capacity and to minimise sedimentation in downstream channels. Such sedimentation may increase the impact of flood runoff by retarding its passage to the sea.

The problem of slope stability

Slope instability or mass erosion occurs when masses of soils move downslope, primarily owing to gravity. Mass erosion may be rapid, as in the case of debris avalanches or landslides, or almost imperceptibly slow, as with soil creep. Changes in vegetation can influence both shallow and deep rooted mass movements, but it is a particularly important influence on the occurrence of shallow slides.

Mass erosion is controlled by the balance of shear stress and shear strength within the soil. Where the shear strength of the soil is greater than the shear stress on the soil, the slope remains stable. Conversely, where the shear stress on the soil is greater than the shear strength of the soil, mass erosion occurs. Figure 4 illustrates this process for a particular forested slope. There are many forces which cause the block of soil marked ABCD to fail or remain stable. The slope angle partitions the force of gravity (G) into a downslope component (S) and a normal component (N). The downslope component provides the shear stress which promotes mass erosion. The normal component adds to the stress strength of the soil by increasing the frictional resistance to the soil block's sliding along the impermeable interface with the parent material along the line BD.

The larger structural roots of individual trees provide localised centres of mechanical soil reinforcement while the dense network of small and medium sized roots reinforces the upper soil layer, so that it acts as a membrane to provide lateral strength and increased slope stability. Soil texture is another important influence on the soil's shear strength. Generally, soil cohesion and, hence, soil strength are greater in fine textured soils than in coarse textured soils. The cohesion of fine textured soils is, however, greatly reduced as soil moisture increases. Soil saturation lubricates the individual particles, increasing their tendency to 'float', thus reducing the shear strength of the soil.

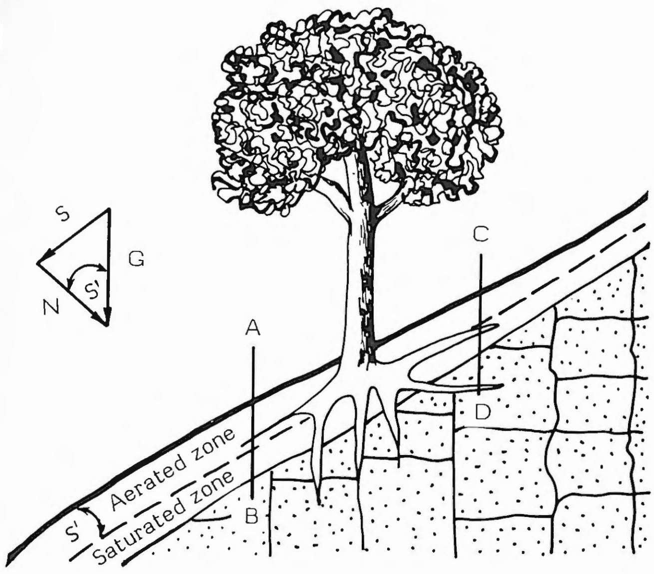


Figure 4. Forces promoting or preventing slope stability.

In steep areas where the shear strength of the soil and the shear stresses in the soil are finely balanced, forest disturbance can lead to a marked acceleration in landslide activity. This appears to be a result of both reducing the mechanical support provided by the tree roots, and the higher soil moisture that follows the removal of the forest's evapotranspiration.

The importance of the riparian zone

The proportion of a catchment that generates rapid surface runoff during storms and contributes to stormflow or floodflow in a stream is termed a 'source area'. Source areas within particular catchments vary with rainfall intensity and the soil moisture content immediately before the storm. Studies on undisturbed temperate forests have shown that these source areas usually form only a small proportion of catchment, generally the area immediately surrounding the stream channel. In the tropical rainforest of north Queensland, research has shown that whole catchments can become source areas during prolonged high intensity monsoonal storms.

In both tropical and temperate environments, protection of the quickly saturated source areas close to the stream channels—the so-called riparian zone—is particularly important for a variety of reasons. With the exception of the more prolonged, high intensity rainfall events, these areas are usually the most important source areas. Maintaining an undisturbed forest buffer in the riparian zone minimises any changes in water quality and quantity associated with disturbance or utilisation of the catchment area.

Undisturbed riparian buffer strips can benefit aquatic organisms by reducing fluctuations in stream temperatures following disturbance. The buffer also acts as a filter, which minimises the movement of sediment and sediment borne pollutants into the stream channels.

In all logging and plantation establishment operations in Queensland State Forests, undisturbed riparian buffer strips are now maintained to keep logging debris and soil disturbance away from the stream channel. Maintenance of the forest root network on stream banks is essential if stream bank erosion is to be minimised. Research has shown that this is particularly important in tropical areas that receive prolonged, high intensity rainfall. In these areas, the frequent 'flash' stormflow events provide little opportunity for the revegetation of areas of exposed soil along the immediate stream bank. Research has also shown that even a few of these areas can contribute significantly to downstream sedimentation problems for a long time.

Conclusions

The science of forest hydrology is less than 80 years old and can only be really said to have existed, in a limited form, in Queensland over the last 15 to 20 years. In that time, research in Queensland and elsewhere has generally established the direction of hydrological change induced by manipulation of the forest vegetation.

A summary of this research experience is that:

- reducing the forest cover on a forested catchment increases both the water yield and the sediment yield from that catchment; and
- planting trees in non-forested catchments has the reverse effect.

In some environments, the increase in streamflow following deforestation can be partly expressed as an increase in floodflow in the headwater streams. This in itself can cause stream bank erosion and downstream sedimentation. In many environments, it is critically important to maintain undisturbed riparian buffer zones to mitigate any adverse impact of forest conversion or utilisation. This implies that priority should be given to already cleared stream-bank areas in agroforesty and landscape rehabilitation programmes.

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How to grow hoop pine on farms

P. A. Ryan and M. J. Lewty, Forest Research Centre, Gympie, Queensland Department of Forestry

Hoop pine *(Araucaria cunninghamii)* is one of Australia's native conifers, occurring in a variety of rainforests and scrubs from northern New South Wales to the tip of Irian Jaya (Figure 1). Hoop pine has had a profound influence on Queensland's development from the time of European settlement.

Although hoop pine does not seem to have been very important to the Aborigines (unlike its close relative, the bunya pine) early explorers such as Oxley, Cunningham and Lockyer were particularly impressed by its size and timber quality. Indeed Brisbane owes its establishment, in part, to John Oxley's enthusiasm for this 'magnificent' tree. Although natural stands are now largely depleted, those which remain make a dramatic impact on the skyline and landscape.

However, hoop pine is still one of Queensland's major timber trees, its high quality timber being used for construction, furniture manufacture and veneering though harvesting is now predominantly from plantations rather than from natural stands.

Though hoop pine may be grown on farms for many reasons, such as weed control, agroforestry or beautification, the site requirements and establishment techniques are basically the same in all situations.

This article outlines where hoop pine can be grown, the characteristics that make it particularly suitable for some tree planting schemes and how to go about establishing a vigorous stand of hoop pine.

However, such considerations as planting espacement, pruning and thinning vary depending on the reason for tree planting. Information on the range of management options and their effects on hoop pine growth is provided in the article 'Management options for hoop pine on farms' in this issue.

Characteristics and site requirements

Root system

Hoop pine is a strongly tap-rooted species. Its roots penetrate more than 3 m into the soil, even where the subsoil consists of heavy clay or rock. Consequently it is very resistant to damage by strong winds once established and can capture nutrients leached beyond the root zones of many other plants.

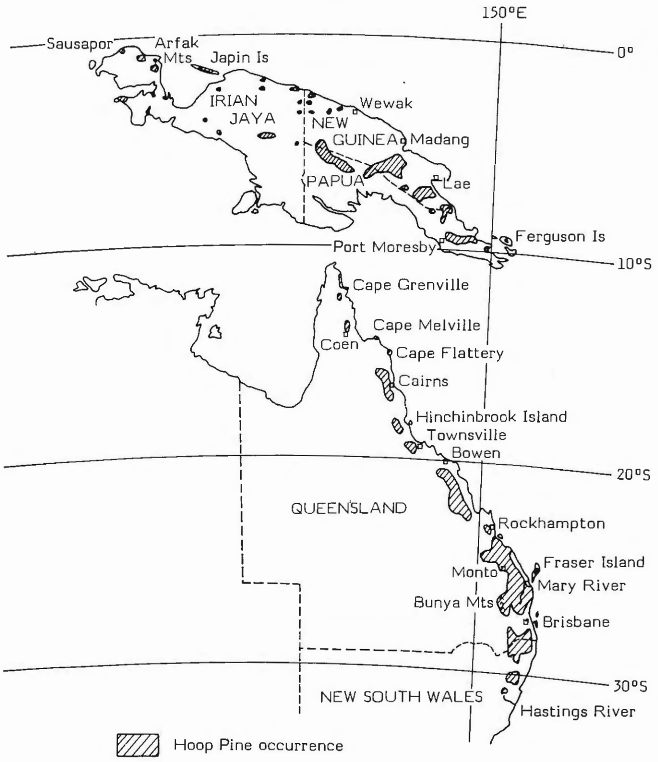


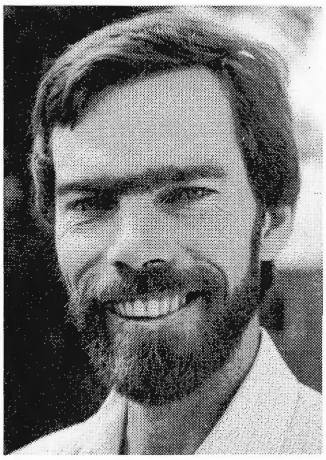
Figure 1. The distribution of hoop pine.

The fine roots are mycorrhizal, that is they are infected with a beneficial type of fungus. These roots are capable of extracting phosphorus which may be present in chemical forms that are normally unavailable for uptake by plants.

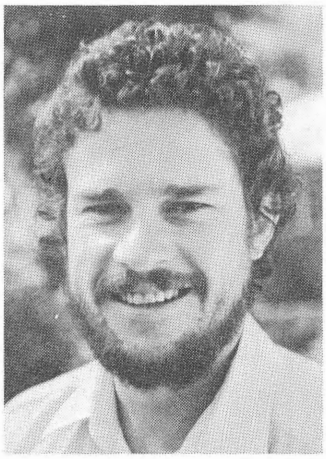
Because of its deep rooting habit and mycorrhizal fine roots, hoop pine is able to make use of nutrients unavailable to other plants and return them to the soil surface via the leaf litter. Decomposition of hoop pine litter is rapid, resulting in a very quick release of nutrients to the soil.

Foliage and branches

Cattle do not generally eat the foliage of hoop pine and tree planting can be carried out without special fences or tree guards in most instances. However, cattle



Paul Ryan Paul is a researcher at the Department of Forestry's Gympie Research Centre. He manages a research programme in the nutrition of hoop pine.



Mark Lewty Mark works at the Department of Forestry's Gympie Research Centre. He carries out research into weed control in the Department's native and exotic pine plantations.

accustomed to rough grazing in drier country may browse the foliage, particularly in times of drought.

The trees hold a deep and relatively dense crown even at quite low light intensities. Branches tend to be fine except when the trees are grown in the open where heavy lower branches develop.

Soils

Hoop pine grows best on well drained alluviums and soils of volcanic origin. However, it grows on a wide variety of soil types having a reasonable depth of topsoil. Good drainage, at least in the top 45 cm, is essential.

Hoop pine needs relatively fertile soils by forestry standards though these requirements are not high by general agricultural standards. Nitrogen deficiency is the major problem encountered on poor quality soils although the addition of phosphorus, potassium, sulphur and trace elements has boosted growth in some cases.

Climate

In general, total average annual rainfall should be greater than 750 mm with an average monthly rainfall greater than 25 mm. However, hoop pine is extremely drought hardy and once established is capable of surviving severe drought periods even when quite young. It is also moderately frost hardy and can tolerate light frosts, though severe frosts kill very young trees.

Fire

Hoop pine is very susceptible to fire. Young trees are killed by fire although older trees may survive light to moderate intensity fires. However, even where trees survive fire, the bark is usually damaged, leading to insect and fungal attack inside the tree. At the least, this weakens the tree and lowers the wood quality while at worst it could eventually kill the tree.

Rehabilitation of degraded land

Land that formerly carried rainforest and that has become too degraded for agricultural use can cause many problems for farmers. The most important of these problems are weed infestation, soil erosion and land slipping. The planting of hoop pine can effectively minimise these difficulties in the long term.

The establishment of a tree cover may provide a long term solution to weed control problems, and hoop pine is particularly effective because of its deep and relatively dense crown. The shading effects of even quite young trees may stop some weeds from flowering and setting seed, while the increasing density of shade after canopy closure results in the weeds' dying out.

Erosion can lead to loss of water storage capacity on the farm through silting of dams, waterholes and streams. An effective tree cover can substantially reduce erosion and improve the stability of steep land by lessening the effect of raindrop impact on bare soil. The deep network of roots of hoop pine also acts effectively to hold the soil in place.

Agroforestry

Agroforestry is the term given the system of mixed agricultural and forestry production. Improved crop, pasture and animal productivity has resulted in many cases where judicious planting or retention of trees on farms has been carried out. The periodic harvesting of timber provides an economic bonus.

Trees may be planted as either windbreaks or at wide spacings in grazing paddocks. As yet, no detailed studies have been carried out on the effects of hoop pine on pasture production. However, you can expect pasture production to stay the same or even to improve under a relatively light stocking of hoop pine.

While the trees may tap some of the nutrients and moisture that pasture would use, there are compensations. The trees return nutrients leached beyond the reach of pasture plants to the soil surface. Reduction of wind by the trees dramatically reduces the water losses resulting from increased water use by pasture under windy conditions. In addition, the intensity of frosts should be substantially reduced. Similarly, a tree shelter can lead to improved animal productivity through reduction of the high and low temperature stress.

The most important effect hoop pine may have on pasture is through the reduction in light levels. This effect is minimised by wide tree spacing and high pruning.

How to go about it

Site preparation

The aim in preparing the site for planting is to give the seedlings the best possible conditions for survival and early growth. In most instances, the only site preparation needed for hoop pine is to ensure that there is no competing vegetation left in a 2 m diameter circle at each planting spot. You should remove broad leaved regrowth such as lantana, particularly to make subsequent operations easier.

Cultivation is generally not necessary except where soils are compacted, or to make planting conditions easier. However, cultivation should only be carried out where soil erosion does not occur. Ploughing of 2 m wide planting strips along contour lines is recommended in such situations.

Firebreaks should be constructed where there is a risk of fire. They should be regularly maintained.

Planting

Planting should be carried out in late spring or early summer. Providing there is good soil moisture at planting and each planting space is free of weeds, most trees should survive even without immediate follow up rains.

The spacing at which the seedlings are planted depends on the objectives of the tree establishment. It also depends on balancing the time and effort required in planting and subsequent operations against the need to ensure that there are a sufficient number of effective trees. It is a good idea to plant more trees than will be needed so that unwanted or useless trees can be removed at a later stage to leave only the best.

Weed control

Good weed control is absolutely essential and is the most important part of the whole tree planting programme. Each tree should be kept free from weed competition for at least the first year after planting. This is best achieved by maintaining a weed free area of 1.25 m radius around each plant.

Experiments conducted by the Forestry Department have shown that the first year after planting is the most critical period of the trees' development. The results of one of these experiments are shown in Figure 2. At 2 years of age, trees maintained free of weeds only for the

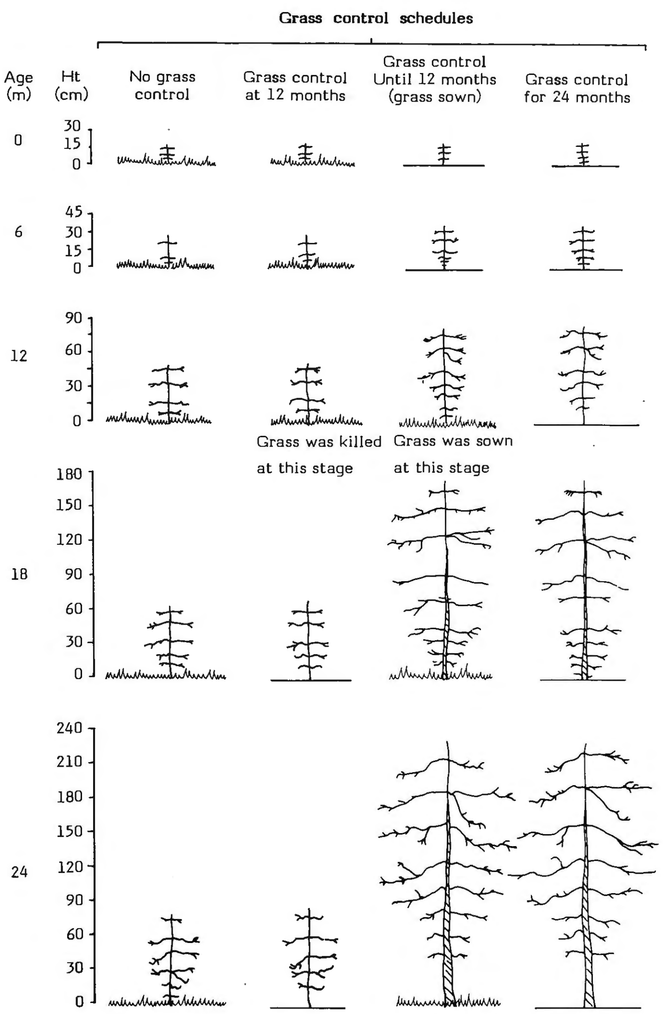


Figure 2. Growth of hoop pine under different grass control schedules.

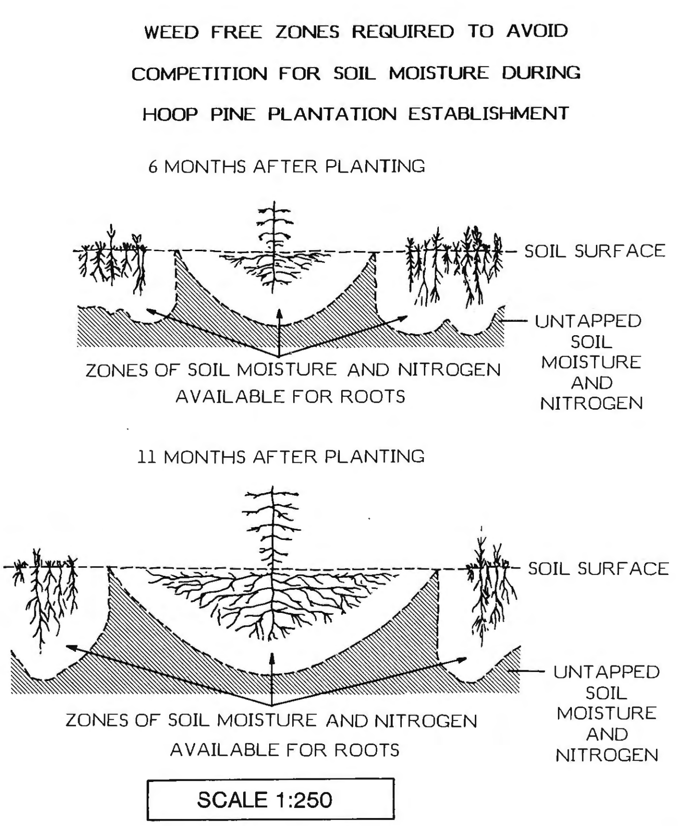


Figure 3. Weed free zones required to avoid competition for soil moisture during hoop pine plantation establishment.

first year were as tall as those that have been kept totally weed free. Trees that were not kept free of weeds till the second year after planting are very small in comparison and only slightly larger than those that have grown with weeds since planting. As these trees grow older, the differences between the larger and the smaller trees become progressively greater.

The aim in maintaining a bare zone around each tree during establishment is to allow the hoop pine roots to develop without competition for soil moisture and nitrogen. Figure 3 is a diagrammatic representation of root development of hoop pine for the first 11 months after planting. As the trees develop, they rely more on their deeper roots for water and nutrients, becoming largely unaffected by competition.

Thus, the size of the young trees rather than their age is the most important criterion for stopping weed control. While this has not yet been determined precisely, trees should be largely unaffected by competition once they are about 1.5 m in height and weed control could stop at this stage.

Chipping, hand pulling of weeds and mulching can be effective if regularly and strictly carried out, but can be both time consuming and tedious. Slashing is not effective in reducing competition though it can be useful in keeping the interrows tidy.

Chemical weed control

Chemical weed control methods are the simplest and most effective. However, considerable care should be taken to ensure that the trees are not damaged by sprays. Safety codes for using chemical sprays should be strictly adhered to always.

Chemicals

The choice of herbicides depends on both the type of weeds to be controlled and the type of control required, that is to kill standing weeds or to prevent weed germination.

Glyphosate is used to kill standing grasses and may be used to kill broad leaved weeds also. The herbicides 2,4-D and 2,4,5-T may be used to control broad leaved weeds but are ineffective against grasses.

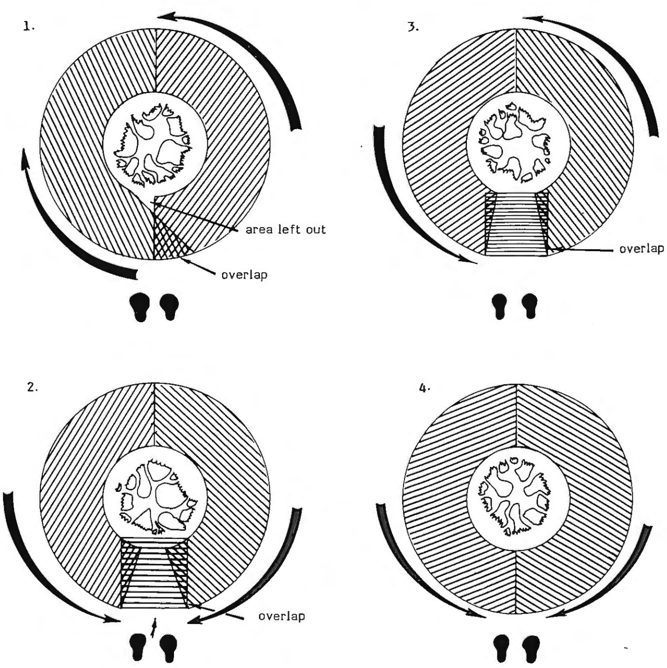


Figure 4. The spraying technique to maintain a weed free ring around a hoop pine tree.

Long term weed control can be obtained by the use of residual herbicides. These chemicals prevent weed seed germination for several months after application but in general do not kill standing weeds. Atrazine is most effective where broad leaved weeds are likely to predominate while simazine is more effective on grasses.

Techniques

A variety of equipment may be used to apply herbicides before planting. It includes:

- Knapsack sprayer
- Controlled droplet applicator, for example Micron Herbi
- Forestry Spot Gun® (a modified drench gun type applicator manufactured by Du Pont)
- Boom spray

The choice of equipment depends on what you have available and on personal preference. In all cases, herbicide application should be restricted to the individual planting spots at the appropriate spacing or to bands along planting rows.

Knapsacks should only be used for applying herbicides after planting. Since hoop pine can be damaged or killed by the herbicides, it is essential that the trees are completely protected from contact with the chemicals. This is achieved most effectively by fitting a guard to the spray wand of the knapsack.

You should apply the herbicide to a ring of about 1.25 m radius around each tree. The technique used by Forestry Department workmen is illustrated by Figure 4. Table 1 summarises the equipment and herbicide application rates that can be used before and after planting. Table 2 gives specific trade names.

Timing

If spraying is necessary in preparing planting spots, it should be carried out at least 2 weeks before planting. Immediately following planting, the appropriate residual herbicide should be applied.

This should provide effective weed control around each tree till the beginning of winter. Further applications of the residual herbicides should be made in the spring of each year.

It may be necessary to carry out occasional spot spraying with glyphosate if weeds are invading the weed free zone around each tree. This is particularly the case where stoloniferous grasses are present or where winter weeds begin to germinate.

A mixture of glyphosate and residual herbicide may be applied in the spring spraying if weeds are growing in the weed free zone. In this case, the concentration of glyphosate should be increased.

Once the trees are about 1.5 m high, there is no need for further spraying. This should be about 15 months after planting if the 1.25 m radius zone around each tree has been kept bare.

Fertilising

In general, fertilising is not required, particularly on more fertile soils or where sound fertility management is already practised.

However, hoop pine may benefit from fertiliser applications on sites that have suffered from past soil erosion or where poor management has allowed soil fertility levels to run down. Even on such sites, fertilising should not be required till the trees are 2 to 5 years of age, when symptoms of nutritional stress begin to appear.

The most obvious symptom is a general change in foliage colour from deep green to a more yellow green colour, which indicates a nitrogen deficiency. The addition of 120 kg/ha of nitrogen as either nitram or urea improves both colour and growth. If the foliage on

Table 1. Suggested equipment and application method for herbicides recommended

Equipment	Herbicide	Application
Knapsack	Simazine or atrazine	Use a blue polijet nozzle and calibrate to apply 12 L of product/ha to a band 1.25 m or wider or to individual planting spots.*
	Glyphosate	Use a blue polijet nozzle and apply a 1 : 100 herbicide: water mixture to a band 1.25 m or wider or to individual planting spots.†
	Glyphosate + residual	Use a blue polijet nozzle and calibrate to apply 12 L of the residual product/ha to a band 1.25 m or wider. Add glyphosate at 12 mL of product/L of mixture.*†
Micron Herbi	Simazine or atrazine	Use a yellow nozzle and apply a 1:1 herbicide: water mixture to a band 1.25 m or wider.
	Glyphosate	Use a blue nozzle and apply a 1:1 herbicide: water mixture to a band 1.25 m or wider.
Du Pont Forestry Spot Gun®	Simazine or atrazine	Apply 20 mL per spot and use a 1.4:10 herbicide: water mixture. Hold gun 1 m above soil to spray a circle 1.7 m in diameter.
	Glyphosate	Apply 20 mL per spot and use a 1:10 herbicide: water mixture. Hold gun 1 m above soil to spray a circle 1.7 m in diameter.
Boom spray	Simazine	Calibrate to apply 12 L/ha to a band 1.25 m or wider.*
	Glyphosate	Calibrate to apply 6 to 9 L of product/ha to a band 2.0 m wide depending on grass species and development (refer to product label).†

* Do not exceed a maximum application rate of 7.2 L/ha of simazine (sprayed plus unsprayed area).

† Do not exceed a maximum application rate of 3 L/ha of glyphosate (sprayed plus unsprayed area).

Table 2. Trade names of herbicides recommended

Herbicide (registered products)	Trade name
Simazine	F. & B. Chemicals Simaflo 500 Sc ICI Simatox 50 Flocol Ciba-Geigy Gesatop 500 GW CIK Australia Farmco Flowable Simazine—500
Glyphosate	Monsanto Roundup

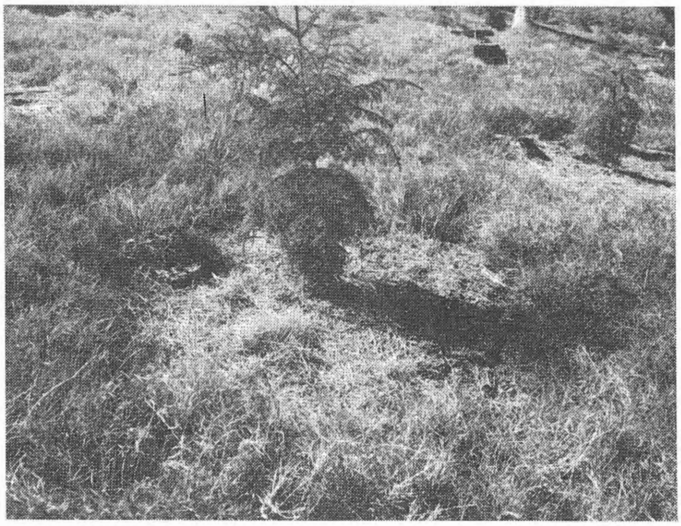


Plate 1. A young hoop pine plantation showing the effect of ring tending with herbicide.

the lower branches becomes quite yellow and begins to die, you can assume that potassium levels are inadequate. This can be corrected by the addition of 50 kg/ha of potassium as muriate of potash in addition to the nitrogen fertiliser.

In both these cases, you can assume that the addition of phosphorus (20 kg/ha as Superking) improves the overall fertility of the site. However, phosphorus should never be added by itself as it could worsen other nutrient deficiencies, particularly that of nitrogen.

In areas of known molybdenum or boron deficiency, it is advisable to add these elements at planting. Elemental rates for each tree should be about 80 mg of molybdenum (for example, as 200 mg per tree of sodium molybdate) and 160 mg of boron (for example, as 1.4 g per tree of borax).

Table 3. Establishment sequence

Time	Phase of establishment	Operation
Early spring	Cultivation	Soil hard—plough or rotary hoe Soil friable—no action
Early spring	Pre-plant weed control	Grass or pasture—apply glyphosate Broad leaved weeds—apply 2, 4-D/2,4,5-T or glyphosate
Spring-early summer	Plant Post-plant weed control	
Spring–early summer	First growing season	Ring size 1.25 m radius—apply residual herbicide
Autumn		Apply glyphosate
Spring–early summer	Second growing season	Ring size 1.25 m radius—apply glyphosate + residual herbicide
Autumn		Apply glyphosate
Spring–early summer	Third growing season (only if necessary)	Ring size 1.25 m radius—apply glyphosate + residual herbicide
Autumn		Apply glyphosate
After thinning (years 2 to 5)	Fertiliser	Yellowish-green foliage—apply 120 kg/ha nitrogen + 20 kg/ha phosphorus Yellowish foliage lower branches—apply 120 kg/ha nitrogen + 50 kg/ha potassium + 20 kg/ha phosphorus

Growing trees on the farm

The Queensland Forestry Department has a number of planting schemes which supply plants at a concessional rate.

Forest plot scheme

Forest plot concession rates apply only to *bona fide* property owners within the State of Queensland whose applications have been approved. It is not the policy of the Department to inspect areas for persons other than the owner of the property concerned, and applications for forest plot concessions should therefore be completed by the owner personally. Application forms may be obtained on request from the local forest office.

Rates quoted apply only to total plantings not exceeding 50 ha. Rates for planting in excess of this will be supplied on request. The concessional scheme for forest plots applies to both plantation establishment and enrichment of natural forests.

Plantation establishment Plants will be supplied at concessional rates only where:

- the proposed planting scheme has been approved.
- a minimum of 300 plants is to be supplied at any one time.
- plantings are made with the approved species and in plot formation of at least 300 trees in any block and with a minimum of 5 rows and 5 trees per row.
- planting spacings are consistent with the manner in which the plot will be managed.

Species which will be supplied at concessional rates are:

*Pinus elliottii** (Slash pine)
Pinus caribaea (Caribbean pine)
Pinus patula (Patula pine)
*Pinus radiata** (Monterey pine)
*Pinus taeda** (Loblolly pine)
Eucalyptus pilularis (Blackbutt)
Eucalyptus sideroxylon (Red ironbark)
Araucaria cunninghamii (Hoop pine)
Araucaria bidwillii (Bunya pine)
Eucalyptus citriodora (Lemon Scented gum)
Eucalyptus cloeziana (Gympie messmate)
Eucalyptus maculata (Spotted gum)
Eucalyptus saligna (Sydney blue gum)

* Plants supplied open root.

Enrichment planting in natural forests. In order to qualify for concessional rates the normal Departmental specifications for enrichment plantings must be followed. For this use, a minimum of 100 plants will be provided at the concessional rate at any one time. Peat pot stock will generally be provided for this purpose.

In order to meet the requirements for concessional rates, the proposed sites and species must conform to general Departmental requirements as being suitable for the production of commercial timber. Some species of eucalypts, which are not used in Departmental natural forest enrichment programmes may be approved if they are considered to be potentially suitable for timber production for the purpose intended, for example for construction purposes on the property.

Windbreak plantings

The species mentioned in the Forest Plot Scheme may also be supplied for windbreak plantings. Application forms are available on request. A minimum order of 150 trees is required to attract the reduced rate.

Rehabilitation

Upon application, we may supply plants at a concessional rate for rehabilitation following mining, quarrying or similar land disturbance. To obtain this concessional rate a minimum of 500 plants must be purchased. The actual rate is determined upon application.

Management options for hoop pine on farms

M. B. Powell and R. W. C. Master, Forest Research Centre, Gympie, Queensland Department of Forestry

For tree growing to be successful, careful thought must be given to the long term management of the trees. The initial spacing, pruning and thinning of plantations all influence tree growth, and can be changed to achieve different aims.

Hoop pine produces valuable timber if the planting site is favourable. The article 'How to grow hoop pine on farms' in this issue covers the soil type and climatic requirements of hoop pine, and the methods of establishing a vigorous crop. This article looks at the management of hoop pine plantations and considers three different objectives you may have:

- commercial woodlots;
- rehabilitation of degraded land; and
- agroforestry.

Spacing

The spacing at which hoop pine should be planted depends on the objectives to be achieved. The two main considerations are:

- Balancing the time and effort required in planting and subsequent operations with the time and resources available to the landowner.
- Ensuring that enough trees are established to satisfy the management aim. This may require planting more trees than necessary and thinning them after a few years, when the danger of early mortality and deformation has passed.

Close spacings in plantations produce large volumes made up of small trees, while wide spacings produce less volume made up of individually larger trees. Individual tree growth is greater at wide spacings,

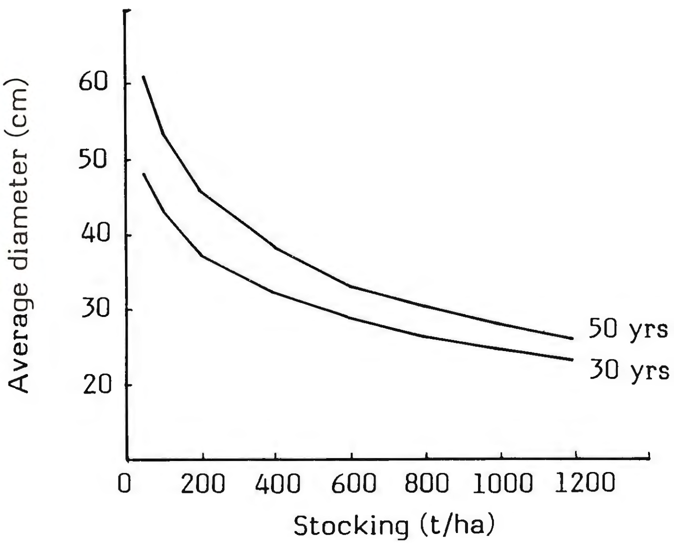


Figure 1. The relationship between diameter growth and tree stocking in hoop pine.

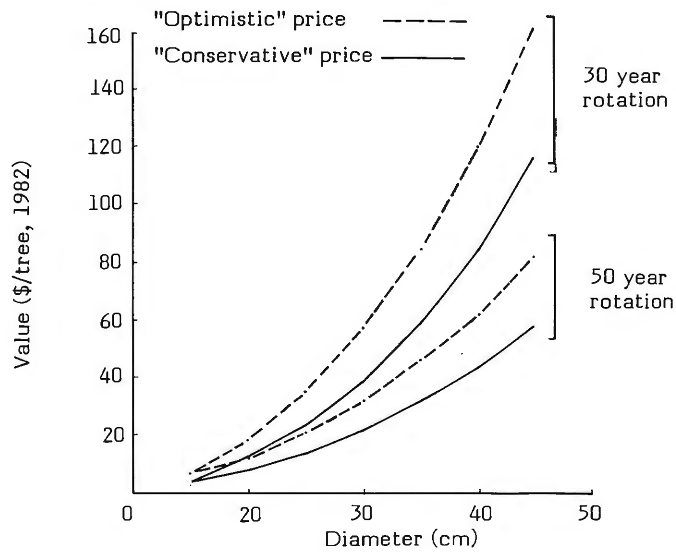


Figure 2. The relationship between tree diameter and value in hoop pine.

Michael Powell Mike carries out spacing and thinning research in native and exotic pine plantations at the Department of Forestry's Gympie Research Centre.

Ross Master Ross is currently researching a means of speeding up and containerising the production of seedlings for the Department of Forestry's hoop pine plantation programme. He is based at the Gympie Research Centre.

owing to the delayed onset of competition between trees and the increased growing space throughout the rotation. This is shown for diameter growth in Figure 1 on an average quality site in south east Queensland (the trees are expected to reach a height of about 25 m in 25 years). Over the range of stockings considered, diameter increases markedly as initial stocking decreases (that is as spacing between trees increases).

Larger trees are more valuable for several reasons:

- A greater proportion of sawn timber can be recovered from each stem.
- They are cheaper to handle. For instance, logging, transport and processing costs per cubic metre are reduced when piece-size increases.
- The potential benefits from pruning are greatly increased if pruned stems are allowed to reach larger sizes.

Figure 2 shows the range of prices that may be expected for individual trees of any given diameter at two ages—30 and 50 years. The upper curve for each age is based on an 'optimistic' price schedule while the lower curve is based on a 'conservative' one.

However, growing timber for sale is by nature a long term investment and the actual revenue received by a grower depends on many factors, for example:

- changes in the general industry price schedule;
- quality of the product—pruned or unpruned, etc.;
- quantity of the product; and
- accessibility to markets and processing plants.

Owing to these factors, it is difficult to give an accurate forecast of the revenues that growers will receive 30 to 50 years hence. However, based on present prices and likely future trends, recommendations can be made on suitable stocking levels for use in small plantings.

Thinning

As mentioned above, it is important to ensure the establishment of sufficient effective trees. At low stockings particularly, up to twice as many trees as necessary should be planted with the excess stems being felled to waste at about 5 to 7 years of age. The straightest and most vigorous trees should be retained and these trees pruned.

Pruning

The removal of branches from the lower part of a tree produces knot-free timber. For some uses, for instance decorative panelling or flooring and the like, knots may be an advantage. However, in general, high value materials such as veneers, cabinet timbers and high grade structural timber has to be made from clear wood. Pruning yields an economic return if you are prepared to invest the time and money.

Pruning needs to be timed and performed carefully. If too many live branches are removed, the growth of the tree slows for a year or two. If it is left too late, the central core of knotty wood is too large to maximise the benefits of pruning. Branches should be pruned flush with the stem.

Generally, pruning is performed in two stages with the aim of keeping the knotty core less than 15 cm in diameter. This is best achieved by pruning when diameter is about 12 cm at breast height. The first stage can be carried out when the stand is 6 m high, which should occur between 5 and 7 years, depending on site quality and early weed control. At stockings less than about 400 trees/ha, you should prune all trees to a height of 2.4 m using light weight chainsaws or handsaws. Badly formed or weak trees with no prospect of growing into merchantable logs are not pruned and should be removed.

You should prune the same trees again, 2 years later, removing all limbs to a height of 5.4 m. This is best done with a handsaw and ladder. Trees can be pruned further, at your own discretion, but you should realise that further pruning is more difficult, takes more time and results in lower returns when compared to the two pruning lifts already done.

Pruning should be restricted to the colder months of May to August to minimise the risk of disease and insect attack.

Fire protection

Hoop pine is sensitive to fire at all ages owing to its relatively thin bark, and you must allow for this in your planting scheme. You cannot use fire to encourage pasture development in planted areas. Firebreaks 10 m wide should be formed and maintained around the planted areas to protect the trees from wildfires. In areas which can carry rainforest cover, a 'green break' of rainforest regrowth is the best means of preventing fire encroachment.

What spacing do you adopt?

There are no hard and fast rules which dictate the adoption of exact stockings for specific purposes. Rather, you are faced with a range of alternatives, all of which give close to maximum benefit.

Based on the discussion presented above, it is reasonable to assume that you want to:

- maximise revenues if the venture is to be commercial;
- minimise the time and effort involved in managing the stand, that is in planting, controlling weeds, pruning and so on.

Commercial woodlots

For the woodlot option, both of the above objectives can be satisfied by planting your trees at a stocking of about 500 trees/ha (4.5 × 4.5 m spacing) and thinning them at 2 to 3 years of age to 400 trees/ha. This recommendation takes into account the increasing value of individual trees as the number of trees per hectare is reduced. When this trend is balanced against the loss in number of trees, revenue is maximised at 400 to 500 trees/ha. Table 1 lists the sequence of operations which should be followed.

2.5 m
Between Trees

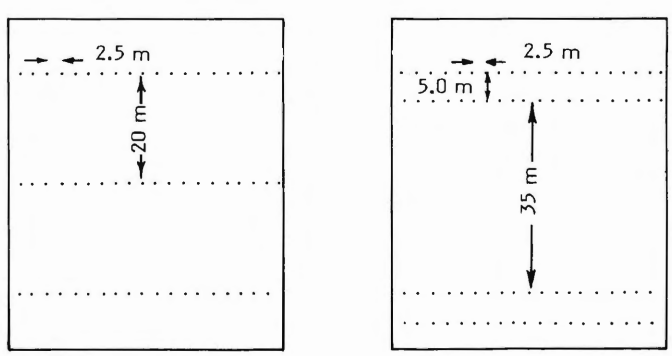


Figure 3. Two different planting configurations at 200 trees per hectare.

Rehabilitation of degraded land

For rehabilitating degraded or eroded sites, a stocking as high as 1 100 trees/ha (3 × 3 m spacing) is worth considering. Such a stocking would give rapid development of a tree canopy to protect the soil.

Stocking reductions of a third to a half could be considered at age 7 to 10 years, especially if some future commercial gain is also desired.

Agroforestry

The most important consideration in agroforestry is that growing trees is an additional benefit, both in monetary and other ways, and the primary land use would be the rough grazing of animals. A final crop stocking of 400 trees/ha permits grazing under the forest canopy for about 12 years into the rotation. However, the pasture will eventually be shaded out. Grazing values could be maintained longer by either reducing the final crop stocking to 200 trees/ha or by using rectangular spacings.

Planting trees in a square spacing, that is where the distance between trees equals that between rows causes greater shading of the pasture as a whole, dependent on stocking, with a resulting decline in pasture production. Rectangular spacing can reduce this problem with minimal effect on tree growth. Figure 3 shows two rectangular spacing layouts for a final stocking of 200 trees/ha. Similar layouts are possible for higher final stocking levels.

Table 1. Sequence of operations

Operation	Timing (years)	Comments
Planting	0	500 trees/ha (4.5 × 4.5 m spacing). Stocking can be reduced or spacing made rectangular if grazing pasture is important.
Weed control } Fertilising }	See 'How to grow hoop pine on farms' in this issue	
Grazing	1+	Grazing can begin once the trees are older than about 1 year. If a stocking of 400 trees/ha is maintained, grazing decreases as the trees grow older
Early thinning	5 to 7	Remove poorest stems to retain a stocking of 400 trees/ha or less if grazing is important
Low pruning	5 to 7	Prune all trees to 2.4 m height when average height reaches 6 m.
High pruning	7 to 9	Prune all trees to 5.4 m 2 years after low pruning.
Clearfalling		30 years +

Care of trees and shrubs

Planting

Ornamental plants are normally grown in plastic pots whilst the majority of plantation type species are raised in metal tubes. Plants in these containers can be held under partial shade with adequate watering until conditions are suitable for planting.

Site preparation on large areas: Some form of general cultivation (for example, strip ploughing, rotary hoeing) or planting spot hand hoeing is recommended to reduce competition from weeds and to improve rain infiltration.

Individual site preparation: In preparing (individual) sites (or beds) in a new garden, especially where topsoil has been removed, a 10 cm layer of organic matter should be tilled into the previously turned soil. Such material as manure, garden compost and lawn clippings should be left for about 2 months to break down. A heavy mulching with pine bark, bagasse, wood chips or straw over the prepared area will conserve soil moisture and reduce weed competition. With heavy clay soils, well prepared mounded beds will provide good aeration and drainage for healthy plant growth.

When planting tubed stock, the metal tube should be carefully unclipped so that the core of earth and roots is undisturbed. Soil is firmed around this core and the tube slid upwards over the plant. Plants in pots can be removed by inverting and tapping the bottom of the pot with a solid object. Plant just deep enough to cover the top of the soil core.

A thorough watering of the surrounding area immediately after planting removes air and settles the soil. Water plants twice a week until established then follow with a good soaking once a week. Infrequent heavy watering encourages deep rooting which promotes drought resistance. Frequent watering encourages the development of surface roots which dry out easily in times of drought. Overwatering may result in death through waterlogging of the soil.

Plants develop greater windfirmness if left unsupported; staking may be necessary in windy locations to provide support.

Pests and diseases

Healthy, vigorous plants are usually much more resistant to disease and insect attack than unhealthy ones. Provided the species planted is suited to the site, good tree health is generally assured by providing suitable growing conditions. This includes adequate water, sunlight and freedom from weed competition.

Any changes to the conditions under which a tree is growing may adversely affect its health. For example, damage to the root system by trenching close to a tree, the addition of fill or excess topsoil, waterlogging, soil compaction and the improper use of herbicides may cause tree disorder. In such cases, insect or fungal attack which occurs is often a symptom rather than the cause of the disorder.

Sometimes trees which are otherwise normal and healthy are also attacked, and even killed, by insect pests or diseases. In any case, it is always important to establish the real cause of a problem before control measures are attempted.

Older trees often suffer because of lack of maintenance in their earlier years. Poor pruning, fires, and wind or mechanical damage often leave dead branch stubs or areas of exposed wood which are prone to attack by wood boring insects and fungi. In particular, rot pockets in the base of trees are often allowed to develop to the point where the tree becomes dangerous. Whenever necessary, tree surgery should be carried out to prevent these problems from developing.

Advice on the control of tree pests and diseases can be obtained by telephoning (07) 371 3533, or by writing to:

The Extension Officer
Department of Forestry
Biology Laboratory
80 Meiers Road
Indooroopilly, Q. 4068

Caution: Insecticides and fungicides should be used only as specified on label instructions. This applies to storage, mixing, concentration and application.

Selection of suitable species: When choosing a plant for a particular purpose you should ensure that the species is suited to the site and climatic conditions. When planting near the beach, salt tolerant species should be chosen. Sites prone to frequent waterlogging should be planted with species from a similar natural habitat.

Tree root problems: There are several species of trees which you should avoid planting near sewerage or other pipes, swimming pools and wall foundations. Root problems are frequently associated with pencil and weeping willows, figs (rubber trees), umbrella trees, oleanders and frangipani.

Planting Caribbean pine on the Atherton Tableland

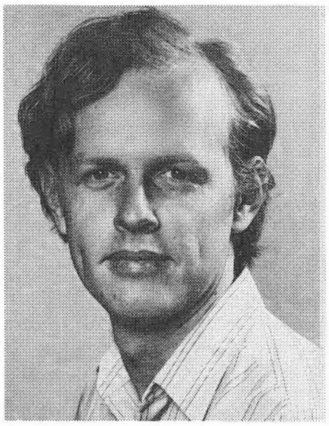
T. M. Anderson, A. M. Harvey and D. I. Nicholson, Division of Technical Services (Research and Utilisation), Queensland Department of Foresty

Introduction

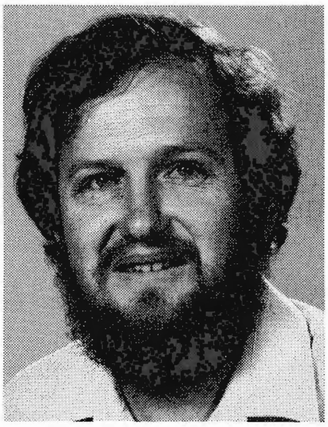
In a 1981 report assessing agroforestry in Queensland, the Queensland Departments of Forestry and Primary Industries said that the Atherton Tableland had the best prospects for success. The reasons were:

- The Atherton Tableland has soils of at least moderate fertility and high annual rainfall.
- Honduras Caribbean pine, the most productive softwood established on a large scale in Queensland, produces its best growth rates on the Tableland.
- Honduras Caribbean pine keeps its straight, small limbed form when grown in the open, and elaborate thinning and pruning schedules are not required to produce valuable timber.
- The necessary industries to use farm grown timber should be well established as a result of Forestry Department plantings in the region.
- With the long term reduction in rainforest timber yield, the demand for locally grown wood in north Queensland should be strong.
- There is a large area of degraded farmland (estimated at 56 000 ha) which could be restored through agroforestry.

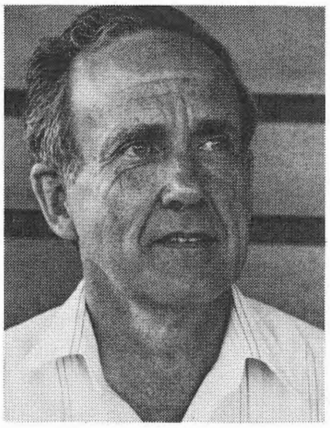
The Forestry Department and DPI are cooperating near Yungaburra in testing an agroforestry scheme. About 3 ha of pasture land have been planted with Honduras Caribbean pine at 500 trees/ha, with all costs and operations being recorded. It is intended to monitor the growth of the trees and pasture to estimate the likely yields and returns from this integrated tree and grazing management. A similar trial will be established on the Evelyn Tableland during 1983–84.



Timothy Anderson Tim works in the Forest Research Branch of the Department of Forestry. He edits the Division of Technical Services' range of research, technical and advisory publications.



Alan Harvey Until recently, Alan worked in the Department of Forestry's Forest Research Branch on the prediction of growth and yield in native and exotic pine plantations.



Don Nicholson Don is the Department of Forestry's Forest Research Officer based in Atherton. He carries out research in rainforest management as well as a programme of exotic conifer and native hardwood research.

The species

Honduras Caribbean pine was first introduced from Central America in the 1930s. It was not until the late 1940s that real interest in it as a plantation species developed. Researchers in Queensland found that despite its rapid growth, the species was easily wind damaged and was very poorly formed. However, an intensive tree breeding programme has produced the windfirm, straight trees now available from the Forestry Department.

It is easily the fastest growing softwood species used in plantations in Queensland and produces an excellent timber for plywood, sawnwood and fibre uses. Trees of 50 cm diameter and 30 m height can be grown on most sites in 25 to 30 years.

Its rapid growth and tolerance of drought once established make Honduras Caribbean pine a good choice for farm plantings where tree cover is needed in pasture areas and a return from tree planting is desired. When grown at wide spacings, it allows good grass development between the trees.

How to grow Honduras Caribbean pine

Honduras Caribbean pine does not grow well in boggy areas and is susceptible to frost when the trees are small. Weed control is important on pasture sites as grass competition may choke the young trees.

Site selection

Soils should be reasonably deep and free draining, and the site should be frost free.

Fencing

Grazing animals are apt to browse Caribbean pine and to deform the young trees by rubbing against them. The planted area should be fenced and stock excluded for 3 years. However, the interrow space may be suitable for cropping from the planting date for hay production.

Site preparation

On pasture sites, ploughing a 2 m wide strip along the planting lines is enough to provide initial weed control. If possible, the lines should follow the contour to reduce the risk of erosion. Alternatively, 'no tillage' using glyphosate herbicide may be a good method.

Planting

High quality seedlings are available from the Forestry Department. They should be planted after the first summer rains to ensure good growing conditions during the establishment period.

Fertilising

Low soil fertility is normally not a problem on pasture sites, but Caribbean pine responds well to adequate phosphate supply. Therefore, an application of 200 g of superphosphate just after planting is recommended. This can be applied as a ring, or in one or two heaps near the seedling.

Weed control

A knockdown herbicide such as glyphosphate, combined with a residual herbicide, provides good control when applied in a 1 m radius ring around the tree (make sure the tree is shielded during spraying). Weed growth in the interrow space can be controlled by slashing or cropping, but it usually does not interfere with tree growth.

Stocking, growth and pruning

Stocking

High stockings (number of trees per hectare) in pine plantings produce large volumes made up of small trees, while low stockings produce less volume made up of individually larger trees (which are more valuable). Low stockings require less maintenance, allow grazing for most of the rotation and produce the most valuable logs more quickly. Such plantings do not require frequent thinning to maintain rapid growth, which is fortunate since thinnings are difficult to sell in small logs.

For these reasons, low stockings are recommended for farm plantings with the best strategy being to plant 500 trees/ha at an 8 × 2.5 m spacing. The stand should be thinned at about 4 years of age to 250 trees/ha. You must plant more trees than are required for the final crop, because it is impossible to guarantee that every seedling will grow into a straight, vigorous tree.

Growth and yield

Table 1 shows the productivity of a stand planted at 500 trees/ha, thinned to 250 trees/ha, pruned and retained for a variety of rotation lengths. By comparison Table 2 shows a stand planted and maintained at 750 trees/ha.

The influence of individual tree size is obvious. Despite producing less volume, the low stocking stand is worth more, based on current wood prices, than the high stocking stand and allows greater returns from grazing or intercropping.

Pruning

Pruning adds value to the tree by removing from the lower stem the branches which cause knots in the timber. Normal practice is to prune a 5.4 m length (equivalent to two 2.4 m plywood bolts) in two operations: first as high as can be reached from the ground, and secondly using a ladder to 5.4 m. Pruning live branches may cause a growth check, so pruning must be delayed until the crown is large enough to withstand the shock. As a general rule, it is best to prune the whole stand to 2.7 m after thinning to 250 stems/ha at 4 years of age. The whole stand should be pruned again to 5.4 m at 6 years of age. Pruning should be carried out in winter.

The schedule of operations

Table 3 shows the sequence of operations in establishing a Caribbean pine stand.

Table 1. Production from 250 trees/ha Caribbean pine stands

Rotation age (years)	Average diameter (cm)	Log volume (m³/ha)	Sawnwood volume (m³/ha)	Stand value ($/ha)
20	40	287	167	4 839
25	45	398	240	7 745
30	48	503	310	10 800

Table 2. Production from 750 trees/ha Caribbean pine stands

Rotation age (years)	Average diameter (cm)	Log volume (m³/ha)	Sawnwood volume (m³/ha)	Stand value ($/ha)
20	29	438	221	4 647
25	32	582	304	7 131
30	34	708	380	9 488

Table 3. Sequence of operations in Caribbean pine establishment

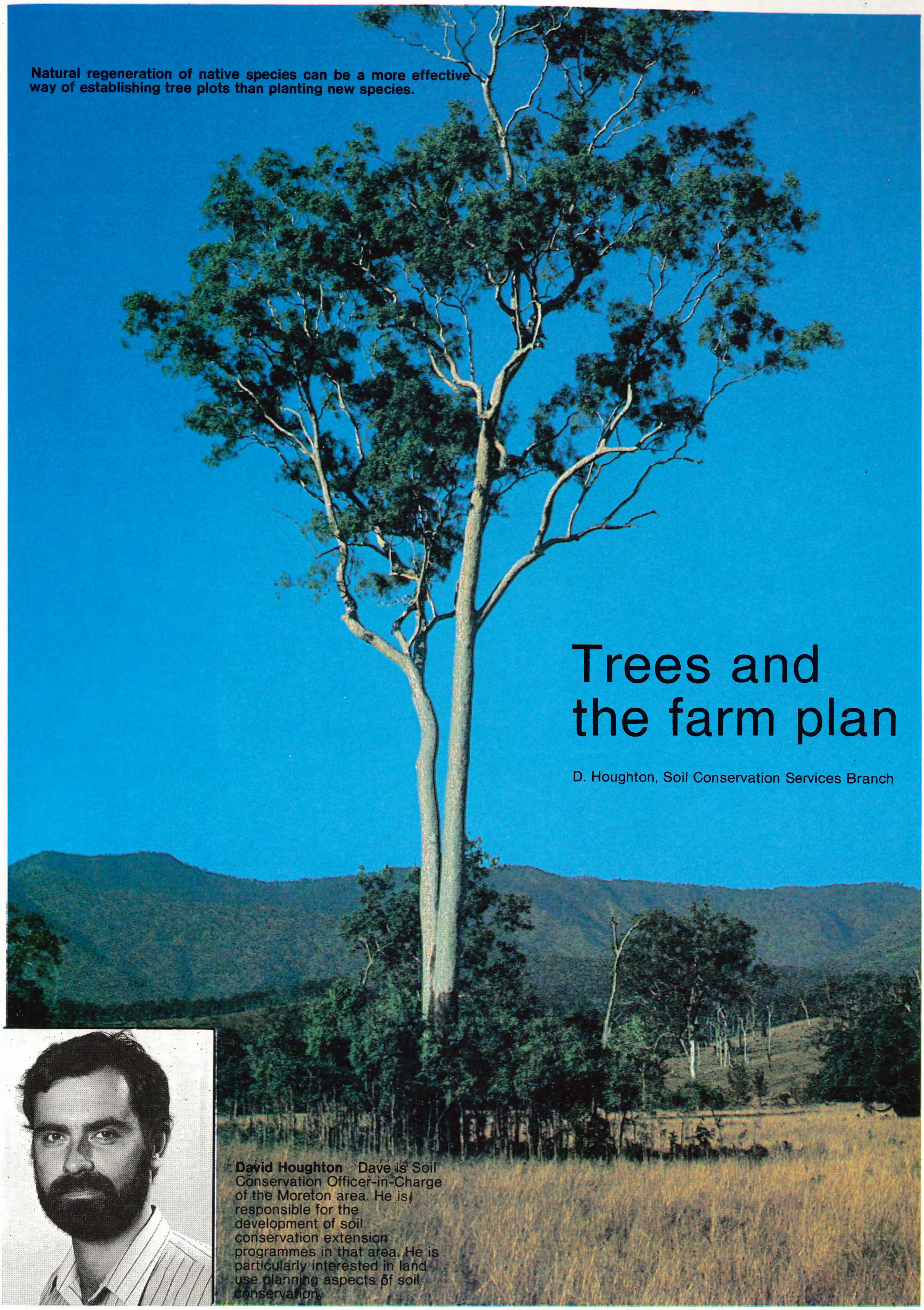
Operation	Timing	Comments
Site selection	—	Avoid boggy and shallow soils.
Ploughing	November to December	Plough 2 m wide strips on 8 m centres following contours.
Planting	Early wet season	Plant each seedling 2.5 m along ploughed strips using container or bare root stock as supplied.
Fertilising	Immediately after planting	Apply 200 g of superphosphate in a ring 30 cm from the tree.
Weed control	As needed	Ring tending with glyphosate during first year with slashing of interrow area to control regrowth.
Grazing	3 to 4 years of age	Grazing can probably be introduced in the third year after planting when the trees are well established. In the interim, the area between the planting lines may be used for hay production.
Thinning	4 years	Thin stand to leave the best 250 stems/ha at an even spacing.
Low pruning	4 years	Prune all remaining stems to 2.7 m height.
High pruning	6 years	Prune all stems to 5.4 m height.
Clearfalling	20 to 30 years	Rotation age can be varied to suit market conditions and the landowner's requirements.

Plate 1. Grass development under a young, widely spaced Caribbean pine plantation.

Plate 2. Grass development under a 15 year old Caribbean pine stand.

Plate 3. Newly planted Caribbean pine, showing the ploughed strip and the need to control grass competition.

Natural regeneration of native species can be a more effective way of establishing tree plots than planting new species.



Trees and the farm plan

D. Houghton, Soil Conservation Services Branch

David Houghton Dave is Soil Conservation Officer-in-Charge of the Moreton area. He is responsible for the development of soil conservation extension programmes in that area. He is particularly interested in land use planning aspects of soil conservation.

Introduction

While the value of trees on the farm is well recognised, the location and type of trees need to be carefully considered when planting additional species or maintaining areas of regrowth. As tree planting is a long term consideration, it is important that decisions made now do not create problems later.

The overall aim of a tree planting programme should be to locate trees:

- where they give optimum control of water and wind erosion, salinity control and shelter for stock and crops;
- where they enhance the attractiveness of the landscape;
- where they cause the least problems with farming operations or productivity; and
- where they grow quickly into healthy specimens.

This article deals specifically with the location of trees on the farm. Information on desirable species for any given situation can be obtained from your local Forestry Department office. Remember that trees native to the area are often the best adapted to that particular environment and the most suitable for the local fauna. Also, more satisfying effects can result from the use of mixtures of species rather than single species.

Planning for planting

The first step in formulating a tree planting programme is to prepare a plan of the property showing the following detail:

- location of residence, sheds and other structures;
- fencelines, access tracks and power lines;

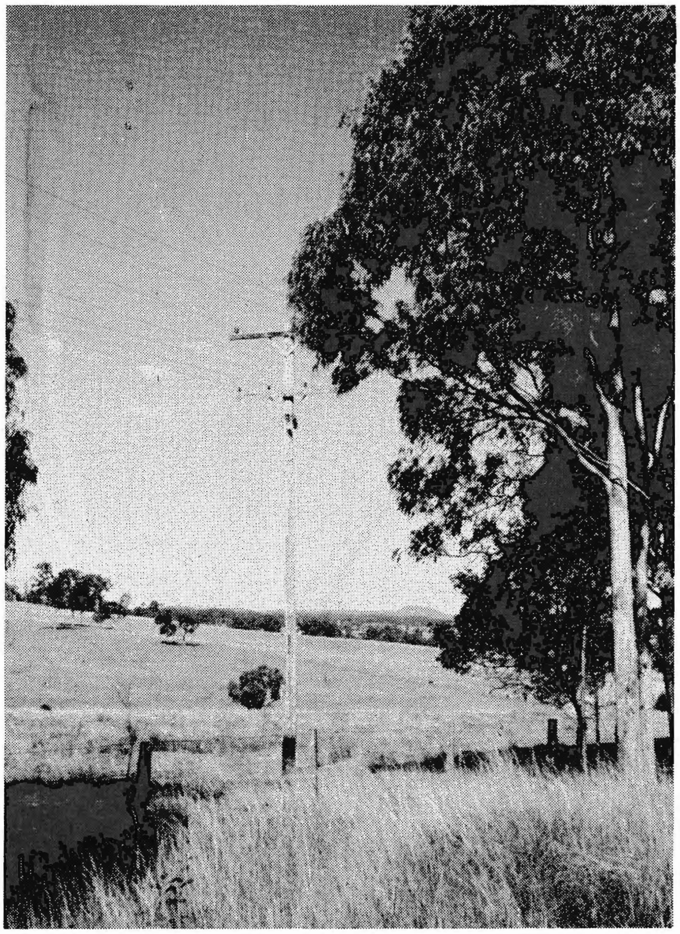


Plate 1. Tall growing trees may interfere with power lines and create a potentially dangerous situation.

- areas of cultivation and pasture;
- exposed, windy areas;
- dams, creek and river areas;
- steep, unproductive and eroded areas;
- salt affected areas;
- firebreaks; and
- existing tree areas and species.

The following discussion highlights the need for and benefits of planting trees in the areas detailed on the farm plan. In any particular location, the planting of trees may alleviate more than one problem.

Around residences, sheds and other structures

Shade and aesthetics would be the main reasons for planting trees in these areas. Plants around the residence usually perform better than those planted in less accessible areas because of the opportunities for regular watering and maintenance. For this reason, more exotic and perhaps less hardy species could be planted. Problems associated with leaf fall and broken branches can be prevented by planting shorter growing species. Tall growing eucalypts and other trees with fragile branching systems should be avoided. Trees with extensive root systems such as jacarandas *(Jacaranda mimosaefolia)* and umbrella trees *(Schefflera actinophylla)* should not be planted near buildings as damage may occur to foundations and pipes.

The flammability of a tree or shrub is important where bushfires pose a threat. Most exotic trees give better fire protection than native species, some of which can create a fire hazard if planted too close to buildings.

Deciduous trees can be beneficial when planted near the house. They give shade from the hot summer sun but let in warmth in winter.

Fencelines, access tracks and power lines

Before planting trees next to a boundary fence, the adjacent property should be considered. Tree planting may be advantageous to one property, but detrimental to the neighbouring property. Trees should not be placed too close to power or telephone lines or in positions where a driver's vision or manoeuvreability is reduced.

Areas of cultivation and pasture

Selected contour banks within cultivation areas can be used for the planting of trees. This is a particularly important consideration if the land is to be cropped for a certain period and then returned to pasture. The trees are then useful as shade for stock. To avoid stock damaging the bank, a fence may be needed close to and just below the bank. To reduce the number of strainer posts, small islands of land are often left between the bank and the fence. These pieces of 'dead' land are ideal for groups of trees; a single line could be planted along or below the bank. Similarly, odd corners or non-parallel areas between contour banks can be used for tree planting.

Groups of trees concentrated in small areas are more effective as shade for stock than single trees widely separated in a paddock. Broadleaf and evergreen species give more shade than narrowleaf and deciduous species. The number and location of shade areas depend largely on the climate and number of beasts grazing an area. For beef cattle and horses, no part of a large area should be more than 400 m from good shade or, for dairy cattle, 200 m from shade. Cattle camps

Plate 2. Tree clumps give more effective shade and shelter than single trees spread throughout a paddock.

Plate 3. Trees should not be planted on dam walls as they may affect the dam seal and attract stock onto the bank.

should not be positioned in areas where concentrated water flows can occur, such as in gullies. Flat areas and ridges are preferable. Shade trees are particularly beneficial where in hot weather stock are held in high concentrations such as in stockyards.

In dry areas, consideration should be given to selecting species which have a high degree of fire resistance, so that shelter belts are not destroyed in the event of a fire. Narrow-leaved ironbarks *(E. crebra)* and spotted gums *(E. maculata)* are particularly resistant to burning.

Exposed, windy areas

Trees and shrubs arranged to form windbreaks can alleviate the problems of wind erosion and exposure. To be effective, windbreaks need to be planned properly with suitable species, a suitable planting arrangement and at right angles to the wind from which protection is required. Winds from the west or south west create the most discomfort in south east Queensland. To protect animals, pastures and crops, windbreaks need to be at least 3 rows wide. The windbreak should not form a total barrier to wind penetration if only crop and pasture protection is required. Dense windbreaks can give a highly sheltered area very close to the trees but may create turbulence further away from the break. Reduced yields in crops and pastures in the immediate vicinity of trees can be partially offset by planting deep rooted species and by ripping the soil to a depth of at least 60 cm alongside the windbreak. This treatment should be repeated at about 2 year intervals.

Dams, creek and river areas

By reducing wind velocity, windbreaks can reduce evaporation losses from dams. Breaks should be planted near enough to provide optimum reduction of wind velocity on the water surface but not so close that the roots draw water from the dam or affect the strength of the wall. Most shrubs and trees should not be planted any closer to a dam than the equivalent of the expected height of the tree. Tree clumps need to be located below dams so that runoff does not wash large amounts of loose soil and dung from animal camps into the dam. Trees should also be planted some distance from windmills so they do not impede their performance.

The protection and stabilisation offered by trees and shrubs are vital for the prevention of streambank erosion. The most important area to plant trees is on the steep banks of the stream and, in particular, on the outside arc of a bend in the stream, as this is where erosion is usually most severe. Trees and shrubs should not be planted in the channel of a stream as this reduces the waterway capacity and tends to divert the flowing water against the streambank. If the bank is unstable, erosion could then occur. Dead trunks of trees should be removed from streams for the same reason. River red gums *(E. camaldulensis)*, most casuarina species and callistemon species are well adapted to streambank plantings.

Steep, unproductive and eroded areas

Slopes over 25% are unsuitable for grazing and should not have been cleared due to the risk of erosion and landslip. Soil types on these steep slopes and eroded areas are often infertile, shallow and stoney with little moisture holding capacity. Trees selected need to be well suited to these conditions and planted at a sufficient density to stabilise the terrain effectively. The planting density should increase with steeper slopes and on more erosion prone areas. Eroded areas should be fenced off to avoid disturbance by stock. Unproductive or low grade pasture areas are the obvious choice for the establishment of commercial tree plots.

Salt affected areas

Salinisation is one of the most difficult and irreversible problems facing the landholder. The cause is often excessive tree removal on properties some distance from the affected area.

Reforestation of the area initially giving rise to the salt may help to prevent further spread of salinity. Establishment of trees on a saline area can prove difficult. There are a limited number of species that can tolerate high salt concentration. Poor drainage of these soils adds to the problem. Species with some degree of salt tolerance include the river red gum *(E. camaldulensis)*, river oak *(Casuarina cunninghamiana)* and swamp mahogany *(E. robusta)*. For small, isolated patches of saltland, trees planted around the fringes may lower the watertable enough to avoid further spread of salinity.

Firebreaks

Trees can be used as an effective long term firebreak if they are of a suitable species and arrangement. Trees are preferable if the land is steep and where clearing for a ploughed break would increase the risk of landslips.

Trees with a high retention of leaf moisture and low flammable resin and oil content can act as spark arrestors. Trees with these properties include the silky oak *(Grevillea robusta)*, poplars, white cedar *(Melia azedarach)* and kurrajong *(Brachychiton populneum)*. Smooth barked species are preferable to stringy or rough bark species for fire protection.

Trees arranged to create a firebreak can often form an effective windbreak and also create a corridor for wildlife.

Existing tree areas

All trees and shrubs have a certain life span depending on environmental conditions and the growth characteristics of the plant.

Some species have an inherently short life span. Some acacias may live for only 20 years whereas most eucalypts live to 100 years before they reach senescence.

Some strategic planting may be required in existing tree areas so there are replacement trees to compensate for those trees lost through natural causes or dieback.

Purchase of trees from the Department of Forestry

The Department's nurseries in Brisbane and country areas can supply young trees either on a cash sale basis, or by mail order. Write to: The Director, Division of Forest Management, Department of Forestry, G.P.O. Box 944, Brisbane. 4001.

Alternatively, telephone (07) 224 8340 or 224 8335 between 8.15 a.m. and 5 p.m. Monday to Friday. Brochures and information on species available and the addresses of nurseries will be supplied.

The Men of the Trees

K. N. Robinson, Information and Extension Training Services Branch

On a world scale the loss of trees year by year is frightening. Each year, millions of hectares of forest are cleared. The impetus derives simply from population pressure—ever growing numbers needing fuel wood, more cropland or cash from timber exports. Many losses of these forests represent cases of immediate and nearly irreparable loss in that they take hundreds of years to regenerate.

In Australia, CSIRO have estimated that 36% of our original forest and woodland has been severely modified since European settlement.

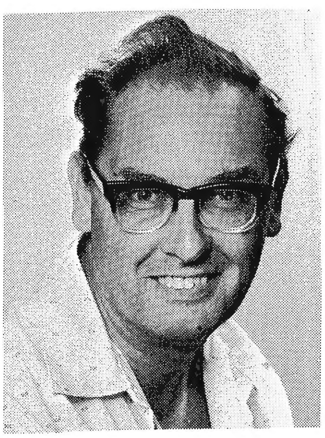
Such deforestation has caused a number of serious environmental problems, due to the effects on the land ecology, caused by the removal of important life support systems. Natural cycles have been interrupted resulting in desertification, erosion of top soil, river siltation, flooding, rising water tables, salinisation of land (all causing destruction of farmlands), loss of natural and sometimes rare ecological systems, atmospheric pollution, reduction in variety and size of habitat for preservation of wildlife and vegetation, and devitalisation of the urban environment.

These effects have further repercussions depending on the extent of deforestation. Eucalyptus dieback can be seen in this context, as it seriously threatens the survival of large scale forests and is spreading throughout rural and urban areas.

Relatively speaking, there are plenty of trees in and around most cities, in most country towns and along many country roadsides. However, they are absent in and between paddocks, in farm wood lots, and even around homesteads.

Since trees and allied understorey plants reduce soil and wind erosion, shelter useful insect and animal species, produce timber, boost stock and crop production, and can provide animal and even human fodder, almost every farm needs more of them.

The Men of the Trees is a non-profit, non-political organisation dedicated to preserving and planting trees. The object of society members is simply put—to encourage everyone to plant, protect and care for trees.



Kenneth Robinson Ken is the editor of the *QAJ* and production editor of the DPI's *QJAAS*. He joined the Department 2 years ago with many years' experience in book and journal editing.

Put more broadly the society fosters a tree sense, promoting interest in and knowledge and appreciation of trees. It says in short that the world becomes a better place when more trees grow. Members on enrolment swear to plant at least 10 trees each year. They also act as a nucleus of a labour force in tree planting projects working with other interested groups.

Australia is one of the most urbanised countries in the world. Most of the people are in the capital cities or in the bigger country towns. Men of the Trees' potential tree-raisers and planters are grouped away from where trees are needed. Since propagation and planting need people—they are labour intensive activities—we have somehow to use urban people to get the trees on the land.

Men of the Trees is doing this by offering free trees and labour from urban people. If a landowner wants trees, they help with design of shelter belt systems by getting an expert to visit, raise the trees and help plant and mulch them (no watering, or very little is required if proper mulching techniques are applied). The landholder has to provide fencing from stock and tree guards against rabbits (Mott may be able to help with labour here). And in many instances the landholder needs to rip soil along planting lines.

They need to know well ahead of time if a property owner wants trees. The process of propagating, potting into tubes and hardening off begins in late spring or early summer, and the design of shelter belts and woodlots has to happen before that. Planting takes place in May–August. The job is split up among the groups into which Men of the Trees is formed.

'The Men of the Trees' translates a phrase in a Kenyan tribal language and indicates the origin of the society. These tribesmen, because of their nomadic and destructive methods of agriculture, had earned themselves the name of 'Forest Destroyers'. The local Forestry Officer, Richard St Barbe Baker, tried to teach them that it was essential, for the fertility of their land, rather to protect and propagate trees. In 1922 he enrolled 50 volunteers from among them to plant trees, and in time the tribe became known as forest planters not forest destroyers.

The volunteers, for their part, were the first Men of the Trees, a title chosen when the society was formally founded in 1924 when Baker had returned to England. The original Kenyan branch still thrives today, planting millions of trees annually, while Baker himself increasingly devoted his energies to the aims of the society till his death in 1982. Under his guidance it spread to many countries, and now has branches in most States in Australia. The Queensland branch was formed in late 1980 and now boasts hundreds of members throughout the State, from Brisbane to Port Douglas to Longreach. And already there are two groups outside the capital, in Toowoomba and the Sunshine Coast. They are proud of having established 10 000 trees in the State in their first year of operation.

Plate 1. The founder of the Men of the Trees, Dr St. Barbe Baker demonstrates how it should be done to Guides, Brownies, Scouts and Cubs as well as Brisbane City Council employees and volunteer Men of the Trees at Grenier Park, Brisbane.

The Queensland branch, in only its first years of activity, has been associated with CSIRO, Brisbane City Council, Scouts and Guides, Lions International, The Australian Society of Soil Science, the Railways Department, Australian Nurserymen's Association and the United Nations Association of Australia. This is plain illustration of the Society's motto from its Kenyan inception, 'Twahamwe', which means 'Pull together'.

Examples of actual projects in the State make clear how the Society realises its aims. At Mayne Railway Junction, with the cooperation of the railways Department, 600 trees were planted as part of a greening programme at the Junction. While the Railways prepared the land and dug the holes, members of the Australian Association of Soil Science tested the soil in the area, CSIRO Forest Research Division helped with drawings, General Nurseries donated the trees and Community Service Orders helped 18 Men of the Trees with the planting itself. In this way technical support is mobilised to plant the right tree in the right place.

Another large scale planting of 600 trees took place at Kin Kin on degraded slopes. On 2 ha of privately owned and barren land near Esk in the Brisbane Valley 1 000 saplings of various species were established. This was in part a demonstration planting, to try to get trees back on to cleared land and prove their value to the man on the land. Often a landowner is asked to prepare his site and erect fencing to protect the young trees from stock and other hazards. The saplings themselves, however, and the labour are offered free, the planting material being gifts themselves or bought with gifts. To quote only two instances, the Timber Board donated 2 000 trees in both 1981 and 1982, while the Myer Foundation has given a $1,000 cheque to each State branch. Even maintenance of plantings—weeding and feeding of trees as they grow—is allowed for by the Society.

The Year of the Tree in 1982–83 was a great stimulant for the Men of the Trees, but soon merged into the Decade of the Tree. However, the rallying cry now being used is 'Greening Australia' since specific periods, while rousing and concentrating interest, are coming to be seen as too limiting.

The long term goal is to get Australia properly planted by the year 2050— one lifetime from now. It's a big task, but not an impossible one. To get it done we need:

- Landowners to come forward and ask for trees.
- More members to help the Men of the Trees plant, educate and organise.

Any reader willing to help or wishing more information is encouraged to write to: Mrs N. Brennan, President, P.O. Box 283, Clayfield, Brisbane 4011; by phone (07) 262 1096.

Information: Tree Raising Kits

In conjunction with the Decade of the Tree and Greening Australia campaign, Men of the Trees have announced the release of a tree raising kit which is now available for general distribution. The kit provides the opportunity for local Shire Councils, business houses and Parents and Citizens committees to purchase and involve local community groups including schools, Scout and Guide groups, etc. in the raising and planting of trees in their immediate area.

Not only does the community benefit from these large scale tree plantings but, more importantly, the kit serves as a learning experience for the school children, Scouts and Guides who participate in their growing and planting. The Men of the Trees believe that such learning experience helps create and strengthen the awareness of the necessity for tree planting, and helps create a richer and more balanced living environment.

The 500 tree kit comes complete with biodegradeable pots, trays, potting mix, seed, marking pens, fertiliser, sowing trays and information sheet. The small pots quite happily accommodate a small tree to approximately 15 to 20 cm in height, which is their ideal planting size for rapid development and survival. During optimum growing periods, Spring–Summer, plants reach plantable size in only 3 to 4 months. Only 1.5 square metres of space is required to raise the 500 seedlings. The complete kit is packaged in a small box weighing about 15 kg.

Cost is $75.00 per kit, which includes free delivery in the Metropolitan area. For country areas kits are railed on a freight forward basis. Because of its small size and weight, cost of freight is minimal.

Men of the Trees can provide information as to species suitability and site preparation techniques required for your area if desired.

An order form is attached for your convenience.

For further information, please contact 'Men of the Trees', Box 283, Clayfield, Q. 4011.

ORDER: TREE RAISING KIT

NAME ....

ADDRESS ....

PHONE ....

PLANTING SITE DETAILS

*Location/s: 1. ....

2. ....

3. ....

4. ....

Area/s: .... ha .... ha .... ha

Purpose of planting/s: i.e.

	1	2	3	4
Erosion Control				
Rehabilitation				
Beautification				

No. of Plants Required: 1 .... 2 .... 3 .... 4 ....

Site Description: Soil Type:

	1	2	3	4
Sandy				
Sandy clay loam				
Clay				
Shale				

Other ....

Drainage:

	Wet	Poorly Drained	Well Drained
1.			
2.			
3.			
4.			

Rainfall/annum .... mm

Seed Supplies: 1. Please make a selection for me ☐

2. I would prefer the following:

Species Preferred (maximum 10 per kit)

Acacia aneura (Mulga)		*E. drepanophylla* (Qld. Grey Ironbark)	
A. pendula		*E. grandis* (Flooded Gum)	
A. baileyana (Cootamundra Wattle)		*E. maculata* (Spotted Gum)	
A. decurrens (Ferny Wattle)		*E. microcorys* (Tallowwood)	
A. fimbriatea (Brisbane Wattle)		*E. microtheca* (Coolibah)	
A. podalyriaefolia (Qld. Silver Wattle)		*E. pilularis* (Blackbutt)	
A. saligna (Golden Wreath Wattle)		*E. robusta* (Swamp Mahogany)	
Baeckea virgata (Wild May)		*E. saligna* (Sydney Blue Gum)	
Callistemon citrinus (Crimson Bottlebrush)		*E. tereticornis* (Forest Red Gum)	
C. salignus (White Bottlebrush)		*E. torelliana* (Cadagi)	
C. viminalis (Weeping Bottlebrush)		*Grevillea banksii* (Red Flowering Silky Oak)	
Casuarina cristata (Belah)		*G. robusta* (Silky Oak)	
C. cunninghamiana (River Oak)		*Leptospermum flavescens* (Wild May)	
C. equisetifolia (Beach She-Oak)		*L. patersonii* (Lemon Scented Tea Tree)	
Eucalyptus argophloia (White Gum)		*Melaleuca armillaris* (Bracelet Honey Myrtle)	
E. camaldulensis (River Red Gum)		*M. linariifolia* (Flax Leaved Paperbark)	
E. cloeziana (Gympie Messmate)		*M. quinquenervia* (Paperbarked Tea Tree)	
E. curtisii (Plunkett Mallee)		*Tristania conferta* (Brush Box)	

Special arrangements will be required for species other than those listed above.

Place a tick in appropriate column for species required. Also place an S (substitute) for a further 5 species should some be unavailable.

DELIVERY INSTRUCTIONS

Please deliver to following address: ....
(Brisbane metropolitan area only)

Please rail freight forward to: .... Railway Station

Other arrangement: ....

....

Please note:

In conjunction with the Queensland Nurseryman's Association. Men of the Trees have agreed to the following sale conditions:

1. Trees raised are not for resale.
2. Kits will only be supplied for bona fide reafforestation, reclamation and beautification purposes.
3. Payment is required prior to despatch. Cost of kit is $75.00/500. Cheques should be made out to 'Men of the Trees' and forwarded to P.O. Box 283, Clayfield, Q. 4011.
4. If required, Men of the Trees will provide technical advice on all aspects of tree raising through to establishment.

*If it is intended to plant more than 4 locations, please attach details on separate sheet.

For further information please contact Men of the Trees, Box 283, Clayfield, Q. 4011.

'Save us from a brown Australia— Give a hand to green Australia'

The Water Research Foundation of Australia Limited

These words summarise one of the current major thrusts the Foundation has adopted and is actively supporting for the 1988 Bicentenary. The relationship between the Water Research Foundation and Green Australia may seem a little tenuous to some but this could not be further from the truth. The relationship is clear once there is an understanding of the Green Australia concept and a knowledge of the Foundation, its history and current activities.

Background

The Foundation was formed in 1955 by concerned businessmen, farmers, consultants and academics who thought that too little was known about our unique water problems and that additional innovative research could lead to long term rewards. It won the support of the Commonwealth, State, Territory and Local government, industry and many others who agreed that an independent body, spurred by citizen initiative, could contribute invaluably to the promotion of water research—a subject which did not exist then in its own right. This private non-profit Foundation has been fulfilling that role ever since with their continuing support.

Primary objectives

The chief functions of the Foundation can be summarised as:

- To initiate, promote and advance research into the development, control and use of water and related land based resources.
- To cooperate in research by other organisations into the supply, treatment, use and re-use of water and related land based resources.
- To disseminate knowledge on water and related land based resources.

Management

The Foundation is a national organisation with headquarters in Sydney and branches in all States. There are regional offices in north Queensland and Illawarra. There are about 250 scientists, engineers, industrialists, businessmen and laymen serving gratis on the National, State and Regional Committees under an elected Board of Trustees. No other single assemblage of skills of such wide diversity is applied to water research activities.

Foundation research proposals are assessed by a highly qualified multidisciplinary Research Committee. Most research projects are conducted through Fellowships at tertiary institutions. This highly efficient and economical method taps the resources of the tertiary education system. Their independent standards of inquiry promote objectivity and expose Fellows to qualified supervisors. Some embark on a lifetime career in water resources. Many Fellowships have led to higher degrees.

Research direction

Research into water resources and related land based resources is the major concern of the Foundation. Five major areas of concentration exist at present:

- hydrology and hydraulics,
- water quality,
- water management,
- environmental projects and
- agriculture/forestry.

Projects in Queensland which have attracted Foundation support include research into:

- soil salinity,
- catchment management,
- design and construction of dams,
- effluent and waste disposal and
- water movement in aquifier material.

These achievements, when combined with the efforts of the Foundation to date throughout Australia, symbolise what can be won through cooperation, unity of purpose and plain hard work. These achievements have not caused the Foundation to rest on its laurels but have spurred it on to bigger and more ambitious programmes.

Today's Research—Tomorrow's Practice

The Foundation has thrown its organisation and efforts behind the national programme known as 'Green Australia'. It envisages a 25 year programme integrating soil conservation, tree planting and water resources to 'rejuvenate our continent and support anticipated economic growth'. Green Australia projects include:

- soil conservation on a catchment basis,
- land capability and conservation farming,
- improved irrigation techniques,
- multipurpose water projects,
- massive tree planting,
- farm woodlots,
- roadside planting,
- landscape beautification,
- dust and noise barriers,
- flora and fauna conservation requiring habitat conservation and
- feral animal control.

The Foundation believes that the alternative is continued degradation of the environment, a stagnation of the economy and inevitably lower living standards.

A very large percentage of the natural environment has been manipulated by humans in some way. Not all of this development has resulted in the long term productivity envisaged. Indiscriminate clearing has caused massive soil erosion, landslips and general degradation of the landscape.

The Water Research Foundation is urging the involvement of individuals and organisations to help attain its goal of a 'Green Australia'. National benefits envisaged by the Green Australia programme include:

- an enhanced environment,
- agricultural systems which enable long term productivity,
- minimal flood and drought damage and
- quality water for domestic and industrial use.

The future

While continuing to seek solutions to everyday water problems, the Foundation intends broadening the scope of its research programme. Among the topics will be:

- drought-proofing techniques,
- waste water processes and re-use,
- water–energy relationships,
- water economics,
- water and the environment,
- flood mitigation,
- upgrading water quality,
- estuarine management and coastal erosion control,
- computer age technology,
- desertification of arable land and
- forest hydrology.

Enthusiasm is not the limiting resource of the Foundation. Undoubtedly, as with so many similar organisations, funds are the constraint. The Foundation has to compete with so many worthy opponents for available funds. All donations or subscriptions to the Foundation are tax deductible and offer the opportunity for you to participate actively in water research and to contribute to the continued growth of Australia.

Water is important to every facet of Australia's future. Australia needs your help.

Further information about the Water Research Foundation and the 'Green Australia' programme can be obtained from the Honorary Secretary, The Water Research Foundation of Australia, c/- Water Resources Commission, GPO Box 2454, Brisbane 4001.

60983—S. R. Hampson, Government Printer, Queensland

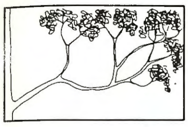
Casuarina dieback in the Mary River catchment

P. J. M. Johnston, Land Resources Branch, and F. R. Wylie, Division of Technical Services (Research and Utilisation), Queensland Department of Forestry

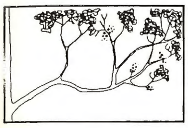
NATIVE TREE DIEBACK SURVEY QUEENSLAND

10.2 Using the drawings provided, what is your impression of the general health or condition of trees on your property? (list proportion of trees in each health category as an approximate percentage of the total number of trees on your property: for example - if you feel that one quarter of the trees on your property are showing signs of severe dieback put 25% in the box opposite category 4).

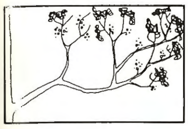
% trees in each category



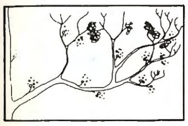
Category 1: **Normal healthy crowns** - very few dead or leafless branches; no obvious sucker (epicormic) growth — 60



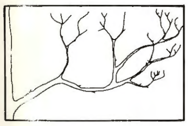
Category 2: **Slight dieback in crowns** most of crown healthy; some death of minor branches; some sucker growth obvious — 5



Category 3: **Moderate dieback in crowns** - approximately half of crown with death of both minor and major branches; remaining crown with high proportion of sucker growth — 5



Category 4: **Severe dieback in crowns** - most branches dead or leafless; crown comprised mainly of sucker regrowth on branches or stem — 15



Category 5: **Dead** - (do not include trees deliberately killed during clearing) — 15

TOTAL — 100

If **all** trees on your property are healthy (i.e. category 1), the remaining questions in section 10 need **not** be answered.

If you have any trees showing dieback symptoms (i.e. categories 2 - 5), **complete** the remaining questions in section 10.

A questionnaire survey has been conducted by the DPI and Forestry Department to determine the nature and extent of dieback in Queensland.

During 1980 and 1981 there were several reports of severe dieback in river sheoaks *(Casuarina cunninghamiana)* along creeks and streams in the Mary Valley. These reports came from Local Authorities, Community Action Groups, conservation bodies and landholders. Property owners expressed concern at the loss of shelter for stock, blockage of waterways by fallen dead trees and resultant streambank erosion.

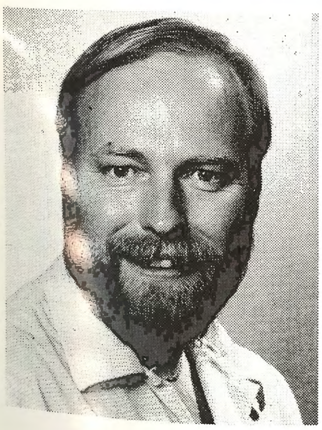
Initial investigations by a forest entomologist and a forest pathologist showed that a major factor contributing to the decline was the defoliation of the trees by a small, leaf-eating chrysomelid beetle, *Rhyparida limbatipennis.* This insect is widespread in coastal Queensland. Its larval or grub stages feed on the roots of grasses, improved pastures and some agricultural crops while the adult beetle grazes the foliage of a wide range of tree and plant species.

While most forest trees are able to tolerate the periodic loss of foliage without serious adverse effects, repeated defoliation in successive seasons may exhaust the tree's energy reserves and thus its ability to produce new leaves. This may result in severe dieback of the crown and eventually tree death. In the case of river sheoak in the Mary River catchment, the responses of property owners to a questionnaire survey on native tree dieback (on this page) showed that this pattern of insect defoliation, tree regrowth and dieback development had occurred annually since 1974.

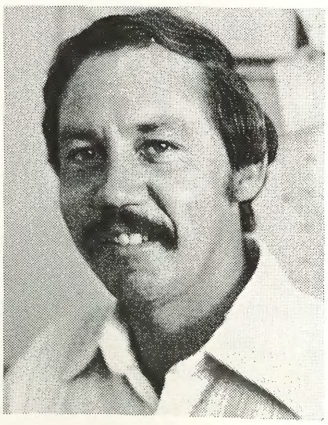
Following the formation in late 1981 of an Interdepartmental Committee on rural tree decline (comprising representatives of the State Departments of Forestry, Primary Industries, and Lands, Queensland Water Resources Commission, National Parks and Wildlife Service and CSIRO) a working party was appointed to examine the problem more closely.

Initial field surveys by the authors showed differences in the distribution and severity of dieback between stream systems. Reasons for these differences are presently being investigated. Soil and water analysis and identification and mapping of areas of dieback were conducted over the past 2 years. Assessment of this data from some 220 stream sites in the catchment suggests that increasing streamwater salinity in some sites may be predisposing the tree to insect attack. A relationship has been found between water conductivity levels and severity of dieback in both *Casuarina* and *Eucalyptus* trees along the streams. Generally, dieback is less severe along streams with better water quality.

Possible relationships between streamwater quality and the pattern of tree clearing, land use and geology of the catchment are being examined. Land use factors may also relate to the area of grassland, crops or improved pastures available for the larval stages of *Rhyparida limbatipennis* and in turn to dieback occurrence.



Peter Johnston Peter, a Senior Land Resources Officer with the DPI, has conducted projects concerned with trees on farms since 1970. At present he is responsible for several Branch programmes on agroforestry, rural tree dieback and local authority land use planning.



Ross Wylie Ross is an entomologist in the Department of Forestry's Forest Research Branch. He has been centrally involved in research on rural tree dieback in southern Queensland.

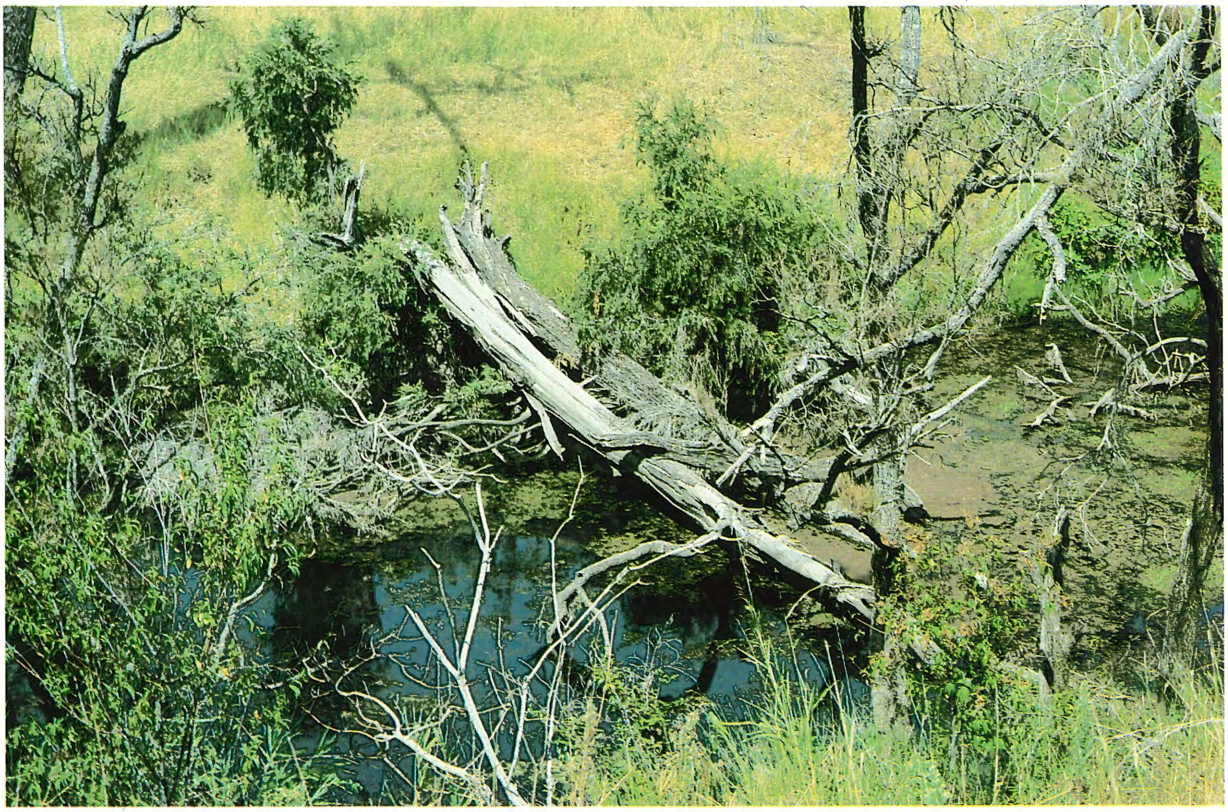


Plate 1. Dead sheoak *(Casuarina cunninghamiana)* killed by dieback have fallen into this stream and increased flooding and streambank erosion hazard.

Plate 2. Trees of all ages are affected by the small beetle *Rhyparida limbatipennis.* Here a mature tree has been completely defoliated.