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# Retention of native woody vegetation on farms in Australia: management considerations, planning guidelines and information gaps

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**Abstract.** Australia's forests and woodlands have been extensively cleared since European settlement. Cropping regions have the least retained native vegetation, with the greatest depletion of forests and woodlands being observed in Western Australia and South Australia. Salinisation, erosion and landslides have resulted from excessive clearing and inappropriate tree removal from particular units within the landscape. Major problems in cropping regions are the dramatic reduction in total woody cover and the fragmentation of retained vegetation into isolated remnant patches which tend to be very small (< 10—15 ha). Those states with little remnant vegetation have legislation which restricts further clearing and the main emphasis is on managing remnant patches for conservation. For those states with a large proportion of woody vegetation uncleared, the main priority is to ensure that past mistakes are not repeated and that any vegetation clearance is based upon sound ecological principles.

Throughout Australia, the condition of the remaining vegetation is of great concern and management guidelines for both conservation and production are being sought. Clearing may lead directly to soil erosion, but often the cause of erosion is inappropriate post-clearing management. Overgrazing is a major cause of vegetation and soil degradation, particularly in semi-arid regions.

An understanding of the complex inter-relationship between woody vegetation, grazing and fire is necessary if 1) flora and fauna are to be conserved; 2) hydrological balance is to be maintained; and 3) rural industries are to remain viable. Planning at the catchment level is necessary to implement strategies to meet conservation and hydrological goals. Within that framework, individual property planning must include consideration of the area of native woody vegetation to be retained and its configuration. In many cases, the purpose of retention will influence the decisions of where and how native vegetation should be retained.

## 1. Introduction

Before European settlement, forests and woodlands covered 33% of Australia's land area. An estimated 50% of forests and 35% of woodlands have now been cleared or severely modified [19]. The resultant decline in animal

and plant populations over the last two centuries has been marked with 78 species of plants and 17 species of mammals thought to be extinct [50]. Much of the land degradation in southern Australia is a consequence of excessive clearing of vegetation. More than half of grazing and cropping lands — over 2.6 million square kilometres — may require treatment for forms of degradation [19]. In Western Australia alone, losses associated with land degradation are estimated to be $600 million annually.

Thus, the economic benefits of clearing native woody vegetation in Australia have incurred substantial costs. Clearing continues in some states, despite the knowledge that retaining woody vegetation on farms has advantages including direct economic benefits (timber, honey production, shelter for stock), indirect benefits (maintenance of soil fertility), off-site benefits (maintenance of water quality in rivers) and natural heritage value. This occurs because landholders often see retention of native vegetation as an unacceptable cost in foregone production.

The challenge for Australia is to meet multiple land use requirements and to reach compromises where there is conflict between the requirements for different uses. The concept of sustainable agriculture requires a basic change in attitude of many landholders and agricultural scientists. The aim of maximising production and optimising income in the short term must be accompanied by an objective to achieve sustained yields over the long term by the maintenance of resources.

Landholders make a living from rural resources. Action to conserve the native vegetation resource may incur direct costs (e.g. fencing) and these costs must be balanced by some economic benefit if the business enterprise is to survive. To date, conservationists have not paid sufficient attention to documenting the economic benefits of native vegetation retention, especially in relation to crop and animal production. It is imperative that the person who makes a decision to clear vegetation does so only after collecting and evaluating all available information on the full impact of any clearing. However, if technical specialists (conservationists, ecologists, agronomists) cannot provide objective, quantitative information, the landholder cannot be blamed for making inappropriate decisions.

## 2. National consideration of vegetation retention

The Australian community generally wishes to ensure that their standard of living is maintained through profitable agriculture and other industries, and accepts that modification of the original vegetation has been necessary to achieve current levels of agricultural production. However, there is concern about the sustainability of current practices and these have been the subject of a recent federal parliamentary report [25] which makes 27 recommendations on sustainable agriculture.

## 2.1. *Extent of clearing*

Under the Australian constitution, states have the responsibility for protecting and regulating natural resources. Differences exist between the states in the extent of clearing and in the regulation of land use, with climate, history of development and vegetation resources dictating the major variations. Compared to the other states, for instance, Queensland, Northern Territory and northern Western Australia have a large proportion of native vegetation remaining intact (see Prinsley [48] in this issue for location map). In these states, grazing by sheep and cattle is the main form of land use and the emphasis is on ensuring any vegetation clearance is based on sound ecological principles. By contrast, emphasis is on retention and management (conservation) of the limited area of remaining native vegetation in most agricultural (cropping) zones.

The degree of clearing of native woody vegetation communities varies greatly across Australia (Fig. 1 [5]). The area of grassland has doubled, and small increases in low open woodlands and tall open shrublands have been recorded since European settlement. These changes have resulted from clearing other vegetation communities. However not all undesirable changes in Australia's vegetation have been associated with removal of native vegetation. Increased densities of native woody species in *Acacia aneura* and *Eucalyptus populnea* woodlands in eastern Australia have been significant

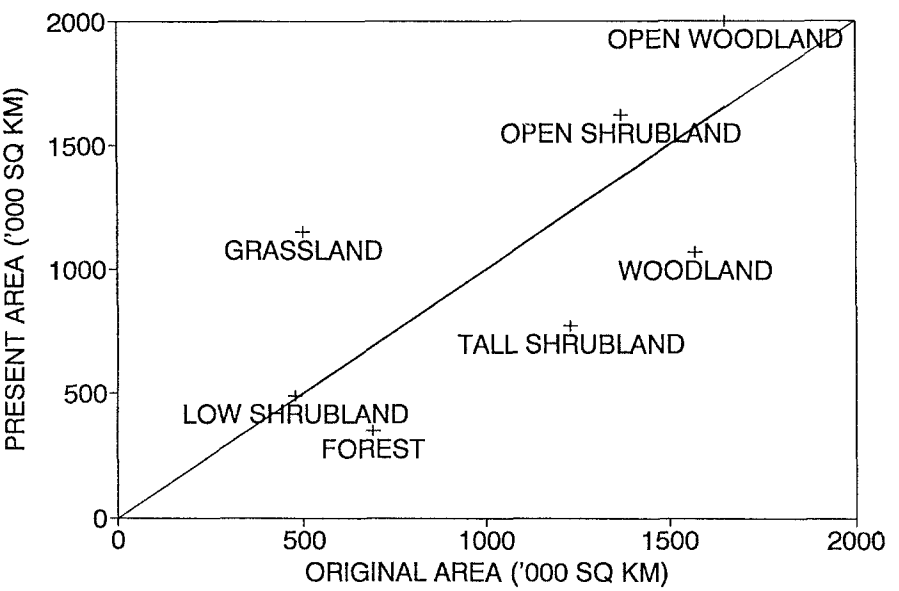


*Fig. 1.* The current area of vegetation types in Australia (1980s) compared with the estimated area in the 1780s [from 5].

[27] with inedible species of *Eremophila, Cassia* and *Dodonaea* causing decreased pasture production and increased mustering and management costs. The introduced *A. nilotica* is present in 6 million ha of northern mitchell grasslands [13] and these productive grasslands are in the process of becoming thorn shrublands of little value for grazing. Other introduced trees and shrubs are also increasing in area and density in northern Australia [62].

The degree of clearing and some associated impacts are shown in Table 1. Some examples of associated degradation are highlighted in the following section. Detailed discussions of the situation in each state are provided in the proceedings of the conference on 'Role of Trees in Sustainable Agriculture' [2].

*Table 1.* The extent and consequences of clearing within each state of Australia. (Data drawn from [2] where not shown).

| State | Extent of clearing | Major forms of degradation |
|---|---|---|
| Queensland | ~ 16% of state [10]; mainly on freehold land | native and exotic woody weeds are serious [62] |
| Northern Territory | < 2% of state cleared | potential exotic woody weed threat [62] |
| Western Australia | 88% of cropping zone cleared; < 1% of pastoral zone cleared; 33% is unoccupied | widespread salinisation of cropland in south-west [63]; fragmentation of remnant vegetation serious in cropland; 5 of 11 macropod species locally extinct in south-west [4] |
| South Australia | 84% of cropping zone cleared; < 1% of pastoral zone | 27% of land mammals extinct [26]; 33 plant taxa extinct [35]; fragmentation serious in cropland |
| Victoria | 65% of native forests cleared | 25% of flora extinct, rare or endangered; 33% of vertebrates rare or threatened; 3.2 M ha eroded, acidified or compacted; 7.8 M ha at risk of degradation |
| Tasmania | 24% cleared | ~ 20% of plants poorly represented in conservation areas; 18% of state shows some form of land degradation [51] |
| New South Wales | 40% of forests and woodlands cleared | 7% of eastern and central divisions seriously eroded; 70% of western division with native woody weed problem |

## 2.2. *Adverse impacts of clearing*

### 2.2.1. *Land degradation*

Eighteen percent of Tasmanian land has suffered some form of land degradation [51], much of this associated with tree clearing. While there is general recognition of degradation problems at state or regional level, few landholders accept that problems exist on their own properties [53] and even fewer associate economic losses with the loss of farm trees [40].

Clearing of native woody vegetation for agriculture is accepted as the primary cause of land degradation in the agricultural regions of South Australia and Western Australia. Dryland salinity, waterlogging, water erosion, wind erosion, water repellency, soil acidification, soil structure decline, subsoil compaction, decline of remnant native vegetation, management of the conservation estate, rehabilitation in the mining industry and degradation of waterways are prominent issues [72, 73]. Soil acidification has great potential for land degradation and is predicted to affect 10.5 million ha, or 55% of the agricultural agroecosystem, over the next 100 years. Overall, the annual loss of production is estimated to be $600 million.

Less than 1% of the pastoral zone of Western Australia has been cleared but pasture degradation has been extensive e.g. up to 40% of the Nullarbor region has been degraded [42]. Land degradation in this state's grazing lands is estimated to cost $37 million per year with the greatest problems being experienced on more productive and better watered parts of the zone [46].

In Victoria, recent data on land degradation are summarised in the draft 'Decade of LandCare Plan' [69] and include:

- 240,000 ha of irrigated land are seriously salinised (likely to increase four-fold over 50 years whether or not remedial action is taken);
- 3,200,000 ha of land are affected by erosion, acidity or compaction;
- 7,800,000 ha are at high risk of degradation;
- 65% of streamlength in cleared areas is in poor condition.

### 2.2.2. *Salinisation*

Dryland salinity problems are widespread in Western Australia and Victoria as a result of excessive tree clearing (see Schofield [63] in this issue). The risk of dryland salinisation may not be as severe in northern Australia as in southern states [9]. The major argument for this view is that in the Mediterranean climate of southern Australia, rainfall during the winter growing season often exceeds evapotranspiration, resulting in deep percolation and mobilisation of incipient salt, whereas in Queensland, very high rates of evapotranspiration occur during the summer growing season. However, monsoonal regions of Australia can also be characterised by substantial deep drainage and leaching of salts [74] and recent work in subtropical *Acacia harpophylla* forests also suggests increased deep drainage and movement of salt as a result of tree clearing [66].

2.2.3. *Woody weeds*

Increased density of native woody species in semi-arid woodlands causes economic hardship for graziers in northern and eastern Australia. Regrowth from native *Eucalyptus* and *Acacia* is also an economic problem for landholders in the eucalypt woodlands of eastern Queensland [10, 58]. A majority of the *Eucalyptus populnea* and *Acacia aneura* communities of New South Wales and Queensland is affected to some degree by increased density of native woody species (*Eremophila, Cassia, Dodonaea*). This leads to reduced lambing percentages, reduced wool cut per head, reduced carrying capacity and increased stock handling costs [8]. Overgrazing and soil erosion also result from the proliferation of these native species.

The introduced exotic tree, *Acacia nilotica*, is spreading rapidly through the northern mitchell grass (*Astrebla lappacea*) zone in Queensland which is one of the world's most extensive and productive natural grasslands. At present some 6 million ha of the grassland contains at least some of this woody weed [11] and these areas are likely to be transformed into thorn shrublands. The introduced woody climber *Cryptostegia grandiflora* is widespread in the woodlands of central and northern Queensland [14]. Riparian zones become completely covered with this plant with severe reductions in the value of these areas for domestic livestock production and wildlife habitat. Other woody weeds in pasture lands of northern Australia also interfere with livestock production [62].

2.2.4. *Fragmentation*

In the main cropping regions of Australia, the proportion of remaining native vegetation is very small. Added to this is the fragmented nature of this remaining vegetation. In a survey of remnant vegetation in the Midlands Division of Western Australia, two-thirds of patches were less than 16 ha in size and only 8% exceeded 50 ha [4]. Only 60% of the 53 patches were regarded as relatively undisturbed. Many of these remnants had high edge to area ratios [57], leading to increased probability of ingress of flora and fauna of neighbouring vegetation types, and to increased fire risk. Associated with this clearing and fragmentation, 5 of 11 macropods present at the time of European settlement are locally extinct and only 2 are still common [4]. Local extinction of bird species [55] and invasion of woodlands by birds of the pastoral regions has also occurred [56]. Decreased water quality has been observed where more than 50% of catchments in the south-west has been cleared [64].

A study of the extent of fragmentation of native vegetation on the Fleurieu Peninsula of South Australia revealed that only 9% of the region was carrying original vegetation and 67% of this was located in blocks less than 10 ha in size [75]. In an area of 150,000 ha, there were only 3 patches in excess of 500 ha.

### 2.3. *Greenhouse gas emissions*

Global climatic changes may result from increased atmospheric concentrations of radiatively-active ('greenhouse') gases such as carbon dioxide, methane and nitrous oxide. The gases can be directly linked to agricultural development, e.g. methane is emitted by herbivores and termites; burning releases carbon dioxide, carbon monoxide, methane, and various oxides of nitrogen (see [44, 20] for a general discussion of agricultural contributions to greenhouse gas emissions and global warming). The proportion of fixed carbon that becomes organic matter with a long half-life, and the proportion that is decomposed directly versus that consumed by herbivores have a marked impact on the greenhouse gas emissions. Forests and woodlands contain a large bank of carbon sequestered in woody material and a large proportion of this is released into the atmosphere following tree clearing. Since white settlement, land clearing in Australia has resulted in the loss of 7 Gt of carbon (14 Gt of standing biomass) (Gt = 1,000 million tonnes), with the present standing biomass containing an estimated 20 Gt of C (calculated from vegetation areas [5] and biomass estimates [6]). This represents a contribution of 3—5% to the world's increase in $CO_2$ within the atmosphere.

Methane is more effective as a greenhouse gas than $CO_2$. Increased grazing animal populations are one source of increased levels of this gas in the atmosphere. Minor changes in pasture and stock management can result in significant decreases to total greenhouse gas emissions, without a commensurate decrease in farm income [31]. A 20% reduction in greenhouse gas emissions from grazed pasture systems in northern Australia could be achieved by lowering stocking rates with little economic cost in terms of lost production [31]. An added benefit would be reduced soil erosion resulting from greater ground cover [23].

## 3. Role of legislation in management of native woody vegetation

The way to achieve sustainable use of native vegetation resource is not clear. Regulation can result in reduced environmental damage by forcing particular forms and levels of activity. Such regulations can be politically unpalatable as well as hard to enforce, slow and difficult to adapt to change, and their consequences may be off-target. Possible alternatives include price-based measures (charges and subsidies) and rights-based measures (right to use or abuse). Although largely untested in Australia, market-based measures may increase the relative returns from environmentally benign options compared with management or processes that cause damage to the environment [54]. Such measures may be easier to fine-tune than direct regulations, and may allow a smoother integration of economic and environmental considerations. However, market forces do not necessarily reflect ecological stress, and biological systems may pass an irreversible threshold before the economic

impacts force a management change [54]. Subsidies may actually increase resource degradation by reducing the cost of production and encouraging overuse of resources [41].

At present, legislation governing native woody vegetation varies quite considerably between the states. There are 33 Acts of Parliament within the states and territories that are partially or wholly concerned with vegetation management, with ten separate Acts in New South Wales alone. These range from voluntary conservation schemes to stringent regulations which effectively prevent large scale clearing of native vegetation (e.g. in South Australia). Many farmers have short-term financial pressures which force them to clear native vegetation. Schemes offering financial assistance (18 of the 33 Acts have some financial support for landholders) may enable some of these landholders to refrain from clearing. However, voluntary conservation schemes and financial incentives may not provide sufficient protection where conservation is a high priority (e.g. to protect an endangered species). In these cases, legislation may be necessary.

A relatively small proportion of northern Australia (Queensland, Northern Territory, and northern half of Western Australia) has been cleared (Table 1) and clearing legislation is not as stringent as in southern Australia. However, these state governments are concerned about adverse environmental aspects of excessive tree clearing. The procedure for applying for permits to clear trees on leasehold land within Queensland is under review. One proposal is that a whole-farm management plan must accompany any clearing application, and the Queensland Department of Primary Industries and Queensland National Parks and Wildlife Service should be involved in assessing applications [78]. Consideration is also given to the possibility of controlling clearing on freehold land.

In Western Australia, new soil conservation conditions require fencing of all newly cleared land. The maximum clearing allowed is now viewed in the context of the remnant vegetation within the whole catchment rather than simply the amount remaining on any particular farm. This can lead to conflict where landholders need to clear a high percentage of their farm to remain profitable in the short term.

Clearing native vegetation in Victoria is controlled by a number of Acts and regulations [39], including the Planning and Environment Act of 1987. This act and the sudden temporary clearing controls in 1989 were reinforced by an amendment which provided permanent clearing controls. On introducing the controls, the Victorian Government adopted the policy that there should be no further broadscale clearing in Victoria. Introduction of these controls has already been effective in substantially slowing the rate of clearing [39].

A system of Heritage Agreements was introduced in South Australia in 1980 to protect native vegetation and to encourage landholders to manage native vegetation for conservation. From 1980 to 1985, this voluntary scheme resulted in 10,500 ha being covered by 125 agreements. Landhold-

ers receive rate relief, and the state government erects all fences and assists with additional costs above those required by various acts. In 1985, a stronger legislative and economic base for the Native Vegetation Management Act was introduced. Since then, an additional 400 landholders have entered into Heritage Agreements, protecting some 270,000 ha in the agricultural region. The scheme is expected eventually to protect 50% of the remaining native vegetation in the agricultural areas outside the state government reserve system.

## 4. Economic aspects of management of native woody vegetation

### 4.1. *Valuing natural resources*

Insufficient monetary value is placed on Australia's natural environment by the community [25], and whenever resources are undervalued or free, they are overused or abused. There is a need to put an appropriate value on resources, and to define clearly the rights and responsibilities of landholders and the wider community to ensure that resources are used in a sustainable manner. Many of the proposed solutions, including legislation and subsidies, can be criticised from an economic viewpoint [34].

The value placed on a natural resource can have a significant effect on its use. In Queensland, the Brigalow Development Scheme of the 1970s resulted in the formation of hundreds of new grazing properties based on the clearing of *Acacia harpophylla* (brigalow) woodlands and their replacement with perennial grass pastures (based on *Cenchrus ciliaris*). These lands were allocated by ballot with a major requirement being that a minimum area had to be cleared within a certain time. This resulted in some inappropriate clearing being undertaken and some marginal lands were also cleared and 'developed'. Current agricultural production (beef and grain) in the region is vastly in excess of the meagre beef production possible under the original woodlands, but there has been a substantial environmental cost. The scheme was so successful that very few stands of uncleared brigalow remain intact. Because the heavy clay soils have high pH and high soluble salts at depth, there is increasing concern that these lands may suffer salinisation problems in the future and that stream and groundwater quality may be adversely affected [66]. Thus, costs to the community of additional clearing may include expenditure to prevent or ameliorate degradation of land and water resources.

### 4.2. *Economic benefits of native vegetation*

Managed native forests offer farmers income diversity, however the low financial inputs may be mirrored in the modest income generated by most native forest production [45]. In an evaluation of alternative uses of black-

wood swamp forest in north-west Tasmania, management for production of *Acacia melanoxylon* (high value cabinet timber) was compared with clearing and development of pastures for dairying. Forestry was shown to be more profitable if the cost of capital was high (20%) while dairying was superior at a rate of 15% interest [33]. This analysis was based on timber royalties of $AUS15 $m^{-3}$, but royalties are currently $40 $m^{-3}$ and may rise to > $100 $m^{-3}$. Such increases in the value of timber products are likely to be common and will make forestry much more attractive economically in the future.

In 1971, the advent of a Tasmanian woodchip export industry stimulated logging of native forests and 40—50% of cleared forests were converted to agricultural usage. In many situations, the money from timber sales was used for subsequent pasture development. Only 36% of the logged areas were actively replanted with trees [65]. Over the next 40 years, most private land supporting native forests will be sold at least once, potentially making these areas available for timber production [65]. There is strong landholder support to lift the current ceiling of 800,000 tonnes/year of woodchip from private land [21, 49] to enable logging of old-growth forests while a secure market exists. Under the proposed Tasmanian Forest and Forest Industry Strategy [22] the ceiling will only be lifted once a mechanism to protect environmental values on private land has been developed.

Tree clearing may not be the most economic form of development in the eucalypt woodlands of north Queensland [24] with legume augmentation of native pastures being more viable and sustainable. Legume augmentation with *Stylosanthes scabra* does not require any tree removal nor does it require any destocking during establishment. Water use by the shrubby *S. scabra* resembles the pattern of tree water use rather than that of grass water use [74]. Such a pasture system (perennial stylo in an undisturbed *Eucalyptus* woodland) will cause little disruption to the regional hydrological balance and will not lead to rising water tables as is possible following tree removal.

### 4.3. *Cost of retaining native vegetation*

Costs of retaining native vegetation fall into three categories: 1) direct costs associated with protecting remnant vegetation, e.g. fencing and other management required to prevent grazing, fire damage and weed invasion; 2) potential production may be foregone and this may influence the viability of a particular property; 3) the density of native species may increase to such an extent that production is severely restricted and threatens property viability.

The direct cost of the Native Vegetation Retention Program in South Australia has been $40 million since 1985. This is by way of compensation for 400 landholders being refused permission to clear land on their properties on biological grounds and where the landholder has entered a Heritage Agreement. A further $1—2 million per year will be spent on the management of these lands. Despite the high initial outlay, the program has been economical in terms of the cost per tree retained, being about 15c per tree

[67]. This compares with $2—10 for tree seedlings planted and about 19c per tree for direct seeding costs.

Loss of potential production is seen as a severe impact of not clearing native vegetation. In Victoria, clearing at the rate which occurred up to 1987 added less than 0.1% per annum to the area of already-cleared land. On a statewide basis, this is an insignificant contribution to economic activity. Fluctuations in markets for agricultural commodities such as wheat and wool alone cause much greater changes in the gross value of agricultural production.

Increased density of native shrubs and trees is common in the majority of the western division of New South Wales. Reduced lambing percentages, reduced wool cut per head, reduced carrying capacity and increased stock handling costs [8] adversely affects property viability in the region. The estimated gross margin for land free of unwanted woody plants is $30 $ha^{-1}$ compared with $13.50 for land with high densities of woody species.

## 5.Vegetation management at the property level

### 5.1. *Property planning*

A property plan should form the basis for any major change to the management of a property, particularly when clearing or replanting native woody vegetation is concerned. This has not been common practice in the past. Currently, there is a move to encourage all landholders to develop detailed property plans which not only include the physical resources but also enable management changes to be identified and implemented [25]. Where the clearing of native vegetation is concerned, state departments either require or recommend the production of a property plan to ensure a balance between development, the owner's physical and financial resources, and environmental considerations.

### 5.2. *Retention of remnant vegetation*

#### 5.2.1. *Area of remnant vegetation*

About 5% of Australia is protected by World Heritage Agreements or parks and reserves [25]. There are large areas in Western Australia, Northern Territory and South Australia that are either vacant crown land or are under leases that involve low levels of land use, particularly traditional aboriginal land use. The problem in Australia is not that there is insufficient total area of undisturbed vegetation, but rather that the distribution of this vegetation is non-uniform and that many vegetation types are grossly under-represented in the reserves system. The arid parts of the continent are uncleared but have been disturbed by the grazing of sheep, cattle and feral animals. Thus native vegetation has not been removed but it has been markedly disturbed. Over-

grazing, herbaceous vegetation change and subsequent soil erosion are major issues in these lands, as is the increase in undesirable native woody plants [27]. In contrast to the arid zone, areas suitable for agricultural crop production and to a lesser extent for pasture development have undergone the greatest degree of clearing. Also, naturally treeless areas with fertile clay soils (e.g. the Darling Downs and Central Highlands in Queensland) have been cropped to such an extent that few areas of natural grasslands still exist.

Two separate considerations relate to appropriate retention of native vegetation. The first is the total area that should be retained, and the second is configuration (spatial arrangement) of retained vegetation. The total area to be retained may depend on regional hydrological, wildlife and soil movement considerations. As discussed in Section 4, it is difficult to determine an appropriate resource value for native vegetation. Extensive tree clearing has been associated with the relative ease of showing some economic benefit from tree clearing (at least in the shorter term of c. 10—15 years). Once the total amount of vegetation to be retained has been determined, the aim must be to maintain the maximum degree of biodiversity possible. The habitat size required for, and appropriate population sizes of flora and fauna are not well understood for even the most common species, making judgements about the required size of reserves more subjective than desirable.

5.2.2. *Fragmentation of remaining vegetation*

A consequence of agricultural development has been the vast reduction in native vegetation remaining intact, and the high degree of fragmentation that exists within the remaining vegetation [71]. Fragmentation leads to two problems. Firstly, the viability of isolated small blocks of vegetation is generally poor [29], even when these are protected from use by landholders and their domestic livestock. Conservation of flora may be achieved by reserving such areas, but fauna is at risk. In South Australia, 27% of land mammals have become extinct [26] whereas only 6% of plant taxa have become extinct in the state [35]. The second aspect of the problem is lack of habitat diversity. In well developed agricultural areas, remaining vegetation tends to be a non-random sample of former habitats: swamps that could not be drained; steep hillsides; small patches of rainforest maintained for 'conservation'. These remnant patches support a narrower spectrum of flora and fauna than if all habitats were represented. Isolated blocks are not efficient in supporting a wide variety of native fauna and are prone to degradation from salinity, grazing, weed invasion and rising water tables [28]. Interconnecting these remnant areas with wildlife corridors may enhance the value of reserved areas. A framework for the re-integration of remnant vegetation patches has been developed [30].

Reserves must be large enough to encompass the spatial processes and ecological gradients of the system being conserved [68]. Arguments can be proposed in favour of several small reserves as opposed to one large reserve. Those in favour of many small reserves concentrate on the number of species

in these reserves and on which particular species can be protected (e.g. endangered species). A network of smaller reserves contain different (and more) species than a single large reserve of equivalent total area [37]. Arguments favouring large reserves focus on the lower probability of extinction in large populations. A mixed collection of small reserves and large areas may be the best policy as some species are best protected by small reserves and others by large ones. Obtaining an answer to the question of the appropriate reserve size involves studying the biology and habitat needs of individual species, their minimum area requirements as well as factors restricting species distribution [1]. Explicit procedures for selecting reserves for a nature conservation network have been proposed [36, 37].

5.2.3. *Configuration of remnant vegetation*

Once a decision to retain a given area of native vegetation has been made, the next issue is where to leave that vegetation. The trend has been to clear the most productive elements within a landscape completely and to leave surrounding, less productive areas intact. While this may ensure that a large area of the property or paddock remains covered in woody vegetation, it reduces habitat diversity. Therefore any clearing should not exceed a maximum proportion of each habitat type. That proportion will vary between regions and the appropriate values to meet the multiple goals of agricultural production, water quality and fauna and flora conservation are unknown for most regions.

The most appropriate configuration of retained vegetation will depend on the planned land use. Where potential salinisation is a concern, intake areas should support native woody vegetation; where shelter from cold winds is required, south and south-western slopes should be left covered by trees; where trees actually encourage growth beneath their canopy, some scattering of trees may be beneficial. Scattered trees may also reduce temperature extremes and in tropical to subtropical environments this may be sufficient to prevent frosting of pastures [J.G. McIvor, pers. comm.].

Retained vegetation can be in the form of strips or clumps. Clumps are more effective in that a greater proportion of the total area is natural (no edge effect) compared with strips (Fig. 2). The wider the strip, the larger the natural habitat area for the same reserved area. Clumps must be large enough to support a viable population of wildlife and should be joined to other native vegetation areas to allow movement between major reserved areas.

A disadvantage of a high proportion of edge habitat is that this transition zone is prone to degradation and is not representative of the central zone of clumps or strips. The edge zones support some flora and fauna typical of the adjacent vegetation type. In cases where the retained vegetation borders sown pasture, plant invasion can be a significant form of natural habitat degradation. One sown pasture species, *Cenchrus ciliaris*, has been regarded by some groups to be one of Australia's top environmental weeds [32], even though it is one of the most widely planted pasture species in Queensland

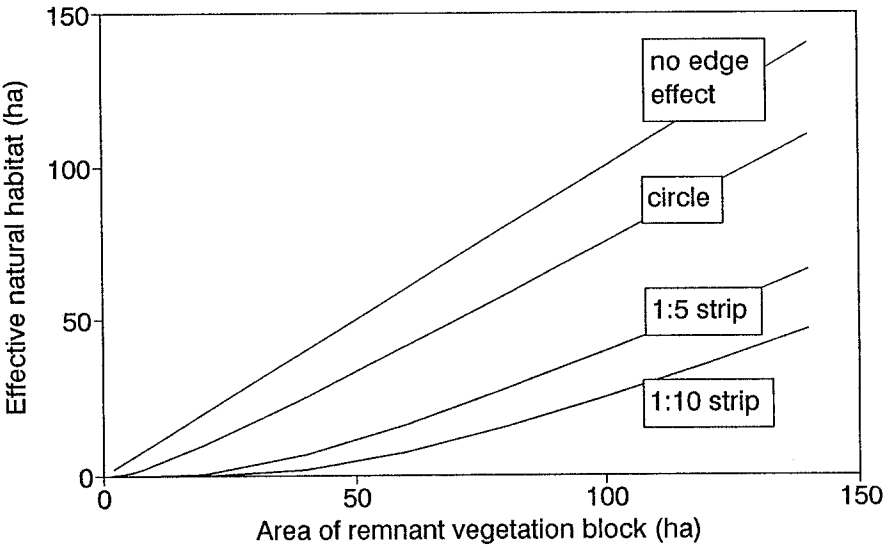


*Fig. 2.* The effect of shape of retained vegetation on the area of natural habitat with that vegetation. Natural habitat is defined as that part of the block greater than 75 m from the nearest boundary. The 1:5 strip is 5 times as long as wide, and 1:10 strip is 10 times long as wide. The difference between the 1:1 line (no edge effect) and the particular configuration line is an indicator of the area of 'edge' habitat (from calculations by JCS).

[70]. The weed potential comes from its ability to spread, especially along watercourses in the arid and semi-arid interior. The presence of *C. ciliaris* increases local stocking pressure and many native herbaceous species are depleted by the combination of direct competition with *C. ciliaris* and grazing.

Another option for retaining some woody vegetation and increasing livestock carrying capacity is to thin the existing stand, leaving a savanna landscape. This has aesthetic appeal, but in most situations a savanna is undesirable. Problems include 1) that the habitat for native fauna and flora is dramatically altered; 2) that remaining trees are likely to have a shorter lifespan, and are more prone to insect and disease attack, and to fire damage; 3) that pasture production is often less from a savanna landscape than from an area in which the equivalent number of trees was retained in undisturbed habitat while the complement of the area was cleared [10]; 4) the mature remaining trees are seed trees that ensure a seed source to re-establish new trees, thereby creating an inherent regrowth problem. As few as 40 trees/ha, each 10 m high, can result in three quarters of an area being subject to seed rain (Fig. 3), whereas the same number of smaller trees potentially impact a mere 10% of the area.

A savanna landscape can be desirable where the canopied zone is more

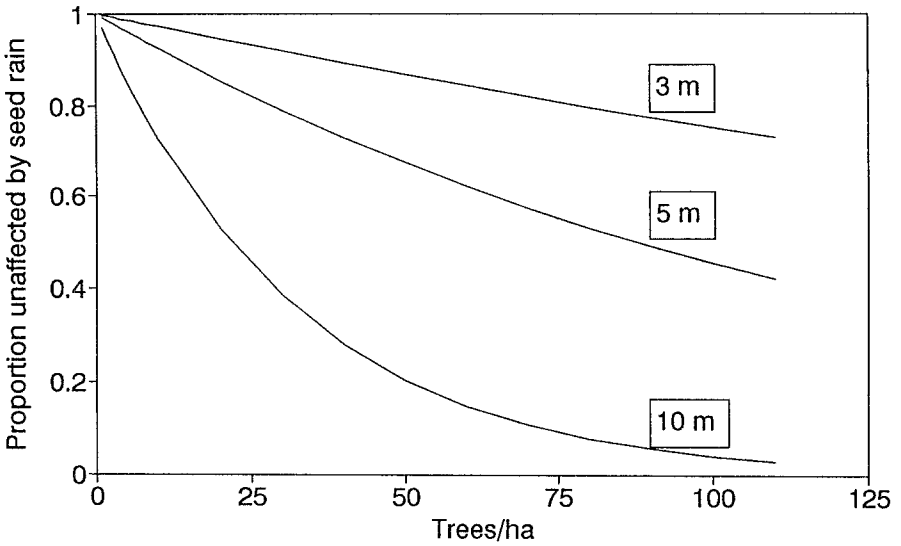


*Fig. 3.* The proportion of an area that is not subject to 'seed rain' for a range of plant heights and densities. Seed is assumed to fall within a distance equal to plant height: particular species will vary widely from this rule but the principles remain (from calculations by JCS).

productive than the interspaces. Reasons for this include increased total soil nutrient levels [17, 18], and indirect effects of shade [76, 77].

### 5.3. *Soil erosion*

Clearing woody vegetation is often equated with land degradation and soil erosion. While this is certainly true where disturbance leads to the exposure of a dispersive B horizon in the soil, it is not a necessary consequence. In most cases, it is post-clearing management of grazing that leads to soil erosion in grazing lands rather than the act of clearing per se. This separation of the causes of damage into direct effects of clearing and post-clearing management is necessary if degradation is to be avoided or minimised.

Heavy grazing may cause sheet erosion irrespective of the presence of trees [23] as soil erosion in pasture land is greatly influenced by the extent of surface cover of vegetation. Densely timbered areas may have either more or less total cover of understorey plants and tree leaf litter than a cleared site depending on the species involved (Fig. 4). Trees compete directly with grass for water and nutrients and, in all but the monsoonal zones, this usually results in less herbaceous cover under trees than in cleared areas [43]. Tree litter complicates this effect. This is exemplified by comparing Figs. 4a and 4b. In *Eucalyptus populnea* woodlands (Fig. 4a), there is a decline in total ground biomass (tree leaf litter plus pasture) as tree density increases due to the overriding negative effect of increasing tree density on grass cover. In

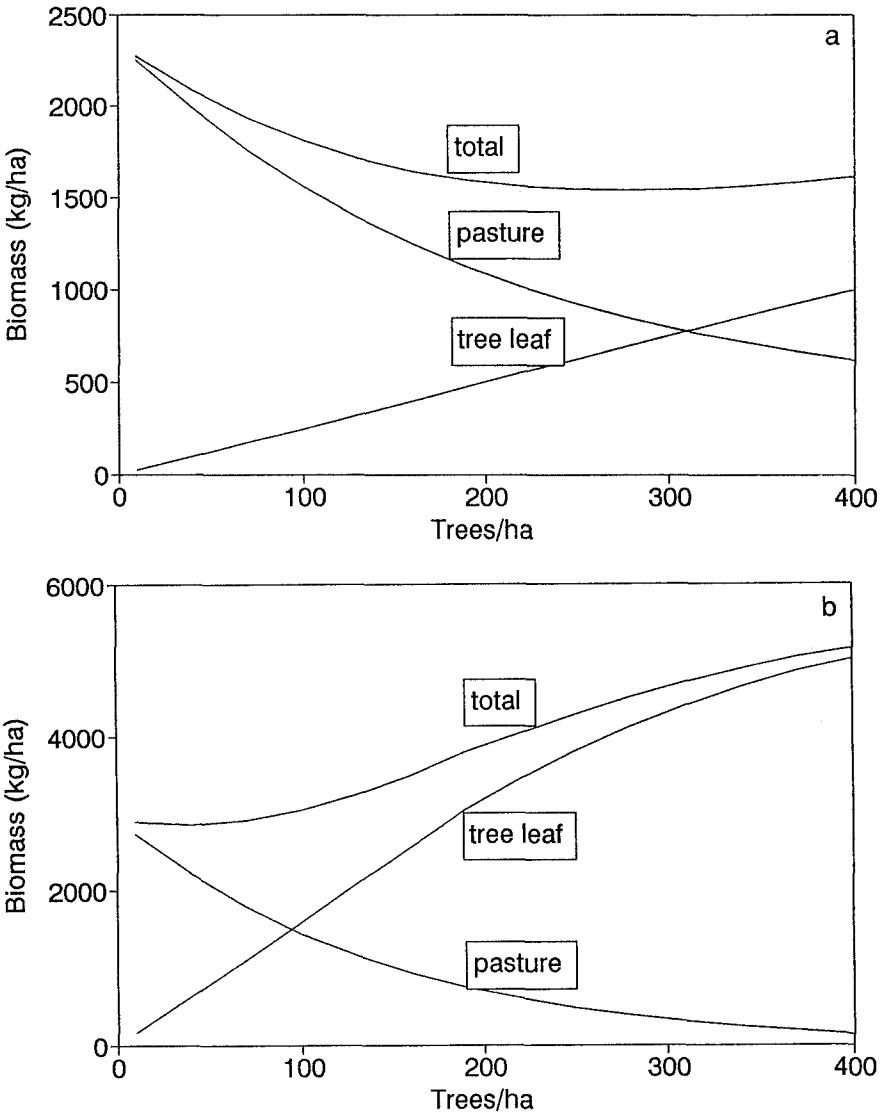


*Fig. 4.* Biomass of tree leaf and pasture within (a) *Eucalyptus populnea* and (b) *Acacia harpophylla* communities in Queensland. Data for *E. populnea* from [11] and for *A. harpophylla* from [59].

*Acacia harpophylla* communities (Fig. 4b), however, the highest total ground biomass is at the highest tree densities due to the higher relative production of tree litter. Ground cover is further modified by the interaction of grazing pressure, tree cover, use of fire, and rainfall amount, intensity and distribution. In the Northern Territory, these factors combine to produce less surface runoff from natural woodlands than from cleared pasture [16]. This contrasts with north Queensland where much greater runoff was reported from natural

grazed woodlands than from cleared native pastures [23]. The interaction of grazing pressure, tree cover, use of fire and the amount, intensity and distribution of rainfall creates a complex set of erosion responses. Therefore generalisations about tree cover and surface soil erosion are not possible.

Clearing initially exposes the soil surface to higher surface temperatures which break down organic matter and reduce aggregate stability. Any associated mismanagement (such as overgrazing, combined with raindrop impact) may lead to high surface strength of soils [3, 7], impeding seedling establishment. Thus, grazing and use of fire are important management practices that can override the direct effects of clearing. A number of projects in northern Australia are or have been concerned with soil loss and runoff in grazed ecosystems [15, 23, 47] and these will be used in a project (LAMSAT) that will investigate the impact of land use on these processes in the semi-arid tropics [P. Hairsine, pers. comm.].

### 5.4. *Tree-grass relationships*

In grazing lands, trees are cleared in the expectation that pasture production will be increased. As pasture production is a determinant of stock carrying

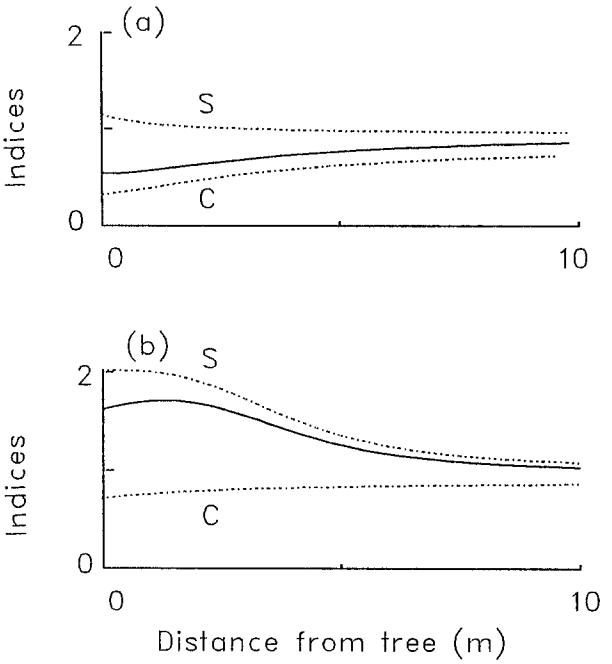


*Fig. 5.* The net effect of trees (solid line) on understorey pasture production, and the component stimulatory (S) and competitive (C) effects (adapted from [60]). In (a) trees have a net competitive effect on pasture growth, as is typical of many *Eucalyptus* spp. communities; and in (b) trees have a net stimulatory effect on understorey vegetation, as is often seen in nutrient poor situation with leguminous shrubs. These individual tree effects have different community level responses (see Fig. 6).

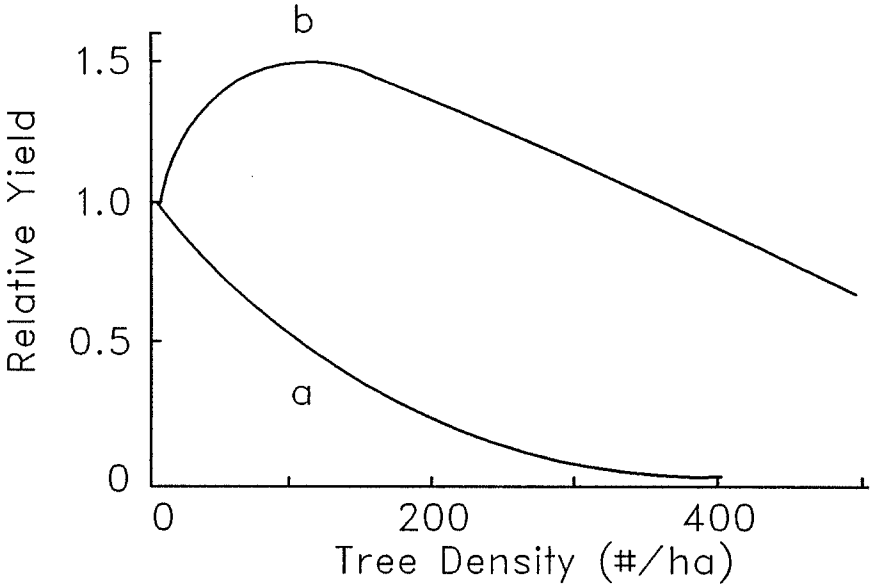


*Fig. 6.* The community level effects of tree density on pasture production for (a) situations where individual trees have a net competitive effect on the understorey; and (b) where the net individual tree effect is stimulation (adapted from [60]). These situations (a and b) are shown in Fig. 5. The reason for the decline in line (b) is that the stimulatory effect of trees reached some maximum whereas the competitive effects increase for each additional tree on the landscape. This results in some optimum value of tree density which also maximises pasture production.

capacity, a greater understanding of the impacts of trees on pasture is required. Recent simulation studies [60] have begun to develop this understanding for tropical and sub-tropical areas (Figs. 5 and 6). As seen in these figures, tree effects on pasture growth range from strong competition to stimulation. Studies on the effects of tree cover on understorey growth [76, 77] and a recent agroforestry study [12] are examples of the biological studies required to improve the understanding of tree-grass relationships.

Further studies are underway on the impact of rainfall distribution, soil fertility and soil water holding capacity on tree-grass balance. This work involves the inclusion of tree competition for water in a simulation model (GRASP) which estimates native pasture production given measurements of soil fertility and water holding capacity [38, 52]. Marked differences in the effect of trees on herbaceous understorey are due solely to differences in the amount and distribution of rainfall (Fig. 7). This wide range of responses makes the management of timbered areas for livestock production complex, as trees increase the variability in safe stocking rates of woodlands [62]. This is further complicated by the need to take into account the benefits of retaining trees for other purposes such as shelter and shade.

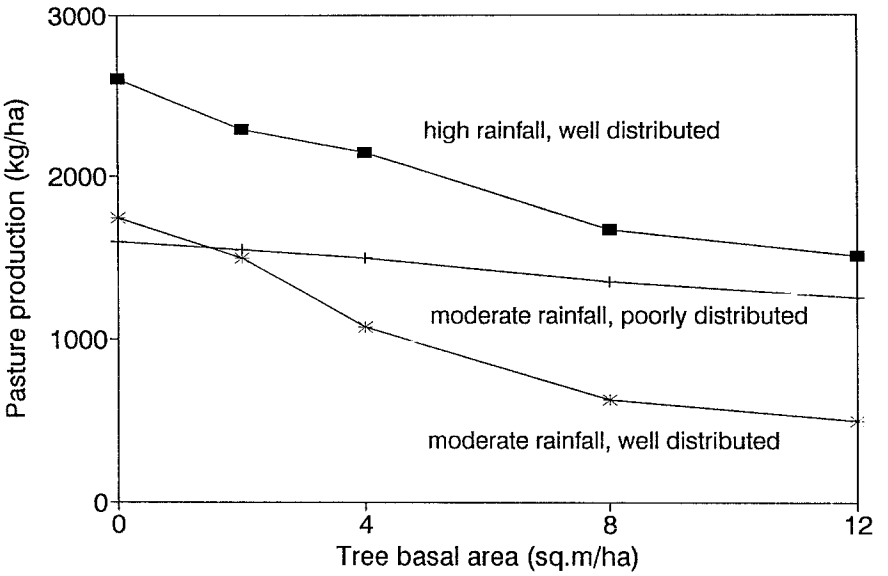


*Fig. 7.* Dry matter production of pasture at a range of tree basal areas for three selected years for a site near Duaringa, Qld. These results were simulated using a version of GRASP [38] modified to simulate the effects of trees [61]. All simulations used the same nutrient status and water holding capacities from a 12 year simulation period (1967—1978). Years were selected to show the range of responses observed.

## 6. Catchment level processes

Decisions that are appropriate at a property or individual paddock level may be totally in opposition to national goals. The clearing of a virgin *Acacia harpophylla*-softwood scrub in Queensland may be economically viable and may result in sustainable production, but it would be inappropriate as there is almost none of the vegetation type remaining in the state. The national level of organisation is not appropriate for making recommendations on what should be done on any particular management unit although it is necessary for setting general goals and targets for retention and for deciding national priorities for conservation. River catchments (or sub-catchments) are the most appropriate levels at which to plan and implement strategies for effective retention of native vegetation.

Tactics for individual land units can be devised to agree with catchment goals. Management decisions made at the catchment level ensure that regional hydrological balance or wildlife population survival goals can be met. Also, national goals (e.g. maintaining habitat diversity or ensuring suitable wildlife movement corridors) can be achieved by planning at this

level. An increasing emphasis is being placed on the individual properties as all states move toward implementing property planning schemes. However, the most appropriate planning and implementation scale is the catchment, and insufficient attention has been placed on understanding processes at this level of organisation.

## 7. Future needs

### 7.1. *Legislation*

South Australia and Victoria have effective working systems regarding retention of native woody vegetation that other states may build upon and modify for their own needs. The current regulatory and incentive programs in these states provide a basic level of protection for all native vegetation. The challenges of the future in Victoria and South Australia are to provide native vegetation management programs to ensure the ongoing health of retained vegetation, and to make available financial and non-financial incentives to encourage improved management [39].

The range of agroclimatic zones present in Australia, and the vastly differing status of native vegetation among states will result in different legislative approaches being taken by the states. Some of the actions or approaches that should be considered in any legislation include:

- planning and implementation of overall controls should be at the catchment level with specific management and planning structures developed on a regional or sub-regional level (Recommendation # 3 [25]);
- all landholders should develop property *management* plans, i.e. these must be more than an inventory of natural resources and capital improvements (Recommendation # 4 [25]);
- all state departments and agencies involved in land and water use should have input into planning and implementation levels of any clearing proposals;
- local government should be enabled to provide rate rebates to landholders who are conserving areas of native vegetation;
- State Governments should be enabled to purchase, restructure and resell private land to conserve areas of remnant vegetation;
- tax relief should be provided for fencing and works designed to protect or manage native vegetation;
- counselling (financial and other) should be provided to rural landholders who are aggrieved by planning restrictions on native vegetation removal.

### 7.2. *Research*

Many issues concerning the management of native vegetation have to be

resolved if our society is to develop a balance between conservation and agricultural production. These include the following:

*Economics*

- How can native vegetation management enhance property viability?
- How are appropriate values placed on intact native vegetation, and on the commercial products of forests and woodlands?
- How should an individual be compensated if added costs or lost income is associated with conservation?
- What are the most effective means (e.g. legislation, subsidies, penalty taxes) of encouraging conservation?

*Fauna and flora*

- What are the relationships between size, shape and degree of disturbance of vegetation blocks and long-term viability of flora and fauna?
- What fauna populations currently exist, what are desirable or acceptable populations and what are their specific management requirements?
- What is the value of native vegetation corridors and 'stepping stones' for movement of wildlife and how should these be maintained or established?
- What is the impact of exotic weeds, feral animals and agricultural chemicals on flora and fauna in remnant vegetation?
- We must improve our understanding of less-well researched vegetation communities and the fauna that depends on them, and must target programs at critical areas for conservation.

*Management*

- Can the potential problems with clearing-induced salting be predicted?
- How can reserved areas be managed to minimise plant and animal pest problems?
- How can native fauna (e.g. macropods) be managed to co-exist with agricultural production?
- What are the effects of fire management practices on remnant vegetation?
- Can degraded areas be rehabilitated?
- What are the effects of stock grazing on the regeneration of woody and herbaceous vegetation?
- We must improve the understanding of the management needs of native vegetation at all levels of government, statutory and semi-statutory agencies, and in the general community.

*Monitoring*

- Monitoring methods to assess the status of herbaceous and woody

vegetation in remnant areas should be developed and the current condition of soils, pastures and woody vegetation on farms should be assessed.

*Social*

— We must improve the general understanding and acceptance of the importance of native vegetation amongst the community, especially in rural areas.

*Legislative*

— Various models of legislation need to be developed to provide for planning and control of native vegetation management at the catchment and regional levels.

## 8. Conclusion

Australia is at an important stage in its management of native vegetation resources. Cropping regions have little remnant vegetation in good condition and serious degradation is already obvious and further degradation is inevitable. Management in these areas must focus on maintaining what natural vegetation is present and rehabilitating degraded areas. Replanting areas with native woody vegetation is undoubtedly required. In grazing regions generally a high proportion of the original woody vegetation is intact. However, considerable damage has been done to herbaceous vegetation, and soil erosion is widespread. Introduced woody species are increasing in area and density, particularly in northern Australia, threatening both the natural heritage value and agricultural production.

Better integration of existing knowledge is required to develop land use plans that meet the multiple goals of agricultural production, hydrological balance and nature conservation. Economic aspects of native vegetation resource use must be studied to ensure that the goals above can be achieved.

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