CURSED BY TOO MUCH WATER IN A DRY PLACE: IMPLICATIONS OF DRYLAND SALINITY FOR FARM MANAGEMENT, POLICY AND RESEACH IN AUSTRALIA

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Abstract
Dryland salinity is one of the most prominent and intractable problems facing farm managers in the extensive non-irrigated farming systems of southern Australia. The issue was ignored by policy makers until late in the twentieth century, but is now the sole or partial subject of government programs with budgets totaling several billion Australian dollars. Salt occurs naturally at high levels in the subsoils of most Australian agricultural land. As a result of clearing native vegetation, groundwater tables have risen, mobilising the salt and causing adverse impacts to farmland, infrastructure, water resources, and biodiversity. The main action required to prevent groundwater tables from rising is establishment of perennial plants, either herbaceous (pastures or crops) or woody (trees and shrubs). Recent technical and economic research has emphasised how difficult it will be to establish sufficient perennials to get control of groundwater tables. Where watertables are already shallow, the options for farmers are salt-tolerant plants (e.g. saltbush for grazing) or engineering (e.g. deep open drains). The existing options for farm-level salinity management are reviewed. There are also a number of good prospects for development of new and better options for plant-based management of salinity, and these are described. Past and current policy programs are described, and a number of changes to future policy programs are proposed to better meet the needs of farmers suffering the impacts of dryland salinity.

Introduction
This paper provides an overview of the dryland salinity problem in southern Australia. It focuses on the issue at the farm-level but also touches on a range of off-farm issues, including the impacts of dryland salinity on a range of public assets, particularly water resources, infrastructure and biodiversity. The paper is primarily relevant to winter rainfall and mixed winter/summer rainfall systems.
Although dryland salinity occurs in the tropics, some of the issues are a little different there.

The paper briefly outlines the causes of dryland salinity and provides recent quantitative estimates of its main impacts. We describe how policy responses to salinity have developed over time and summarise the results of rapid recent advances in technical and economic research. These results highlight weaknesses in the existing policy approaches of government, and weaknesses in the suite of salinity management options available to farmers. We describe the array of farm-level responses to salinity currently available and discuss their viability at the farm level. Finally we discuss the various possible approaches to salinity policy, focusing to some extent on prospects for R&D to develop new management options for farmers that are more economically attractive than the existing options.

Causes of dryland salinity
Salt, mainly sodium chloride, occurs naturally at high levels in the subsoils of most Australian agricultural land. Some of the salts in the landscape have been released from weathering rocks (particularly marine sediments) (National Land and Water Resources Audit 2001), but most have been carried inland from the oceans on prevailing winds and deposited in small amounts (20-200 kg/ha/year) with rainfall and dust (Hingston and Gailitis 1976). Over tens of thousands of years, it has accumulated in sub-soils and in Western Australia, for example, it is commonly measured at levels between 100 and 15,000 tonnes per ha (McFarlane and George 1992).

Prior to European settlement, groundwater tables in Australia were in long-term equilibrium. In agricultural regions, settlers cleared most of the native vegetation and replaced it with annual crop and pasture species, which allow a larger proportion of rainfall to remain unused by plants and to enter the groundwater (George *et al.* 1997; Walker *et al.* 1999). As a result, groundwater tables have risen, bringing dissolved accumulated salt to the surface (Anonymous 1996). Patterns and rates of groundwater change vary widely but most bores show a rising trend, except where they have already reached the surface or during periods of low rainfall. Common rates of rise are 10 to 30 cm/year (e.g. Ferdowsian *et al.* 2001).

Impacts of dryland salinity
The National Land and Water Resources Audit (2001) estimates that the area of land in Australia with "a high potential to develop dryland salinity" is currently 5.7 million ha and will reach 17 million ha by 2050. Western Australia has by far the greatest affected area, with 80 per cent of current national total, and 50 per cent of the 2050 forecast area. The proportion of agricultural land at risk of being affected to some extent by 2050 exceeds 30 per cent in Western Australia and 15 per cent nationally.

In the Murray Darling River system, average salinity at Morgan will exceed the WHO desirable limit for drinking (500 mg L^{-1}) between 2050 and 2100 (Murray Darling Basin Ministerial Council 1999). Salinity is rising in most rivers of southern Australia (Hatton and Salama 1999).

According to George *et al.* (1999b), in Western Australia, without massive intervention, most or all of the wetland, dampland and woodland communities in the lower halves of catchments will be lost to salinity. There are at least 450 plant species and an unknown number of invertebrates which occur only in these environments and are at high risk of extinction (State Salinity Council 2000; Keighery, 2000). National estimates by the National Land and Water Resources Audit (2001) are that by 2050, there will be a high salinity hazard for 2,000,000 ha of remnant and planted perennial vegetation, 41,000 km of streams or lake perimeter, and 130 important wetlands.

Increased flood risks have been studied for only a small number of case studies (e.g. Bowman and Ruprecht 2000). Extrapolating from these, George *et al.* (1999b) concluded that, with the predicted two- to four-fold increase in area of wheatbelt land with shallow watertables, there will be at least a two-fold increase in flood flows.
Infrastructure at risk has also been identified. According to the National Land and Water Resources Audit (2001), assets at high risk from shallow saline watertables by 2050 include 67,000 km of road, 5,100 km of rail and 220 towns. Campbell *et al.* (2000) estimated for a sub-region of south-west Western Australia that 1200 buildings (15 per cent of all buildings in the region), 3,300 km of roads (26 per cent) and 16,000 farm dams (44 per cent) face the risk of damage or destruction from salinity.

Evolving knowledge of dryland salinity

History of perceptions and policy responses

Salinity has been recognised as a problem in Australia for almost a century, but largely ignored for much of that time. In Western Australia, dryland salinity was correctly diagnosed by Wood (1924). In Victoria, irrigation-induced salinity became evident on soldier-settlement irrigation blocks around 1911 (Wilkinson and Barr 1993). In both states, as elsewhere in Australia, the warnings of scientists and affected individuals and communities were not heeded as successive governments had a strong focus on commercial development of the land (Beresford *et al.* 2001, Cook 2001).

In the 1980s, many people started to take dryland salinity seriously, particularly in the states where the problem was most obvious: Western Australia, South Australia and Victoria. The basic 'prescription' was to increase water use of agricultural systems by:

- Increasing water use of annual crops and pastures
- Establishing high water using perennial crops and pastures
- Establishing trees
- Preventing further clearing in susceptible regions

The main aim was to prevent watertable rise, and there was an implicit assumption or hope that action taken by landholders would be sufficient. There was some investigation of engineering responses (particularly drainage). Salt-tolerant plants were planted in some scalded areas, although outside a small group of enthusiasts, this was mainly for cosmetic reasons.

The National Landcare Program (NLP) emerged in the late 1980s in response to salinity and other land degradation problems. The philosophy was, and still is, for local participation and priority setting, landholder co-operation and joint action. By 1997 there were over 3,200 locally based Landcare groups (Anon. 1997). However, while Landcare appeared successful in mobilising the farming community to pay more attention to natural resources and the environment, by the late 1990s there was increasing evidence and opinion that investment in the program was only being moderately effective at best. Volunteer participation seemed to reach its limits (Curtis and Van Nouhuys 1999). Further, evidence began to emerge that the sorts of small scale interventions being undertaken under the banner of Landcare were not being effective in preventing or even slowing the emergence of salinity.

In 1997, the Natural Heritage Trust (NHT) was established. Its design was partly in response to concerns that Landcare was not achieving sufficient change on the ground. The NHT differed from Landcare in having a greater emphasis on partial subsidies for on-ground works. In turn, the National Action Plan for Salinity and Water Quality (NAP), has attempted to respond to concerns that NHT funds were not sufficiently well targeted, and with a recognition that some regions have more urgent (or sometimes more politically important) salinity problems than others. Furthermore, under the NAP, there is a greater devolution of power to regions through catchment management bodies, although with varying degrees of funding autonomy in different states. Priority catchments have been selected in each state and investment priorities are being selected by regional communities based on local needs.

The NLP, NHT and NAP are programs of the national Government. Over broadly the same time period, individual states also developed their own salinity policy plans (e.g. Anonymous 1996, Anonymous 2000). Altogether, these policies and programs represent a very substantial emphasis by governments on natural resource management in agriculture, with salinity as a particularly focus. Despite this emphasis, the current scientific knowledge of salinity indicates that we have made relatively little progress towards changing practices on the scale that would be effective in preventing groundwater rise, and thereby dryland salinity.

Current state of knowledge

In the past decade, and especially the last five years, there has been a dramatic improvement in knowledge of salinity and its management. Some of this new knowledge is forcing us to reconsider what it will really take to successfully manage salinity. There are strong implications for farm management, for government policy and for researchers. Key aspects of our current understanding are summarised here.

- It is much harder to prevent rising water tables and saline discharge than was previously thought. The area of land under perennial vegetation needs to be very great (in excess of 50 per cent in most cases) if salinity is to be controlled at the catchment scale (George *et al.* 1999b) rather than just locally (George *et al.* 1999a).
- Increasing the water use of annual crops and pastures alone is not sufficient.
- The range of assets under threat is much broader than agricultural land, and includes water resources, town infrastructure, roads and biodiversity. Water quality issues are of major concern in eastern Australia, particularly because the city of Adelaide is partly reliant on the River Murray for its water supply. The deterioration of water quality in rivers is also adversely affecting irrigators, who draw on that water, and biodiversity in the rivers.
- Some assets can only be protected by engineering methods. Examples include a number of rural towns in Western Australia for which revegetation of surrounding farms will not help (Dames and Moore – NRM, 2001).
- There is significant variability in the responsiveness of groundwater flow systems to management interventions. Regional-scale systems (e.g. in part of the Murray-Darling Basin) are least responsive. There is greater scope for management of salinity in localised systems (more common in Western Australia) although the challenge remains very great even there.
- With large areas already affected by salinity and further increases unavoidable even with major interventions, options for making productive use of saline land are clearly very important.

There has been a rapid growth in interest among farmers in engineering responses to salinity, although there remain some areas of controversy and uncertainty about that.

There also remains considerable interest in the use of perennials for recharge management, although efforts are now focused much more than they were previously on developing new perennial options that are profitable in their own right, in order to achieve adoption at sufficient scale to have an impact on salinity.

Possible farm management responses

Farmers vary widely in their circumstances (soils, rainfall, farm size, machinery, knowledge, skills, …) and their farming decisions vary accordingly. In particular, their adoption of salinity management practices has been variable. A number of high-water-using farming systems are in use around Australia. However, their adoption has been primarily based on their production and profit advantages compared to alternative systems. Their contribution to management of the water table may have been considered, but in most cases as a secondary factor.

More productive annuals

Substantial efforts to improve the performance of annual crops and pastures through plant breeding and agronomy has had a large impact on "water use efficiency" but minimal impact on water use. For water use to increase, the annual plants would need to transpire longer in spring thereby creating a large dry soil "buffer". For this to occur, crops and pastures would generally need to be tapping a substantially increased soil volume and the scope for such changes in limited, especially for cereals. There is evidence of increased water use in annual pastures such as *Ornithopus* spp. (serradellas) where selection for indeterminance and rooting depth in hostile sub-soils has been successful (Nutt 1999). While deeper-rooted annual pasture plants can more fully dry the profile in spring than the more shallow rooted annuals they replace, they have limited capacity to respond effectively to summer rainfall and are likely to be less effective in water use than a well-adapted perennial. A future requirement will be for productive annuals that perform effectively in mixtures with perennials, particularly in low rainfall regions where the productivity and persistence of perennials can be poor if grown as a monoculture.

Perennials for recharge areas

Using perennial plants to reduce recharge in agricultural regions remains a challenge. Current commercial use of perennials is dominated by a small number of plants (e.g. Lucerne, *Medicago sativa;* Phalaris, *Phalaris* spp.; Tasmanian blue gum, *E. globulus*) and the spatial extent and diversity of suitable perennial species is lower in regions with low rainfall, particularly if they have drier summers.

Current successful examples of perennials vary widely in form and function. This raises the prospect that an expanded array of perennials can be developed to allow much wider adoption in the future.

Perennial form ranges in a continuum from tree through shrub to herb and there is a strong link between form and product outcome. Herbaceous species (e.g. lucerne, perennial grasses) are closely linked to livestock production while trees have generally produced structural timber. Currently, shrubs are generally used for fodder production (tagasaste) but wider and/or multiple uses are possible (i.e. acacia for fodder, wood chips, seed and chemical extracts). Similarly, a much wider array of uses is now envisaged for woody perennials, as discussed later.

System configurations can be helpfully categorized as segregated (permanent perennial pasture, forestry plantation), rotated (phase farming using lucerne) or integrated. Systems can be integration in space (alley systems and inter-row elements) or in time (companion cropping using cereals and lucerne).

A number of currently useful perennial plants are described below with attention given to their climatic adaptation and the systems into which they fit. We also draw attention to gaps in the array of current perennial plants.

- *Herbaceous perennial* pastures are a prominent landuse, producing forage for a range of livestock production systems. Sown perennial grasses are an established component of many high rainfall permanent pastures. Mainly exotic species (Phalaris; Perennial ryegrass, *Lolium* sp.; Tall Fescue, *Festuca arundinacea;* Cocksfoot, *Dactylis glomerata*) are from temperate climatic zones. More recently species of sub-tropical origin such as Kikuyu (*Pennisetum clandestinum*) are also beginning to have an impact and are of particular relevance to recharge control because of their summer activity. Native grasses are widely distributed in eastern Australia but new sowings remain at very low levels despite the availability of a number of commercial cultivars. Key challenges for perennial grasses revolve around extending their use into more stressful environments (e.g. low rainfall zones, acid soils and waterlogged soils). In moving into lower rainfall environments, an associated challenge is the development of systems to allow the integration of perennial pastures with cropping. Lucerne is the most widely used herbaceous perennial legume and is well suited to rotational systems (phase farming). However, its use is currently constrained by plant and soil factors such as intolerance to acidity, waterlogging and low rainfall as well as management factors such as the requirement for intensive grazing management. Until now, perennial legumes other than lucerne have been confined to high rainfall zones, where species such as Birdsfoot trefoil (*Lotus corniculatus*) have shown potential.
- *Shrubs* are a rarer component of current land-use systems for recharge areas because they rarely outperform herbaceous perennials in profitability when grown for forage, and because industries that might utilize woody forms have yet to be fully developed. The most prominent and successful shrub is tagasaste, which is estimated to have been sown on 100,000 ha in Western Australia. Adoption of tagasaste has occurred because it is able to recover water and nutrients on certain deep and infertile soils with poor water holding capacity. For this reasons it is more productive than shallower rooted alternatives. Additional factors have been the development of low cost direct seeding systems and systems of utilization with cattle that avoids the need for high cost pruning to make the feed available to livestock while maintaining a balance between woody plant structures and higher quality growth of leaves. Tagasaste, like other shrubs, can be established in a plantation but it is also suited to use in alley systems with pastures or crops grown in the inter-row. The isolated success of tagasaste highlights the need to identify more plants with this growth form for use in settings where herbaceous perennials are unsuited or in integrated systems with other crop or pasture species.
- *Trees* have been planted on agricultural land in substitution for long-term pastures in high rainfall zones. The uptake of commercial tree plantations was assisted during the 1990s by low profitability of livestock-based enterprises that dominated in areas with more than 700 mm annual rainfall. Much of the commercial activity has been based on Tasmanian blue gum (*E. globulus*) but other species for both timber and wood chip for paper production have been used. The productivity of Tasmanian blue gum plantations declines with declining rainfall and they become unprofitable compared to other land uses in lower rainfall areas. The cut off point depends on relative prices, but has in recent times been considered to be about 600 mm. In marginal rainfall zones, tree performance can be enhanced by planting in water accumulating positions in the landscape and in agro-forestry plantings (alley planting). Plantation tree production for timber is not a major land-use in areas receiving less than 600 mm, with Maritine Pine (*P. pinaster*) being one of the few examples of commercial initiatives. The use of agro–forestry in lower rainfall areas has been highlighted as a land-use opportunity and development of mallee (*Eucalyptus* spp.) has proceeded in Western Australia with eucalyptus oil, activated carbon and energy as expected co-products. The production system based on alley plantings of mallee species suited to regular harvest and coppice regeneration is a major departure from traditional timber production and highlights an important opportunity for low rainfall agro-forestry across southern Australia.

Plants for discharge areas

A common response by landholders to salinity has been to fence off affected areas and then to manage any plant growth with low intensity grazing. Where such areas are sufficiently large, some producers have looked to improve productivity by introducing plants that are tolerant of the stresses experienced low in the landscape: salinity, waterlogging and inundation. Plant choice is dependent on the expected level of salinity and waterlogging stress in addition to usual soil constraints such as fertility and acidity. While a group of plants has been identified that can tolerate salinity and waterlogging, production rarely matches that possible in unstressed environments.

Legumes as a group are at the low end of the salinity and waterlogging tolerance range. Among the most tolerant species so far identified, Balansa clover (*T. michelianum)* and Persian clover (*T. resupinatum)* have been widely sown in areas with mild salinity and their tolerance of waterlogging has made them profitable over large areas. A perennial legume, Strawberry clover (*T. fragiferum*) also has an established commercial role in saline areas but this perennial only persists where water is available for almost all of the year. A major gap is an array of legume species capable of tolerating substantially higher levels of salinity and with general adaptation to a full range of saline soil environments.

Salinity tolerance is more highly expressed in some grasses and two species have been widely used commercially. Puccinellia (*Puccinellia ciliata)* is more salt-tolerant and waterlogging-tolerant than is Tall wheat grass (*Thinopyrum elongatum*) but both species have been usefully introduced into saltland pastures. A key issue is the maintenance of pasture production and quality in the absence of a companion legume.

Shrubs are the most salt-tolerant and waterlogging-tolerant options currently available, but their adoption has been constrained by the relatively high costs involved in their establishment and by concerns about the quality of their forage for livestock. Initially landholders with severe salinity looked on species like saltbush (*Atriplex* spp.) and blue bush (*Maireana brevifolia*) as tools for rehabilitating severely salinised areas and plantation style systems were used. Experience has indicated that livestock production from saline areas is enhanced when sheep have access to both saltbush and other higher quality forage. This has given rise to saltbush being more widely used on less severely degraded saltland sites, where the plants are sown as rows or alleys with inter-row plantings of species providing higher quality feed. In this way the investment costs of pasture establishment are kept low, a mixture of pasture species is available and a synergy is established between the perennial shrub (which keeps the water table suppressed) and annuals (which benefit from reduced salinity through leaching). Producers have noted that saltland pastures that provide high quality grazing opportunities in autumn have an economic impact greater than predicted by biological productivity because they reduce the need for expensive and labour-intensive supplementary feeding. This explains the profitability of such systems despite relatively high initial investment costs.

Engineering

Engineering methods may provide an alternative or a supplement to management with vegetation. On farms, shallow surface drainage contributes to prevention of water table rise and reductions in water logging and has been widely adopted for many years.

Many farmers would like to repair salinised land and continue with traditional agriculture, if that is possible. To this end, taking a lead from farmers in the Upper South-East of South Australia, many farmers in Western Australia have been installing deep open drains to enhance discharge. Early research on deep open drains in WA found that they reduce groundwater levels within only a few metres of the drain on high-clay soils and rarely more than 40 metres on favourable soils (Speed and Simons, 1992; Ferdowsian *et al*. 1997). However, more recent research on drains at Narembeen in WA has found positive impacts over considerably greater distances. It now seems clear that their effectiveness ranges from very high in some locations to extremely low in others. A challenge is to identify accurately and cost-effectively those locations where these drains can be effective.

Probably an even greater challenge is the cost-effective and environmentally safe disposal of discharged waters from deep open drains. There remains a tension in WA between the farming community and regulatory authorities, and its resolution is greatly hampered by lack of knowledge of the risks and impacts from different disposal options.

A full range of engineering responses to salinity are currently the subject of detailed investigation in WA, in the state government's Engineering Evaluation Initiative. In addition to drainage options, this is examining siphons, relief wells and pumps as alternatives.

Proposals to construct major regional engineering systems, fed by pumping or drainage from agricultural land, have been made (e.g. Belford 2001; Thomas and Williamson 2001). Particularly in view of the very great resources involved, these proposals would need very careful investigation before funding could responsibly be provided.

It is worth noting that drainage options are likely to be less politically acceptable for dryland salinity mitigation in eastern Australia, particularly in those locations where the main salinity concerns relate to rivers rather than land salinisation. The higher population density in eastern states may also contribute to greater community resistance due to concerns about aesthetic impacts of widespread installation of prominent drainage systems.

Feasibility of the options

For strategies that aim to keep groundwater tables at bay (i.e. perennials on recharge areas), the requirement for success is a very high level of adoption. There is still debate and discussion about what proportion of the landscape would need to be sown to

perennials, but all the proportions under discussion are dramatically higher than are currently present on farms. This leads to the conclusion that perennials need to be commercially attractive to farmers. Without this, there seems no prospect of them being adopted on the scale needed to effectively manage salinity (Pannell 2001).
Kingwell *et al*. (2003) collated existing evidence on the economic performance of current salinity management practices on cropping-oriented farms, and completed a large number of additional analyses for grain growing regions of southern Australia. They concluded that lucerne is currently profitably on at least some areas of most grain farms. The indicated areas of production are small relative to the scale that would be necessary to control salinity over whole catchments, but they would contribute to local water-table management. Soil acidity is a key factor inhibiting expansion of the area suitable for lucerne.

Trees and shrubs are not yet profitable over large areas in grain-growing regions. Oil Mallees appear to have prospects if grown within reasonable transport distance of processing plants.

There are some issues that are not specific to particular perennials.

- Farming systems based on perennials often require more intensive management than do annual plants. Not all farmers have the capacity (financial and/or management) to meet these requirements (Cary *et al*. 2002).
- In higher rainfall zones not too distant from cities and major towns, uptake will be limited by demand for land for uses other than traditional large-scale agriculture (Barr *et al*. 2000). This demand results in small farms, high land prices relative to its value for agricultural production, and a group of land managers who are not driven to embrace innovative commercial farming practices to anything like the same extent as are traditional farmers.

The challenges for strategies that allow farmers to cope with high water tables (salt-tolerant plants, deep-open drains) are somewhat different. They do not require adoption at huge scale, but can be evaluated at whatever scale they are applied to. The economic viability of salt-tolerant plants also has an additional advantage over perennials intended to prevent watertable rise: salt-tolerant plants are established on land that has a low productive value for other uses. Their viability therefore depends on whether their productivity is sufficient to offset establishment costs, and on how long they persist. Long-term persistence has been demonstrated in a large number of cases in Western Australia, but may be more problematic in areas with significant lateral movement of groundwater, due to accumulation of salts in the root zone. Kingwell *et al*. (2003) concluded that saltbush-based systems are often profitable, though usually not highly profitable. O'Connell and Young (2002) conducted a detailed analysis of the economics of saltbush systems. They concluded that the economics most favour saltbush on moderately saline areas. On highly saline areas, the productivity of saltbush is low. On slightly saline areas, the productivity of saltbush is higher, but so is that of competitive land uses, like barley. In general commercially viable saltland pasture systems are low input in character.

An economic analysis of deep open drains on agricultural land by Ferdowsian *et al*. (1997) reached negative conclusions about their cost effectiveness, but given the new evidence that is emerging about their effectiveness in at least some situations, further research and analysis is needed. It is striking that there is so much current investment by WA farmers in deep open drains despite the lack of economic analysis to support their viability. From a community-wide perspective, the knowledge gap is even greater, as fully evaluating the economics of drains is complicated by the prominence of downstream concerns, particularly where those concerns relate to environmental impacts of intangible value.

The economics of engineering methods to prevent damage to infra-structure has been evaluated in the case of six rural towns in Western Australia. The evaluations were based on an assumption that any saline waters pumped from under the towns would be disposed of in constructed evaporation basins. Given this assumption, the engineering works looked viable in two cases, marginal in one and highly uneconomic in three (Dames and Moore – NRM, 2001). This highlights the importance of cheap disposal options, and of obtaining better information about downstream impacts from disposal into waterways.

The implications of all this seem to be that:
(1) there is scope for enhanced salinity management with existing options, and
(2) there is a need for considerably more work to prove and improve the options.

For plant-based options, there is a key need for R&D to develop more profitable new options (both herbaceous and woody, and for both recharge and discharge areas). This is being undertaken by the CRC for Plant-Based Management of Dryland Salinity, which involves nine core partners from four states (http://www.crcsalinity.com).

For engineering options, there is a need for more information about their performance in different circumstances, their design, their economics and their downstream impacts. These issues are being addressed by the WA Government's Engineering Evaluation Initiative.

Policy responses to support farm-level action

Cary *et al*. (2002) broke down the options facing farmers into the following broad categories:

- Tackle the problem to prevent it occcuring (e.g. perennial pastures),
- Adapt to the problem (e.g. saltbush, drains),
- Add to knowledge,
- Do nothing.

The options facing government policy makers have some similarities to this list. We are now better placed to more strategically design salinity policy to suit the wide range of impacts and situations. No single policy approach is appropriate for all cases, with the best choice for a specific location depending on a wide range of factors. The following subsections consider the possible components of a policy package for salinity.

Information

Government is involved in at least three ways with salinity information.

(a). *Enhancing communication of existing information to land managers or among groups of landholders*. The aim is to allow informed decision making about salinity management options. This category includes Landcare-style group processes, traditional technology transfer, activities to engage with private sector information providers and Environmental Management Systems (EMS). Of these, Landcare groups, supported by publicly employed facilitators, have been the most prominent, but their effectiveness in helping to address salinity has increasingly been called into question. Traditional extension/technology transfer services have declined in some states, and there has been a marked increase in private providers in certain regions (Marsh and Pannell, 1998). Agribusiness companies (e.g. Wesfarmers Landmark, Elders) are now also involved in information provision, primarily technology transfer related to production issues. To the extent that commercially viable plant-based systems are available, these technology transfer activities are very relevant (probably more relevant than the Landcare approach), and may warrant support from government. On the other hand, where commercial systems do not exist, information provision is probably the wrong policy tool for the salinity problem. Finally, tools such as EMS (Morelli 1999) span the border between commercial and non-commercial issues, and may give extension providers a way of integrating both production and environmental impacts of farming systems.

(b). *Generating new or better information about the processes, impacts and management of salinity*. Various types of R&D are relevant here, including field experiments, hydrological modelling, social research and economic analysis. Notwithstanding the enormous amount of information that already exists, there remain important knowledge gaps when it comes to making specific decisions in specific locations, particularly in relation to the benefits of particular responses. Hydrological modelling that provides improved tools for addressing this (e.g. Beverly *et al.* 2003) seems a particular priority. For Western Australia, as discussed earlier, another high priority need is information about the economic and hydrological performance of engineering approaches, and their downstream impacts.

(c). *Using information to guide decisions by governments and catchment managers about where to invest in salinity management*. In Western Australia, the so-called Investment Framework for Public Investment in Salinity is in a pilot phase, involving intensive collection and analysis of information about the assets at risk. Under the NAP, catchment management bodies are charged with a similar task.

New technologies

Consideration of current perennial plant technologies has highlighted the low general current use of perennials and some gaps and opportunities for new technologies for both salinity prevention in recharge areas and for living with salinity in discharge zones. For new technologies to gain wide acceptance with land managers it will need to match the profitability of current systems. Even then, adoption may be constrained if the new technology is too capital-intensive or too demanding of management.

The variability of our physical resource base at both a regional and farm level makes the framing of new technologies to fit within current profitability constraints a complex task. Realistically, the needs differ region by region, depending on local circumstances and the existing technologies. Economic analysis of Western Australian wheatbelt farms indicate that the profit associated with best current technologies vary over at least a five-fold range.

In general, investment costs associated with introducing perennial production systems are likely to be greater than for current annual systems. As a result, profit maintenance will either require an increase in production or a change to products of higher value. Both of these mechanisms appear to be feasible. Perennials can potentially increase production by utilizing more water through greater rooting depth.

For recharge areas there is opportunity for new technologies for both herbaceous and woody perennials. For herbaceous perennials the biggest needs are for plants suited to low rainfall zones and for stressful environments such as acid soils and waterlogging-prone areas. It makes sense to adapt existing successful technologies to their biological limits. For example, soil acidity currently limits the more widespread use of lucerne. Efforts to develop more acid-tolerant lucerne would substantially increase the commercial impact of this species. Similarly, increasing drought tolerance in species such as Birdsfoot trefoil and Tall Fescue would expand the effective use of these well-understood species.

An additional set of new perennial pasture technologies is likely to arise from the exploitation of species not currently in commercial use. Amongst the grasses, species of tropical and sub-tropical origin offer important prospects through their combination of summer activity and general adaptation to stress. This opportunity is given credibility by the well-documented performance of kikuya in high rainfall temperate and Mediterranean zones and more recent experience with Rhodes grass (*Chloris gayana*). Developments that allowed the introduction of these or similar grasses to lower rainfall environments could make a real difference to salinity management. The development of new perennial legumes based on novel germplasm is also a realistic prospect. The genus *Lotus* is rated the best initial prospect but other genera are already identified as potentially useful and many remaining to be studied.

Development of novel herbaceous perennial pasture systems is probably essential if we are to have a substantial impact in low rainfall wheatbelt environments. In this setting many perennials struggle to provide consistent productivity and persistence. A model with some promise involves a well-adapted annual grown in mixtures with sparse perennials with the potential to regularly dry the soil profile late in each spring, combined with the ability to respond rapidly to out of season rainfall. Such a system would allow full use to be made of current infrastructure for annual-pasture development. Suitable perennials might be available from within the native flora.

While herbaceous perennial crops should not be written off as inappropriate technology, there are few examples internationally in extensive agriculture and any new technology would need to be based around a substantial and sustained R&D effort.
New woody perennial crops are likely to be needed if a significant impact on salinity is to be achieved. As with herbaceous perennials there is scope to manipulate existing long-cycle timber production systems at the margin to facilitate their use outside existing industry boundaries. This would have the particular advantage of allowing use of existing processing and handling infrastructure.

The development of novel systems based on short production cycles is likely to be of greater long-term importance. This will probably take the form of harvest and re-growth from coppice (although there is also some attention being paid to phases of woody perennials undertaken between periods of an alternative land use, perhaps cereal cropping). The oil mallee production system is a prototype for the short-rotation coppice system. However, other woody species with other product outputs will be needed if large areas of low rainfall forestry and agro-forestry are to come to fruition. Plant selection will focus on suitability for large-scale commodities (pulp, paper, panel board and energy) that could stimulate the scale of planting required to have an impact on salinity.

While the Australian native flora appears to offer the best opportunities for novel germplasm to fit these systems, exotic species should not be ignored. Evidence is mounting that woody crops may compete economically with current land uses in low rainfall environments, but compared to current land uses these woody crops will require substantially different methods of management, different patterns of investment, and make different demands on regional infrastructure. These differences may be barriers to uptake that will need to be countered. On the positive side, woody perennial crops offer the prospect of diversification of risk.

We have been discussing woody perennials in the context of systems for recharge areas. There is also the hope that woody perennials may provide new options for saline discharge areas, although realistically, new options for discharge areas are more likely to be pastures or perhaps grain crops. Cereals with combined salinity and waterlogging tolerance would allow profitable cropping systems to be undertaken on mildly salt-affected areas for substantially longer than is currently the case where salinity is encroaching. A system based around alleys of salt tolerant shrubs for water table management with inter-rows of crop/pasture rotations is also feasible. Crops for use in this environment will require a substantially enhanced level of both salinity and waterlogging tolerance over current standards, and salinity tolerance alone as widely promised from transgenic programs will be of little value in the field.

The option with the greatest potential for impact in discharge zones is the identification of novel legumes with substantially increased tolerance to salinity and waterlogging. Even modest levels of increased tolerance would allow low-cost production systems to be applied more widely and allow the benefits of tolerant grasses to be more fully expressed through the availability of legume-fixed nitrogen. While an increased array of legumes with moderately increased tolerance seems likely through the use of genera such as *Melilotus*, more substantial tolerance would have wide field significance.

This discussion of potential new technologies has focussed on plant-based systems. Clearly there are a large number of new possibilities, some very promising indeed, although all will take time to reach their full commercial potential. At this stage, we are not aware of brand new, previously undiscovered engineering technologies being sought for salinity management. The emphasis in the case of engineering options is on fully understanding the performance, design and downstream impacts of existing engineering technologies (see previous section).

Financial support

The NHT has provided partial subsidies to farmers for on-ground works, some of which are intended to have benefits for salinity management. The NAP is investigating so-called "market-based instruments" (versions of them which are, in essence, sophisticated forms of subsidy), which could also provide financial payments to encourage establishment of perennials.

While financial payments to farmers do, no doubt, have a role to play in promoting change on farms, recent developments in our understanding reveal that it is likely to be a somewhat limited role. The main benefits from use of such payments will be in a small proportion of locations where off-site benefits from on-farm revegetation are outstandingly high. For the majority of agricultural land, off-site benefits from revegetation are low, or on site costs are high, or both. In these situations, use of market-based instruments or subsidies are unlikely to be effective in altering farm management on the scale needed for technical effectiveness against salinity, unless the incentives created are greater than the off-site benefits. The use of such large incentives would actually reduce economic efficiency, rather than increase it, because they would encourage adoption of perennials in situations where the total costs exceed total benefits.

This also has implications for other policy approaches, such as regulation, provision of information and use of persuasion. To the extent that these approaches are successful in altering farmers' management strategies, they run the risk of reducing efficiency overall unless they are targeted to situations where off-site net benefits are greater than on-site net costs.

For any form of government intervention to address salinity to be desirable from the point of view of economic efficiency, the following conditions would be required:

- Groundwater systems should be responsive to changes in land management. This is more likely on land with greater slope, and with more "transmissive" soils. Both of these conditions tend to be more common in the higher rainfall regions.
- The practices being supported should not require the farmer to give up the use of land that is productive for traditional farming purposes, unless the change does not result in excessive costs to the farmer (e.g. because equally profitable perennial options are available). In economist-speak, the "opportunity cost" of land use change should not be excessive. If the private opportunity cost is too high, it will exceed the public off-site benefits. Again, this tends to favour higher rainfall regions as the more likely sites for effective government intervention, because that is where perennials tend to be more competitive with existing land uses.
- Assets of high value are at risk. In general, to justify government programs to influence on-farm action, we would need a public asset of outstanding value to be (a) at risk and (b) cost-effectively protected by on-farm treatments. A likely example is the Collie catchment in Western Australia, which provides water for the Wellington Dam. In the Murray-Darling Basin, the resource under threat is similar in some ways to the Collie case, but the scale of revegetation required to protect it is vastly greater, and the responsiveness of groundwater systems is generally much lower. In most parts of the Murray-Darling Basin, it seems unlikely that direct financial support for establishment of perennials will achieve very much at all for the rivers. A more realistic prospect is to pursue the development of new technology options, as outlined earlier. In the case of threatened country towns, most of the effort needs to be within the town boundaries rather than on surrounding farms, so the use of economic instruments to influence farmers is of little or no relevance. Threatened environmental assets (e.g. lakes, nature reserves) are likely to vary in their need for on-farm action. In some cases, government intervention may be justified.

Responses beyond agriculture

It is important to appreciate that agricultural solutions are not the only relevant responses to salinity. Non-agricultural responses may take a number of forms.

(a). Localised responses (probably engineering) to protect non-agricultural assets. Pumping to remove saline groundwater is expensive and has only local effects on the groundwater level, but it may be a viable strategy where particularly valuable assets are at stake (e.g. the infrastructure of a town, or an important environmental asset). In situations where a valuable asset is located in a catchment where the process of watertable rise is well advanced, the benefits of revegetating the catchment may be too little and too late to save the asset. In these cases, pumping is probably the only strategy available with the technical capacity to protect the asset (Campbell *et al.* 2000). The Murray Darling Basin Commission is using pumping extensively to intercept saline groundwater before it discharges into rivers.

(b). Where water resources are salinised, desalination is another option that appears to warrant further investigation. Desalination is more likely to be viable in locations that are remote from fresh water supplies. The cost of pumping water over long distances is high and desalination avoids that cost. Alternatively, if water resource protection requires massive revegetation at high cost to the public, desalination might be a cheaper option.

(c). Adoption of non-agricultural practices by current farmers. Some of the options for making productive use of saline land and water may draw farmers into very different types of enterprises. New commercial uses for salt water may include the following.

- Saline aquaculture. Some farmers are already stocking salty dams with trout.

- Saline water can be used for electricity generation, algae production (e.g. for agar, β-carotene, pigments, or fish food), seaweed production and, if it is not excessively saline, irrigation water.
- There is potential to process saline water to extract valuable salts and minerals, including magnesium, bromine, potassium chloride.

(d). Potentially, policies to help some farmers to move out of farming may be appropriate. For example, in parts of Victoria, Neil Barr has found that a large proportion of the existing farmers are within a decade or so of retirement, and so may have little incentive to take up new perennial farming systems that will pay off over a longer term. Bring the new farm managers into place sooner may therefore have benefits for salinity management. Another option to consider is to encourage or support farmers who are willing to retire agricultural land (Edwards and Byron 2001), perhaps actively revegetating it, or if feasible, allowing natural revegetation. Related to this would be mechanisms to prevent clearing of remaining vegetation (particularly relevant in NSW and Queensland).

Do nothing:
Beyond all these options, there are also circumstances where the best option, both for farmers and policy makers, is to do nothing. From a farmer's perspective, the cost of preventing salinity given the available options may be too high, and the options for making productive use of salinised land or water not sufficiently attractive, for a range of possible reasons. From a government perspective, there are plenty of areas where the off-site benefits from agricultural interventions are too low to warrant support with public funding. It is important to recognise these circumstances so that limited resources are not wasted, and can be focused onto more productive investments.

Conclusion
Salinity is such a multifaceted issue that one needs care when drawing generalisations about it. All of the farm management responses outlined here have their place in at least some situations in some locations, and none is appropriate in all cases. Similarly, the policy approaches can all contribute to some extent, but need to be targeted. Nevertheless, some important generalisations are possible, including the following.

Firstly, our knowledge of salinity has advanced rapidly, and we are better placed to chart a well-considered path forward than we have ever been. Unfortunately the new knowledge reveals that comprehensive prevention of dryland salinity is dramatically more difficult that previously assumed.

Secondly, each of the sets of existing farm-level options for salinity management has problems or limitations of various kinds. Existing perennials plants suitable for recharge areas are usually not profitable on a sufficient scale to fully control watertables. Existing plants suitable for saline and waterlogged soils in discharge areas are profitable to some extent, but not so strongly as we would wish. And the dominant engineering response being explored by farmers, deep open drains, is variable in its effectiveness and hampered by uncertainties about where it will work and what the downstream impacts will be.
Thirdly, government policy has paid too little attention to the development of profitable responses to salinity, relying excessively on voluntary action, provision of information and partial subsidies at the expense of R&D and support for new industry development.
Fortunately there are good prospects among the plants currently being investigated. It will, no doubt, take some time before these prospects are delivered as commercial products. However, at least we can say for the first time that a serious effort is underway to develop the technologies that farmers have, in fact, needed all along.

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