A framework to select policy tools for dryland salinity

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Abstract. Appropriate management and policy responses for dryland salinity vary depending on bio-physical and socio-economic conditions, and on the resources in question (water resources, biodiversity, infrastructure, agricultural land, salt-affected land). In this paper we present a framework for selecting responses consistent with economic and scientific evidence. Current policies rely heavily on communication, education and payment of incentives, but a broader range of responses is needed, including engineering works for key infrastructure, selective use of regulation/permits to limit planting of perennials in certain areas of high-water-yielding catchments, and development of improved salinity management technologies for farmers. We are over-relying on incentives and communication, which are only likely to be cost-effective in certain situations.

Key words. Salinity, policy mechanism choice, natural resource management, environment, integrated catchment management

Introduction

Several factors have contributed to changing understanding of the management and policy of dryland salinity in recent years, including:

(i) New evidence about the effectiveness of plant-based systems in preventing the impacts of salinity. In most regions, prevention of discharge requires much larger areas of perennials to be established than was believed in the 1980s and 1990s.
(ii) Increased knowledge about the diversity of groundwater flow systems with their varying responses to plant-based salinity management systems;
(iii) Recognition of the potential for plant-based options to have adverse impacts on fresh water flows into rivers in some situations;
(iv) Evidence about the disappointing economic performance of most existing plant-based salinity management systems and, related to that, their insufficient current levels of adoption; and
(v) Increasing prominence of engineering-responses to manage dryland salinity.

Past salinity R&D has produced detailed knowledge of the salinity problem and its causes, but has not produced an adequate range of systems and technologies to manage it. Salinity policy programs take for granted the availability of appropriate salinity management tools, but this optimistic position is often not justified (Pannell 2001*a*).

In this paper we report on our efforts to integrate a full range of hydrological, biological, economic and social research to develop a clear and well-founded position on the roles and limits of different responses to dryland salinity. Our aim is to clarify the roles of different responses for salinity management, based on the latest research and evidence. We call the resulting framework SIF3, for Salinity Investment Framework version 3.

We recognise that salinity is one of a number of degradation issues and that, where possible, governments and catchment management organisations seek multiple benefits in natural resource management. However, we have kept the paper tightly focussed on salinity for several reasons (a) to maintain clarity and tractability; (b) because salinity management has particular policy needs that differ from some other natural resource management issues; and (c) to provide a first step towards a possible more general framework covering other issues.

The paper has been written based on our experience in salinity management in southern Australia, where salinity is more manifest than in the less cleared and summer-dominant-rainfall areas of northern Australia. The logic should also apply in northern Australia, although we expect the emphasis will be more on prevention of salinity before it occurs.

Factors influencing the roles of alternatives for managing dryland salinity

The choice of response for addressing dryland salinity depend on a range of factors, including the types of assets that salinity affects, the hydrogeology, the value of the affected assets, and socio-economic considerations. These issues are briefly described in the following sub-sections as background to discussing the role and scope for different management and policy responses.

Types of impact

The main impacts of dryland salinity can be summarised as those on:

(i) *Agriculture through land salinisation.* Two million ha of agricultural land is affected by shallow water tables (Anon. 2002). The most serious problems are currently in Western Australia (WA) and to a lesser extent South Australia (SA) and Victoria, but increases are predicted in New South Wales (NSW) and Queensland (National Land and Water Resources Audit 2001).

(ii) *Water resources.* Dryland salinity will contribute to the future salinisation of currently fresh rivers, affecting the supply of irrigation and drinking water (National Land and Water Resources Audit 2001).

(iii) *Infrastructure.* Roads, communication infrastructure, pipelines and buildings are amongst the infrastructure assets affected. Rising water tables threaten a number of towns in WA, NSW and Victoria (National Land and Water Resources Audit, 2001).

(iv) *Vegetation and biodiversity.* Large areas of remnant vegetation and plantation forests are affected, with increases predicted in all states. In WA it has been estimated that 450 plant species are endemic to low-lying areas in salinity prone regions and are at risk of extinction (Keighery 2000). Aquatic biota are also affected by rising salinity (Kefford *et al.* 2003).

(v) *Flood risk.* Shallow water tables result in increased flood damage to roads, fences, dams, agricultural land and wetlands. Increased flood risks have been studied for only a small number of case studies (e.g., Bowman and Ruprecht 2000). With the predicted two- to four-fold increase in area of wheatbelt land in WA with shallow water tables, there will be at least a two-fold increase in peak flood flows (Richard George, *pers. comm.* 2000).

(vi) *Aesthetics.* Aesthetic changes occur as a result of all of the above impacts, affecting the sentiment of the broader community and raising political support for policy action.

Hydrogeology

The appropriate salinity investment depends on the responsiveness of groundwater to establishment of perennial vegetation, and this responsiveness depends on the gradient and the permeability or conductivity of the material through which water flows (gravel, sand, clay). These factors vary among different groundwater flow systems (GFSs).

Three categories of GFSs (local, intermediate and regional) have been classified (Coram *et al*. 2000) to indicate the broad spatial scale over which groundwaters flow. The different flow systems indicate the distances over which changes in agricultural land use may have off-site impacts, and have been used to suggest the scales over which such changes would need to occur to achieve long-term equilibrium in groundwater levels. We acknowledge that there are some limitations to the current GFS classifications, but they have been widely used and proved useful.

For local GFSs the estimated on-site responses are less than 10 years for cases where conductivities are low and 10-30 years for others. Off-site response times are approximately 20 years where conductivity is high and 50 years where conductivity is low. Note that the impact of low conductivity is different for on-site and off-site effects. For on-site effects, low conductivity enhances the ability of land-use changes to be effective locally, but it reduces their capacity to be effective at a distance. There is considerable potential for runoff reduction with planting of perennials on duplex soils and in steep areas within some GFS types, so careful targeting of plant-based solutions is required in these regions. These situations are likely to occur more in high rainfall regions of eastern Australia than in WA or SA. In locations with high rainfall and a local GFS, only very deep rooted perennials can use sufficient of the winter rainfall excess.

For intermediate and regional GFS responses, on-site responses can be rapid (<10 years) where conductivity is low. Off-site responses take considerably longer (e.g., 100 years or more). The response time has a major influence on the economic value of any off-site benefits. Other things being equal, the economic benefits of off-site salinity prevention resulting from establishment of perennials or engineering works will be higher (because they are more rapid) in local than in regional GFSs. For more background on related hyrdogeological issues, see Ridley and Pannell (2005).

Value of assets

In considering whether intervention to avert salinity impacts is justified, a key factor is the value of the assets at risk. Putting values on some salinity impacts is difficult because they include both market values (e.g., financial value of water resources to be used for irrigation and town water) and non-market values (e.g., non-financial value of irreversible loss of biodiversity, sometimes referred to as passive or non-use values).

For impacts on terrestrial assets, the values per hectare of land affected vary widely among the asset classes. Financial losses per hectare are greatest for impacts on infrastructure, due to high cost of repair or replacement. Non-financial losses per hectare are greatest for some environmental assets of outstanding significance. By comparison the potential losses (either financial or non-financial) per hectare of non-irrigated agricultural land are much smaller. The areas of land are very large, so the total value is high, but in considering investment in protection of particular pieces of land, the analysis needs to consider the values threatened on that land, not more generally. For protection of water resources, each case has a particular mixture of financial and non-financial values at stake.

Economic and social factors

The factors involved in adoption behaviour in response to natural resource management problems have been discussed by Guerin and Guerin (1994), Cary *et al.* (2002) and Ridley (2004). Pannell (2001b) reviewed the issues in the context of dryland salinity. At the farm level there are two main considerations:

(i) The perception by farmers of likely net-benefits from adopting new salinity-management options relative to existing land-use systems, including any on-site salinity-related benefits.
(ii) The capacity of farmers to incorporate new practices into the farming system. Factors affecting capacity include financial resources, labour resources and managerial resources.

The key factor affecting adoption by commercially-oriented farmers is their perceptions about on-site benefits (profitability of harvested products and the value of any local salinity benefits), which should outweigh the on-site costs (direct input costs as well as opportunity costs of activities displaced). Policy makers who make decisions about salinity intervention must additionally consider the off-site benefits (e.g., reduction in salinity) and costs (e.g., reductions in water volumes in rivers). The crucial importance of farm-level economics in adoption behaviour is underscored by studies showing that existing perennial plant-based options in most regions of southern Australia are either unprofitable or lack profitability on a scale that would generate more than localised benefits (Bathgate and Pannell 2002; Lefroy 2002; O'Connell and Young 2002; Abadi *et al.* 2003; Kingwell *et al.* 2003), and that the economics of engineering works are highly variable (Ferdowsian *et al.* 1997; John 2005).

Social issues also affect adoption of salinity management options. Over 16 million hectares of Australian land is managed by farmers with an estimated value of agricultural operations of less than $22,500 (Hooper *et al.* 2002). These small and "lifestyle" landowners manage a significant quantity of relatively high value, potentially highly productive land, usually in areas that are close to (perhaps within one hour's drive of) cities or larger towns that provide opportunities for employment. The states with the greatest numbers of small farms are Victoria and NSW (Barr *et al.* 2000), with more than a quarter of the agricultural land in Victoria being on small farms (Neil Barr, unpublished data, pers. comm. 2004). Many are in high rainfall areas (and therefore have the potential to influence significant amounts of freshwater runoff) in the Goulburn-Broken region and parts of the Upper Murray region in Victoria. There are also some significant areas close to regional centres within the NSW and ACT catchment areas of Murray and Murrumbidgee that have many non-commercial land managers (east of Albury and Wagga Wagga, and surrounding Canberra).

There are likely to be a number of differences in policy approach needed to effectively influence land managers whose main income is not from agriculture. As well as having different priorities and objectives, some have limited time and resources available for making major land-use changes. Others have limited interest and management capacity to do so. One implication is that management options would need to be low cost, low risk and low effort. There may need to be attention to providing incentives for land retirement, rather than only having emphasis on profitability. Beyond this, it seems possible that a different mix of incentives and penalties may be appropriate and in some cases no action may be most appropriate. Extension activities should also be targeted differently for this group of farmers (Hollier *et al.* 2003). Further investigation is needed to assess the components of this mix, particularly research on the likely responses of these land managers to the various policy instruments available to governments. Barr and Wilkinson (2005) discuss these issues further.

Management of dryland salinity in a policy context

In this section and the next, management and investment options are considered from the perspective of an idealised policy maker choosing among a suite of policy options and attempting to maximise community-wide net benefits. We realise that the concept of an idealised policy maker is an over-simplification, and that the process of policy formation is more complex than considered here, in part because a range of policy objectives can be sought. These issues are covered in more depth by Pannell (2005).

Circumstances are identified where it would or would not be logical for policies to promote uptake of existing management options, and situations where the best response would or would not include R&D to develop improved options. This perspective involves consideration of on-farm and off-farm issues, both positive and negative.

Policy makers have a number of choices on the policy 'menu' for investment that aims to manage salinity, either by influencing how landholders respond or by directly funding works. The full menu (Table 1), includes extension, incentives, penalties, engineering, plant-based R&D, other R&D, and no action. Further details of these options are discussed below.

Extension. This is usually the appropriate response where perennials are already economically competitive, although in some cases where they are competitive, penalties may be warranted to discourage adoption. Extension may also be appropriate in cases where farmers generally lack information or have mis-perceptions about the salinity problem or its management. This second type of extension is not specific to particular hydrological or economic circumstances.

Incentives and penalties. The choice between incentives and penalties is somewhat arbitrary. We have assumed that, where a policy instrument is used to change current land use or common farming practice, the instrument used would provide a positive economic incentive (e.g., a form of subsidy or compensation). This is the main mechanism by which policy would be used, for example, to promote adoption of existing plant-based options that have non-agricultural benefits but which are not sufficiently attractive to farmers to be adopted spontaneously. In contrast, a policy instrument used to prevent a change away from existing land use or common farming practice (e.g., to prevent the planting of trees where their off-site costs exceed their benefits, or to prevent the installation of deep open drains where this would generate excessive downstream environmental costs), would be based on a penalty (e.g., a regulation backed with fines, or a requirement to purchase a tradeable water right, a land-use zoning constraint).

The use of incentives or penalties, as opposed to one of the other policy approaches, is considered to be appropriate where there is "market failure" due to externalities (e.g., off-site impacts on other types of assets). The criteria for market failure require not just that there are externalities, but also that the overall benefits from changing the off-site impact would outweigh the costs (the net-benefit test). (i.e., the mere existence of a negative externality is not sufficient to ensure that there is market failure, if the costs of abating the externality are too great.) This is important for dryland salinity because analyses have found that the net-benefit test fails in many locations, often because the off-site (public) benefits are outweighed by the on-site (private) costs (e.g., Pannell *et al.* 2001; Dawes *et al.* 2002; Heaney *et al.* 2000) or because preservation of fresh-water flows, where they occur at high levels, tends to be more important than prevention of additions to groundwater (Heaney *et al.* 2000; Bathgate *et al.* 2004). The chances of failing the net-benefit test are greater where groundwater flow systems are regional or intermediate-scale (since hydrological response times are slow and required changes in land use would be large) and where the cost to land managers of changing their land use in the desired way would be high. A particular use of incentives that may be appropriate in some cases is to promote land retirement, where the costs of doing so are less than the alternatives, including do nothing. Where incentives are deemed appropriate there are commonly used in combination with extension, where the extension is targeted towards increasing the chances of establishment and persistence of the new plant-based system. Extension in such cases would be directed towards known management issues, such as fertiliser application and grazing management.

Table 1. Major policy response options for management of salinity.

Policy response	Explanation
Extension	Technology transfer, education, capacity building. This is relevant to promotion of existing plant-based options where they are attractive to land managers. It can include education of town residents where appropriate.
Incentives	Positive financial incentives to encourage a change of management. Examples include subsidies, market-based instruments and cost-sharing. This is relevant to promotion of existing plant-based systems for agriculture in some circumstances. It can also be used to encourage land retirement where appropriate.
Penalties	Negative incentives to discourage a practice or land use. For example, to require purchase of water rights, impose regulation on land use or on drainage installation. This is relevant to the discouragement of existing plant-based systems in some circumstances. It can include land use zoning for particular purposes, or government acquisition of land.
Engineering	Salt interception through pumping saline water to avoid discharge into rivers. This is an alternative or a supplement to plant-based systems. Local engineering works on-site to protect public assets where part or all of the salinity problem is generated locally, not from farm land (e.g., in many salt-affected towns). This category represents direct investment in public engineering works. Engineering for agricultural land is represented in other categories (extension, incentives, penalties or other R&D)
Plant-based R&D for profitable farming systems	Invest in development or improvement of technological options for salinity management, particularly plant-based R&D systems. The category may also include investment in infrastructure, market institutions, etc. to support profitable plant-based industries.
Other R&D	Research to provide information to support planning and decision making, such as remote sensing to pinpoint salt stores and research to measure the performance of existing management technologies (as distinct from developing new ones). Research into land retirement (e.g., into the speed and type of perennial revegetation that would occur naturally if land was removed from agriculture). Research into the performance and design of engineering options.
No action	No response is justified because the costs of intervention outweigh the benefits.

Acquisition of land can be justified where the administrative costs of providing incentives and/or enforcing regulation exceeds the costs of land acquisition and administration. These circumstances may arise in potable water supply catchments, or where the values of downstream biodiversity or irrigation water supply assets, (including the threat to dams from sedimentation, as was the case in the Snowy Mountains) are high.

We note that non-targeted incentives (e.g. taxation concessions) have influenced the adoption of woody perennials and led to resource-management benefits in some cases (e.g. lower salinity in the Kent River in Western Australia due to widespread commercial planting of *Eucalyptus globulus*). However our focus is on achieving cost-effective NRM improvements, so we do not consider such non-targeted approaches.

Engineering. Capital-intensive works such as groundwater pumping are only justified where a high value asset is under threat and it is judged that plant-based management options will not be cost-effective or will not act quickly enough to protect the asset. Two different versions of this response are included in our analysis: salt interception schemes to protect waterways (i.e. pumping of saline groundwaters that would have discharged into rivers, with disposal of effluent into evaporation basins) and localised engineering works (usually pumping) to protect terrestrial assets. We have narrowed down the circumstances where these approaches are most likely to be relevant (as explained in detail below), but have further qualified our recommendation with the phrase "if economic", since their economic performance is variable and case specific.

At the farm level, engineering is relevant to management of salinised land in some regions (deep open drains in the Upper South-East of SA and parts of the wheatbelt of WA). In cases where engineering has primarily on-site costs and benefits, it is arguably not a subject for government intervention, although government funds have been used in SA, and some farmer groups in WA are increasingly pushing for government to provide and fund infrastructure (large arterial drainage systems) to facilitate disposal of effluent from farm drains. Complicating this issue are concerns about possible downstream impacts. There is still considerable uncertainty about the extent and significance of these. Given the impetus behind some proposals for large drainage schemes, research to quantify likely downstream impacts appears a high priority.

Plant-based R&D into profitable farming systems. We suggest plant-based R&D for profitable farming systems to be the best option where there is not likely to be market failure from externalities, and where perennials are likely to generate worthwhile salinity benefits (without unduly compromising water yields) if the economics of their production could be turned around. Implicit in this recommendation is that there are worthwhile and as yet untapped opportunities for technology development (Ewing 2005; Pannell and Ewing 2005), or needs for investment in infrastructure or market development to support new industries based on perennial plants. Plant-based R&D can be a valuable strategy to supplement incentives in some cases. Even if it is not successful in producing economically competitive perennial land uses, such R&D has the potential to reduce the public cost of providing incentives in the medium term, by reducing the farm-level cost of converting to perennials.

Other R&D. This category includes all other relevant research.

No action. In situations where none of the other responses can be justified, due for example to expense, low effectiveness or a low salinity threat, "no action" becomes the best response.

Recommended policy responses for specific circumstances

The recommendations that follow are based on a mixture of research results, theory, rules of thumb, assumptions, judgements and logic. The recommendations are not 'hard-and-fast', but provide transparent arguments as a broad guide, a basis for further debate and for reconsidering salinity policy on a more sophisticated and realistic basis.

Recommended policy responses are shown for four sets of cases: recharge areas with salinity impacts on waterways (Table 2), recharge areas with salinity impacts on relatively small scale terrestrial assets (Table 3), recharge areas with salinity impacts on dispersed assets such as agricultural land (Table 4), and salt-affected agricultural land (Table 5). The suggested responses are different for different categories of assets at risk. Research to assist with planning of policy interventions (within "Other R&D") has an overarching role and is relevant to all scenarios in all four tables.

Responses for recharge areas with salinity impacts on waterways

There are four main factors driving the choice of policy approach to protect water resources:

(i) The potential input of salt from groundwaters into the waterway. This depends on recharge rates (dependent on soil texture and slope), salt stores in soil and salt concentration in groundwaters, all of which can be highly variable, even within a sub-catchment.

(ii) The responsiveness of groundwaters in potential discharge areas to establishment of new perennial vegetation in recharge areas. "Low" responsiveness equates to intermediate and regional GFSs and "High" responsiveness represents the more rapidly responding local flow systems or perhaps on-site effects in the cases of intermediate and regional GFSs.

(iii) Issues surrounding the importance of fresh runoff water. This includes both the level of use of the waterway for consumptive use and the volume of surface or near-surface flows of fresh water entering the waterway (dependent on soil texture, slope, vegetation type and rainfall).

(iv) Farm-level economics, particularly whether existing perennial plant-based options for reducing recharge on farm-land in the sub-catchment are more or less profitable than agriculture based on annual plants.

The most common recommended policy response in Table 2 is penalties or permits (e.g. tradable water rights) to limit loss of fresh runoff that would provide both dilution of salinity and a volume of flow. The Council of Australian Governments (COAG) has endorsed this approach through the National Water Initiative. States that have signed the Initiative (i.e., all except WA) will be required to address all forms of development that "intercept" water, including forestry, groundwater use, and on-farm dams. The policy options are regulation of land and water management (backed with penalties for non-compliance) or a requirement to purchase tradeable rights for the water that is intercepted. Historically, the most common form of strong government has been through acquisition of land, especially in catchments for city water supplies.

The high frequency of this response in Table 2 is not an indication that it applies to most land in water-resource catchments, only the high rainfall, upper parts where the majority of fresh water runoff is generated. Penalties are thus predominantly relevant to the upper catchments of North-East Victoria, Goulburn-Broken, Murray, and Murrumbidgee, which supply 70% of the divertable water resources of the Murray-Darling River system (Crabb 1997). This includes the small river valleys of the Ovens, Kiewa and Murray, which comprise 3% of the Murray-Darling Basin area but produce 38% of the total river flows (Vertessy 2001).

Detailed work at the paddock level has shown that soil type has a major influence on whether water is lost as deep drainage or as runoff (Ridley *et al.* 2003) and so would influence the categorisation of land into areas of high or low fresh runoff. Many high rainfall areas (greater than 700 mm per year) are currently being targeted for forestry development.

Where the potential input of salt from groundwaters is low and fresh runoff is low, no action is usually the most appropriate response from a waterways salinity management perspective. Where perennial plant-based options are more profitable than traditional agriculture, we suggest extension to promote the existing options, although this situation is not applicable to large areas. Salt interception schemes (where economic) are suggested where the salinity threat is high but groundwater responsiveness to revegetation is low.

Five categories have R&D for plant-based options as part of the recommended approach (cases 3, 5, 6, 11 and 12) to protect water resources. The strongest case for development of profitable plant-based options can be mounted for cases 5 and 6, where groundwater systems are responsive and runoff generation is low. Where runoff generation potential is high, and current options are unprofitable (case 3 in Table 2), case by case analysis is needed to assess whether applying penalties to discourage land use change or development of plant-based options to encourage it is the better option. Incentives for land retirement are likely to be more appropriate than development of profitable plant-based options in areas at risk of salinity where demographic trends suggest commercial agriculture is unlikely to remain a major economic activity. R&D into land retirement responses is also appropriate in a minority of such cases where the outcome of removing agriculture is unknown (e.g., the speed and perenniality of natural regrowth).

Cases 11 and 12 (low responsiveness to groundwater and low runoff potential) occupy the largest areas in cropping regions, for example the Riverine Plains in Victoria and NSW, much of the Mallee and the WA wheatbelt. The case for development of profitable plant-based options for these cases is less straightforward. The argument is that there are simply no responses other than plant-based R&D that could conceivably lead to perennial plant-based systems being established over wide areas in these regions. Plant-based R&D offers the prospect of generating salinity benefits in the long term (up to 100 years) at a cost that is low enough to justify the investment. The value of salinity-related benefits per hectare of perennials will certainly be low, due to the large areas required and the long time lags, but the only realistic alternative is "no action", inevitably resulting in major additions of saline groundwater to rivers in the long term. Where plant-based R&D is judged to be infeasible or unwarranted, an alternative for some downstream water users may be desalination.

Table 2. Suggested policy responses for recharge areas with salinity impacts on water resources (i.e. salinity in streams/rivers), including consideration of potential loss of flows.

Case no.	Potential input of salt from groundwaters	Groundwater response to vegetation[A]	Supply of fresh runoff	Farm-level economics of perennial plant-based options relative to existing land use	Policy response
1	High	High[A]	High	More profitable	Penalties[B, C] or extension[D]
2	High	High	High	Slightly less profitable	Penalties or incentives[D, E]
3	High	High	High	Much less profitable	Penalties, plant-based R&D[F] or incentives for retirement [D, G]
4	High	High	Low	More profitable	Extension
5	High	High	Low	Slightly less profitable	Profitable plant-based R&D or incentives[E]
6	High	High	Low	Much less profitable	Profitable plant-based R&D or incentives for land retirement[G]
7	High	Low[A]	High	More profitable	Not applicable[H]
8	High	Low	High	Slightly less profitable	Not applicable
9	High	Low	High	Much less profitable	Not applicable
10	High	Low	Low	More profitable	Extension + engineering if economic
11	High	Low	Low	Slightly less profitable	Profitable plant-based R&D + engineering if economic
12	High	Low	Low	Much less profitable	Profitable plant-based R&D + engineering if economic
13	Low	High	High	More profitable	Penalties
14	Low	High	High	Slightly less profitable	Penalties
15	Low	High	High	Much less profitable	Penalties
16	Low	High	Low	More profitable	Extension
17	Low	High	Low	Slightly less profitable	No action
18	Low	High	Low	Much less profitable	No action
19	Low	Low	High	More profitable	Not applicable
20	Low	Low	High	Slightly less profitable	Not applicable
21	Low	Low	High	Much less profitable	Not applicable
22	Low	Low	Low	More profitable	No action
23	Low	Low	Low	Slightly less profitable	No action
24	Low	Low	Low	Much less profitable	No action

[A] High responsiveness equates to local groundwater flow systems (GFSs), low responsiveness equates to intermediate and regional GFSs.
[B] Penalties would be applied to discourage conversion of annual or, in some cases, herbaceous perennial-based agriculture to higher water using systems (e.g., forestry). The penalty would reflect the loss of water values for downstream users.
[C] Preliminary analysis (Heaney *et al.* 2000, Bathgate *et al.* 2004) shows that preservation of fresh-water flows is more important than prevention of additions to groundwater.
[D] Whether penalties or extension applies requires analysis to determine net off-site effect of perennials.
[E] Incentives paid to establish/manage existing perennials if the net effect is positive.
[F] Plant-based R&D could be for profitability or land retirement, depending on the demographics.
[G] Analysis required to determine whether it is in society's interests to retire land from agriculture.
[H] Low responsiveness to groundwater and high fresh runoff are unlikely at the same location.

Incentives to grow existing plant-based options are only an appropriate response in cases 2 and 5 (high groundwater response, perennials slightly less profitable than annuals). This response would be appropriate for areas within the Great Dividing Range with local GFSs, in those parts of the landscape where the profit shortfall comparing perennials with annuals is less than the off-site benefits from perennials. In case 5, site-specific analysis would be needed to assess whether incentives, development of plant-based options or a mixture provides the greatest net benefit.

Responses on recharge areas with salinity impacts on terrestrial assets

Table 3 shows recommended policy responses for non-agricultural terrestrial assets threatened by salinity where impacts occur in relatively small, concentrated areas. The key drivers of the policy response are the value of the asset, the groundwater responsiveness, the urgency of the problem, and the farm-level economics of adopting perennial plants.

The main examples of non-agricultural terrestrial assets are physical infrastructure such as roads and buildings, and environmental assets, including important areas of native vegetation, probably in reserves. Rural towns contain some of the most threatened infrastructure. One of the features of many threatened rural towns is that their salinity problems are largely generated locally within the towns, through release of scheme water (e.g., from watering gardens) and poor management of storm water. These problems, which are among the most economically important impacts of salinity, are not amenable to the sort of policy responses that have traditionally been applied to dryland salinity (e.g., encouragement of revegetation on farms). Rather, their prevention would require on-site actions, particularly engineering works. Some actions may be relatively cheap (improved storm-water management) while others may be very expensive (groundwater pumping). In some cases better management of urban vegetation (less lawns, more trees) can provide partial solutions, or a means of extending the time to the need for other interventions. Analyses (Dames and Moore – NRM 2001) have demonstrated that the benefits and costs of these measures vary widely between cases, so careful economic analysis is required.

Engineering for on-site responses are suggested when the value of the threatened asset is high and the urgency of action is high. The more expensive engineering responses will only be economically justified in such cases, and even then only in a sub-set of them. Extension is recommended in all the scenarios where perennials are more profitable than annuals.

Incentives to grow existing plant-based options are only appropriate in two of the scenarios (cases 2 and 5) where the asset value is high, groundwater responsiveness is high and perennials are only slightly less profitable than annuals. In case 2, the problem is urgent, meaning that plant-based systems alone would not protect the asset in time, requiring on-site engineering works (if economically justified), potentially supplemented by incentives. If modest incentives are sufficient to achieve substantial land-use change in these sub-catchments, they may be justifiable, provided that the problem is caused by water from agricultural land rather than sources local to the threatened assets. In case 2, incentives to grow plant-based systems may allow cost-savings due to reductions in running costs of on-site engineering works in the long run. In case 5 where the situation is not urgent, analysis would be required to assess whether development of plant-based options, incentives or a mixture provided the most benefit.

R&D for development of new plant-based options is suggested for all remaining cases, apart from where the asset value is low and groundwaters are unresponsive when no specific action is suggested. The low value, unresponsive categories are relevant to much of the agricultural areas, and thus for most land, no specific action will be justified to protect terrestrial assets.

Where the value of the asset is high, the response to groundwater under the asset is low and urgency is low (cases 11 and 12), the rationale for recommending development of plant-based solutions is similar to cases 11 and 12 in Table 2. We recognise that the economic value of off-site benefits from revegetation will be low in many cases, due to the scale of perennial vegetation needed to be effective and the time lags involved. However, the cost of successful plant-based R&D per hectare of perennials established is also low. It can be adopted and have impacts over very large areas, eventually resulting in worthwhile public benefits in cases where farms are contributing to off-site salinity. Although the salinity-related benefits from technology development for assets in this category are likely to be modest, they are benefits that are not efficiently attainable by any other means. Further, ‘successful’ R&D in this context means that the development results in solutions that are more profitable than current farming practices, resulting in economic benefits to farmers. Of course, in cases where perennials on farms would have no impact on the assets, or where opportunities for development of plant-based solutions do not exist or are too expensive, the recommendations would revert to "no action", at least with regard to salinity.

Table 3. Suggested policy responses for recharge areas with salinity impacts on terrestrial assets (infrastructure and biodiversity).

Case no.	Value of asset under threat	Response of ground-water under asset to vegetation on farms	Urgency	Farm-level economics of perennial plant-based options relative to annuals	Policy response
1	High	High	High	More profitable	Engineering (on site responses) if economic + extension
2	High	High	High	Slightly less profitable	Engineering (on site responses) if economic + incentives
3	High	High	High	Much less profitable	Engineering (on site responses) if economic + plant-based R&D or incentives for land retirement
4	High	High	Low	More profitable	Extension
5	High	High	Low	Slightly less profitable	Incentives + plant-based R&D
6	High	High	Low	Much less profitable	Plant-based R&D
7	High	Low	High	More profitable	Engineering (on site responses) if economic
8	High	Low	High	Slightly less profitable	Engineering (on site responses) if economic
9	High	Low	High	Much less profitable	Engineering (on site responses) if economic
10	High	Low	Low	More profitable	Extension
11	High	Low	Low	Slightly less profitable	Plant-based R&D or no action
12	High	Low	Low	Much less profitable	Plant-based R&D or no action
13	Low	High	High	More profitable	Extension
14	Low	High	High	Slightly less profitable	Plant-based R&D
15	Low	High	High	Much less profitable	Plant-based R&D
16	Low	High	Low	More profitable	Extension
17	Low	High	Low	Slightly less profitable	Plant-based R&D or no action
18	Low	High	Low	Much less profitable	Plant-based R&D or no action
19	Low	Low	High	More profitable	Extension
20	Low	Low	High	Slightly less profitable	No action
21	Low	Low	High	Much less profitable	No action
22	Low	Low	Low	More profitable	Extension
23	Low	Low	Low	Slightly less profitable	No action
24	Low	Low	Low	Much less profitable	No action

It is possible that land may not remain in one category, as groundwaters rise or technological progress occurs. For example, in the longer term, the situation for an asset may become urgent, potentially justifying on-site engineering responses that were not previously appropriate.

Responses for agricultural land and other dispersed assets threatened by salinity

In contrast to the salinity impacts in relatively small, concentrated areas referred to in Table 3, Table 4 refers to more dispersed effects of salinity and shallow water tables, including impacts on agricultural land, on remnant areas of native vegetation on farms, and on flood risk. The common feature of these impacts is that, relative to some of the scenarios in Tables 2 and 3, there are low benefits per hectare from establishing perennials to prevent salinity. For agricultural land, this is partly because even highly productive agricultural land is not comparable in value per hectare to expensive public infrastructure; all agricultural land would be rated “low” using the value scale in Table 3. For flood risk, the reason is that the establishment of perennials on any given hectare of agricultural land makes only a tiny contribution to flood prevention. For protection of remnant native vegetation the reason is that many small remnants would be of lower conservation value than larger reserves, either due to small size or to environmental deterioration. (When that is not the case, the remnant would be considered within Table 3 rather than Table 4.)

Table 4. Suggested policy responses for recharge areas on agricultural land that is contributing significantly to salinity on dispersed assets, including agricultural land, flood risk, and remnant native vegetation on farms.

Case no.	Response of groundwater to vegetation[A]	Farm level economics of perennial-based options relative to annuals	Policy response
1	High[A]	Profitable	Extension
2	High	Slightly less profitable	Technology development
3	High	Much less profitable	Technology development
4	Low[A]	Profitable	Extension
5	Low	Slightly less profitable	Technology development
6	Low	Much less profitable	No action or technology development

[A] High responsiveness to groundwater equates to local groundwater flow systems whereas low responsiveness equates to intermediate and regional systems.

In aggregate, the impacts represented in Table 4 would be very large indeed, but the key point is that the contribution *per hectare of perennial plants established* to reduce those impacts would be small (Bathgate and Pannell 2002). This rules out incentives or penalties as defensible methods of promoting land use change. They may be successful in promoting change, but to do so they would need to be so large that they would cost more than the modest benefits generated. A similarly adverse assessment would apply to the option of government directly funding engineering works to protect dispersed assets such as farmland, because the cost would be excessive. In addition, in the case of farmland such an approach creates concerns about the appropriateness of government funding works on private land for private gain.

Given these conclusions, the policy response in Table 4 is simple. For protection of this category of assets, where commercial farms have perennial plant options that are economically competitive with annuals but have not yet been adopted, the main policy tool should be extension. Where current plant-based solutions are not profitable, plant-based R&D should be undertaken to attempt to develop better options. “No action” may be relevant if the expected outcomes from plant-based R&D are not sufficiently positive.

The prescription applies regardless of the responsiveness of the GFS and so regardless of whether the benefits of planting perennials are highly localised or broader reaching. It is relevant to any farm land that is at risk of becoming salt-affected but which will not have gone saline by the time profitable perennials for recharge areas would become available. If recharge areas will be converted to discharge areas too soon for appropriate new options to be developed, the response should be no action in the short term, and one of the responses in Table 5 once the land becomes saline.

Table 5. Suggested policy responses for salt-affected agricultural land.

No	Downstream impact from management of salt land or water	Economic performance of existing management options for salt-land or salt water	Policy response
1	Positive	Positive	Extension
2	Positive	Slightly negative	Incentives + plant-based or engineering R&D
3	Positive	Negative	Plant-based or engineering R&D or incentives for land retirement
4	Neutral	Positive	Extension
5	Neutral	Slightly negative	Plant-based or engineering R&D
6	Neutral	Negative	Plant-based or engineering R&D
7	Negative	Positive	Penalties
8	Negative	Slightly negative	Penalties (or no action if no adoption)
9	Negative	Negative	Penalties (or no action if no adoption)

Responses for salt-affected land

Table 5 refers to land that is currently salt-affected. The two factors driving the recommended policies are the downstream impacts and the on-site economics. It is believed that revegetation of saltland can generate downstream benefits from improved water quality (salinity, sediment and nutrients), reduced flood risk and potentially provision of habitat for biodiversity but quantitative evidence is currently lacking. Deep open drains that are popular among some farmers in WA and SA may have negative downstream impacts due to the disposal of sediment and saline effluent in waterways, potentially contaminated with acidity and heavy metals in some cases. They may also worsen downstream flood risk by concentrating flows into a shorter period of time, although there are also suggestions that they may reduce flood risk. Again, quantitative evidence is lacking, either way. Surface water control (shallow drainage) is also relevant in many salt-affected areas where salinity and water-logging interact.

We suggest that where downstream impacts of drains are positive or neutral, the policy approach should be broadly similar to that in Table 4; that is, extension where the management options are profitable, development of new options (plant-based or engineering) where they are not. In this case, of course, the plant-based options would be based on productive salt-tolerant species. There may be cases where treatment of saltland would have downstream impacts that are sufficiently positive and on-site costs that are sufficiently low to justify payment of incentives, but this needs further analysis. Where a practice that is being adopted has downstream impacts that are sufficiently negative, penalties (e.g., a regulatory approach) may be justified.

Discussion of the role of plant-based systems and plant-based R&D

The role for existing plant-based options in managing dryland salinity in our framework is somewhat different to the traditional view, so some discussion of the differences is warranted. Plant-based systems are represented in Tables 2 to 5 by three policy options: *extension* in cases where profitable plant-based systems already exist, *incentives* in cases where off-site benefits from perennials exceed the on-site costs (including opportunity costs from foregoing production of annuals) and *penalties* where plant-based systems have adverse impacts on non-agricultural values, particularly reduced water yields in waterways.

Overall, it is rarely possible to justify intervening to force or provide incentives for adoption of perennials for salinity benefits alone. The time lags are so long and the required scales of planting are so high that the present value of salinity benefits per hectare of new perennials is generally small. This is true for all regional and intermediate GFSs and some of the local systems. If we want to do something about salinity in these catchments, the most realistic policy option is to invest in plant-based R&D, meaning the development of new and improved types of plants, plant-based systems and industries that are more economically attractive to landholders (e.g. House of Representatives Standing Committee on Science and Innovation 2004). This approach applies to the largest area of land, by far.

Plant-based R&D is not as direct an instrument as other policy options. It is unrealistic to expect that ideal plant-based options will be created for all of the categories where plant-based R&D has been recommended. The R&D that delivers benefits may not even have been targeted at the particular category it ends up addressing. It may be best to think of plant-based R&D as a process of attempting to create opportunities for the community to benefit in a variety of ways: environmental, economic and social. Salinity-related benefits would come as part of a package of outcomes, and they may not even be the most substantial of the benefits that result. Indeed, they probably will not be. Nevertheless, plant-based R&D remains the approach that is by far the most likely to generate broad-scale benefits from salinity management.

Testing the framework

We are currently in the process of testing the application of the SIF3 framework with two regional NRM bodies: the North Central Catchment Management Authority (NCCMA) in Victoria, and the South Coast Regionional Implementation Planning Team in Western Australia. Our work with NCCMA is most advanced. It has so far involved presentations to their board, management and advisory committees, identification of assets to be analysed using SIF3, collection of relevant data for the analysis, visits by the researchers to the assets (including discussions with local community members, local experts and CMA staff and board members), and identification of refinements needed to the framework. The aims and logic of SIF3 has been explained. In addition we have been assessing the skills and capacities needed by the CMA to successfully apply a framework like SIF3. We appreciate that it makes considerable demands on those who seek to apply it, and that it needs to be simple enough to be practically usable. In addition to our work with the regional NRM bodies, we have presented the framework to various policy forums in Western Australia, Victoria and nationally.

Insights obtained from this work so far have included the following:

- People appreciate that the issue is complex, that there are new research findings that need to be accommodated, and that the SIF3 framework provides a logical tool. In most environments, it has been accepted very positively.
- There is a need for more sophistication in the choice of sites for investment of public funds.
- There is currently no analysis underlying the choice of policy instruments. The great majority of salinity program funds within the NCCMA region are spent within our “extension” category. SIF3 would indicate that this is an excessive emphasis on extension, particular given the limited availability of adoptable technologies for salinity management.
- Dealing well with transaction costs when recommending policy tools is a challenge.
- There are a number of areas where the CMA needs improved capacity in order to independently apply such a framework.
- The CMA is very receptive to assistance to improve its salinity investments.

The current project concludes in July 2007. We hope that it will have an influence on the shape of the next phase of salinity policy, and will prove useful to regional bodies throughout Australia.

Conclusion

Choices about the most appropriate government response to salinity should be sensitive to the hydrological and socio-economic conditions and to the types of assets under threat. Where the main aim of salinity management is to reduce impacts on water resources, the logical approach in some upper catchment areas is for penalties or permits to prevent loss of fresh water runoff entering waterways. There are few cases where providing incentives to grow existing plant-based options is the most appropriate response. Investment into plant-based R&D is justified in several cases, particularly where groundwater systems are responsive and the potential for runoff generation is low. In a minority of locations, salt interception schemes are technically and economically feasible.

For protection of high value, non-agricultural terrestrial assets (infrastructure and biodiversity), each of the policy approaches is relevant in some circumstances, although the role for incentives is very limited. Engineering (subject to economic analysis) may be appropriate when the value of the asset is high and the urgency for action is high. Plant-based R&D is relevant in a number of situations, particularly where the asset value is high but the urgency is low. It is justified on the basis of reducing the public cost per hectare of treatment.

Compared with infrastructure and biodiversity, agricultural land is generally of low relative value. Where profitable perennial options exist, extension is the main tool. More commonly, where current plant-based options are not sufficiently profitable, R&D to develop improved options should be undertaken.

Where land is already salt-affected, development of plant-based or engineering options is justified where the downstream impacts are positive or neutral and where profitable options are lacking. (Development of new options could potentially be justified even if downstream costs were expected, provided that on-site benefits were expected to be sufficiently large.) A choice between penalties and no action applies where the downstream impact of managing salt-land is sufficiently negative.

Investment in profitable plant-based options remains an important management option to maintain water quality in rivers in the long term, and it still has an important contribution to make to the protection of land and other assets. There are three main plant-based management strategies that remain important in particular situations: (1) to reduce or delay saline discharge with existing plant-based options; (2) to make productive use of salt-affected land; and (3) to develop new perennial and/or salt-tolerant species and systems (using plant-based R&D) that are economically competitive with annual plant-based options. The third strategy, in particular, has a crucial role in achieving salinity management over much larger areas than will be possible with current perennial plant options.

The study has a number of implications for government, R&D corporations, and catchment management organisations. It provides a pathway to more cost-effective and scientifically defensible investments in management of dryland salinity by providing guidance on the broad categories of policy measures that are appropriate in different circumstances. It highlights the need to policy investments to be highly sensitive to case-specific circumstances, and well informed by science. It implies that there should be a number of shifts in emphasis in the funding directions of the existing policy program, most notably less emphasis on incentives and extension, and more on plant-based R&D. It confirms the appropriateness of the attention that has recently been given to engineering and permit-based approaches. Given that two of the more prominent policy responses in our recommendations are plant-based R&D and penalties, and that these are likely to be best considered, managed and implemented at scales greater than existing regional bodies, the degree of emphasis on regional decision making in the existing program should also be reconsidered.

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