INNOVATIONS IN SALINITY MANAGEMENT IN AUSTRALIA

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ABSTRACT

The uniquely Australian phenomenon of dryland salinity is a long term threat to the water resources and other values and assets in the Murray-Darling Basin. In this paper, the magnitude and cause of salinity is described, and the recent and current public policies to address it. Dryland salinity presents many challenges to catchment communities, farming industries, governments and landholders. Controlling it at a level that protects natural resources for continued use, while limiting environment damage, is beyond the land management measures available today. To address the hydrological imbalance that has resulted from the clearing of native vegetation after European settlement, there is a focus on the innovation, research, development and adoption of new land use options that can mimic the highly efficient water use of the original vegetation while giving sufficient profit to the land holder.

The second half of this paper outlines the innovation necessary to deal adequately with all facets of salinity management, including new and novel farming and reforestation systems. It describes briefly some successes to date.

SALINITY IN THE AUSTRALIAN CONTEXT

Soil salinisation under irrigated agriculture, leading to declining productivity and eventually the demise to that form of farming, is widely experienced around the world and well documented. Ancient civilisations have suffered at the hands of irrigation salinity, and today in countries such as Pakistan, large areas are laid bare by sodic and salinised soils.

However, salinity in Australia is of a different sort – dryland salinity. While this nation too has faced threats of irrigation induced salinity, it is the 'dryland form' that represents the greatest threat to farm land, water supplies, regional and urban infrastructure and biodiversity. To understand the origins and cause of dryland salinity requires an appreciation of the unique bio-physical features of the Australian continent. But more of that later.

Occurrence, Extent and Costs of Salinity

Meanwhile, to put dryland salinity in perspective, Table 1 summarises its projected impacts on natural values and built assets for the Nation. In many cases, the area or length of assets damaged will treble in 50 years. In Western Australia, where the salinity threat is most severe, land area with high potential to develop dryland salinity is 40 per cent of agricultural land, 450 plant species are possibly subject to extinction and fauna species could be reduced by 30 per cent (National Land and Water Resources Audit, 2001).

For the Murray-Darling Basin (Figure 1), a "salinity audit" was done in 1999, using best available data and modelling techniques for predicting rise of saline groundwater to the land surface. Here the major threat is to water resources, which are highly developed for irrigation and other uses. Under a "business as usual" scenario, salt mobilisation to the Murray, Darling and tributary rivers, either via direct groundwater intrusion to streamflows or by washing salt off affected land, will raise salinity to such levels by 2050 or 2100 that key tributaries will no longer be available for such use (Table 2). The Loddon, Macquarie, Castlereagh, Namoi and Condamine-Balonne rivers are important water resources and will exceed the 800EC threshold for desirability of drinking water within 50 years. Some will exceed 1500 EC in 100 years, at which point irrigation use is heavily compromised and environmental damage occurs (Murray-Darling Basin Ministerial Council, 1999). Further, River Murray water at the key monitoring site near Morgan in South Australia, and upstream of the diversions to the City of Adelaide, will exceed the 800 EC standard for drinking water for 40 percent of the time, within 50 years. This potential impact has galvanised public interest in South Australia, on the salinity problem.

The Murray-Darling Basin Commission maintains a close watch on river salinity levels and regularly estimates the costs of salinity. At today's levels, which are not a hazard and are much improved from the 1970s, the cost of river salinity to River Murray water uses is about $AU46 million per year, largely in necessary upgrading and adaptation of irrigation application technology and urban plumbing. Should salinity start to rise then for every EC Unit, these costs increase by an average $140,000/year. Elsewhere, in the Basin, the costs of dryland salinity have been estimated for local government authorities and their infrastructure residents and services. These costs are summarised in Table 3. Although the major costs in these eight priority catchments in the Murray-Darling Basin are borne by farmers, there are significant costs to households and utilities.

Compared to some other forms of land degradation, for example soil acidity, or environmental threats such as weeds, the cost of the salinity threat measured in these ways is modest. However, the current cost analysis doesn't factor in two key future costs – the irreversible loss of consumptive use of water resources, and ecological damage, including loss of species and ecosystems.

While all parts of Australia threatened by dryland salinity are involved in policy and strategic responses, the Murray-Darling Basin stands apart in its salinity risk profile because the long term threat to its water supplies is inextricably linked to resource security of 75 per cent of the Nation's irrigated agriculture and 10 per cent of its population.

Understanding the Cause of Dryland Salinity

Australia is an ancient, largely arid continent that has been accumulating salt from sea winds, weathering of bed rock, and retreating oceans over geological time. The dominant perennial vegetation, with its extensive root systems, has evolved to make full use of available water in soils of extremely low fertility. Over the vast areas where salinity is now the greatest risk, typically a zone bounded by the 500 to 800 mm annual rainfall isohyets, native vegetation minimised the amount of water that percolates through the root zone, to an average of one to five millimetres per year. At such low rates of deep drainage, there has not been sufficient flushing of salts brought with this rain or from rock weathering, with their accumulation over 'geological time' reaching several thousand tonnes per hectare. In effect, the extremely high water use efficiency of perennial native vegetation maintained a hydrological equilibrium – low rates of input and output of water and salt, with groundwater levels deep in the landscape (Williams and Goss, 2002).

European settlement disturbed this equilibrium in a dramatic way. Large-scale clearing of native vegetation and its replacement in annual crop and pasture plants has increased the amount of water entering groundwater systems. This leakage has increased to 15 to 150mm per year, depending on rainfall zone. This greatly exceeds the natural capacity of groundwater systems to discharge the additional water to streams and rivers causing the water tables to rise, bringing with them mobilised salt. Eventually highly saline groundwater reaches the lower parts of the land surface, with lateral flow to streams and rainfall washing salt off discharge areas to the streams (Williams and Goss, 2002).

While to the Australian visitor this process may be seen as a benign variant of irrigation induced salinity, dryland salinity is much less amenable to management and control. The time lag between the change in land use that sets the process going and observed impacts on the land surface may range from 30 to 200 years. Given the geographic scale of Australia's groundwater systems, it is arguably one of the most diffuse forms of land pollution, where it is commonly impossible to attribute impacts at one location to actions at another.

Dryland Salinity in the Murray-Darling Basin

For the Murray-Darling Basin, there are unique aspects of dryland salinity, differentiating its expression from the rest of Australia. The Basin is particularly flat, comprising two sedimentary groundwater basins and a mature river system, for which there is a very small outlet to the sea and very low energy in river flow. In this virtually 'blind' Basin, sediments, nutrients and salts are mobilised in upland catchments and largely re-stored on the floodplains; less than 40 per cent reaches the sea. The sedimentary rocks offer little water storage, so it is inevitable that increases in recharge under European farming systems lead to inexorable rises in saline groundwater (Evans et al, 1990).

It is the expression of salinity at the land surface that damages farm land, regional and urban infrastructure, and terrestrial biodiversity. Seepage of groundwater to rivers and washed salts increase river salinity, threatening consumptive use and damaging riparian habitat.

STRATEGIC RESPONSE TO SALINITY

Surprisingly, the first observation in Australia that the clearing of native vegetation was associated with a delayed outset of dryland salinity was made in the late 19th century. It was 1924 when the first scientific article was published by an engineer, W.E. Wood (1924). In these instances in Western Australia, the concern was with salinisation of surface water supplies at railway sidings in the age of steam. From the 1930s to the 1960s, an era of rapid farm development in Western Australia, there were instances where land releases did not proceed because shallow, saline groundwater was present (Bennett and McPherson, 2000).

It is from the 1970s that a national response to the dryland salinity threat has developed, initially in response to damage to farm land – in dryland agricultural zones, and in irrigation areas of the Murray-Darling Basin.

Again in Western Australia, the earliest response was to research methods for establishing salt tolerant forage species on salt-affected land with no thought for preventing further salinity through clearing controls. However, in 1976 in a politically charged decision, the State Government of the day declared a clearing moratorium in five water supply catchments, and paid farmers compensation for the loss of 'property right'. By the 1980s, clearing controls had been introduced across southern Australia, although by this time, typically 90 per cent of the land had been cleared and the hydrological disequilibrium was well under way. It is only in recent years that the northern states of the Murray-Darling Basin have introduced clearing control policies, with associated vegetation management incentives, and even then allowable clearing has continued.

Also, from the 1970s, a unique 'environmental repair' social movement has grown called Landcare, characterised by local community action groups and supported by Federal and State Governments grant funding, and effective national leadership, it has focussed on revegetation and tree planting in response to the salinity threat, although not at the exclusion of other natural resource issues. Landcare, and its variants – Bushcare, Coastcare, Rivercare, is an Australian phenomenon that has diffused to other countries. By the 1990s – the Decade of Landcare – there were thousands of local action groups, with regional coordinating bodies, and a participation rate of 30-40 per cent farmers Campbell, ...).

The irony of continued clearing of native vegetation under government vegetation management policies, and a publicity funded, voluntary social movement re-establishing more than a billion trees at the same time, has not gone un-noticed by the conservation movement. And, there is a harsh message. Despite this extraordinary community effort, it is not at a scale sufficient to limit or reverse salinity.

In the irrigation areas of the southern Murray-Darling Basin, rising salinity induced by excess water application, elevated groundwater levels, and evaporation at the soil surface, was affecting about 96,000 ha by 1987. A total of 559,000 ha out of the 1.5 million ha irrigated had elevated water tables within the dangerous range of 0-2 metres depth. Again, under 'business as usual' this would have risen to 869,000 ha by 2015 (Murray-Darling Basin Council, 1999).

<u>Salinity and Drainage Strategy 1988</u>

The policy response to irrigation salinity was more decisive and more immediate than for dryland salinity. The State governments with the Federal Government agreed to a *Salinity and Drainage Strategy* in 1988 (Murray-Darling Basin Ministerial Council, 1989), which proved to be both innovative and effective. Under the Strategy, land drainage and more efficient water application has reversed the salinity threat. Today water tables are falling in some irrigation areas. At the same time the saline effluent from sub-surface drains and groundwater pumping has either been disposed in evaporation basins, or where it has flowed to the rivers, the governments have funded jointly large-scale groundwater pumping to intercept other saline groundwater flows before they reach the river, under the coordinated management of the Murray-Darling Basin Commission. These salt interception schemes combined with revised river operations to provide dilution flows in the period of high salinity, have significantly lowered River Murray salinity. At the key monitoring site near Morgan, South Australia, the exceedence of 800EC was 42 per cent of the time prior to 1987, and this has been reduced to 8 per cent of the time over the six years to 1998 (Murray-Darling Basin Ministerial Council, 1999).

The *Salinity and Drainage Strategy* was unique and innovative for its time. It had the following characteristics:

- Government funding assistance and coordination of land drainage and rehabilitation under irrigation 'land and water management plans' that established the basis for sound investment, monitoring and reporting
- Revision of the operating rules for the River Murray and Lower Darling River, in the hands of the Murray-Darling Basin Commission, to provide additional dilution flow to the lower river
- Government funding and Commission management of salt interception bores to keep natural and induced saline groundwater flows away from the rivers
- All actions with significant beneficial or detrimental impacts on the rivers, are assigned credits and debits respectively, and placed on a Commission administered register, with the responsible governments and keeping their part of the register in balance.

In meeting their accountability requirements, the States have gone further with measures such as zoning areas for salinity impact and directing new development away from high impact zones.

National Action Plan for Salinity and Water Quality 2000

In 2000, the Council of Australian Governments decided on a nationally coordinated program for salinity management – the National Action Plan for Salinity and Water Quality (NAPSWQ). This Plan did not occur in a policy vacuum; the States had responded to dryland salinity with strategies, public funding and institutional change over 25 years. The NAPSWQ was an initiative of the Prime Minister responding to the Murray-Darling Basin salinity audit published in 1999, that predicted the loss of consumptive water use from several rivers over 50-100 years, and a report to the Prime Minister's Science, Engineering and Innovation Council, recommending that he take such leadership (PMSEIC, 1998).

The NAPSWQ has adopted a 'regional delivery model' for salinity management. Twenty priority regions have been identified nationally, nine in the Murray-Darling Basin, for targeted investment of Federal and State funds under bilateral agreements. A community-based board or statutory authority for each region, defined on a catchment basis, is assisted to revise or develop its catchment plan with a focus on salinity and water quality. Once the plan is accredited, funds flow to implement it, with revegetation a cornerstone of the planned actions. An anticipated $AUS1.4 billion will be invested over seven years.

Under the NAPSWQ, other policy reforms are also being pursued – effective clearing controls in Queensland and New South Wales, and enhancement of water trading for irrigation areas to facilitate high value and more efficient water use (Council of Australian Governments, 2000).

***Basin Salinity Management Strategy* 2001**

For the Murray-Darling Basin, the strategic response is the *Basin Salinity Management Strategy 2001-2015* (Murray-Darling Basin Ministerial Council, 2001). This Strategy succeeds and builds on the *Salinity and Drainage Strategy* of 1988, preserving the benefits achieved on irrigation lands and in the River Murray, with actions to address dryland salinity and to protect values in the tributary catchments. It has a 15 year Basin target – to maintain water quality in the lower River Murray at 800EC for 95 per cent of the time.

At the core of the new Strategy, are principles of State accountability for off-setting salinity impacts of all developments authorised since 1988, and Governments sharing responsibility for 'capping' the salt leaving all tributaries, most of which had its origins in land use change since European settlement in 1788. For every tributary catchment there is an 'end-of-valley' target for river salinity; limiting the salt load and concentration in the year 2015 at a level higher than today. The target is worked out through a community engagement process, supported by science and modelling, such that it gives sufficient 'signal' within the catchment to drive investment to protect agreed values and assets, while sharing the effort with other catchments to limit downstream salinity (Figure 2).

While this system is complex enough, the challenge of extending the salinity credits/debits scheme of the *Salinity and Drainage Strategy*, from the relatively certain impacts of engineering works to the uncertain and time delayed impacts of catchment management actions, is daunting. Under the new Strategy, there are two salinity registers – Register A to continue the State accountability arrangements of the *Salinity and Drainage Strategy*, and Register B where catchment and land management actions are credited. However, with continued increase in salt leaving tributary catchments up to their 2015 river salinity targets, it is obvious that Register B actions are not adequately off-setting the legacy of dryland salinity and the lower Murray salinity cannot be maintained at today's levels of 800EC for 95 per cent of the time, by these means alone.

The short term answer is to further expand the downstream salt interception works program, earning salinity credits at such a rate that half are quarantined to off-setting the legacy of history, and only half used on Register A for States to off-set new developments. The States and Federal Government have agreed to bolstering Register B in this way for seven years and to shared responsibility for keeping their parts of Registers A and B in balance, while land and catchment management actions take affect.

In effect, the Basin Salinity and Management Strategy is trialling a 'tradeable pollution rights' approach to a diffuse source problem. Realistically, for the time being, salinity credits on Register B will only have a value in the hands of the participating governments, on behalf of their catchment communities. While there is interest in investing and trading such credits, it will take the 15 year life of the Strategy to establish the pre-conditions for such market behaviour. Each State with the Commission is developing its predictive modelling to estimate the impact of large-scale catchment actions in terms of river salinity and their contributions to end-of-valley targets. The Commission will establish an independent audit process for assigning and reviewing credits and debits on the registers.

In summary, by combining the proven *Salinity and Drainage Strategy* and salinity Register A with the new *Basin Salinity Management Strategy* incorporating dryland salinity credits and debits on Register B, the participating governments through the Murray-Darling Basin Commission are setting out to operationalise a diffuse source tradeable pollution rights scheme as large as any attempted elsewhere. The *Basin Salinity Management Strategy* has set a new benchmark for salinity strategies nationally and may prove to be highly innovative in time.

However, the Strategy is more than an accountability arrangement and a potential salinity credits trading scheme. Its objectives are to maintain the current improved river salinity in the Lower Murray, cap the future salinity in the tributary rivers, and protect highly valued farm land, regional and urban infrastructure and terrestrial and riverine biodiversity from further damage. From an understanding of the causes of dryland salinity and its expression in the river systems, the options for control and management are dilution flows, salt interception works, reforestation and vegetation management, new and novel farming systems, and where salt impacts are occurring, new production systems with 'salt as a resource'. With limited scope for further dilution flows, and escalating costs of salinity benefits from salt interception works, the priority focus is on development of farming and forestry systems that can mimic the high water use and low recharge rates of native vegetation.

We know from a comprehensive research review that there are very few current farming systems and rainfall zones where such a water use standard can be achieved, even if fully adopted at the best practice level (Walker et al, 1999). While there are farm forestry options available now and re-establishment of native perennial plants is a proven practice, neither can generate sufficient net income to displace current unsustainable farm enterprises. The obvious conclusion is to invest in research and development of farming systems that can meet the twin objectives of sufficient reduction in recharge and returning satisfactory profitability.

This is not as easy as it sounds. Annual crops and pastures while efficiently converting the in-season rainfall into product, can't cope with extremely wet events or out of season rainfall. Introduced perennial plants while having the rooting systems to more effectively exploit moisture in the soil profile, cannot cope with the highly variable and arid Australia climate (without irrigation) and native species put most energy into survival not potentially commercial products. Forestry meets both criteria in the small part of the Basin with more than 900mm rainfall and little salt, but does not provide adequate returns to investors in the 'salinity target zone' of 500 to 800mm rainfall due to lower yields.

For the *Basin Salinity Management Strategy* to achieve its objectives, for the governments of the Basin to meet their targets in 2015, and for the 100-year 'business as usual' scenario in the Basin salinity audit to be avoided, requires upwards of three million hectares to be re-established to deep-rooted perennial plants targeted on salinity mitigation. The Strategy advocates development and adoption of forestry outside its traditional zone, re-vegetation and vegetation management, and research and development of novel farming system that meet the criteria above. In effect, it calls for a "revolution in land use" and is to be supported by cutting-edge innovation in research and on farms (Stirzaker et al, 2000). These emerging land use options are to be integrated with the continuation of conventional farming systems on land most suited to high returns and improved water use.

There is another catch to this Strategy's dependence on reforestation however. When land was cleared of native vegetation and farmed, the surface water runoff increased along with groundwater recharge. This increased stream flow has long since been captured in the allocation and diversion of water to consumptive use. However, River Murray water resources are considered over-allocated today, and substantial returns to environmental flow are under negotiation. Therefore, it goes without saying that the reversal of land use to forestry or re-vegetation, for purposes of salinity control, comes at a cost to surface water resources. On land re-established to trees the runoff may be reduced by about 20 per cent. In the short to medium term, the salinity concentration in rivers may actually rise due to less dilution flow, before salt mobilisation is slowed sufficiently by the lowering of groundwater levels (Vertessy et al, 2002).

These trade-offs in commercial returns and in surface water security, for delayed benefits in salinity control, are not a reason to abandon reforestation. The Strategy will surely fail without it. Another key part of the Strategy is to direct more sustainable farming and forestry systems to land "fit for that purpose". This can be done through the catchment management planning processes supported by the NAPSWQ, provided they have the necessary knowledge on land sustainability, catchment hydrology and location of stored salt. New technologies are being developed and applied in this regard.

From this treatment of the challenges facing dryland salinity management in the Murray-Darling Basin, it is a truism to state that further innovation is a necessary component.

INNOVATIONS IN SALINITY MANAGEMENT

Innovation has been an enduring characteristic of Australian agriculture. From its earliest beginnings, farming was export-oriented and subjected to commercial forces both in an expectation of returns on capital brought from abroad and in the relative lack of dependence on domestic consumption. It was not long before the natural resource and environmental constraints unique to the Australian continent – climate variability, low fertility soils, and absence of exploitable indigenous flora and fauna – had to be overcome. In these respects, there is a stark difference between the 'drivers' and fate of the European farming model in Australia and in North America (Williams and Goss, 2002).

However, on-farm innovation and sustained assistance by public investment in research and development, extension and education from the 1890s, a close parallel to the United States, did overcome early problems. Two examples are fallowing to conserve moisture, and application of phosphate fertilisers. Yet, the greatest legacy today is from the clearing of native vegetation, aided by all manner of innovative engineering devices to prepare the ground for cropping. Today, the pursuit is for innovation to reverse that legacy.

For the purposes of tracking innovations relevant to salinity control and management, they are categorised as follows:

1. Irrigation technologies
   a. Water application
   b. Land rehabilitation
   c. Salt interception
   d. Salt as a resource

2. Dryland technologies
   a. Farming systems development
   b. Reforestation and vegetation management
   c. Productive use of salinised lands

3. Policy initiatives
   a. Research and development
   b. Market-based instruments
   c. Catchment planning

4. New frontiers

Irrigation Technologies

There has been a continued evolution in water application technologies, that has significantly reduced deep drainage and evaporation losses; for instance, changes from flooding, sprinklers and drippers to sub soil 'tape irrigation'. The capability to adopt these technologies depends on crop type, value of production, and irrigation infrastructure. As table 4 shows, water use efficiency is greater for higher value crops, typically horticulture and viticulture. Other important policy initiatives important to reducing water use are a water trading market, and industry self-regulation. One technology is highlighted here – partial root zone drying.

Partial root-zone drying

One of the most innovative breakthroughs in water application technology is 'partial root-zone drying' now widely adopted in the wine industry. From research partly funded by the Murray-Darling Basin Commission, it has been found that stressing the vine of water at a key fruiting time, improves wine quality without a large cost to production. With water application tapes running either side of the vines' roots, one side is shut down then the other to get the desired result while saving water. Typically, water consumption has been reduced to 4ML per hectare per crop.

Land rehabilitation and sub-surface drainage have been of critical importance to de-watering soils and leaching salts away. Everyday technologies include laser guided levelling of land for better water distribution under flood irrigation, and groundwater pumping to evaporation basins. Over-watering on farms is not the only cause of groundwater mounds, leakage from irrigation supply channels and seepage from water storages also contribute. Where cost-effective, earth channels are being converted to piped supplies with public funding. Much of the investment in tackling these problems has been directed through irrigation land and water management plans.

Land and Water Management Plans

In the Murray-Darling Basin, 'land and water management plans' have been the vehicle for directing private and public investment in upgrading irrigation supply infrastructure and limiting off-farm impacts of water application, and nutrients and pesticides. Plans are developed by irrigators, the irrigation authority and relevant government agencies in a self-regulating environment. They are registered with the State environmental protection agency and subjected to annual reporting on performance. Since their introduction, water quality in local streams has improved, gravity channels have been converted to pressure piping, and on-farm water use bench-marked. The rice industry, which is still dependent on flood irrigation for mitigating cold damage to germinating crops, has reduced its water application from up to 20ML per hectare per crop to 11ML per hectare under the rigours of the land and water management plan.

Under the joint salt interception works program, so central to the *Basin Salinity Management Strategy*, about 400,000 tonnes of salt per year are pumped away from the river. Using 'run of the river' salinity readings and groundwater mapping, the most concentrated saline flows reaching the river channel are identified. After extensive investigation and due diligence, with each government assessing its needs for credits and the cost effectiveness in getting them, bore fields are installed along the river reach to draw down the water table so that it 'clears' the base of the river (Figure 3). Most schemes have been installed in the reaches of the lower River Murray; to date the program has generated credits under the *Salinity and Drainage Strategy* equivalent to 80EC at Morgan, South Australia, at a capital cost of $1,000,000 per EC and maintenance cost of $30,000 per EC per year. Under the new Strategy, another

61EC of credits is required in seven years and the indicative capital cost has risen to more than $2 million per EC. Clearly there is an incentive to get greater efficiency from current and new schemes.

Control of Iron Bacteria

A major problem limiting efficiency of salt interception schemes in South Australia, has been the fouling of bores, pumps and pipes by 'iron bacteria'. These naturally occurring bacteria, when the environment is suited to them chemically and physically, will thrive and metabolise soluble ferrous salts to the insoluble ferric oxide. A reddish-brown gelatinous mass of the iron oxide, bacteria and water forms and blocks screens, bores, pumps and pipelines. Their efficiency is vastly reduced driving up power costs, and making a critical component of the *Basin Salinity Management Strategy* uneconomic. Control techniques used by operators world-wide have varied widely in type and effectiveness.

The main contractor to the Murray-Darling Basin Commission, South Australian Water, has devised and refined an iron bacteria control system to combat the problem. It generates a chlorine solution by electrolysis of the water being pumped, for an hour each day, which is sufficient to disinfect the pumps and prevent build up within them. Pumps that previously had their flow reduced by up to 45 per cent within 50 days of installation, now operate continuously for up to six years with no significant loss of efficiency. This method is augmented by physical means to force build-up from pipelines. For one scheme alone with an annual electricity cost of $550,000, the saving is about $50,000 for an annual treatment cost of less than $5,000. The viability of current and future salt interception schemes has been assured (Forward, 2002).

With these tonnages of salt accumulating from the joint salt interception works and much more from other schemes run by irrigation authorities, there is a very significant build-up of salt in evaporation basins. As the salt accumulates the evaporative efficiency of these ponds decreases, thus increasing the cost. There has been a lot of developmental work and some small scale industries around the commercial use of salt as a resource. Such uses include production of industrial grade salt, saline aquaculture, and through a serial concentration process, the potential of electricity generation. The Commission has an obvious interest in finding commercial uses of the salt it generates, and is currently exploring two options. A chemical company and merchant bank are doing a feasibility study on producing high grade industrial chemicals. At the same time, the Minerals Division of the Commonwealth Scientific, Industry and Research Organisation (CSIRO) has been commissioned to do a major scoping study on the chemical composition of salt resources across the Basin, the potential products and their market prospects. One prospect is the use of pumped salt in the southern Basin as feed stock in processing of mineral sands to titanium, because of its proximity to mine sites and processing in the Murray groundwater basin.

Pyramid Salt

There is already a success story in commercial use of salt. A small company in northern Victoria (about 25km south of the River Murray near the small town of Pyramid Hill) is currently extracting local groundwater to produce a range of salt. Pyramid Salt specialises in pure crystal salt flakes, as well as gourmet salt products made from Australian herbs, such as 'Pepperberry', 'aniseed myrtle', 'Native mint' and 'Lemon myrtle' packaged under the brand 'Horizon'. Although Pyramid Salt are currently producing between 3,000 and 5,000 tonnes of salt each year, the company over the next five years is aiming to increase annual production to around 100,000 tonnes of crystal, table grade, stock food and food processing salt.

Over the past six years existing bores in the area have lowered the groundwater from 30cm below the surface to between 6.5m and 2m below the surface over 1,000 hectares of land. This has resulted in the reclamation of salt-affected farmland around the Pyramid Salt operation.

Dryland Technologies

Much has already been said about the challenge of developing farming, forestry and land use options better adapted to Australian conditions, mimicking native vegetation in their water use and still competitive in profitability with contemporary farm enterprises. It is here that there are some exciting innovations but much work to be done.

Earlier references were made to a review of current and potential farming systems by CSIRO. The key conclusion was a call for "a revolution in land use" which has been alternatively described as "re-designing agriculture for Australian landscapes" or "farming without harming" (Williams 2001). Given the constraints of high profitability annual crops in reducing recharge sufficiently, and high water using tree crops in providing a competitive commercial return, a logical area for further R&D is whether the two can be combined. In fact, several approaches are under test – opportunity cropping, phase farming, companion farming and alley farming. Opportunity cropping is a useful strategy in the northern Basin on more fertile soils, where annual crops are sown in both summer and winter, according to seasonal circumstances. Where at least five crop phases are compressed into four years, recharge to groundwater can be limited to double that of native vegetation. In phase farming a deep-rooted perennial is grown for a several year period to dry out the soil profile between periods of repetitive annual cropping. Typically, lucerne (alfalfa) is used for this purpose. Companion farming is where annual crops are over sown with a perennial pasture that is largely dormant during the crops growing season (winter in the southern Basin), but produces in the off-season while soaking up rainfall.

Alley Farming

Here is an example of a farmer developed technology; the establishment of parallel bands of perennial trees or shrubs across a paddock to intercept and transpire excess water, but with enough space between the bands for conventional cropping practice. From the time the farmer, Dean Melvin of Western Australia, first experimented with the method to its acceptance as a prospective farming system for publicly funded research and development, was about 20 years. Today it is common to see saltbush (a forage shrub) as the perennial but increasingly eucalypts and wattles are grown. Alley farming is the design principle for oil mallee production (see later).

Under the new formats for farming systems integration, combined with reforestation, re-introduction of native vegetation and active management of existing vegetation, it is not hard to understand why farming of the future is referred to as 'mosaic farming'. Among the many prospects for forestry and forest products in the salinity target zone of 500 to 800mm annual rainfall, there are few successes as yet. One exciting prospect, which sets a standard for innovation and industry development, is oil mallee production.

Oil Mallee Industry

The mallee is a multi-stemmed form of eucalypt, comprising many species, some of which contain oil in their leaves of sufficient concentration and quality to be extracted for commercial uses. These range from industrial solvents to perfumes and medicines. Harvesting mallees in the wild and distilling oil from their leaves in boilers over an open fire on location was a bush industry in early European Australian history. Such primitive production techniques would not be commercial today.

Today's oil mallee has been bred specifically for its oil qualities and is grown on farms in an alley farming format. The trees are harvested mechanically on a three year rotation and the oil distilled off with a gas-fired steam boiler. The largest wheat cropping farms in Western Australia now have many kilometres of mallee rows across their paddocks often adjacent to interceptor drains, another technique for limiting salt hazard. However, the potential breakthrough to an oil mallee industry is integrated production of activated carbon for industrial use, and energy from the biomass after oil removal. A five million dollar pilot plant is under construction funded by the government-owned energy supplier Western Power. A fully fledged industry would comprise several such integrated power generators on the electricity grid. Several factors are key to achieving a viable industry combined with a salinity management 'footprint'; they included scale and proven cost of electricity generation, quality and price of activated carbon, and reducing the cost of harvesting and processing the raw material. While not yet a proven industry, the method by which the government agencies, farmers and commercial interests went about its development is a lesson for other prospective tree-based industries (Bartle, 2002).

Again in Western Australia, where salt-affected land is already greater than 10 per cent of farm land, and now in the States of the Murray-Darling Basin, there has been considerable success in developing forage and livestock production systems on such areas. Most commonly saltbush is used, a highly salt tolerant shrub that can withstand sheep grazing. Over 30 years, problems of plant establishment and persistence under grazing have been solved, and now some farms with extensive areas of salt land are claiming enterprise profitability on land once considered an eyesore. Today there are several major R&D and extension initiatives, supported by farming industries' own funds and public investment, promoting productive use or 'sustainable grazing' of saline land.

While a controversial notion several years ago, the catch prase "living with salinity" is now more widely accepted, and while the Murray-Darling Basin Commission will place most of its resources to plant-based prevention of future salinity damage, it makes sense to support commercial use of salt as a resource, whether it be accumulating in evaporation ponds or on the land surface.

Policy Initiatives

Under the Australian model of R&D investment in agriculture, each commodity based industry (grains, meat, wool, dairying, horticulture, cotton, etc) is levied a percentage of gross farm income for this purpose. Statutory corporations, which also receive public funds according to a cost-sharing formula, contract the R&D under a strategic plan and reporting arrangements to industry and government. Two R&D corporations are not commodity-based, one for new industries and a 'public good' one for land and water management, and environmental protection. The commodity R&D corporations can legitimately claim a significant contribution to growth in productivity and water use efficiency, in their respective on-farm enterprises. Also they direct funds to sustainability R&D under requests from the Federal government.

CRC for Plant-Based Management of Dryland Salinity

It is the Murray-Darling Basin Commission's view that the R&D corporations should invest more in the innovation necessary for future production systems to mimic the low recharge of native vegetation. The Commission is using its shareholding and Board position on another R&D institution, the Cooperative Research Centre for Plant-based Management of Dryland Salinity, to require a water use standard for all prospective R&D projects. Project proposals are not only required to address potential economic benefit, which is usual practice, but estimate potential recharge rates in relation to native vegetation. Tools for estimating recharge are required, and achieving the water use standard will be a matter of corporate governance.

Beyond R&D there is a policy imperative to partition market and non-market values in salinity-targeted reforestation and vegetation management, to leverage the public and private investment, and to identify farm land on sufficient scale to get the job done. The preferred and popularly advocated approach in "developing a market for ecological services" is in this case, dryland salinity control. Currently, there is high profile work developing the concept (Cork et al, 2001), comparing ways of leveraging private investment (Allen Consulting Group, 2002; Buffier and Allen Consulting Group, 2002), and trialling a market-based approach based on the United States' Conservation Reserves Program (Stoneham and Chaudhri, 2001). The Federal and New South Wales governments are funding further trials in environmental services.

Regardless of the outcome of this work, there is no commitment yet within the National Action Plan on Salinity and Water Quality to divert the necessary funds to establish an environmental services program of sufficient scale to meet salinity targets in the Murray-Darling Basin. Rather, the funds have been allocated to the catchment management bodies to implement their plans on a regional scale. On the other hand, prospectus driven forestry companies, energy corporations and large greenhouse gas emitters are highly interested in attracting public investment in the salinity component of these ventures if they are to plant outside tried and proven yield zones. There is growing frustration that such opportunities don't yet exist, as planting seasons slip by in the countdown to the first accounting period under the Kyoto agreement on greenhouse gas emissions.

Vegetation Bank

The Murray-Darling Basin Commission is developing the Vegetation Bank for this purpose; or more accurately called, a "salinity services investment bank". The likely model is a statutory corporation controlled by a skills-based board with the charter to invest pooled government funds in commercial forestry ventures where salinity benefits are maximised at least cost. Experience to date is that current forestry options in the salinity target zone are not capable of giving investors a satisfactory internal rate of return. The gap between estimated rate of return and the 'hurdle rate' is construed to be the salinity benefit. To minimise this gap and reduce it further in time, the Vegetation Bank would call for tenders and assess each on projected salinity benefit and cost per unit benefit. Under the provisions of the *Basin Salinity Management Strategy* the governments would be assigned the salinity benefits as credits on Register B, in proportion to their contributions. Thus, the Vegetation Bank is part of the evolutionary process to salinity credits trading and a true tradeable pollution rights scheme.

For the Vegetation Bank to work successfully however, there are a number of essential ingredients:

1. The governments are prepared to pool funds and enter into contracts for salinity benefits on a scale that will build industry confidence.
2. The governments with the Murray-Darling Basin Commission have developed their modelling capacity to reliably estimate impacts on river salinity targets and transcribe them to credits on Register B.
3. Catchment plans are sufficiently well developed and supported with spatial natural resource data, that land "fit for purpose" can be identified.
4. Farmers have sufficient knowledge and incentive to offer land for such joint ventures or 'share farming' schemes.

Whether there is one Vegetation Bank or more than one remains to be seen. However, anecdotal evidence to date suggests that catchment management boards and authorities can't offer the scale and expertise on their own to attract and successfully negotiate with the larger corporations that will be involved. Companies say they want a Vegetation Bank; the governments aren't so sure.

Further, for catchment management bodies to prepare maps of land "fit for purpose" with sufficient detail and confidence for forestry joint ventures, requires precise information on land suitability, catchment hydrology and salt stores, if trade-offs are to be minimised. State government agencies and the bodies themselves are building this capacity as rapidly as they can. This has been aided by a groundwater flows map for the Basin, and a modelling tool linking reforestation patterns on a local scale with river salinities over the following decades. Perhaps the more innovative component of this evolving knowledge base is the use of airborne geophysics to identify areas of high salinity.

Salt Hazard Mapping

Detection of magnetic, radiometric and electro-magnetic signals by low flying aircraft (emitting the source signal in the case of electro-magnetics) is a well calibrated method for mineral exploration. While magnetics and radiometrics interpret the geology and regolith, the electro-magnetic response is a measure of electrical conductivity under the land surface. After a decade of development, this technology can map salinity, which is highly correlated with conductivity in three dimensional space. Although this application of airborne geophysics is too expensive ($5 per hectare for the flown product, $15-$20 per hectare including validation and full interpretation) for universal coverage, it has potential application in areas where priority values are at risk or greater precision is required if land management actions are to minimise trade-offs.

New Frontiers

It is a challenge to predict where the next innovations will come from in the pursuit of solutions to salinity. Perhaps continued technology development and lower unit costs in desalinisation will make it a more cost effective option in treating river salinity than capping it at current target levels with land use changes. Alternatively, the pursuit of an agriculture uniquely adapted to the Australian environment may yield success.

FloraSearch

The CRC for Plant-based Management of Dryland Salinity (mentioned above) is embarking on such a pursuit called FloraSearch. Australia' flora is mega-diverse and under this initiative 25,000 species are being scanned for potential products, from their stems, leaves and fruits. The more promising ones are sampled and laboratory tested for fibre, oil or other qualities. The objective is to look for prospects of sufficient scale to develop a sustained industry, rather than boutique markets which are already being developed; for instance, wattle seed. Those plant products passing the bench top-test will be planted out and taken down an industry development path much the same as for oil mallees in Western Australia. The Murray-Darling Basin Commission is jointly funding FloraSearch.

CONCLUSION

The rise of dryland salinity in Australia is symptomatic of the limitations of farming systems introduced by European settlers, and which have yet to adapt sufficiently to restore a hydrological equilibrium. In the process enormous damage may be done over the next 100 years, if we can't augment short term engineering solutions with a "radical change in land use". Currently, the uncertainties and trade-offs involved challenge the capacity and confidence of farmers, scientists, catchment managers and policy advisers.

However, if the problem was a long time in the making and will take as long again to reach its full expression, there is an opportunity for innovation, research and development of land use options and other technologies that are much better adapted. This requires far sighted policy, and fully testing the prospects for profitable, plant-based enterprises that mimic the water using features of native vegetation. It requires public-private partnerships in reforestation, where the governments purchase and retain salinity credits, in the first step of a 15 year program to establish a tradeable pollution rights scheme. To apply such a market-based approach to such a diffuse source problem would be a major achievement for Australia.

Table 1. Assets and values in areas at high risk from shallow watertables or with a high salinity hazard, Australia, 2000-2050.

Asset	2000	2020	2050
Agricultural land (ha)	4,650,000	6,371,000	13,660,000
Remnant and planted perennial vegetation (ha)	631,000	777,000	2,020,000
Length of streams and lake perimeter (km)	11,800	20,000	41,300
Rail (km)	1,600	2,060	5,100
Roads (km)	19,600	26,600	67,400
Towns (number)	68	125	219
Important wetlands (number)	80	81	130

Source: National Land and Water Resources Audit (2000)

Table 2. Estimated river salinity Murray-Darling Basin 1998-2100

River [*1]	Average River Salinity (EC) [*2]			
	1998	**2020**	**2050**	**2100**
River Murray				
Morgan, South Australia	570	670	790	900
Merbein, New South Wales	360	400	450	510
Torrumbarry, Victoria	110	110	140	140
River Murray Tributaries				
Murrumbidgee, New South Wales	250	320	350	400
Avoca, Victoria	1,440	1,470	2,220	2,990
Loddon, Victoria	870	880	900	970
Campaspe, Victoria	600	600	610	610
Goulburn-Broken, Victoria	130	140	230	230
Ovens, Victoria	70	70	75	80
Kiewa, Victoria	45	45	45	45
Darling River				
Menindee, New South Wales	360	430	490	530
Lachlan River, New South Wales	530	780	1,150	1,460
Darling River Tributaries				
Bogan, New South Wales	730	1,500	1,950	2,320
Macquarie, New South Wales	620	1,290	1,730	2,110
Castlereagh, New South Wales	640	760	1,100	1,230
Namoi, New South Wales	680	1,050	1,280	1,550
Gwydir, New South Wales	560	600	700	740
Macintyre, New South Wales	450	450	450	450
Condamine-Balonne, Queensland	210	1,040	1,040	1,040
Warrego, Queensland	210	1,270	1,270	1,270

Footnotes: *1 Unless the location is stated, the river salinity estimates are at the most downstream monitoring point on that river, where salinity is highest.
*2 For operational reasons, the Murray-Darling Basin Commission measures salinity as "electrical conductivity units" or micro-Siemens per centimetre (µS/cm). A rough conversion factor to mg/L is 0.6.

Table 3. Annual costs to all stakeholders in eight priority catchments in the Murray-Darling Basin, 2000

	Lower estimate ($m/yr)	Upper estimate ($m/yr)	Best estimate ($m/yr)	Proportion (%)
Local Government	-	-	14.69	6
Households	41.03	139.23	90.13	36
Businesses	8.45	8.96	8.71	4
State government agencies & utilities	-	-	16.31	6
Environment	?	?	?	-
Agricultural producers	-	-	121.80	48
Total	**202.28**	**300.99**	**251.64**	

Source: Wilson (2000)

Table 4. Annual returns to water and intensity of water use, Australia 1996/97*

Land Use	Percentage Water Used	Water Use ML/ha	Water Returns $/ML
Fruit, vegetables	13	3-7	500-1,300
Cotton	16	7	450
Dairying	40	7	100
Rice	11	11	30
Extensive agriculture	9	3-4	0-120
All irrigation	100	7	195

* The figures in this table have been aggregated from the source table, and approximations included.
Source: National Land and Water Resources Audit, 2002

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