

A revolution in agriculture is needed if we are to manage dryland salinity and related natural resource issues

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Abstract

Australian farming systems are notoriously 'leaky'. Compared with the natural vegetation, where between 0 and 10 mm of rainfall penetrates to the ground water, agricultural systems based on annual crops and pastures leak more than 150 mm to the water table. When this occurs the ground water, which in the ancient Australian landscape is usually salty, rises to the surface bringing with it its load of salt. As a result large tracts of land are threatened by dryland salinity.

While the answer to dryland salinity may seem obvious – restoration of the water balance using perennial plants – there are a number of impediments. To begin with a change from annuals to perennials involves significant changes in cropping practice, and the perennials that we currently have are not able to produce the economic returns that are supplied by annuals. Secondly, changes in farmer lifestyle will also be necessary and may be uncomfortable. Thirdly, quick fixes, which may be unsuitable in the long term, are sought by both governments and farmers. Fourthly, many of the perennial crops will require the development of new industries and associated infrastructure. Fifthly, there is reluctance by some governments to invest in the necessary research. Finally, we have little understanding of the impact of new farming systems on catchment management, water quality and wetland ecosystems.

The paper outlines some of the perennial-based farming systems available to address dryland salinity and other natural resource issues.

Introduction

Dryland salinity affects much of south-western Australia and increasing areas of the Murray Darling basin and adjacent parts of South Australia and Victoria. It has been observed in Queensland in the Fitzroy River basin as well as in the northern Murray Darling basin. Some 5.6 million ha of land has already succumbed to salinity and this will increase six fold, according to the National Land & Water Resources Audit. A recent Australian Bureau of Statistics estimate puts the number of farms affected by salinity at 14% in Australia as a whole and 51% in Western Australia. A Murray Darling basin working group estimates that salinity is spreading at a rate of 2-15%/year (1).

However, it is not only land that is affected. In the Murray Darling basin many of the rivers and wetlands are under threat. Urban water supplies, irrigation water quality, roads and urban infrastructure are all at risk. In Western Australia it is estimated that 450 plant species may become extinct and even greater numbers of invertebrate animals. Many water birds will disappear from the wheat belt. In the opinion of some economists, collectively these consequences of salinity pose a far greater cost to the nation than does land degradation itself.

Nevertheless, whether land or the associated rivers, biodiversity and infrastructure bear the greater cost it is to land management that we must turn for solutions. Water quality depends on how catchments are managed, and rising water tables will only reverse if land is managed more sustainably. The way we manage our farm land goes well beyond the farm gate and increasingly will dominate discussions about the future of agriculture. Agricultural scientists and land managers cannot isolate themselves from what is happening.

The causes of dryland salinity

The title of W.E. Wood's (2) paper on the emergence of salinity in Western Australia succinctly outlines its causes: 'increase of salt in soil and streams following the destruction of native vegetation'. Much more recently Clark *et al.* (3) have simply re-affirmed what was outlined by Wood. The removal of deep-rooted perennial plants with the capacity to maintain leaf area index throughout the year has resulted in significantly less use of water, rising water tables, increased stream salinity and increasingly saline landscapes. It is

estimated that 90% of the vegetation of the wheat belt in Western Australia has been removed (4) and the figure may well be higher in the wheat belt of south-eastern Australia.

Both Wood (2) and Clark *et al.* (3) describe salinity in Western Australia. Salinisation occurs also in eastern Australia, most notably in the Murray Darling basin. There are however, important differences. For example, while in Western Australia most ground water flow systems are local, in the Murray Darling basin many are regional or intermediate. This has meant that the time interval between clearing and the expression of salinity is much longer in the Murray Darling basin and it often expresses itself many hundreds of kilometres from its source.

The difference in water use between native vegetation and the annual vegetation which has replaced it (annual crops and pastures) depends primarily on incident rainfall. The drier the site the smaller is the difference, although soil type also plays a role. The amount of leakage under native vegetation is often very small; eg, Nulsen *et al.* (5) accounted for all of the 376 mm of annual rainfall falling on Western Australian mallee/heath vegetation as either evapo-transpiration or run-off. At higher rainfall there is some leakage into the groundwater, although quite small amounts. In comparison, annual crops contributed 0-390 mm of water to the water table at Moora, WA (mean rainfall 460 mm/year) and 0-230 mm at Merredin, WA (310 mm/year) (6). With these massive contributions to the water table it is no wonder that water tables are rising and the area of salinity increasing.

In view of the early recognition of the causes of salinity by Wood (2) and Bleazby (7) it is somewhat surprising that little was done to combat salinity until recently. Indeed, expert committees warned governments of the dangers of clearing land throughout the history of land clearance, at least in Western Australia (8). Governments however, chose to ignore the warnings, partly because the advice they received from scientists was often contradictory. One only has to look at the debate raging over genetically modified organisms to see that scientists have as much difficulty as anyone else in coming to consensus about the costs and benefits of new technology. The use of fertilizers, annual legumes, trace elements and new wheat varieties was a seductive mixture and easily over-rode environmental concerns. I see little evidence that conflicts of this kind are easier to resolve today.

Engineering solutions to dryland salinity

Engineering solutions to problems are often conceptually easier to follow than more complex biological solutions. In some ways they offer a 'silver bullet' – one action that of itself overcomes the problem. A good example of this might be the 'Whittington' drains advocated in Western Australia during the 1980s. For a short while they were successful, but in the longer run they proved to be ineffective.

Engineering solutions fall under several headings:

- Deep drains placed in the bottom of valleys.
- Ground water pumping.
- Relief wells and siphons.
- Surface management of water, such that water does not accumulate and the plants avoid waterlogging.

Deep drains (1-3 m below the surface) work well in permeable soils (eg sands and some duplex soils) where the lateral flow of water is relatively unrestricted. In such conditions drains may have a considerable lateral influence and open up the possibility of returning land to conventional agriculture. The major problems with deep drains are their expense (which has to be recouped from increased grain yields), their unsuitability for many soils and the problem of effluent disposal. The latter in particular is a constraint, where drains empty into existing salt lakes (changing their hydrology), rivers, adjacent farm land or even National Parks. Unfortunately, unregulated draining in Western Australia is contributing to all four of these environmental problems.

In eastern Australia the option of using drains may be restricted to areas where it is impossible for salty water to reach major river systems. Reclaimed salty land may also profoundly change the physical and chemical properties of soil. There is some evidence that salinity causes irreversible changes in soil chemical and physical properties, such as very high or very low pH values (9, 10). Nevertheless, for high value assets and for reclaiming land where the lateral flow of water is high deep drains show considerable promise.

Ground water pumping is expensive and restricted to the preservation of high value assets. A good example is Lake Toolibin in the Western Australian wheat belt. This lake is the last fresh water lake in the region and is considered worth saving for its biodiversity and historical value (11). Disposal of water is again an issue, and, in the case of Lake Toolibin, an adjacent lake has been sacrificed. Relief wells can be effective where ground water is under pressure, but disposal of effluent is again a problem.

Surface water can be managed in a number of ways – banks, shallow drains and raised beds. Of these the most promising is raised soil beds, which are particularly effective to control waterlogging (12). Raised beds are used extensively in irrigated agriculture to improve drainage (13), but their use to manage salinity is uncertain. The problem would appear to be what happens to roots when they come into contact with saline water in the subsoil.

Plant-based solutions

In this section I will focus on the possibilities of reducing recharge through the use of perennials.

It will be difficult to improve the water use of farming systems based on annual crops and pastures. Small improvements have been observed under best management practice, but these contribute little to reducing leakage into the ground water. There seems little doubt that we must work towards farming systems based on perennial plants. This will require profound change in land use, farming system and even lifestyle of farming communities. Such a change will need to be driven by strong economic signals.

The concept that farming systems should mimic natural ecosystems was strongly advocated through the 1990s culminating in a workshop held in Western Australia. In particular, it was concluded that the way natural systems capture and distribute resources, especially water, could be applied to agricultural systems (14). Lefroy and Stirzaker (15) examined a system in which tagasaste (*Chamaecytisus proliferus*) played the role of perennial in company with standard annual crops. These authors concluded that although tagasaste manages water far more effectively than the conventional crops, for it to be planted closely enough to have an impact on salinity it would need to be as profitable (or more so) than lupins and wheat. Other authors go further however, and believe that functional mimicry will only be realized when the leaf area index of perennial plants in agroecosystems approaches that of natural ecosystems (16).

This is the nub of the problem. For perennial plants to be widely adopted they need to be able to compete economically with annuals. Farmers are unwilling to change unless there are substantial rewards and these rewards currently do not exist. The most promising systems, and therefore the most competitive, are systems in which perennial pastures play an important role. Most importantly this includes lucerne-based systems, which are in use in eastern Australia and have recently been introduced to Western Australia. There is little doubt that lucerne, even in rotation with annual crops, manages water far better than annual crops alone (17, 18, 19, 20, 21, 22, 23). Perhaps one of the more striking examples is on the Liverpool Plains where models predict that annual recharge falls from 48 mm under wheat/sorghum rotations to only 8 mm under rotations involving lucerne.

A diverse range of factors will influence the adoption of lucerne, primarily its economic performance. There are indications that lucerne phases in crop rotations are profitable, especially compared with farming systems involving annual pastures (24). The evidence suggests that lucerne is most profitable where its adaptation is best, but it seems likely that further improvements in its economic performance are needed for it to be adopted widely even where it is well adapted. Perceived impediments are:

- Sowing lucerne does not guarantee success – there are risks in establishment.
- Many farmers believe that lucerne requires strict adherence to rotational grazing, a difficult proposition on large farms.
- More animals are required to make full use of lucerne.
- Later lambing to maximise market returns involves complex changes to farming systems.
- Lucerne may adversely affect subsequent cereal yields because of its effectiveness at managing water.

It is worth commenting further on this last point because maintenance of wheat yields in wheat/lucerne rotations will be crucial if the economic benefits of lucerne are to be realized. There is little doubt that in the first year after lucerne there is less water in the soil (25). This is beneficial in soils that are normally

waterlogged, which is the case in the higher rainfall parts of the Western Australian wheat belt. Anecdotal evidence suggests that wheat yields after lucerne are often higher than after annual crops or pastures in these circumstances. In the heavier soils of northern New South Wales there may be some penalty in the first year but this disappears thereafter when crop yields are normally higher (26, 27, 28).

However, lucerne is not the only possibility (29). Cocks presents a list of more than 40 perennial legumes that may have some value in the management of salinity. *Dorycnium hirsutum* and some *Lotus* spp. are showing promise in trials in Western Australia and New South Wales. There are at least as many grasses, including Australian native grasses (30, 31), and some native perennial herbs (eg *Ptilotus*). In a program run from Wagga Wagga and Rutherglen some 37 grass species were targeted from acidic and low fertility soils. Promising species were identified in the following genera: *Chloris*, *Austrodanthonia*, *Digitaria*, *Elymus*, *Enteropogon*, *Microlaena*, *Bothriochloa* and *Themeda*. It is possible that native perennial legumes may also be identified in a project recently commenced at Rutherglen, Victoria.

The problem with all these species however, is that even once identified a great deal of work will need to be done by both researchers and farmers before they can be integrated into farming systems.

Difficult although the successful adoption of perennial pastures is likely to be, that of woody perennials will be far greater. This is because, once successfully established on farms, perennial pastures will support and improve the productivity of existing commodities. The adoption of woody perennials on the other hand, will almost certainly depend on the development of new industries.

With the exception of softwood plantations the Australian timber industry has been based on native forests. Those located in high rainfall areas have contributed sawn logs and wood pulp both for local consumption and export. The plantations, which are 90% softwood, are increasing in area but are still only a small proportion of the productive forest area. Indeed, of the total area of forests in Australia, the plantations constitute only 0.1% of the area (1.04 million ha). If plantations are to contribute to salinity management they will have to firstly, be planted on a much greater proportion of the landscape, and secondly, be planted in areas of much lower rainfall. To do this there will need to be products other than the traditional sawn logs and paper pulp.

The magnitude of the task can be seen by some simple statistics. The current area of plantations is increasing by 35,000 ha/year, mainly in the high rainfall zone. The requirement is that we establish plantations on up to 90 million ha. At the current rate of progress it will take 2,500 years to achieve this end.

Where rainfall is above 600 mm the option of producing sawn timber remains open. *Eucalyptus globulus*, *E. botryoides*, and *E. camaldulensis* have been tried successfully in Western Australia (32). Even in salty land there some hardwoods showing promise: selections of *E. globulus* and *E. grandis* (33). *Pinus pinaster* and *P. radiata* continue to be the main softwoods.

At lower rainfall the oil mallees and certain *Acacia* spp. have been planted experimentally, mainly in Western Australia (31). The products from these trees are rather different from the traditional products in high rainfall areas. Biomass for energy production, oils for pharmaceuticals and fuel, and timber for pulp and particle board. To be economic however, it is likely that all products would have to be processed in integrated plants distributed throughout the wheat belt. To test this concept a pilot plant is being constructed at Narrogin in the higher rainfall Western Australian wheat belt. For it to be successful the plant will need a constant supply of material from the surrounding countryside, because transport costs will be too high if the material comes from more than about 50 km.

The Narrogin concept, if repeated throughout the wheat belt, would have a huge impact on not only salinity but also on the diversity of agricultural production and therefore its stability, and on the welfare of the regional communities.

Variation in the oil mallees exists for most of the quality parameters involved in developing these new industries. For example, up to 32 constituent oils were found in *E. loxophleba*, *E. kochii*, *E. horistes* and *E. polybracteata*, their relative abundance varying from species to species. Even within species oil content and type varied between genotypes (34).

But by far the largest problem is to establish the infrastructure necessary for these new industries. It is interesting to reflect on the scale of government investment to establish the large agricultural industries that exist today. Not only were roads built, but an astonishing network of railways penetrated almost every part of the countryside. More recently there has been investment in bulk handling, more efficient ports and, of course, research and development. I argue that a much smaller investment in small generating and processing plants will develop the perennial-based farming systems that are necessary to manage salinity and make our farming systems sustainable.

A note of caution has been sounded by weed scientists, who fear that new perennial species may become weeds (35). In a survey in South Australia it was considered that *Pinus halepensis*, *Acacia saligna* and *Ehrharta calycina* are high weed risks while most eucalypts, saltbushes and lucerne are low risk. Unfortunately these risk assessments were taken in hindsight: it is much more difficult to assess a new introduction. The current approach is one of caution and the view is usually taken that if you are unfamiliar with the species it should not be introduced. In principle this is a sound approach, but weed scientists on the one hand and environmentalists on the other must balance the costs and benefits of introducing perennial plants that might be used to increase sustainability.

An integrated approach

In this section I will discuss the integration of recharge areas with saline areas, the integration of plant-based management with engineering solutions and the integration of cropping systems with perennials.

It is inevitable that no matter what we do to prevent salinity that much of our best agricultural land will become saline (3). Making use of this land is an integral part of management.

There is remarkably little information on the sustainable use of saline land. The use of halophytes as a source of animal feed has aroused some controversy with recent evidence suggesting that the apparent increases in liveweight are caused by increased consumption of water, and that body condition does not change (36, 37). Supplementation with even small amounts of non halophyte material increases liveweight gain and palatability. Nutritional aspects of grazing halophytes need to be clarified if they are to realize their full potential.

As green material however, they fit well into farming systems where seasonal growth of annual pasture limits the capacity of sheep to maintain staple strength during times of low nutrition and to promote the production of out-of-season lamb. Indeed, a farm with some lucerne and some green pastures from saline land may be far more productive in terms of animal production than farms without these qualities. The economics and nutritional aspects need to be explored.

Anecdotal evidence suggests that halophytes can use even saline water and lower salty water tables. If this is true then the use of halophytes could lead to the rehabilitation of saline land in a similar way to drainage without the effluent problem. Halophyte pastures have persisted for more than 50 years on some farms in the Western Australian wheat belt, suggesting that they are at least controlling the water table. Measurements of reduced water levels of up to 2 m in some saline areas occurred where the water salinity did not exceed 5,000 mg/l (38). There is evidence from Montana (USA) that both water tables and salinity can be reduced by plantings of perennials in both recharge and discharge areas (39).

Drainage will also contribute to the lowering of saline water tables. With both trees and drains effectiveness depends on the lateral flow of water. In some cases trees are known to lower water tables up to 3 km from the plantation, but more commonly their impact is between 10 and 30 m (38). No doubt drains will have a similar hydrological impact to trees.

Rehabilitated land will need salt tolerant plants, at least in the short term. Provided that the perennial options are retained in the recharge areas the use of annual crops and pastures in saline land will become increasingly possible. Salt and waterlogging tolerant pasture plants already exist: *Trifolium michelianum* (40), *Melilotus alba* (41), *Distichlis spicata* (42), *Puccinellia ciliata* (43) and *Thinopyrum elongatum* (44), to name but a few. The salt tolerance of some *Hordeum* spp. suggests that salt tolerance of barley may be improved, and recent wide crosses between sea barley grass (*Hordeum marinum*) and wheat open up the possibility that the

salt tolerance of wheat can be improved. Salt tolerance of wheat is an objective of some plant breeding programs. In barley, breeding for salt tolerance using conventional means has not been successful (45).

A word of caution is important here. While salt tolerant cereals are superficially an attractive option they will only deal with the symptoms of salinity and not its causes. Salt tolerance will buy us time but is not the answer. Farming systems based on perennials and/or drains is the only way forward.

It is important to accept however, that perennial based farming systems do not mean the end of cropping. Alley farming with cereals, phase farming with cereal/lucerne or other perennial pasture rotation, companion cropping with herbaceous perennials and crops growing together, and mixtures of all three are all possible. Agricultural systems will continue to produce conventional products into the foreseeable future. What will be different is that the quality will rise, farming systems will be more diverse and therefore more stable, and there will be a raft of new products.

Conclusions

A revolution in agriculture is needed and is what we should aim for. By 2020 there should be a landscape based on perennial plants, using most of the incident rainfall and maintaining green leaf area for the whole year.

Dryland salinity is not the intractable problem that is often suggested. It will however, take a concerted and coordinated research and development approach to come up with solutions that are attractive enough for most farmers to adopt. No single solution is likely to be effective. Integrated solutions involving perennial plants, new industries, drains, plant breeding and conventional crops are necessary. Although in some cases glimmerings of solutions are apparent it is likely that widely applicable solutions will not be available for some years. Governments will need to support research and development during this period and will need to encourage adoption of solutions that are less than optimal.

Finally the human factor must not be neglected. What we are proposing is landscape change, which involves complex changes in the behaviour of human communities. We must encourage and support the economic and sociological research that is needed to minimize the impact of salinity on rural communities and farms. We need to be able to present to governments and industry policy options leading to stable change (46). We need to know the constraints that farmers face when introducing new farming systems: in eastern Australia, for example, small farm size and lack of income may be foremost among these constraints (47). Finally, to avoid mistakes during the transfer of technology, we need to understand the sociological, agricultural and hydrological differences between eastern and Western Australia.

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