Initiatives in land use - soil salinity

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Introduction

In the latter half of the twentieth century in southern Australia we are beginning to experience the full impact of agricultural development on our soil, water and environmental resources. We have inherited the consequences of changes to the hydrological balance brought about through the adoption of land management practices which were less efficient with respect to water use than the original native vegetation. Agricultural development has provided more water for runoff and groundwater recharge than that which was available under pristine environments, and extensive erosion and salinity problems have developed as a consequence.

Watertables have risen in response to increased recharge, the consequent discharge of saline groundwater has affected soils and streams alike. Both dryland and irrigated lands have been degraded. Today in Australia at least 800,000 hectares are affected by dryland salinity, and 1.3 x 109 cubic metres of divertible water is lost annually as a consequence of salinities exceeding 1500 mg/l (7). Irrigated lands are plagued by salinity and high watertables. In the Murray Darling Basin 559,000 hectares, or 26% of the land in state sponsored irrigation schemes now have shallow watertables (within 2 m or less of the land surface). About 65% of the actual area irrigated is threatened by shallow watertables and salinity (Murray Darling Basin Ministerial Council, 1987).

In the 1970s and 1980s State and Commonwealth Governments became increasingly aware of the enormous threat that salinity poses and began committing resources to understand the development of the problem and plan strategies for its control. Today, as a consequence of this on-going work, we are well placed to consider the direction of our efforts in the future. Macumber and Fitzpatrick (5) outlined three options:

- We can choose to do nothing and accept the consequences;
- We can choose to live with the problem by adapting to saline conditions through saline agriculture, or;
- We can choose to cure the problem by lowering watertables, either by artificial means (pumping and drainage) or through agricultural management that limits groundwater recharge.

Salinity - why did it happen?

In the temperate, winter rainfall lands of southern Australia the salinity problem began its development 100 to 150 years ago when the land was first settled and developed for European based agriculture.

Prior to clearing, native vegetation had adapted to optimise water use in a land that was often arid and subject to drought. Rain that fell in the winter months when potential evapotranspiration was low was stored in the soil zone and used in the spring and summer. This water was extracted by deep roots that penetrated the solum. Some of the rainfall was also intercepted by foliage and evaporated back to the atmosphere.

In regions with high rainfall, or in very wet years, the soils saturated during the winter months and groundwater recharge occurred *as a* consequence of water percolating beyond the solum. With the development of agriculture, however, this balance between water stored in the soil and water used by vegetation changed significantly. Shallow rooted pastures failed to penetrate the subsoil and fallowing for crops encouraged water entry to the soil and reduced evapotranspiration. Heavy grazing reduced leaf area and limited transpiration, and the annual species failed to be opportunistic with respect to the distribution of rainfall. In addition unfavourable physical and chemical conditions often meant poor plant vigour and poor water use. All of these circumstances led to the same result; an increase in the incidence of soil saturation and a consequent increase in deep percolation of water, that is, increased groundwater recharge.

In irrigated regions the development of the problem was simply accelerated by the artificial application of water in addition to rainfall. Shallow watertables developed beneath irrigated zones leading to waterlogging and eventually salinisation. In some instances irrigation areas were located over ancient regional groundwater discharge zones which were subsequently reactivated by changes in regional hydrology. In these circumstances salinity became very severe and widespread. The intense degradation resulting from establishing irrigation regions over regional groundwater discharge zones is particularly graphic and evident at locations such as Kerang and the Tragowell Plains in northern Victoria.

Rising watertables and salinity

Increased groundwater recharge following agricultural development led to rising watertables and eventually salinity as aquifers 'filled' and saline groundwater began discharging through soils and streams in the lower landscape (3). As groundwaters rose they became increasingly saline as they dissolved salts previously stored in the unsaturated zones above the watertable. Eventually this saline groundwater rose up into the root zone of plants and soon after began discharging to the surface.

The affect on soils was dramatic where high salinity (>10,000 mg/1) groundwater emerged. Pastures and crops either died or failed to germinate and the soil was left either barren or supporting only salt tolerant volunteer species. In the early stages the affected areas appeared as a patchwork of barren soil amongst areas retaining some growth. Ultimately surface soils were destabilised by salt and subsequently removed by wind erosion.

Where the salinity of groundwater was lower a range of salt tolerant volunteer species established.

Where does it happen?

Salinity now threatens the soil and water resources of southern Australia in most areas where the land has been cleared and developed for agriculture. While its development is accelerated in some specific hydro-ecological zones, no area or region in the temperate lands of southern Australia can be considered to be totally exempt from the problem. This is particularly evident in Victoria. Victoria is a microcosm of the wide range of geological, soil, land-use, and climatic environs present throughout southern Australia (4). In the northwest of the State salinity affects the arid and semi-arid cropped lands of the Mallee. But, equally it devastates the valley floors of the high rainfall pastoral country of the Dundas Tablelands in the southwest. In the Mallee, saline groundwater discharges from a regional surficial sand aquifer (the Parilla Sand) whilst in the Tablelands local groundwater systems discharge saline groundwater from deeply weathered granitic rocks. Saline groundwater discharge from regional aquifers that lie beneath the coastal plains of Gippsland effect salinity in the southeast and similarly both irrigated and dryland salinity occur extensively on the Riverine plains of northern and north central Victoria. The problem is equally extensive throughout the valleys of the Great Dividing Range of Victoria and NSW, where saline groundwater associated with fractured sedimentary rocks emerges affecting the land and the quality of streams. Even small creeks in these highlands typically carry thousands of tonnes of salt into our river systems in most years.

What can we do?

As previously stated we have three options for addressing salinity (5). We can ignore it, live with it, or control it. If we aim to control it there is no other choice but to lower watertables either through artificial or agricultural means. In this respect salinity control in irrigation areas is very different to that which must be practiced in dryland regions. Under irrigation our options are limited to increasing the efficiency of water application and lowering watertables largely by pumping or drainage. The disposal of saline groundwater in irrigation areas under such circumstances is a primary concern.

In dryland regions, however, we have the option of developing agricultural systems that are more efficient with respect to water-use. We are able to develop and promote farming systems that encourage vigorously growing, well managed, deep rooted crops and pastures together with the judicious use of trees.

What are the constraints?

The constraints in respect of the development or adoption of any salinity control program whether it is in an irrigated zone or a dryland zone are considerable. They are imposed by factors such *as* the physical nature of salinity processes, social and economic influences, and environmental concerns.

Physical processes determine options for salinity control but social, economic and environmental factors determine if the option will be adopted. For example groundwater pumping or drainage is often suggested as a means of lowering watertables in irrigation regions, however, there has to be an economic benefit to the farmer or perhaps the community identified before it proceeds. If the groundwater is saline there is a disposal problem, and that leads to consideration of evaporation basins, disposal entitlements and cost sharing. In addition the disposal of saline groundwater has obvious implications for the environment of streams and wetlands and there may be very real costs to the community if these issues are not adequately addressed.

In dryland regions we have the option of attacking the problem where it begins by opting for land management practices that reduce groundwater recharge. Again, these land management options need to be identified as having an economic benefit before they will be adopted, and even then there are social factors that prohibit adoption. Physical factors may make control programs difficult to adopt. Often recharge areas are remote from discharge areas and there is a need to adopt alternative management in areas that are not affected by salinity in order to assist areas that are affected.

Options for salinity control are thus seldom 'straight forward'. There are many problems and issues to be addressed before a clear course of action can be identified. This is why it is so important to have adequate planning based on a sound technical understanding.

Processes and planning

Over the last two decades we have come to know a great deal about the processes important in dryland salinity. We now understand that whilst the overall cause of the problem is the same in most instances, that is, a shift in the hydrological balance, the processes may vary considerably from one site to another. Within any major river catchment the groundwater processes and groundwater systems operating to effect salinity may be quite diverse. The major governing factors determining these processes are geology, geomorphology, climate and land-use. Geological factors determine the nature of the aquifers and groundwater flow, and geomorphic, climatic and land-use factors determine the extent and spatial distribution of groundwater recharge.

Our knowledge of these processes is not yet perfect, but it is sufficiently well advanced to examine catchments from a perspective based on the above factors and recognise components with similar characteristics. The components represent areas which share the same groundwater flow processes, in similar climatic regimes, with similar soil types sharing the same general land-use management.

We have called these catchment components land management units or LMUs. They allow us to characterise catchments in respect of salinity processes and offer a logical basis for consideration of regional priorities in regard to both on-site and off site effects of salinity. They provide a tight framework for consideration of the changes in land management that must occur if the problems are to be addressed.

To illustrate LMUs and their advantages in respect of salinity planning consider the following two units common to the hills and foothills respectively of the Great Dividing Range of Victoria and NSW.

Gently undulating foothills

The gently undulating foothills of the lower slopes of the Great Dividing range of south-eastern Australia form an LMU common to most major river systems. The regions generally have a Mediterranean climate, with winter dominated rainfall and hot dry summers, an annual rainfall of 400-500 mm; red sodic duplex soils, on deeply weathered fractured sedimentary rocks; and they represent the marginal cereal cropping lands on the rim of the Murray Darling Basin.

The unit has very high salt storage due to great age and low permeability as a consequence of deep weathering. High salt storage causes high groundwater salinity which typically ranges from 15,000 to 25,000 mg/l. When this groundwater reaches within 1.5 m of the soil surface capillary action draws it to the surface and the land degrades very rapidly. Large areas of cropping land have been devastated in the last 40 years *as* a consequence of this phenomenon. In many instances 500 to 1,000 hectares of land at individual sites has been degraded. Kamarooka, north of Bendigo in central Victoria, and the Sheep Pen Creek catchment near Violet Town are examples of areas suffering such intense salinity within this LMU.

Deep weathering has largely destroyed the capacity of the rock aquifer to transmit groundwater great distances and therefore most groundwater flow is 'local', that is, confined to the boundaries of the immediate surface catchment.

Groundwater recharge is low and occurs throughout most of the catchments where they have been cleared. Under traditional cropping rotations groundwater recharge is estimated at approx. 15 to 20 mm/annum (2).

If we are to control salinity in this LMU we need to know a great deal more about the effect of cropping practices on salinity. With a general move away from traditional cropping rotations there is a need to investigate the water balance of the alternatives. The effects of minimum tillage, direct drilling and alternative cropping rotations which incorporate cereals, grain legumes, oilseeds and perennial pastures in economically viable rotations need to be assessed in respect of their affect on groundwater recharge (6).

Example 2

Another common LMU is the hilly sometimes rocky lands formed on the sedimentary rocks that make up most of the slopes of the Dividing Ranges. This is pastoral country with a higher annual rainfall, typically 500 to 600 mm per year.

In this LMU the principle effect of salinity is on water quality in streams.

Unaltered fractured rock lies immediately below the soil zone in these hilly lands and fractures are often open to depths of 50 to 100 m and capable of transmitting groundwater for tens of kilometres.

Groundwater salinities are lower than in the gently undulating foothills as a consequence of lower salt storage. They generally range from 3,000 to 10,000 mg/I, and discharge zones are more commonly vegetated with salt tolerant weeds rather than being present as barren soil.

In these areas the rocky head-waters of the sub-catchments contribute most to the salinity problem. A combination of poor pasture growth in concert with shallow soils with high permeability and low water holding capacity facilitates high groundwater recharge (typically 50-100 mm/annum). Elevated groundwaters develop in the head-waters (1) as a consequence of high groundwater recharge and high relief. Regional groundwater discharge zones occur immediately beyond the steeper headwaters. At this point in the landscape groundwater discharge develops simply because under the steeper gradients of the upper catchment more groundwater flows into these 'break of slope' zones than is capable of flowing out of them.

In the sedimentary hill country our options for salinity control lie with the development of farm management systems that promote vigorous perennial pasture growth on shallow, often acid soils. This must be achieved in concert with better pasture management to promote sufficient leaf area for increased evapotranspiration. The judicial use of trees particularly on the less arable land is also a favoured option.

The development and adoption of acid/aluminium tolerant perennial pasture species, and increased knowledge of their management for optimum productivity and water use are key objectives within this LMU.

A framework for action

The above are just two examples of the many major units of land that catchments can be subdivided into for consideration in respect of dryland salinity control. This approach has been found extremely useful in Victoria in providing a logical framework for land and water management planning for salinity control in dryland sub-catchments. The aquifers can be identified, the land use of the recharge areas can be assessed, and the priorities in respect of land and stream salinity can be easily identified between one unit and another. Each unit can then be assessed in respect of the land management changes necessary to address the salinity problem.

In some LMUs acid soil problems may need to be addressed, in others a revegetation program may be required, or widespread adoption of dryland lucerne, or pastures that can cope with waterlogging, or cropping systems that incorporate a deep rooted grain legume in a minimum till rotation. The options are many and varied but all are apparent when viewed in the context of climate, land-use and geology.

Conclusions

Salinity is a serious problem in southern Australia. It already affects production from vast areas of agricultural land, has an enormous impact on the quality of our water resources, and devastates our wetlands. Moreover, it is clear that the problem has not yet been arrested nor has it yet reached a peak. It is likely that over the next few decades we will see a dramatic expansion of the problem if nothing is done. Dryland salinity alone is expected to increase in area between two and fourfold over the next few decades based on our current knowledge of trends.

In our irrigated lands the future lies with finding more efficient irrigation practices, and managing high watertables largely through artificial means including pumping and drainage. The disposal of saline groundwater will continue to be a problem.

In dryland areas our future lies with the development of farming systems that are more efficient with respect to water use. We need to develop a much greater appreciation of the influence of a vast range of farming practices on groundwater recharge.

Ultimately our success will depend on our capacity to develop farming practices that offer increased production as a consequence of increased water use efficiency, and our capacity to market these to the community as exciting profitable initiatives within a Landcare ethic. Our success will also depend upon continued support from all levels of Government.

References

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