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Preventing Salinity –Scientific and Community Dimensions

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Résumé

Salinity is an insidious soil conservation issue. Its expression can be greatly removed in time and space from its causes, so a focus on prevention is preferred. To avoid over or under-investment, salinity needs to be staged, the risks defined and the assets at risk identified. This paper describes a risk assessment schema designed to build the information base and community support for preventative actions. It describes a new approach to salinity risk using the concepts of diagnosis and staging by physicians for diseases such as cancer. It outlines the diagnostic tools now being developed to define stage and risk and matches this with a complementary community process. The diagnosis and staging process is being applied in the Fitzroy Basin, an area of approximately 150,000 km2 straddling the Tropic of Capricorn.

La salinité est un problème de conservation de sol insidieux. Son expression peut-être enlevée fort dans le temps et l'espace de ses causes, donc un foyer sur l'empêchement est préféré. Pour éviter par-dessus ou le sous-investissement, la réponse à la salinité a besoin de procéder par étapes, les risques définis et les biens au risque identifié. Ce papier décrit un schéma d'évaluation de risqué, conçu pour construire la base d'information et le soutien de communauté pour les actions préventives. Il décrit une nouvelle approche au risque de salinité utilisant les concepts de diagnostic et de processus par étapes utilisé par les médecins pour les maladies telles que le cancer. Il esquisse les outils diagnostiques étant maintenant développés pour définir l'étape et le risque et lie ceux-ci avec un procédé de communauté complémentaire. Ce schéma est appliqué dans le Bassin de Fitzroy, un secteur d'approximativement 150,000 km2 enfourchant le Tropique de Capricorne.

Introduction

Salinity is an insidious soil conservation issue. Its expression can be greatly removed in time and space from its causes and it can take a lot longer to fix than to cause. In Queensland, Australia, the focus in salinity work is on prevention – the preferred approach given salinity's intractable nature and its later development in Queensland than in southern Australian states. But prevention is challenging; there is no visible and clear threat and, therefore, either over or under-investment is likely. This paper describes a developing and comprehensive process of staging and risk assessment designed to match investment to the prevention need.

Rationale

In medicine, stratification and staging are essential aids to identifying the elements of the progress of disease where different treatment modalities are indicated and/or which reflect a range of prognoses. Diagnosis requires tools that directly sense the infection or tumour, indirectly sense it or sense indicators reflective of the disease. Increasingly, multiple lines of evidence are sought with more weight given to those with best accuracy and precision.

Salinity diagnosis and treatment can be staged in the same way. There are tools that directly sense salt or saline groundwater and those that sense aspects of the salinity process. To understand the process of diagnosis, it is necessary to state the conceptualisation of the salinity process which treatment is aimed at. The model we use is summarised thus:

> Change in salinity expression comes from increased recharge of subsurface water. This arises, after some time lag, from increased deep drainage after a change in land use/management. The increase ranges from small (limited clearing and grazing) to large (irrigation and water storage).
> Salt is stored in the landscape and can be mobilised through water movement. This salt is unevenly distributed and unevenly susceptible to mobilisation.

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Water can move salt through shallow episodic movements or in the dynamics of the groundwater layers. Severity will depend on the degree of hydrologic change and the amount of salt mobilised.

Finally, we are interested in whether the salinity expression intersects with valuable assets. This can range from deterioration of groundwater assets, water quality in streams and water storages, effects on infrastructure such as roads or buildings to salinised land where the salt reaches the surface.

Stages, risks and assets

Table 1 Stages and risk factors for salinity (factors are not related across the table)

Stage of salinity threat	Level of risk factors[1,2]	Value of assets
1. Salinity absent as an issue. Salt has been flushed from the system by high constant rainfall. 2. Salinisation processes have commenced but there is no evidence of a threat to assets in < 100 years. 3. Salinisation processes have commenced; no current threat to assets but a threat is likely within 100 years. 4. Salinisation processes have commenced; no current threat to assets but a threat is likely within 50 years. 5. Salinisation processes have commenced; no current threat to assets but a threat is likely within 10 years. 6. Salinity currently threatens assets but evidence suggests that equilibrium has been established and the scale of threat will vary around a static mean. 7. Salinity currently threatens assets; evidence suggests that the scale of threat will increase over time.	A. Land use essentially unchanged from natural systems; deep drainage occurs through historic recharge areas B. Deep drainage increased minimally. Land use is water conserving eg. Perennial pastures C. Deep drainage increased slightly. Non-irrigated land use designed to maximise water use eg. Opportunity cropping D. Deep drainage increased moderately. Non-irrigated land use that allows deep drainage due to the nature of the system eg. Winter wheat on stored summer rainfall E. Deep drainage increased markedly. Land use with irrigation. F. Deep drainage increased substantially. Locally intensive additions of water to the land surface eg. Water impoundments, unlined irrigation channels	I. Low value asset either economically or socially; asset is not valued or there is a large supply II. Moderate value asset; asset is directly valued in its current setting or the supply is dwindling III. High value asset; asset is highly values generally or would be expensive / impossible to replace or is rare

The salinity process can be seen to have three independent components (Table 1). The first component describes the degree of threat to defined assets. The second measures the level of risk factors, which are related to the relative increase in deep drainage, groundwater characteristics and salt stores in regolith and groundwater. The third measures the value of the asset under threat. Each component is as important in deciding on appropriate management and each benefits from being assessed independently. Figure 1 exemplifies their use in a risk map.

[1] Risk factors can be mitigated by water use efficiency measures.
[2] Deep drainage (the loss of water below the root zone) is used here as a measure of risk. The level of deep drainage is a complex resultant of land use, climate and soil / terrain characteristics. Modelling is used in developing these factors.

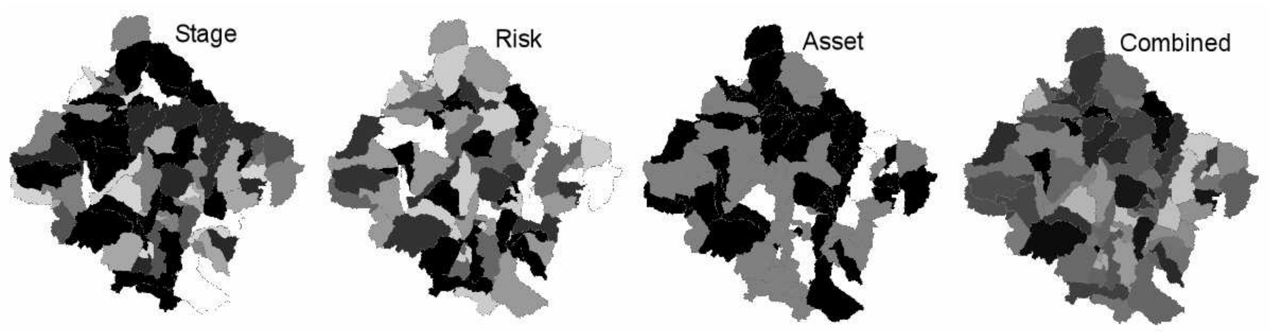

Figure 1 Illustration of how the three dimensions of stage, risk and asset threatened could be displayed in a hypothetical area. The combined image adds degrees of grey shading. Lighter areas require more action to address salinity and the components can be identified.

Treatment options then depend on the combination of stage and risk factor. For example for the same value of asset, stage 3/ risk factor B would only require monitoring; whereas stage 3/ risk factor F may require intervention in the medium term such as the lining of irrigation channels. Extremely rare or valuable assets may attract intervention even where the threat is remote and the risk is small. This scheme is designed to be applied across large areas eg. the Fitzroy Basin and replace relatively simplistic hazard and risk maps (Figure 1). The scheme fits well within a GIS approach and the detailed diagnostic reasons for the categories can be built into the scheme and accessed where necessary. So, for specific instances of salinity risk, the nature of the stage, risk and asset can be described and illustrated with as much detail as necessary.

Matching diagnostic tools to the staging process

Effective use of the staging and risk approach requires a matching of diagnostic tools to the components of staging and risks. The range of diagnostic tools and their reliability has increased substantially with recent research and development and are listed in Table 2. In addition, salinity diagnosis depends on characterisation of groundwater systems and an understanding of the geomorphological setting of salinity processes in the regions. Salinity occurrences in the state have been characterised in terms of the landscape factors driving the occurrence. Airborne geophysical tools such as electro-magnetic sensing, magnetics and gamma radiometrics have been used to deepen the understanding of the regolith systems in which salinity occurs in high priority areas.

Table 2 Diagnostic tools used in identifying salinity stages and risks.

Current salinity indicators	**Salinity process indicators**	**Salinity risk descriptors / models**
Purpose: provide evidence of the development of existing salinity processes. These are relatively static indicators of stage and are most effective in indicating the existence of a late stage salinity process (Stages 5-7).	Purpose: look beyond the existing salinity evidence for the trends and are essential for early staging or for determining the extent of disequilibrium in the water and salt balance. They are therefore required for stages 1-7.	Purpose: provide the predictive ability to either measure the extent of risk (A - F) or to establish trajectories with the continuation of existing processes or of scenarios of changed land use. All models have either been developed and validated in Queensland or have been refined for valid use in the state's regions.
Salinised land – diagnosed with satellite interpretation, field sampling and induced electromagnetic sensing Groundwater depth and quality – diagnosed by sampling bores located in key sites within representative groundwater flow systems Stream concentrations and loads – diagnosed by stream gauging	Catchment salt balances which indicate whether land use/hydrologic changes in the catchment are being reflected in the streams. They use the ratio of salt input in rain and output in streamflow Groundwater trends – diagnosed by sampling bores located in key sites within representative groundwater	Deep drainage under the range of land uses in the region – diagnosed by lysimetry, soil chloride mass balance and soil water balance modelling A model (2CSalt) that integrates all of the soil water balances in a catchment (e.g. <2000 km^2) to give stream flows, base flows and salt loads The Integrated Quality Quantity Model (IQQM) which provides basin-wide water and solute balances in a

at key points in the stream network Base flow levels and duration (ie. the contribution of groundwater to stream flow) – diagnosed by sampling stream flow at dry times in the climate cycle	flow systems at various times Surface water trends and baseflow interaction trends – diagnosed by sampling and ionic and isotopic analysis Water content of the vadose zone ie. the extent to which the excess deep drainage has extended into the vadose zone and towards groundwater – diagnosed by deep drilling and soil psychrometry	gauged stream network The Biophysical Capacity to Change model (BC2C) which calculates response times of stream salt export after a change in land use, comparing sub-catchments across broad scales

Not all diagnostic tools are available for use everywhere or need to be employed but the capacity is now available to reliably diagnose the stage of salinity processes in Queensland catchments.

Treatment options

By developing concepts of stages and risk factors, research, monitoring and action can focus on the options appropriate to address the need for change. Of the range of variables associated with secondary salinity, treatment options focus on deep drainage and groundwater recharge associated with land management or discharge control using pumping and diversion. The variety of land use management options available range from relatively minor changes to the vegetation and cultivation practices through to extensive strategic vegetation options to the use of engineering drainage works. The earlier a salinity degradation process is identified and addressed, the smaller the effort required for prevention and the greater the chance of success. Likely options for the Fitzroy Basin area are listed in Table 3.

Table 3: Salinity treatment options likely to be used in the Fitzroy Basin

Salinity treatment options	**Examples**
Variation within the current landuse to reduce deep drainage in general or at specific times	Improvement in irrigation scheduling Change in irrigation type (e.g. furrow to sprinkler or drip) Change in dryland cropping water management eg. opportunity cropping Change pasture species to increase percentage of perenniality
Change of land use	Irrigation to dryland cropping Cropping to grazing Grazing to agroforestry
Land use placement	Changing the mix of land uses so that water efficient uses are in sensitive landscape positions Planting deep rooted vegetation in recharge / discharge areas

Assets

The listing of assets in Table 1 is deceptively simple. In practice, identification and valuing of assets is a time-consuming and often controversial task. At the broad level, the key issue is value / rarity of the asset and the level of threat. For example, a pristine wetland is likely to be highly valued but if it is distant in time and space from salinity threats then other less valuable but threatened assets may require intervention initially. The presentation of information about assets is scale sensitive. At the broad scale, it will reflect the broad classification in Table 1. At the scale of community action, the assets are identified and used as a prime motivator for action.

Community dimension

A salinity problem that is yet to happen is difficult to observe. The type, scale and focus of intervention depend on the stage of the salinity process and the position of the individual within the community response. So success depends on matching the scientific effort and the community response to an agreed assessment of salinity stage, risk and the assets under threat.

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The community approach is based on developing a shared understanding of risk and priorities. The community model for the Fitzroy Basin is based around:

- A concentration on neighbourhood catchments – areas small enough to contain a commonality of interest but which reflect hydrological processes
- Focus groups in the neighbourhood catchments who are involved in the developing understanding of salinity processes
- An over-arching community body (the Fitzroy Basin Association) which receives government funding to carry out on-ground changes to address environmental concerns
- Extension support to the key neighbourhood catchments and a simple paper-based tool to carry the developing scientific understanding and to guide a simple staging of salinity in the neighbourhood catchment which reflects the risk assessment across the Basin as a whole.

The overall system provides the required background for community investment in preventative actions.