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RIRDC Short Report No 40:

Groundwater uptake and salt accumulation by trees over shallow water tables

THE FULL REPORT

This is a summary of the full RIRDC research report of the same title by Peter Thorburn, CSIRO Tropical Agriculture. Ph (07) 3214 2200, fax (07) 3214 2325. The report will be part of the Water & Salinity Issues in Agroforestry series available from RIRDC on phone 02 6272 4819.

Introduction

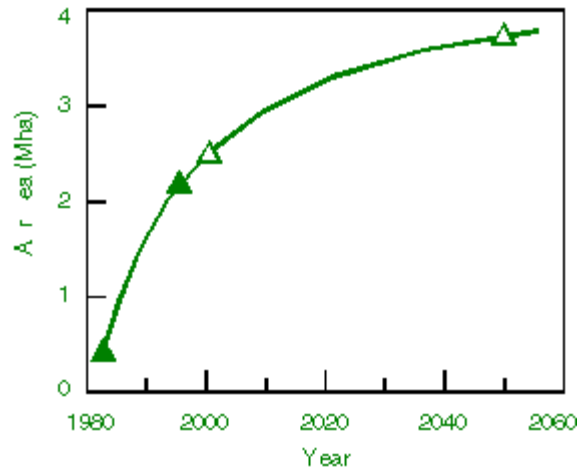
The area of shallow water tables in Australia is increasing, in both irrigated and dryland regions (see Figure 1).

While altering land use to control recharge of groundwaters is an attractive, sustainable option for managing the problem, it is not always practical to implement.

Some reasons for the impracticality include: difficulty defining recharge areas in catchments, high paddock-scale productivity of current land uses in recharge areas, and the long time scales involved in reversing the current trends in water table depths.

Figure 1. Area affected by shallow water tables in Australia (after Robertson 19961).

The open symbols are estimates of future areas.



An alternative management strategy is to adopt a land use in areas with shallow water tables (that is, groundwater discharge areas) that has high rates of groundwater discharge while, ideally, providing site stability and a reasonable return to the land manager.

Agroforestry is widely seen as a land use that achieves these objectives. Early studies suggested that rates of transpiration and groundwater uptake by trees underlain by shallow water tables were very high.

This, coupled with the growing interest in timber production in Australia, led to the popularity of this management strategy.

However, when trees (in fact all plants) take up water from, or above a water table, groundwater flows towards the roots. With it, the groundwater carries salts, most of which are excluded from the root and so accumulate in the root zone. High root zone salinity limits transpiration and growth of plants. This process has not been widely recognised by protagonists of agroforestry in saline areas.

Over the past 10 years considerable effort has gone into examining this issue and enormous progress has been made. Field sites have been established in five states (WA, SA, Vic, NSW and Qld), covering a wide range of plants (crops, pastures, shrubs, and native and planted trees) in both irrigated and dryland settings. The research has been conducted by people from at least six disciplines (agronomists, foresters, ecologists, physiologists, soil physicists and hydrologists). There is also other relevant knowledge, such as data bases on tree performance under saline conditions. Thus, there is a wealth of knowledge and experience of the topic and, internationally, Australia is at the forefront of research on this issue.

Despite this knowledge, the issue of salt build up in tree root zones underlain by shallow water tables was identified as a key issue for further research at the recent Agroforestry and Hydrology workshop2 sponsored by the Joint Venture Agroforestry Program. Groundwater uptake, which is intimately involved in the processes of root zone salinisation, was also identified as a substantial gap in

modelling. Both these processes are important in determining the impact of agroforestry systems on shallow water tables, and the sustainability of these systems.

Unfortunately, much of the knowledge and experience recently gained is fragmented and dispersed. This situation is expected in a relatively "young" area of research, conducted over such a diverse range of locations and disciplines. Also, there has been no single focus for communicating the results of these studies, especially for process level understanding. Thus, rather than having a broad, coherent view of the problem, the situation more resembles a group of disparate observations of site specific processes. For future research to be conducted efficiently, our current knowledge must be more thoroughly integrated.

Twenty researchers, who had been active in these studies, both in the field and via modelling, came together at a workshop to compare experimental results and examine recent advances made in modelling the processes determining the sustainability of trees planted over shallow water tables. The workshop consisted of technical presentations and group discussions and had the following aims:

- To collate and examine results of different field studies conducted in Australia.

- To describe and examine recent advances made in modelling these processes.

- To identify similarities and differences in processes operating in the different studies.

- To identify areas of inadequate knowledge and limitations of current modelling approaches.

- To provide growers with a consensus scientific opinion on the most likely outcomes for various situations

The outcome of the workshop will be the development of a broader view of the processes operating in these systems than could be gained from the studies independently.

Outcomes and recommended actions

Current state of knowledge

Presentations at the workshop described advances in the areas of irrigated and dryland agricultural lands, and natural ecosystems. More details of these presentations are available in the full research report. There is a great deal of knowledge about the processes controlling groundwater uptake and salt accumulation in the root zone trees over shallow water tables. The following two

statements encapsulate our current understanding about the sustainability of trees planted over shallow saline water tables:

A. Salt accumulates in the root zone in response to groundwater uptake -

Salt accumulation constrains transpiration and growth and salts need to be removed from the root zone for plant survival.

There are several mechanisms by which salts can be removed from the root zone: leaching by floods, rain, or irrigation; fluctuating water tables; diffusion.

B. Tools, based on experience and process knowledge, exist to judge the long-term fate of tree plots over shallow water tables -

Models can be applied where there is detailed information on the site and detailed predictions are wanted.

Guidelines are available which are suitable for more general recommendations.

Actions to improve knowledge and tools

Despite the clarity of the above statements they are broad and there are still critical gaps in our knowledge and uncertainty regarding the limits of our experience:

What is the time scale of salt accumulation/removal and can this process be managed?

How reliable are the tools and how widely can we apply them beyond the studies/locations on which they were based?

To overcome these deficiencies, 10 actions were proposed to (1) improve knowledge of groundwater uptake and salt dynamics (accumulation and removal) in the root zone of trees over shallow water tables, and (2) provide more soundly based tools to assess the long-term fate of these systems. These actions, and some immediate benefits leading from them, are (not prioritised):

1. Improve mechanistic understanding of processes controlling water use and salt tolerance of trees in the field (eg, minimum soil water potentials for root

function and growth, carbon partitioning within plants), to provide:

Better species selection/tree improvement programs to allow increased growth and water use in saline areas.

Better process understanding for improving representation of plants in models.

Data sets for validating models.

There are only sparse measurements of tree water use, salt tolerance and water logging tolerance available from which we can gain insights into the processes determining the performance of trees in saline areas. Much of the information has come from glasshouse studies. Where studies have been conducted in the field, they generally have been conducted in the short term (eg, over a few years) with the sites being poorly characterised (eg, little soil and groundwater information). Thus the results are specific to the site and experimental period and difficult to generalise. Differences between species in tree water use and salt tolerance have been well characterised but the reasons behind the differences are not well understood.

2. Refine/further develop rules for describing the depth and temporal distribution of salts in the root zone (initially by a review of current data) and further develop relevant models, leading to:

Improved site predictions of time to equilibrium, and magnitude of, root zone salt accumulations.

Salt accumulation is well documented. However, salts are also removed from the root zone but this process is not as well characterised. There are different mechanisms of salt removal that can occur at field sites, such as leaching by floods or rain, groundwater level fluctuations, diffusion. The role of diffusion is not well understood (eg the process is often confused with dispersion) but it may be an important process given the time scales involved in salt accumulation in these areas. There is uncertainty about the application of the physics of diffusion and dispersion in the field (as opposed to the laboratory) and argument over appropriate diffusion coefficients. This existing information needs to be collated to better describe and synthesise our current knowledge.

3. Further develop and refine rules for describing root water uptake in saline environments (initially by a review of current data) and further develop

relevant models, leading to:

Improved understanding and model-representation of a process fundamental to short- and long-term performance of trees in saline environments.

Root function is poorly understood. It is very important to differentiate between root distribution (ie presence) which is better known, and root function (ie water uptake). Different mechanisms of root function appear to be operating at different sites, but we are currently unable to predict which mechanism will operate at new sites. Experimental methods have been developed over the past 5-10 years that allow better information to be gained on root function, particularly in drier areas. However, a first step in improving our knowledge is to collate existing information and provide databases on which to test new modelling approaches.

4. Monitor root zone salinity at existing field sites and sites used in past studies (selected to represent different environments), to provide:

Data sets for validating models.

More extensive soil salinity data is required for testing hypotheses about, and models of, salt movement (accumulation and leaching) in soils under tree plots, particularly in eastern Australia. Re-sampling past experimental sites (provided they were originally well characterised) would be an efficient means of collecting long-term data. However, there are general problems with characterising soil salinity profiles. These include the variations in laboratory methods used to measure salinity as well as difficulties in characterising spatial and temporal variations in the field. A more standardised approach is required to allow better inter-site comparisons.

5. Test existing modelling approaches for predicting tree performance and changes in soil salinity and water table depths in areas with shallow, saline water tables:

at appropriate scales (eg. paddocks to catchments, depending on the model),

in a variety of hydrologic and hydrogeologic environments,

where there is an adequate database (in terms of both quantity and quality),

where there is also good local practical knowledge of dryland salinity processes and management options, to provide:

Improved understanding of model performance for providing management oriented predictions of dryland salinity risk and management.

Increased acceptance by non-modellers of the contribution that modelling can make to practical management problems.

The framework of current models is good. The physical system is generally well understood and all existing models provide some level of understanding and response. Lack of data constrains application of groundwater models, and this will always be a problem. However, the problem needs to be more widely recognised and a basis for decision making in the absence of good quality data needs to evolve. Many different modelling approaches are used in the unsaturated zone in a wide variety of applications. Not all of them may be valid, and certainly not all are appropriate in all situations. However, data (or suitable approximations) are more readily obtainable in the unsaturated zone than for the saturated groundwater case. Similarly, the uncertainty of the approximations may be greater, due to the larger fluxes within the unsaturated zone - there is more happening over shorter time scales. There is a better chance of validating models and their assumptions in the unsaturated zone simply because observations are more easily made.

6. Develop guidelines for planting trees in saline discharge areas, to allow:

Improved deployment of the substantial human and financial resources already being directed towards this activity.

Currently, many landholders and community groups are investing considerable resources (time and money) in establishing trees in saline areas to control and prevent salinity. This activity is being undertaken in the absence of any guidelines. However, there is considerable knowledge about site selection and possible long-term performance of such tree plantings as well as limitations to their benefits which could be brought together as interim guidelines. Further research and experience can be used to update these guidelines in the future.

7. Link biophysical models to commercial values to allow economic analyses of management recommendations, to provide:

A more relevant analysis of the financial implications of management plans identified in modelling exercises.

A significant effort is required to integrate our knowledge into a "whole catchment" picture, and then a regional framework, so that implications of different management scenarios can be evaluated. This needs to include the

economic and commercial factors that influence decision making, as well as environmental factors. The biophysical models currently available need to have commercial values added to put "dollar" values on treatments and outcomes. Once models were developed in this way, the economic outcomes of many (eg, thousands) of management scenarios should be tested. This path of action leads to a dilemma, however: do we try to distil our experience and knowledge into a simple broadly applicable model which produces approximate outputs or enhance existing detailed models to attempt to give detailed, more site specific outputs?

8. Improve documentation and peer review of models, to give:

Greater confidence in the scientific/technical integrity of models.

Too many models are developed and applied "in house" without being properly documented or peer reviewed. The value of results from application of such models can not be properly judged and it is easy (and correct) for potential users of this information to be sceptical of the validity of the information.

9. Standardise and cross check (wherever possible) techniques used in studies and report errors in measurements, to provide:

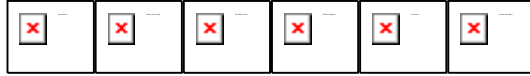
Higher quality information from studies and improved ability to judge the significance of the results.

Techniques used in different studies need to be, as far as possible, standardised and the errors associated with results reported. Also, results from a technique need to be cross checked with those from other techniques (eg, comparing transpiration measurements with changes in soil water profiles). This would provide higher quality results and improve the credibility of the study. These comments apply equally to established methods and new techniques. Limitations of techniques and the assumptions on which they are based are generally forgotten through time.

10. Undertake initial site characterisation (climate, hydrogeology, soil information, etc.) before large trials and treatments are instigated, to provide:

Improved data for model initialisation, and hence improved model testing and predictions.

More attention should be paid the "down stream" use of information coming from major experimental sites. Information from these sites has great potential value in testing, developing and calibrating models. However, models often can not be applied to data from these sites because important information about the site (eg, soil details) has not been determined. Thus, the potential benefit from the community's investment in the experimental site is limited.



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