REBUTTAL TO THE RETURN OF THE RGM FOR DRYLAND SALINITY

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Abstract

Recent publications extend the rising groundwater model (RGM) previously applied to dryland salinity from surficial aquifers to include deep aquifers used for water production. Separate correlations between rainfall and bore water levels and the extent of dryland salinity were used to draw the conclusion that dryland salinity is mainly due to change in climate rather than land use. The validity of this conclusion is examined to demonstrate that it has no basis in science and cannot apply.

Introduction

The rising groundwater model (RGM) is again being presented to explain dryland salinity with the key proponents being hydrologists (DECC 2009, Summerell et al. 2009). In particular, extensive observations on bore water levels and rainfall, and general observations on the extent of dryland salinity, have led to the conclusion that the extent of dryland salinity is related to change in climate (Rančić et al. 2009). This conclusion is used to identify that dryland salinity is primarily caused by variations in climate rather than land use. The only land use addressed is tree clearing, and then only in relation to water use.

> *Natural climate variability over the past century has emerged as the main trigger of soil salinity problems in south-eastern Australia, according to the surprise outcome of a major new groundwater study.*
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> *The finding overturns decades of accepted wisdom by revealing that land-clearing - which has long been attributed with the major role - has only a secondary part to play in the development of dryland salinity in south-eastern Australia[1].*

Numerous issues arise with these conclusions. They include whether the consideration of climate in dryland salinity is new, whether bore water levels have any causal relationship with dryland salinity, the validity of observations of the extent of salinity used in the study, and whether the data analysed can be used to separate the effects of land use and climate.

The issues are addressed logically to identify whether the conclusions have any validity. However, it is noted that the conclusions have arisen without consideration of the numerous recent publications identifying that dryland salinity in the uplands of southeastern Australia has little to do with groundwater (e.g. Acworth and Jankowski 2001; Bann and Field 2006a,b,c, 2007; Dahlhaus et al. 2008; Edwards and Webb 2006; Fitzpatrick 2008; Rengasamy 2002, 2006; Thomas 2007; Wagner 2001, 2005).

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[1] http://www.connectedwaters.unsw.edu.au/news/salinityrainfall.html Accessed July 2009

Extent of Dryland Salinity

The extent of dryland salinity was obtained through visual interpretation of aerial photography and simulated information on expected patterns of surficial accumulations in the landscape[2]. Numerous issues arise with the study but the key ones are that the methods cannot reliably identify the salinity of soil or water. The salinity was inferred from indicators that are known to be unreliable in identifying adverse salinity, particularly when aerial photography is used.

The procedure used for the salinity assessment is based on an assessment of land use impacts visible in vegetation or the soil surface. Any change with the interpreted extent of salinity with climate therefore represents a change in the relationships between land use impacts and climate. Effects of land use and climate are combined in the observations and this confounding prevents use of the results to draw any conclusion concerning the effect of climate alone.

While the information on the extent of salinity cannot be used to identify the effects of climate alone that is what has been attempted by Rančić et al. (2009). For any such conclusion to be made there would need to be observations of the extent of salinity in landscapes unaffected by land use as well as in those impacted by land use. As this was not done any conclusion as to whether climate is more important than land use in determining salinity has no validity.

Climate

The identification of climate as being causal in dryland salinity is presented as being new when climate is central to all considerations of soil salinity. As the name implies the development of dryland salinity is associated with climate. The Mediterranean climate of cool moist winters and hot dry summers is most conducive to the development of adverse soil salinity. Soil salinity is common in dry areas but tends not to occur in areas of high rainfall.

Historically the term dryland salinity related to salinity that occurred in dry lands, but it is now usually applied to salinity associated with dryland agriculture. This change in the use of the term resulted in some discriminating between primary and secondary salinity. Primary salinity is considered to be 'natural' whereas secondary salinity arises through land use and is therefore anthropogenic. This discrimination has caused confusion as there is no means of reliably identifying whether observed salinity is natural or anthropogenic as the mechanisms and outcomes are the same. The outcomes may differ in magnitude depending on land use, and they usually do, but they do not differ in kind.

The identified change in extent of soil salinity with change in rainfall accords with known mechanisms, and it applies with soil degradation being the cause of dryland salinity. That is, a correlation between the extent of soil salinity and change in climate does not negate land use as being causal in the occurrence of adverse soil salinity. It simply indicates that a change in water availability can change the soil salinity. The increased water availability mobilises salt in soils which then accumulates in lower positions in the landscape through evaporation.

While a change in rainfall can alter soil salinity the outcome depends on the condition of the soil as well as position in the landscape. The pattern of water movement depends on factors such as vegetation and soil condition as well as rainfall, and all combine to produce observed outcomes. Salts are leached through the profile with permeable soils where they usually drain out of the system without affecting soils elsewhere. This applies whether the soils are on the slopes or flats.

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[2] http://www.environment.nsw.gov.au/resources/salinity/09107Landsalinisation.pdf Accessed July 2009

With impermeable soils the water flows tend to be lateral with water containing salt being spread across flats. The salt is not removed from the system and is dispersed across low lying areas. However, if the higher rainfall continues for a sufficient period the salt tends to drain from the system through surface and/or subsurface water flows. Areas with high rainfalls seldom have saline soils and, where they do, it is related to the salinity of a particular geological formation.

This process is dynamic. Through periods of low rainfall salts accumulate locally by aeolian accession and the weathering of minerals. Their distribution in the soil is related to patterns of infiltration of water into soils which relate to patterns of water use by vegetation as well as the magnitude and patterns of rainfall and potential evaporation. With increased water inputs these salts can be mobilised and redistributed within the system. The main direction of water movement is lateral due to the structure of the surface topography, soil and underlying material, but there is a significant vertical component as the flows are driven by gravity.

With gravity as the driving force the main vertical vector for water draining through systems is down, with upward movement only occurring under specific conditions. As the salts are transported by water the patterns of salt movement mirror those for water.

This increase in salinity expressions with increase in water availability is transient as, with time, the salt is leached from the system.

Upward Movement of Water in Soils

The RGM has water moving vertically upwards in soils, and thereby ‘rising’. For the upward movement of water to be of any consequence for dryland salinity it must occur in the surface 1m of ‘soil’.

Water movement in soils occurs along a gradient in water potential where, with saturated soils, gravity is the dominant component. As soils become dry other components of the soil water potential increase and become much greater than gravity. The direction of water flow is then from wet to dry parts of the soil essentially regardless of gravity.

With a saturated subsoil and dry surface soil the gradient in soil water potential is from the subsoil to the surface: the gravitational force is then less than the other forces that produce water movement. Water can flow upwards along this soil water potential gradient, but the flow is unsaturated and very slow due to high resistances. The resistance to water flow increases markedly as the soil dries and dry soil is necessary for such upward flow to occur.

This upward movement of water in soils is generally restricted to around the surface 10 to 20 cm and, in natural systems, it results in the immediate surface soil being more saline than at 10cm. Upward movement of water from deeper in the profile is very limited and only arises under the specific circumstance of the subsoil materials being saturated and the surface soil being dry.

In local systems not receiving accessions of water from elsewhere the vertical pattern of water movement can be inferred from the salinity patterns in the soil profile. This pattern primarily relates to water use by plants interacting with the infiltration of rainfall. Plants tend to remove water from the entire profile whereas rainfall percolates in from the top. Salt therefore tends to be leached into lower parts of the soil profile. Other aspects of the pattern arise through the identified small accumulation of salt at the soil surface, and the leaching of salt below the depth of water extraction by plants.

Knowledge of physics can be further used to identify the relative magnitudes of upward and downward water flows. If the surface is dry and the subsoil saturated then water can flow upwards over a limited distance, albeit slowly. However, if the surface and subsurface are both saturated then the vertical direction of water movement is down. As the soil invariably becomes wet through rainfall there is always some period when the water movement is down. As the rate of downward flow relates mainly to saturated flow but the upward movement is unsaturated, the downward flow can readily exceed the upward flow even where rainfall is sporadic. The net direction of water flow in soils is almost invariably down.

Surface Water – Groundwater Connections

The applicability of the RGM depends on a suggested widespread occurrence of subsoil saturation due to water deriving from elsewhere, with this water rising to the soil surface. However, for subsoil water to rise to the surface to any significant extent the water must be under pressure to counter the effect of gravity.

Upward pressure can arise with confined and semi-confined aquifers[3] wherein water is under pressure from the weight of the water at higher points in the aquifer. This can readily be demonstrated for surficial systems using piezometers. However, the existence of such pressure arises through confinement hence there is a barrier to the flow of water from beneath the soil to the surface. Where there is upward flow it is usually localised, as with springs. There is no observational evidence of widespread flow of subsoil water to the surface, and logically it cannot occur. Indeed, dryland salinity has been shown to occur where there is no connection between soil water and underlying aquifers (Bann and Field 2006c; Edwards and Webb 2006; Paulin, 2002; Rengasamy 2002; Thomas 2007).

The groundwater bores analysed in the study of Rančić et al (2009) are deeper than the groundwater systems normally considered in the RGM. There is no possibility of such groundwaters rising in a general manner to supply water to soils.

Many observations exist of adverse soil salinity arising through water seeping to the surface and spreading laterally. However, with dryland salinity this water typically arises from the soils immediately upslope. The main direction of water movement is lateral, predominantly perched on a largely impermeable B soil horizon, and the vertical movement is always down. The water is not associated with groundwater systems as defined by hydrologists, and the water certainly does not derive from groundwaters associated with production bores.

Situations exist where groundwaters do cause adverse soil salinity but these have localised expressions due to structural geological constraints, as with the fault line that runs through Cootamundra (Trethewey and Gourlay, 2001)[4].

Land Use

The only land use considered as an alternative to climate change in causing dryland salinity by Rančić et al. (2009) is tree clearing, predominantly on the hills. This arises because the RGM was traditionally linked to tree clearing with the logic being the same as with climate. Trees use water. Remove the trees and there is more water in the soil than was usual. This water was said to percolate into groundwater systems (recharge) on the hills and rise to the surface

[3] Technically with any outlet an aquifer becomes semi-confined. In practice it is a matter of degree.

[4] As water preferentially flows along a rock fracture the fault line is technically an aquifer. However, it has a different structure than the fractured rock aquifers examined by Rančić et al (2009) and for dryland salinity is functionally very different.

on the flats where it brings salt to the surface (discharge). The salt was said to derive from stores presumed to exist beneath the soil. The mechanism thus depended on the existence of surficial semi-confined aquifers and salt stores beneath the soil. Infiltration of water on the flats was not considered despite the rainfall there being as high as on the hills[5].

The hydrologists have replaced tree clearing with climate change (read rainfall change) as being the source of increased soil water. Also, they have replaced the surficial aquifers with deeper groundwater systems.

The original versions of the RGM failed because of an inability to identify that the suggested upward flow of water actually occurs. Also, the essential subsoil salt stores do not have general existence. The new version based on climate has not resolved these issues. Indeed, it has been made even more improbable by linking soil water accessions to deep groundwaters whilst still ignoring the processes occurring at the surface.

Tree clearing has been negated as being the cause of dryland salinity. Soil degradation has been identified as being the logical cause and this has not been negated. Indeed, there are numerous and increasing observations that provide support. In particular, the ability to reverse adverse salinity through management provides the best indication of cause. Many of these remediations follow fencelines where the existence of fenceline effects identifies that climate is not causal and that land use is.

The solution given to dryland salinity with the RGM taken as being the cause is to plant trees on the basis that trees use more water than other plants. While this conclusion on water use is debatable (on existing knowledge they may or may not) there is a classic scene in a TV program addressing salinity showing eucalypts planted to remediate salinity alongside a field that was previously saline and subsequently planted to lucerne (Coulthart 2006). The soil under the eucalypts is bare, wet and saline while that under the lucerne is moist, friable and non-saline. Such situations are typically interpreted as identifying that the eucalypts were planted in the worst affected areas when they actually identify that planting trees can be ineffective in providing remediation.

Lucerne is effective in remediating adverse soil salinity because the management regime improves the soil structure. Eucalypts are ineffective as they don't. Eucalypts have been promoted as being beneficial due to their high measured rate of water use but, in an ironic twist, much of this water is likely brought into the system by the eucalypts (Tunstall, 2009). That is, depending on the climate the eucalypts can exacerbate the problem. Conditions are most favourable for direct accession of water by plants over winter.

Any increase in water is always beneficial with lucerne because the management regime produces a friable soil structure. The improvement in structure results in salt being leached through the soil profile thereby improving conditions in the root zone.

Images obtained from Google Earth provide examples of salinity expressions in the area studied by Rančić et al. (2009). A common form of salinity expression has the same pattern as gully erosion (Fig. 1). Soil erosion arises through the concentration of water flows across the soil surface whereas the salinity arises through drainage through the surface soil (surficial drainage). This surficial drainage occurs because the surface soil (A horizon) is much more permeable than the subsoil (B horizon). As these soil horizons generally mirror the surface topography the spatial patterns of surface and surficial drainage are often the same.

[5] The lateral and vertical spatial separations between flats and hills are insufficient for there to be a significant orographic effect.

Surficial drainage is restricted to conditions when the surface soil becomes saturated, which in the region is over winter when rainfall exceeds evaporation for an extended period. Salts mobilise in winter when conditions are wet and concentrate over summer when conditions are dry. As sodium is usually the dominant salt, and as sodium disperses clay, the salinity promotes increased gully erosion.

The drainage patterns in Fig. 1 are natural and arise in systems that are not subject to land use. However, the patterns are exaggerated due to land use degrading the soils and vegetation throughout the entire paddock. The gully erosion and salinity expressions receive most attention as they are obvious, but the cause of this damage is the degradation to soils that has occurred throughout the entire paddock.

Fig. 1. High spatial resolution satellite image obtained from Google Earth.
34° 38' 27.94'' S
149° 42' 32.81'' E

This effect of land management on the development of erosion and salinity is illustrated by a fenceline effect (Fig. 2). The level of impact along the drainage line depends on the level of degradation of the associated paddock

Such fenceline effects identify that the differences in salinity expressions are not due to climate or tree clearing. They also identify that they are not due to water rising from any groundwater system. Any suggestion that fences could constrain the upward flow of water from ground water systems would be bizarre.

A critical consideration is that the patterns of soil salinity existing before the development of agriculture cannot be known. All observations of salinity expressions therefore incorporate natural as well as land use induced effects. Another consideration is that salinity expressions depend on changes to patterns of soil water flows where these are affected by many factors including climate, vegetation, topography, and the structure and condition of the soil.

The number of factors involved, and the confounding of their effects in observations, makes it difficult to determine the prime cause of expressions of dryland salinity. Determination of cause definitely cannot be achieved through simple correlations and requires detailed consideration of the processes involved (Bann and Field 2006a,b,c; Dahlhaus et al. 2008; Tunstall 2001, 2004, 2005a,b, Tunstall & Gourlay 2006: Wagner 2001).

Fig. 2. High spatial resolution satellite image obtained from Google Earth.
34° 45’ 49.75’’ S 149° 48’ 31.98’’ E

What’s New

The only potentially new observations leading to the conclusion that dryland salinity is caused by changes in climate are a correlation between production bore water levels and rainfall. However, such correlations have been observed previously and the conclusions have long been known. While some data may have been analysed for the first time the conclusion as to a correlation between groundwater levels and rainfall is basic knowledge.

The conclusion that dryland salinity is related to climate is similarly not new except that the relationship identified by Rančić et al. (2009) is the reverse of that previously identified. They have dryland salinity increasing with increase in rainfall when with global occurrences of land salinity the reverse applies. This situation arises because change in salinity with change in climate is transient with a new equilibrium eventually being established if the environment is reasonably stable. The time to achieve a new equilibrium depends on the flow pathways for water relative to the salt stores as well as the magnitude of change to water flows (Peck 1973).

The suggested 100 year cycle in climate change is sufficiently short that a new salt equilibrium would not arise in most situations now subject to adverse salinity[6]. However, examination of patterns of native vegetation identifies that the extent of salinity is now much greater than existed prior to extensive land clearing for agricultural development. The native vegetation would have been very different to that which actually existed in many areas if the land had previously been subject to current levels of salinity. Indeed, many remnant stands of native vegetation have been killed in association with the development of salinity[7], indicating that the salinisation is now considerably more severe than anything that had occurred within quite a few hundred years.

The suggestion that dryland salinity arises through change in climate has no observational basis as there were no observations on land that was not subject to land use impacts. All observations on bore water levels, and effectively of the extent of dryland salinity, derive from areas subject to various forms of agriculture. Effects of land use are therefore embedded in the observations such that the separate effects of climate and land use cannot be determined.

[6] While a full equilibrium may not be reached most of the change would have occurred.
[7] Plant mortality is usually associated with reduced soil aeration (‘waterlogging’) rather than salt concentrations.

There was no analysis of the effect of land use on bore water levels when bore water levels are affected by the rate of water extraction. This would exaggerate the changes in bore water levels attributed to rainfall as extraction rates from production bores increase when conditions are dry. As with the evaluations of the extent of salinity, the data used in the groundwater analysis incorporate effects of both climate and land use and there is no way of determining their separate effects.

Despite this, it is suggested that increased monitoring of bore water levels is needed. Additional to the lack of any physical connection between bore water levels and soil salinity, this raises the issue of how such information could be used. If the bore water levels simply reflect the suggested causal factor in rainfall then rainfall is a better indicator and is much easier to measure. Moreover, if change in rainfall was to be the cause it is difficult to see what management practices could be applied to change the rainfall. Monitoring serves little purpose unless it can be used to aid in remediation.

Overall it is being suggested that increased rainfall is damaging. This suggestion is contrary to all experience in the study area wherein productivity is strongly determined by rainfall. Droughts often provide negative income while profits derive from periods of high rainfall.

Conclusions

The conclusion that the bore waters examined have anything to do with dryland salinity has no observational basis other than the existence of two unrelated correlations, one quantitative between climate and bore water levels, the other general between climate and the extent of dryland salinity. Such correlations represent circumstantial evidence and cannot identify cause. The premise that climate rather than land use is responsible for dryland salinity is based solely on the assignment of cause to correlations when such a fundamental error should never occur.

This critical deficiency is compounded by others of equal consequence. Confounding between land use and climate in the land salinity and groundwater observations was not addressed. Also, presentation of existing knowledge was biased with extensive relevant information not being considered. These deficiencies prevent any conclusions on the cause of dryland salinity. Despite this, such conclusions were not only made but it is suggested that others must accept them[8].

The consequences of promoting deficient science as fact can be great. For dryland salinity it would renew the wastage of effort and funds on remediations that do not work, and prolong the wastage of research effort, as with the suggested need to increase the monitoring of bores. Such wastage of the limited resources available promotes ongoing land degradation and greatly inhibits the implementation of remediations that could provide benefit.

[8] "The lack of groundwater monitoring data in the past is mainly responsible for the incorrect conceptual model of the causes of dryland salinity," Professor Acworth says. "Textbooks on the subject will now have to be rewritten." On http://www.connectedwaters.unsw.edu.au/news/salinityrainfall.html Accessed July 2009

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