DRYLAND SALINITY IN QUEENSLAND: HOW DO WE COMPARE?

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INTRODUCTION

Despite a common (mostly southern) perception that dryland salinity in Queensland was instigated by the National Action Plan for Salinity and Water Quality in 2000, some seminal studies of landscape, and particularly soil salinisation processes have been conducted north of the border, with an appreciation of salinity issues around for many decades, as evidenced in the benchmark "Salinity Management Handbook" published by QDNR in 1997.

The complex melange of physical and chemical processes, involving salt, water and the materials in which they reside, comes under many guises. Consequently, we must disentangle the different types, occurrences, causes, origins and expressions of salinity and look for common factors. Then, we can compare and contrast across Australia and determine any spatial and temporal patterns. So, how do we compare salinity in Queensland with that in other States, and how does Queensland compare against them ?

Newton, in 1676, wrote, "If I have seen further, it is by standing on the shoulders of giants." There are a lot of giants to choose from, but institutional and personal vagaries can sometimes obscure similarities and differences, and bias approaches and emphases. I will expose a few of mine.

Investigation of dryland salinity through the National Land & Water Resources Audit web site (http://audit.ea.gov.au) gives the impression that there was no recognition of dryland salinity in Queensland prior to 2000, a sentiment often misquoted (e.g. Cullen 2006), although an estimate of potential dryland salinity for 2050 is given. The reality is that salinity has been recognised as a threat to agricultural production, urban infrastructure and the environment for many decades prior to this, and several surveys had documented this, culminating in a compilation (Figure 1) of the state's salinity hazard by (Hughes 1979). This compilation included both natural (primary) and anthropogenic (secondary) salinity occurrences and subdivided the State into salinity hazard regions. Regions prone to water-table related salinity were then incorporated into an early national compilation of dryland salinity by the Standing Committee on Soil Conservation (1982).

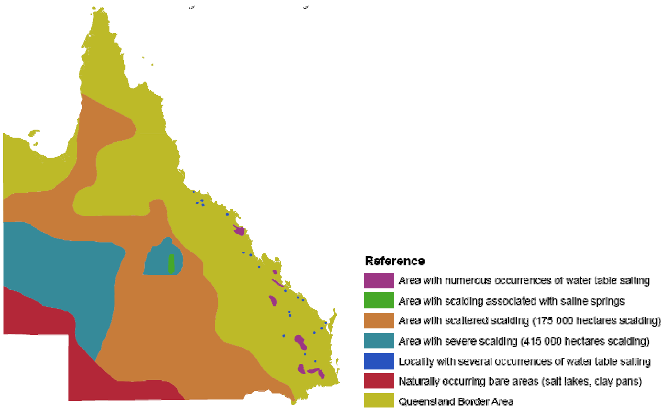

Figure 1. Salinity classification for Queensland (Hughes 1979). The broad regional status remains unchanged; areas affected by water-table salting have increased (Figure 2).

DRYLAND SALINITY IN QUEENSLAND

In the late 1990's a database was established by Queensland's Department of Natural Resources, compiling known occurrences of dryland salinity (Gordon *et al.* 2000). This database lists sites recorded by regional salinity officers and is not a comprehensive survey of the State. This has been maintained and up-dated (Biggs, pers. comm. 2006) and includes data returned from the 2000 ABS Census, which included a question on whether salinity affected any part of an individual's property. Thus, an over-estimation of salinity-affected land is recorded, but only in those areas where salinity is recognised as an issue. For example, extensive regions of salt pan country are not included, regardless of the origin of the salinisation. Also, coastal areas affected by rising seawater intrusion may or may not be included, as are areas where irrigation is the primary driver, rather than rising water-tables caused by clearing and changes in dryland agriculture.

Gordon, *et al.* (2000) identified 10 types of salinity affecting Queensland (Figure 2). These may be assessed by region and show a marked variation in types from north to south and east to west. While in part this reflects differing perceptions of the causes and symptoms of dryland salinity, there are definable differences influenced by geology, geomorphology and climate. Also, in contrast to most salinity sites in NSW and Victoria, most salinised sites in the north occur on the seaward side of the Great Dividing Range (GDR), again reflecting a combination of differing climatic conditions and agricultural practices in the north. Salinity sites in SE Queensland, including the Burnett and Curtis regions, are dominantly caused by either groundwater discharge and evaporation at break-of-slope locations, or due to reduced groundwater transmission and hence rise due to changes in deep soil profiles, known as catena type salinity. Moving north, discharge of shallow, perched groundwaters, generally caused by lithological changes in horizontal beds, causes most salinisation in the Fitzroy region. Further north still, and coastal irrigation and seawater intrusion cause most occurrences, though sites are generally fewer in number and less severe than to the south. To the west of the GDR, inland sites are generally sites of natural groundwater discharge, either as springs, or diffuse inland-draining catchments. Sites on the western slopes of the GDR, located mainly in the Darling Basin, show a variety of causes, many similar to those seen further south in NSW: topographically-induced groundwater discharge; perched water-table discharge, particularly from basalts overlying sandstones and shales of the coal measures; localised sites related to infrastructure impedance of groundwater movement, such as roads and railways; and a significant number of natural groundwater discharge sites. Natural discharge sites are found throughout Queensland and are differentiated from other types through historical knowledge of the areas vegetation history (i.e. no clearing, or present before clearing). The total area affected by salinity was estimated in 2001 to be 107,000 hectares (Table 1), representing a negligible area of the State. Whilst estimates of potential area affected by dryland salinity suggest a huge increase in area (2800 %) affected for Queensland, even this extent (over 3 million hectares) would only account for 2% of the State, or 3% of agricultural land. This expansion is unlikely, for reasons that will be outlined below.

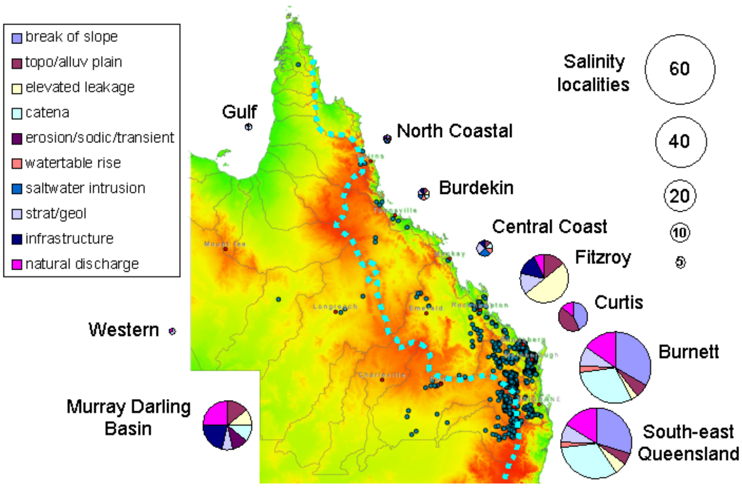

Figure 2. Queensland salinity types and their occurrence. Relative distributions are indicated across the major hydrological divisions (*after* Gordon et al. 2000, *updated* Andrew Biggs, pers. comm.).

DIFFERENCES BETWEEN NORTHERN AND SOUTHERN AUSTRALIA

A significant difference between north and south Australia is the climate, illustrated by 2 rainfall graphs in Figure 3. The north of Australia is dominated by high, but extremely variable rainfall patterns; the south by moderated and lower rainfall. This combined with seasonal rainfall that coincides with maximum evaporation in the north, compared to winter dominant rainfall in the south (Figure 4), means that it is the high extremes of rainfall that will drive salinity in the north, while the south can be more directly and continuously affected by positive rainfall balances.

A direct consequence of this disparity is an increased runoff component to northern Australia's water balance. In other words, a lower proportion of the total budget contributes to recharge of aquifers. Total volumes contributed to groundwater recharge, however, are comparable, but generally this results in fresher waters entering the system in the north when compared to the south. There are 2 major consequences of this with relevance to salinity: (i) Groundwaters are inherently fresher in the north, hence require a greater evaporation to constitute a salinity risk; and (ii) Surface deposition of salts in the soil profile is reduced as most salt will be washed off the catchment through stream flow. The latter process results in salt output to input ratios close to unity for the majority of catchments where we have adequate data to evaluate. The former means that the salinising effects of irrigation and rising water tables can be more readily ameliorated.

Table 1. National Land and Water Resources Audit (http://audit.ea.goc.au) data on areas at risk from dryland salinity and the potential risk for 2050. Note the extreme percentage change postulated for Queensland (column 5), but also the relative proportion of each state that may be affected (column 6).

	Area ('000 ha)		Condition in 2050		
State	**1998-2000**	**2050 (estimated)**	**Estimated change**	**% change**	**% of State**
NSW	**181**	**1,300**	**+1,119**	**720**	**2**
Victoria	**670**	**3,110**	**+2,440**	**460**	**14**
Queensland	**107***	**3,100**	**+2,993**	**2,800**	**2**
South Australia	**390**	**600**	**+210**	**150**	**1**
Western Australia	**4,363**	**8,800**	**+4,437**	**200**	**4**
Tasmania	**54**	**90**	**+36**	**170**	**1**
TOTAL	**5,706**	**17,000**	**+11,235**	**300**	**2**

***Includes data from the 2001 ABS sensus (Ian Gordon, pers. comm.)**

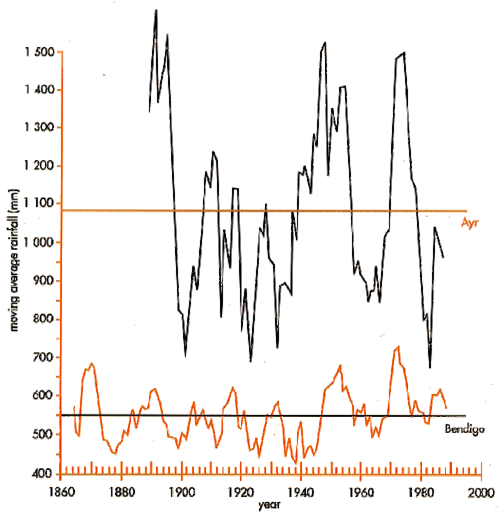

Figure 3. Annual variability in rainfall for northern (Ayr, Queensland) and southern (Bendigo, Victoria) sites, illustrating the extreme variability for northern Australia, but significantly higher rainfall regime. See text for discussion; Figure taken from QDNR, 1997.

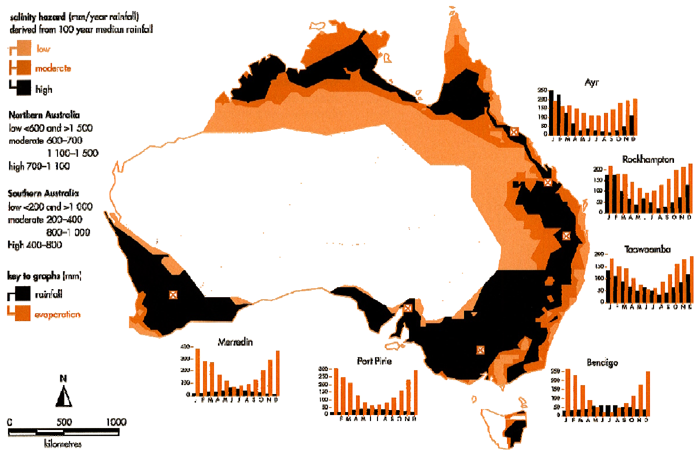

Figure 4. Australian dryland salinity hazard (QDNR, 1997). Also shown are monthly rainfall and evaporation charts across the country. Note the zone of higher risk in the north coincides with a higher rainfall zone as a consequence of summer rainfall dominance.

A further consequence of high run-off rates is illustrated in Figure 5, adapted from McNeil and Cox (2000). Compilation of chemistry data for samples at stream gauges across the State revealed a strong relationship between the concentration of salts in the waters and the dominant species contributing to that salinity. Thus, fresher waters, generally associated with dominant overland flow and high flow rates, are dominated by bicarbonate anions, whilst more saline waters (though still comparatively fresh: <1500 mg/L), are dominated by chloride. This reflects, in part, the contribution of groundwaters (which are generally more chloride-rich) to base flow dominated flow and the effect of evaporation, which drive up the total salinity, while exsolving CO_2 and reducing the bicarbonate contribution through reactions with stream-bed sediments and carbonate precipitation. This process is seen worldwide and is referred as the ‘Gibbs boomerang’ effect (Gibbs 1970). Almost equal concentrations of chloride and bicarbonate in very fresh waters (<100 mg/L) reflect rainfall as the initial source of fresh surface waters.

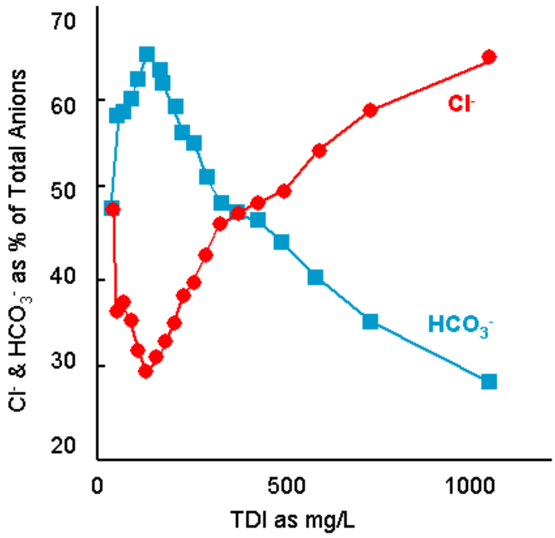

Figure 5. Median percentage of anions compared to salinity for nearly 34,000 surface water samples across Queensland (McNeil and Cox, 2000).

SALT IN THE QUEENSLAND LANDSCAPE

Limited data exist on the quantity of salt stored in the landscape, though we may estimate amounts from chloride profiles and soil salinity tests. Airborne electromagnetics provide a means of showing spatial variability and has been calibrated in some areas such that we have some confidence in the estimates of salt stored in the regolith. Thus, analysis of cores within airborne geophysics fly zones in NSW and Victoria (Cresswell *et al.* 2004) and Queensland (Cresswell *et al.* in press) and across salinised regions of WA (Clarke *et al.* 2002) indicate that comparable amounts of salt are present in all comparable landscapes and are commensurate with accumulation of cyclic salts over the past few hundred thousand years. Chlorine-36 data from cores in NSW give finite ages for the salt indicating that at least part of the salt is of a recent origin (Cresswell *et al.,* 2004). Recent analyses within shallow the unsaturated zone of NSW revealed significant chlorine-36 from nuclear bomb testing in the past 60 years (Lenahan *et al.*, these proceedings).

QUEENSLAND GROUNDWATER FLOW SYSTEMS

The Groundwater Flow Systems (GFS) approach (Coram 1998) has been applied to Queensland (Gordon *et al.* 2000) and is reviewed here. Table 2 lists the 15 GFS described by Coram (1998), using the simplified nomenclature of Clarke *et al.* (2002). Queensland is dominated by salinity occurrences within local GFS, and few instances of intermediate or regional effects. This reflects two aspects of groundwater in Queensland (i) Watertables in intermediate and regional systems are almost everywhere relatively deep, similar to the situation in NSW and Victoria prior to land-clearing, while local systems are either shallow, perched or highly responsive to land change; (ii) Land clearing has been predominantly on the eastern (seaboard) side of the GDR, where GFS are inherently local. On the western side, where intermediate and regional systems predominate, agricultural activity has been less intense and land change has not been widespread. The question therefore remains: Is Queensland sitting on a time-bomb that may go off if the interior is allowed to develop? Or is Queensland naturally predisposed to self-mitigate against serious salinisation?

Table 2. Summary of groundwater flow systems (GFS) with potential to impact on dryland salinity for each state (*after* Coram *et al.* 1998). Red boxes indicate a high incidence associated with this type of system, orange boxes a low incidence, blank boxes are no incidence, or do not occur. Simplified names and summary for Western Australia (*after* Clarke *et al.* 2002). Revised evaluation for Queensland (*after* Gordon *et al.* 2000) indicated in yellow.

		simplified name	WA	SA	Vic	NSW	QLD
Local	1	bedrock high	[red]	[red]		[orange]	[yellow]
Local	2	break of slope	[red]	[orange]	[red]	[red]	[yellow]
Local	3	weath/unweath transition		[orange]	[orange]	[red]	[yellow]
Local	4	alluv/colluv fan			[orange]	[orange]	[orange]
Local	5	layers with contrasting *K*	[orange]		[orange]	[orange]	[red]
Local	6	perched seep	[orange]	[red]	[red]		[yellow]
Local	7	dykes and minor faults	[red]	[orange]		[orange]	[orange]
Local	8	depression	[red]		[orange]		[yellow]
Intermed	1	unconf valley floors	[red]	[red]	[orange]	[orange]	[orange]
Intermed	2	semi-conf valley floors	[orange]			[orange]	
Intermed	3	break of slope			[orange]		
Intermed	4	major faults	[orange]		[orange]		
Regional	1	structural facies change	[red]				
Regional	2	sed facies change			[orange]	[orange]	
Regional	3	undulating		[orange]	[orange]		[yellow]

CAUSES OF SALINITY IN QUEENSLAND

Each of the regions in Queensland can be assessed for the dominant causes of salinity (Figure 6). Whilst land clearing is seen as the prominent cause, irrigation is significant, and local extraction of groundwaters, causing either seawater intrusion, or salinisation through excessive evaporation of extracted waters can be important, the latter particularly in the interior. The predominance of both clearing and irrigation suggests that remediation strategies would be effective, particularly re-vegetation, as the regions most affected have both high rainfall and warm growing seasons allowing rapid recovery of cleared land. Improved irrigation efficiency in some cases would be of benefit, but not in all cases, as the importance of deep drainage to flush near surface salts is important, and periodic high rainfall and consequent flooding allows the systems to flush on a regular basis. The importance of allowing these environmental flows should be stressed.

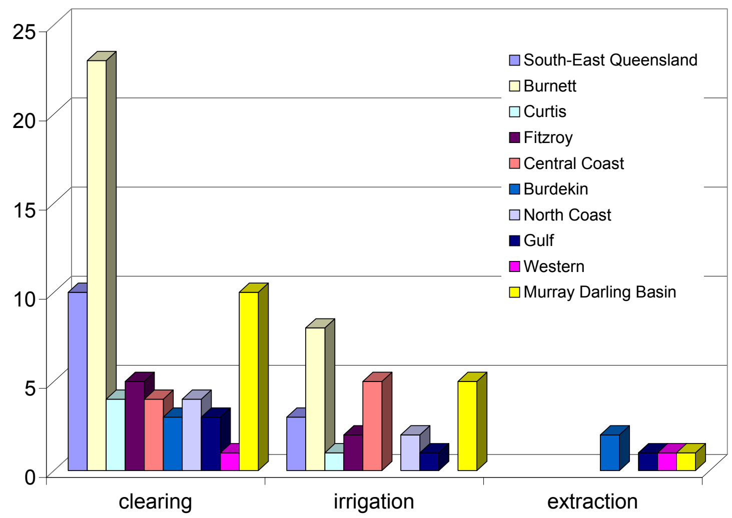

Figure 6. Major causes of salinity in Queensland distributed between the major hydrological divisions.

CONCLUSIONS

In summary:

- Salinity in Queensland is not pervasive, though locally it can be an important factor contributing to poor soil health
- Groundwater rise is currently not the main driver for salinisation; rather exacerbation of pre-existing discharge zones and local over-use of agricultural land, either through clearing or irrigation, has led to land degradation
- Most affected regions are within local groundwater flow systems, that are fast to recover, both because of their small size, and because of the inherent climate conditions (warm and wet summers)
- Water quality is more of an issue in most areas, with gradually increasing salinities due to extraction and changed recharge conditions
- Irrigation salinity is generally of a larger concern than dryland salinity, particularly in coastal regions
- Drought, pests and disease remain higher priorities to land holders.

Dryland salinity in Queensland, whilst locally an issue, is amenable to remediation through re-vegetation and modified irrigation practices. Water balance is key to understanding the systems, and the major question that remains is one of timing. Without careful strategies to monitor and remediate existing salinity sites, it is currently unclear whether continued land-clearing and irrigation practices will eventually result in a serious salinity problem for Queensland, or whether the climatic regime is sufficiently robust to self-moderate. Seasonal and periodic flushing by floods is an important strategy to maintain low salinity levels in streams and the landscape. Increased development of dams threatens to increase the potential for salinity to occur in the coastal regions.

REFERENCES

CLARK, CJ, GEORGE RJ, BELL RW, HATTON TJ (2002) Dryland salinity in south-western Australia: its origins, remedies, and future research directions. *Australian Journal of Soil Research* **40**, 93-113.

CORAM J (1998) National Classification of Catchments for Land and River Salinity Control. (Rural Industries Research and Development Corporation: Canberra).

CRESSWELL RG, DENT DL, JONES GL, GALLOWAY DS (2004) Three-dimensional mapping of salt stores in the southeast Murray-Darling Basin, Australia. 1. Steps in calibration of airborne electromagnetic surveys. *Soil Use and Management* **20**, 133-143.

CRESSWELL RG, MULLEN IC, KINGHAM R, KELLETT J, DENT DL, JONES GL (in press) Airborne electromagnetics supporting salinity and natural resource management decisions at the field scale in Australia. *International Journal of Applied Earth Observation and Geoinformation*.

GIBBS R (1970) Mechanism controlling world water chemistry. *Science* **170**, 1088-1090.

GORDON I, HALL W, PEARCE B (2000) Advancing the understanding and management of salinity in Queensland. QDNR. Queensland Department of Primary Industries.

HUGHES KK (1979) Assessment of dryland salinity in Queensland. Department of Land Utilisation Report. Department of Primary Industries, Queensland.

MCNEIL VH, COX ME (2000) Relationship between conductivity and analysed composition in a large set of natural surfaec-water samples, Queensland, Australia. *Environmental Geology* **39**, 1325-1333.

NLWRA, 2001, Australian Dryland Salinity Assessment 2000. '*Extent, impacts, processes, monitoring and management options*', National Land and Water Resources Audit, Canberra. ISBN 0 642 371067

QDNR, 1997, Salinity Management Handbook. Queensland, Department of Natural Resources, Brisbane: DNRQ97109. ISBN 0 7242 7412

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