Current and predicted minimum and maximum extents of land salinisation for the upland NSW portion of the Murray Darling Basin

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Keywords: *Salinity; climate variability; FLAG; aerial photography*

EXTENDED ABSTRACT

The extent of dryland land salinisation in upland areas of NSW is currently being mapped using aerial photographs from approximately 1997-2000. As part of the Murray Darling Basin (MDB) NSW Salinity Audit update, understanding of the current and historical dryland salinity problem is required to estimate the possible future extents of the dryland salinity expressions. The outcomes of the current MDB NSW Salinity Audit update indicate that groundwater and stream salinity responses are significantly influenced by climatic drivers such as higher rainfall periods. Anecdotal evidence plus other site specific studies also indicate that dryland salinity expressions fluctuate due to climatic drivers. The aim of this work is to determine the spatial extents within which, known saline areas will fluctuate.

This study demonstrates a methodology using spatial analysis techniques, along with aerial photograph reconnaissance, to predict the maximum and minimum extents of saline areas within the NSW portion of the MDB. Five catchments across NSW were surveyed over approximately a 30 year time frame, using recent and archival aerial photographs to determine the change in dryland salinity extent and severity. In general it can be concluded that catchments in the south of the state show a strong oscillating pattern as scalds expanded and contracted. Catchments in the middle and north of the state appear to be continually increasing in salinity expressions over the 30 years and may only now be beginning to contract in size. All catchments are then grouped according to the dominant landform within the catchment as determined by FLAG landforms. It is found that catchments dominated by "Steep" landforms need a buffer from minimum observed extent to maximum observed extent of 150m, to encapsulate the temporal changes in saline area size. In the catchments dominated by "Even" proportion of steep and flat landforms a buffer of 250m is needed and in catchments with a "Flat" landform dominance a 575m buffer is required.

FLAG wetness values are then obtained for the buffered NSW saline areas. The predicted maximum and minimum extents of saline areas are increased and decreased on an area basis which gives preference for including the areas in saline extent with high FLAG wetness values over areas with lower FLAG wetness values. The use of the FLAG wetness index constrains the expansion and contraction of the saline areas within topographic features, as opposed to simply buffering the saline extents. This information is then used to buffer the current mapped NSW saline areas according to landform dominance in upland catchments of 400 – 2000km^2. We assume that catchments nearby to a study catchment, and with a similar landform classification to it, are at a similar stage in their "saline extent cycle" to the study catchment and adjust the area of scald within the buffer accordingly. For example, if the current extent is the same as the minimum observed extend then a increase in area equal to the observed trends from the nearby study catchment is used to extrapolate a maximum area extent. If the current extent is the same as the maximum observation then a reduction in area within the buffer is used to extrapolate a minimum area extent and if the current extent falls between the minimum and maximum then relative proportions are used

Catchments to the South of the state show oscillating patterns in salinisation area through the ~30-40 years of observations from aerial photography. Catchments in the Middle and North of the state have been continually increasing in salinisation area and may be starting to stabilise or fall. Predictions of minimum, current and maximum extents of saline areas for the upland areas of NSW are given for the catchments dominated by steep, even or flat landforms. The current extent of scalds from the NSW portion of the Murray Darling Basin is ~640km^2. The predicted minimum extent is ~530km^2 with a maximum extent of ~710km^2. These estimates are based on a ~30-40 year snap shot of climatic variability. Limitations of the method are also discussed.

INTRODUCTION

The hydrological complexity of the Australian landscape with its ancient landscapes, climatic variability and vegetation diversity has complicated our ability to understand the processes that drive a dryland salinisation problem. The basic understanding of an increase in recharge caused by vegetation clearing leading to a rise in water tables bringing salts to the land surface should only be viewed as a coarse description of the overall process. Current assessments of the current and future extents of dryland salinisation are based on this basic understanding. Under the current status quo using this understanding, the dryland and irrigated salinity problem is estimated to increase nationally from 5.7 to 17 million hectares over the next 50 years (Van Bueren and Price 2004). Anon (1999) roughly estimated that between 2 and 4 million hectares of landscape would be seriously impacted by salinisation. Within the NSW portion of the Murray Darling Basin (MDB) Littleboy *et al.* (2001) reports that dryland salinity or areas with water tables within 2m of the surface is 1505 km^2.

To achieve better estimates of the current problem a better process understanding of land salinisation dynamics needs to be developed. Two recent field studies have attempted to increase our understanding of land salinisation processes. Dominis (1999) studied the causes in the fluctuation of the size of salt scalds in the Baldry Catchment, Central West NSW using aerial photography from 1958-1999. Seven interrelated factors of climate, geology, geomorphology, soils, vegetation, landuse, and measures for remediation were investigated to see which of these variables influence the greatest changes in scald size. Dominis concluded that the factors such as geology, geomorphology and soils dampened to different degrees the impacts of changes in climate, landuse and measures of remediation, making the change not always consistent with the patterns in climate change. However, the average trend was attributable to climate.

The area of bare patches at the Baldry site generally increased in size from 1958 through to 1996. After 1996 the growth of the bare patches (scalds) appeared to have stabilised. Plowman (1999) also studied the changes in scald behaviour in the Spring Creek catchment on the South Western Slopes of NSW. In this study a different scald response was observed where the saline areas appeared to oscillate in size from 1953 – 1994. These oscillations occurred more than once over a relatively short period. The greater amounts of salinity occurred in 1953, 1963, 1973 and 1989 and the low salinity periods were 1970 and 1983. The increasing and decreasing trends observed were considered a short term phenomenon, related to immediate environmental processes occurring in the landscape of which climate appeared to be the main driver. Again, interrelations with other factors such as soil types and landuse changes were discussed.

This study aims to expand on the two case studies above by studying a further five land salinisation areas. The five study catchments are Begalia, Williams Creek, Wattle Retreat, Mumbil and Box Hill (Figure 1). Using terrain analysis techniques, a process understanding of the maximum and minimum extents of the scalds will be determined to allow extrapolation to all mapped scalds within the uplands areas of the NSW portion of the MDB.

Figure 1. Location of the five study catchments within New South Wales, Australia.

Begalia. The catchment lies within the Lachlan Fold Belt as a subcatchment of the Yass River catchment. It covers an area of about 230ha; elevation ranging from 620 to 730m AHD. The geology is dominated by volcanics and the mean annual rainfall for Yass and Blackburn (towns nearby) is 639 and 737mm respectively. Sheep and cattle grazing are the dominant landuse.

Williams Creek. Williams Creek is a small sub-catchment of the Yass River catchment. It is located between Gundaroo and Murrumbateman. The catchment geology is of Ordovician age consisting of siliceous slates which traverse the area from north to south. Elevations range from 400-640m. The mean annual rainfall is about 640mm. Sheep and cattle grazing are the dominant landuse.

Wattle Retreat. Wattle retreat is adjacent to the regional divide between the Lachlan and Murrumbidgee Rivers. The catchment covers 540ha. The mean annual rainfall is approximately 596mm. The catchment consists of undulating hilly country with a flat valley bottom. Elevations range from 340-400m. Sheep and dryland cereal crops are the dominant landuse. The geology is dominated by igneous feldspar-quartz porphyry.

Mumbil. Mumbil is a small sub-catchment of the Macquarie River Basin. It is located 23km southeast of Wellington. The catchment is dominated by undulating terrain of moderate relief. Elevations range from 400-500m. The geology is dominated by volcanics and the mean annual rainfall is approximately 600mm. Cattle, sheep and dryland cereal crops are the dominant landuse.

Box Hill. Box Hill catchment is located in the upper portion of the Gwydir catchment. The area is a sub-catchment of Mount Russel catchment draining west in the Myalls creek system of the Gwydir River Valley. The catchment covers an area of about 640ha and is approximately 4km long and 1.5 to 2km wide. Elevation varies from 660m at outlet to 680m on the eastern side. The geology is comprised of Tertiary basalt which in turn is underlain by Permian granite and exposed at the lower end of the catchment. The mean annual rainfall at Inverell is 809mm with about 25% of the annual rainfall falling during the summer months of December and January. Landuse is mainly cattle grazing.

1. METHODS

The methods in this study are composed of two main areas, (1) the initial aerial photography surveys, (2) spatial representation using terrain wetness indices and extrapolation throughout the NSW portion of the MDB.

1.1. Aerial Photography Surveys

The changing patterns and intensities of salinity outbreaks were determined from aerial photographs. Some of the photograph records go back as far as 1944; others are dated from the mid-1950s. Sequential images are thereafter flown every seven to ten years. The aerial photographs belong to the Department of Natural Resources or are borrowed from the State Archives of NSW. The photos range in scales from 1:25,000 to 1:50,000. The Begalia and Williams Creek sites are mostly 1:25,000 to 1:40,000; the Box Hill, Mumbil and Wattle Retreat sites are mostly 1:50,000.

For each site, an aerial photograph from each of the aerial photograph sets is scanned and rectified to create a base map. A scanning density of approximately 1000 dots per inch is used, as it provides a clear reproduction of the original photograph. Each scanned aerial photograph is rectified against all other scanned images for the same site. This ensures that any identified changes in salinity conditions at the site are true changes and not simply a reflection of differences in scale or distortion.

Changes in site conditions are assessed by viewing the aerial photographs in three-dimension, using a mirror stereoscope. Most of the interpretations are done with a three-times binocular attachment, but detailed viewing for selected sites up to 15.5 times magnification is undertaken using the department’s LEICA APT-2 mirror stereoscope.

Salinity outbreak patterns identified in the aerial photographs are digitised on screen over the top of the appropriate scanned aerial photograph image. Polygons created are tagged to identify the intensity of the salinity outbreaks. Land management practices implemented to treat the salinity outbreaks are also digitised and tagged.

1.2. Spatial Representation using Terrain Wetness Indexes and Extrapolation throughout the NSW portion of the Murray Darling Basin

From the aerial photo interpretation only areas classified as saline were used as the measure of the extent of the saline areas (i.e. features such as water logging were not used, as interpretation of this characteristic is influenced more strongly by seasonal change). The minimum and maximum expressions of scalds from each site were compared and 10 random points selected around the scalds were measured for the difference in length between the extents. These lengths were then averaged to determine what buffer distance was required to capture most variation between the minimum and maximum extents.

An expansion buffer around a saline area does not take into account the topographical spatial variability of the area in which a saline area lies. By incorporating a wetness index into the buffered area, topographical influences could be accounted for. The use of a landscape wetness index to represent the variability will also allow for extrapolation to other areas. For this study the FLAG wetness index from Dowling (2000) was chosen for two reasons: (1) The wetness index of FLAG (specifically the UPNESS index) has shown to give reasonable representation of subsurface soil and groundwater within hillslope landscapes (Summerell *et al.* 2004), (2) Summerell (2004) demonstrated how the distribution of the Cumulative Distribution Function (CDF) of UPNESS provided a good descriptor of landform dominance within a catchment. This attribute of the UPNESS index distribution would also provide mechanisms for extrapolations.

The buffer widths determined for the five study catchments generally fitted into 3 different scales being 150m, 250m and 575m. When observing the landscape shape of the catchments, it appeared that the catchments dominated by lower slopes had greater variation in observed maximum and minimum extents of salinity. It was conceptualised that the greater variation in size of saline areas in lower landscape positions was due to a given rise in water table having more influence on a flatter land surface then in a steep landsurface (Figure 2).

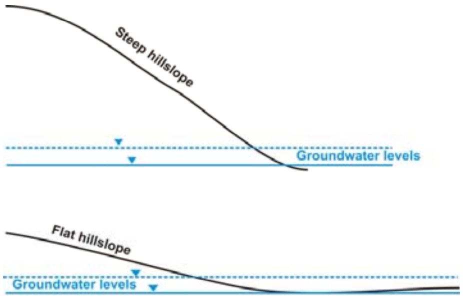

Figure 2. Schematic diagram showing how a similar change in groundwater level in a flat landscape compared to a steep landscape effects more of the land surface.

The 3rd order catchments (mostly between 600-2000km^2) used by the audit were then assessed using UPNESS for their dominance of steep, even (meaning neither dominated by flat or steep landforms) and flat landforms. The method of assessing landform dominance followed Summerell (2004). This work demonstrated how the distribution of the Cumulative Distribution Function (CDF) of UPNESS provided a good descriptor of landform dominance within a catchment. This classification would determine which buffer length to use in the catchments.

The existing data sets that covered the upland areas of the NSW portion of the MDB were then used for the extrapolation. The two main data sets used were the "Outbreaks of Dryland Salinity" (DIPNR 2004) (Figure 3) and the "DSNR-FLAG modelling of soil wetness hazard in upland NSW" (Summerell *et al.* 2003).

The "Outbreaks of Dryland Salinity" mapping represents a snap shot of salinity for approximately the year 2000. The salt outbreak mapping at the five study catchments shows the variation over approximately a 30-40 year time frame. Therefore the buffer applied to the "Outbreaks of Dryland Salinity" coverage was scaled as a percentage, between the current saline expressions in comparison with the known observed maximum and minimum extents. For each region (i.e. Murray) the area of mapped saline areas (within steep, even and flat classified catchments) was determined. The FLAG wetness index was then clipped at the maximum buffer distance for these saline areas.

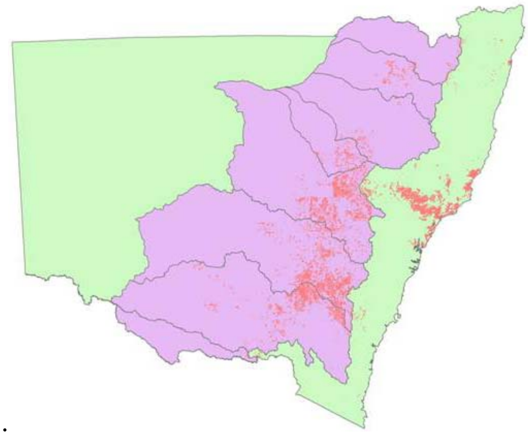

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Figure 3. Current outbreaks of dryland salinity mapping for NSW shown in red. The purple catchments are the regions within the MDB where mapping has been undertaken. Note this data set is still being created and mapping is incomplete in the northern regions.

Next the wetness index was reclassified into wet and dry areas by selecting a wetness value that gave the same area as the observed saline areas plus the percentage of area increase or decrease needed to represent the overall maximum and minimum land salinisation extents. We assume that catchments nearby to a study catchment, and with a similar landform classification to it, are at a similar stage in their "saline extent cycle" to the study catchment and adjust the area of scald within the buffer accordingly. For example, if the current extent is the same as the minimum observed extend then an increase in area equal to the observed trends from the nearby study catchment is used to extrapolate a maximum area extent. If the current extent is the same as the maximum observation then a reduction in area within the buffer is used to extrapolate a minimum area extent and if the current extent falls between the minimum and maximum then relative proportions are used.

All saline scalds in the "Outbreaks of Dryland Salinity" mapping were then expanded or contracted to the maximum and minimum extents.

2. RESULTS AND DISCUSSION

2.1. Historical Variation in Saline Extents

The variation in saline extents for the five study site catchments are presented as a summary graph of the saline area over time and how the area has changed compared to the first mapped record of the scald. For the Begalia catchment the maximum extent occurred around 1973, with the minimum extent recorded around 1998 (Figure 4a). The Williams Creek catchment is physically located very close to the Begalia catchment. Very similar oscillating patterns occurred with the maximum extent occurring in 1973 and a reduction in scalding around 1983 (Figure 4b). The major difference between the two catchments occurs in the amount of variation. Williams Creek has much more marked changes in saline area. Localised site characteristics are most likely the reason for this difference. As the overall oscillating pattern of saline extent variation is similar, this indicates that the major driver determining the saline outbreak severity is being captured even though localised catchment conditions occur, including human induced works (i.e. saline remediation). Wattle Retreat which is in a flatter catchment also shows an oscillating pattern in the expansion and contraction of saline extents. At this site the extent of the scalds peaked in the 1990s and the current extent is at the minimum recorded (Figure 4c).

These three study catchments have all showed general oscillating patterns in the extent of the scalds through time and this description matches the work of Plowman (1999) who also studied the changes in saline behaviour in the Spring Creek catchment on the South Western Slopes of NSW. They reported that “the saline areas appeared to oscillate in size from 1953 – 1994”. However, the Mumbil and Box Hill catchments have shown a different response in saline extents through time.

The Mumbil study catchment shows an increase in saline extent until the early 2000s where it appears to be stabilising or starting to fall (Figure 4d). Box Hill, which is further north again, also shows this trend with the saline extent declining more rapidly in the early 2000s (Figure 4e). The description of a generally increasing saline extent is similar to what Dominis (1999) described for the Baldry site which is “The area of bare patches at the Baldry site generally increased in size from 1958 through to 1996”.

Based on the two previous independent studies and the five new sites undertaken in this study it is assumed that in the southern inland NSW region (Lachlan, Murrumbidgee, Murray) the saline extent will show more oscillation (generally a 10 year cycle between scald extent peaks and troughs). In the central and northern inland NSW regions (Central West, Namoi, Gwydir, Border Rivers) a generally increasing extent occurred up until the later 1990s and early 2000s. This trend may also be part of a larger oscillating system that has ~ 30-40 year cycles between peaks and troughs in saline extents, or it could be an indication that a new equilibrium in salt mobilisation out of the catchment from flushing processes has occurred since major landuse clearing in the early 1900s.

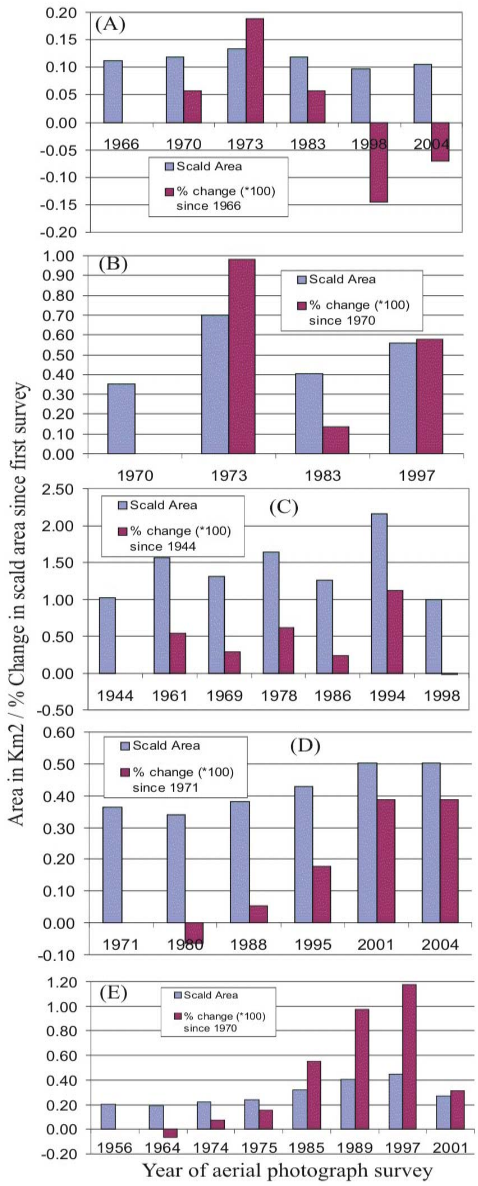

Figure 4. Saline area (salt scald) variation at the (A) Begalia, (B) Williams Creek, (C) Wattle Retreat, (D) Mumbil and (E) Box Hill.

2.2. Landform Classification within the NSW portion of the Murray Darling Basin and Scald Buffering

The study catchments used for the NSW portion of the MDB salinity audit were classified by their dominance of landforms (Figure 5). Catchments dominated by steep slopes had a 150m buffer used for determining the minimum and maximum extents of salinity outbreaks. The catchments classified as an even dominance of landforms had a 250m buffer and the flat catchments 575m.

For the five study catchments they were classified with the following landform dominance: (1) **Williams Creek**, Steep (2) **Begalia,** Even (3) **Wattle Retreat**, Flat (4) **Mumbil**, Even (5) **Box Hill**, Even.

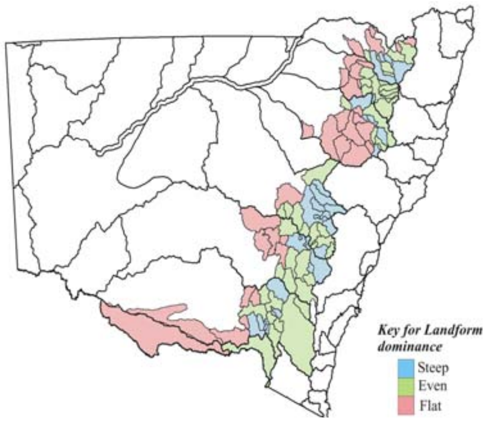

Figure 5. Landform dominance for the catchments from the NSW portion of the MDB.

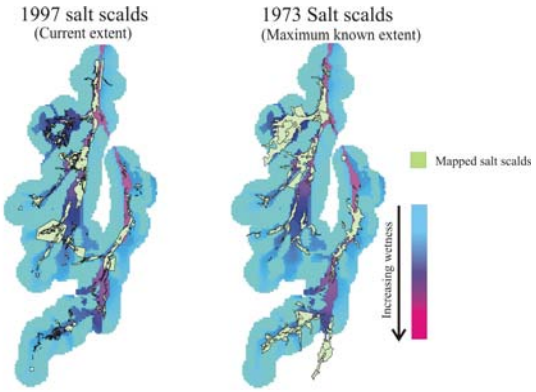

Figure 6. FLAG wetness index for the Williams Creek scalds showing observed current and maximum known extents.

A clipped 150m buffered wetness index from the FLAG model for the Williams Creek scalds is shown in Figure 6. The 150m buffered minimum extent captures most of the saline extent variation within the FLAG wetness index, however new expressions of scalds do not always get captured in the buffering process as shown by the lower right hand corner of the 1973 maximum extent image. The areas of light blue in the wetness image are the drier areas that are classified out when matching the area extents of observed verse modelled saline extents. This is because wet areas are more prone to salinity, and the wetness index is used to modify the size of the scald around the buffer.

2.3. Current, Predicted Minimum and Maximum Saline Extents

The Beglia, Williams Creek and Wattle Retreat study sites plus Plowman (1999) are used to determine saline extent trends in southern NSW.

For the Murray region classified saline areas from the "Outbreaks of Dryland Salinity" (DIPNR 2004) were minimal (Figure 7a). Spiers (2002) reports this is due to higher rainfall areas causing water logging rather then salinity. For the even and flat landform dominated catchments the predicted minimum scald extent equals the current extent. No saline areas occurred in steep landform dominated catchments. The overall maximum extent of salinity is predicted to be about 25% greater then the current situation expressed in 2000 by the "Outbreaks of Dryland Salinity".

In the Murrumbidgee and Lachlan regions, current saline extent in the steep landform dominated catchments is between the predicted minimum and maximum extents. For the even and flat landform dominated catchments the predicted minimum extent is equal to the current extent. The Lachlan catchment also has more scalds in the even landform dominated catchments (Figures 7b, c).

The mid to northern NSW catchments are represented by the Mumbil and Box Hill study sites and Dominis (1999). All three sites have indicated that the current extent of salinity is close to the maximum extent observed and maybe starting to stabilise or fall. For the Macquarie region the majority of scalds occur in the steep to even landform dominated catchments, with the current extent being equal to the known maximum extent (Figure 7d). The extent of the minimum predicted extent of scalds is close to 50% reduction for all the basins in the Mid to Northern NSW regions. This magnitude of difference is driven most likely by the observation that the scalds have generally been increasing in size. For the Namoi region only steep and flat landform dominated catchments occurred. The steep landform dominated catchments reflect landscapes such as the Liverpool ranges and the flat landscapes are areas such as the Liverpool plains. For the Namoi, Gwydir and Border rivers regions the saline mapping is incomplete giving low area extents of salinity (Figures 7e, f, g). The Gwydir region is dominated by even and flat landform catchments while the Border Rivers has a higher occurrence of currently mapped scalds in the steeper landform dominated catchments.

Based on the current mapping from the "Outbreaks of Dryland Salinity" (DIPNR 2004) the current extent of scalds from the NSW portion of the MDB is ~640km^2. The predicted minimum extent is ~530 km^2 with a maximum extent of ~710 km^2

(Figure 7h) based on a ~30 year snap shot of climatic variability

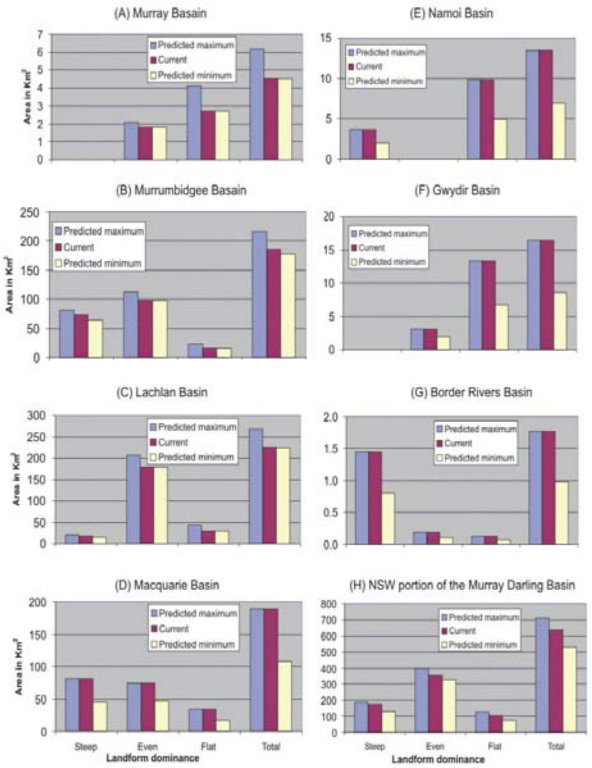

Figure 7. Saline areas for current and predicted minimum and maximum extents for each landform type within each basin. The NSW portion of the Murray Darling Basin is the sum of all basins.

3. CONCLUSIONS

• The "Outbreaks of Dryland Salinity" (DIPNR 2004) mapping needs to be completed.

• More study catchments for determining expected trends and buffer widths would be desirable.

• The wetness index constrains topographically the expansion and contraction of salts scalds within the buffered areas.

• Water logging is not represented in this analysis; therefore potentially saline areas are not identified.

• Catchments in south of the state show oscillating patterns in salinisation area through the ~30-40 years of observations from aerial photography.

• Catchments in the middle and north of the state have been continually increasing in salinisation area and may be starting to stabilise or fall.

4. ACKNOWLEDGMENTS

Thanks to Andrew McMurdo, Stuart Smith, Bradley Cole, Tony Dunphy, Keith & Cherie Roberts for aerial photography interpretation and Andrew Wooldridge for field validation of the Mumbil catchment.

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