Predicting Salinity in the Wadjekanup and Byenup Hill Catchments

A report from the LWRRDC project
"Integrating Remotely Sensed Data With Other Spatial
Data Sets to Predict Areas at Risk from Salinity"

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F. H. Evans[1], R. Ferdowsian[2] and N. A. Campbell[1]
[1]CSIRO Division of Mathematics & Statistics
[2]Department of Agriculture Western Australia

Summary

This interim report summarises the work and findings to date of a project funded by the Land and Water Resources Research and Development Corporation on 'Integrating Remotely Sensed Data With Other Spatial Data Sets to Predict Areas at Risk from Salinity'.

The aim of the study is to evaluate methods for predicting areas at risk from salinity. Previous work, conducted in the Upper Kent River study area, involved the quantification of current expert knowledge, the compilation of existing primary data sets for the study area and the derivation of appropriate derived data sets. Decision tree and conditional probabilistic network methods were used to integrate remotely sensed data with other spatial data sets to predict areas at risk from salinity. The outputs from the project included historical and present salinity maps, and a map showing areas at risk from future salinity. The results showed that historical and present salinity maps, and maps showing areas at risk of future salinity, may be produced using remotely sensed data integrated with several computer-derived terrain attributes. These terrain attributes can be easily derived from digital elevation data.

The Wadjekanup and Byenup Hill catchments have been selected as a second study area for the Predicting Salinity project, so that the implications of using airborne geophysical data for salinity prediction can be assessed. Airborne radiometrics, magnetic and electromagnetic (SALTMAP) data have been collected over the study area by World Geoscience Corporation (WGC).

The project aims to produce the best possible salinity predictions using Landsat TM and DEM-derived data sets alone, as a base-line for comparing predictions that used the airborne data as an input.

This interim report describes the methods used to produce the base-line salinity change and prediction maps.

1 The Study Area

The study was conducted in the Wadjekanup and Byenup Hill catchments, which are located approximately 260km SSE of Perth, west of the townsite of Broomehill.

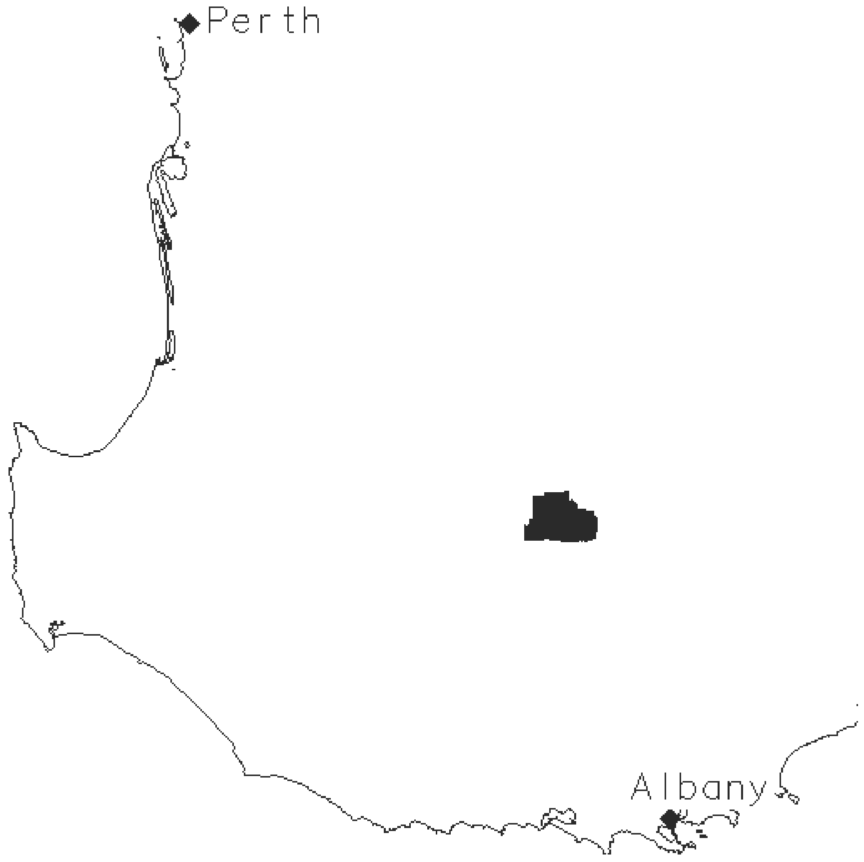

Figure 1: The Broomehill Study Area.

The physiography of the study area was described by Leeming (WGC Interpretation Report, 1994). The report described the Broomehill landscape as gently undulating to hilly in the more elevated south-western half of the study area, which gives way to broad valleys flanked by flat to low sloping terrain to the north-east and south-west. In the upper part of the catchment, drainage is well-dissected, whereas drainage in lower parts consists of sluggish, meandering streams. The Leeming report gives further information.

2 Training and Test Data

Several sub-areas of the catchment were selected as representative of the landform types present in the study area. Aerial photograph interpretation was used to produce maps showing the extent of salinity in 1984 and 1992 for these sub-areas. The photographs were also used to produce an interpretation of potential risk areas. The interpretations were produced by R. Ferdowsian, hydrogeologist with Agriculture Western Australia in Albany WA.

Landsat TM data for 1988 and 1994 were used in conjunction with the air-photo interpretations to select ground truth sites (150m by 150m) where the cover could be accurately assessed as healthy remnant vegetation, non-saline or saline for each year. In addition, each site has been assessed for future salinity risk. These sites were randomly allocated to training and test sites, in the ratio 2:1.

3 Primary Data Sets

Landsat TM data and historical Landsat MSS data have been assembled. Landsat data are acquired every 16 days and an archive of TM data from 1988 is held at ACRES. The earlier MSS image was used to provide historical data on salinity. Spring images were selected, as experience suggests that they contain the most information about crop and pasture growth. The dates of imagery used in this project are listed below:

MSS	September 1977
TM	August 1988
TM	August 1989
TM	September 1993
TM	August 1994

Digital height data were obtained from the Department of Land Administration (DOLA), in the form of 10m contours. The contour data were gridded using spline interpolation to produce a digital elevation model (DEM) for the catchment. Cross-validation techniques were employed to choose the optimal parameters for the gridding procedure.

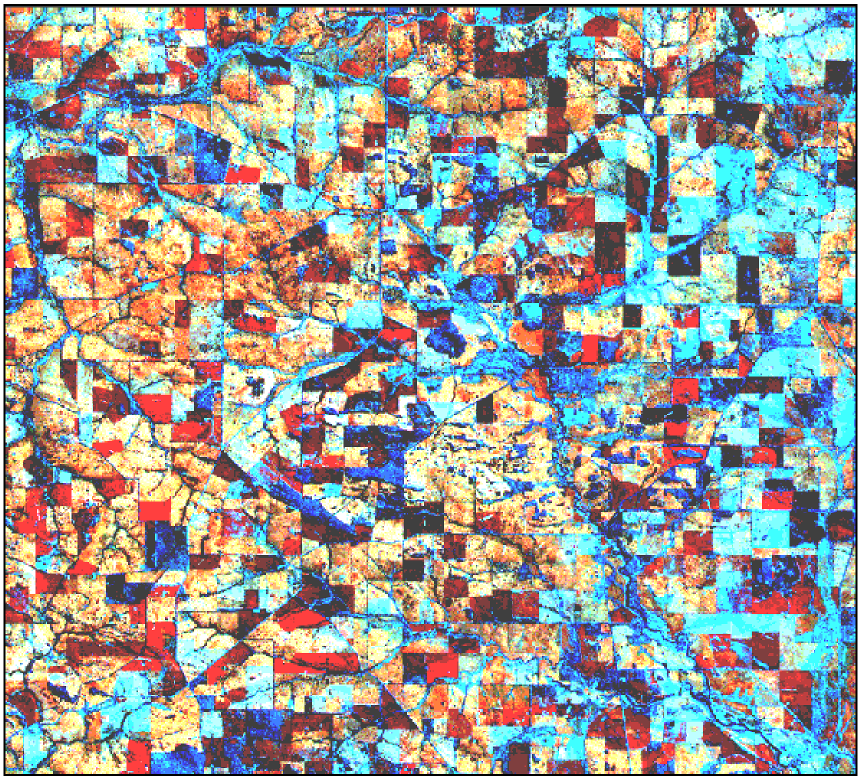

Figure 2: September 1993 Landsat TM Bands 4, 5, 7 in red, green, blue\

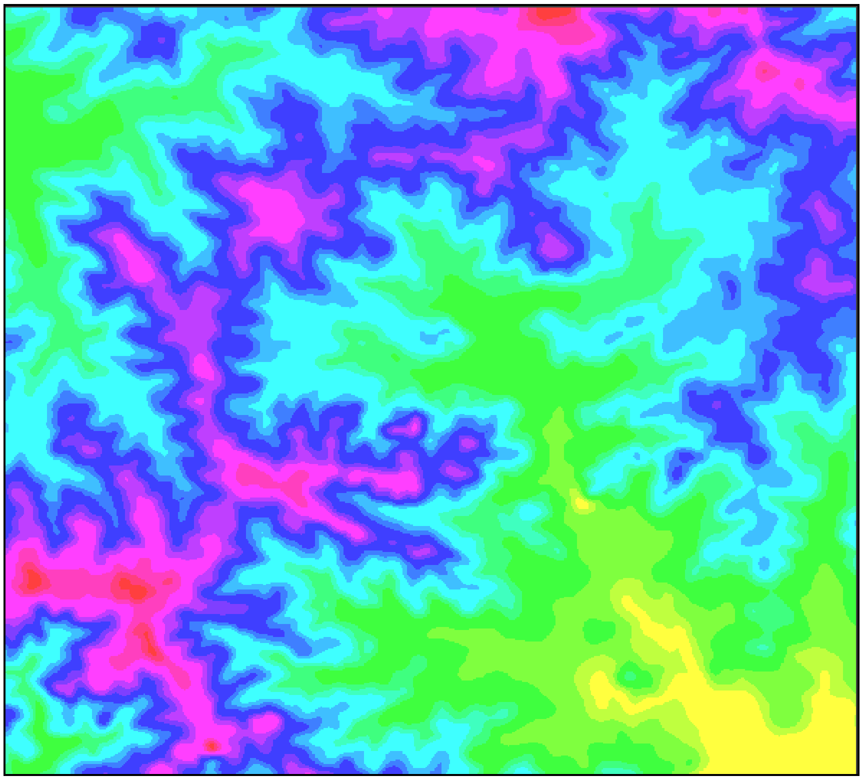

Figure 3: The Digital Elevation Model - low areas are shown in yellow and green to higher areas in pink and red

4 Derived Data Sets

The primary data sets were used to produce data appropriate for predicting salinity.

4.1 Classification of Landsat TM data

The Landsat TM data were processed to produce maps showing broad cover classes for the different years. The processing steps were:

- The satellite images were co-registered to a common map base (AMG coordinates at 30m pixel size). The registered images were imported into a GRASS database as raster maps.
- The image data from different dates were calibrated to ‘like-values’ using invariant targets and robust regression techniques, so that digital numbers from different dates could be compared.
- Sample sites of the major cover types were selected from the satellite images. Spectral data from the ground sites were extracted from the sequence of images. Discriminant analysis techniques were applied to determine which cover types are spectrally similar.
- Image classification maps of ground cover types were produced for each year using maximum likelihood classification techniques. A probability of belonging to each cover class is calculated for each pixel in the image. The pixel is assigned to the cover class for which it has the highest probability.

Classification maps from two successive years were combined to form a final classification into remnant vegetation, non-saline and saline classes for each time period. Three classification methods were investigated: decision trees (c4.5), neural networks and conditional probabilistic networks. The salinity mapping accuracies are shown in Table 1 (see over).

The `best’ salinity maps were produced using decision tree classifiers. The neural network classifications for 1988 and 1993 tended to over-estimate salinity, particularly in areas bare due to management practices (i.e. bare paddocks). The conditional probabilistic network severely under-estimated salinity in 1988.

Table 1: Salinity Mapping Accuracies over the Test Data

Method	decision tree (c4.5)		neural network		cpn	
Year	salt accuracy	non-salt accuracy	salt accuracy	non-salt accuracy	salt accuracy	non-salt accuracy
1988	65%	95%	70%	86%	58%	94%
1994	90%	96%	69%	86%	NA	NA

Field validation was performed over several properties in April, 1996. The properties were selected because they contained areas which were mapped as saline that looked doubtful, i.e. large saline scalds with semi-regular shapes. Three out of four of these areas were correctly mapped as saline. The fourth area mapped the sheds and adjoining bare areas of one of the properties.

The field validation showed that salinity was being mapped effectively. Errors occured where remnant vegtation was degraded; where persistent waterlogging had occured in 1993/94; or where dams and roaded catchments had been built to expose the underlying saprolitic clays.

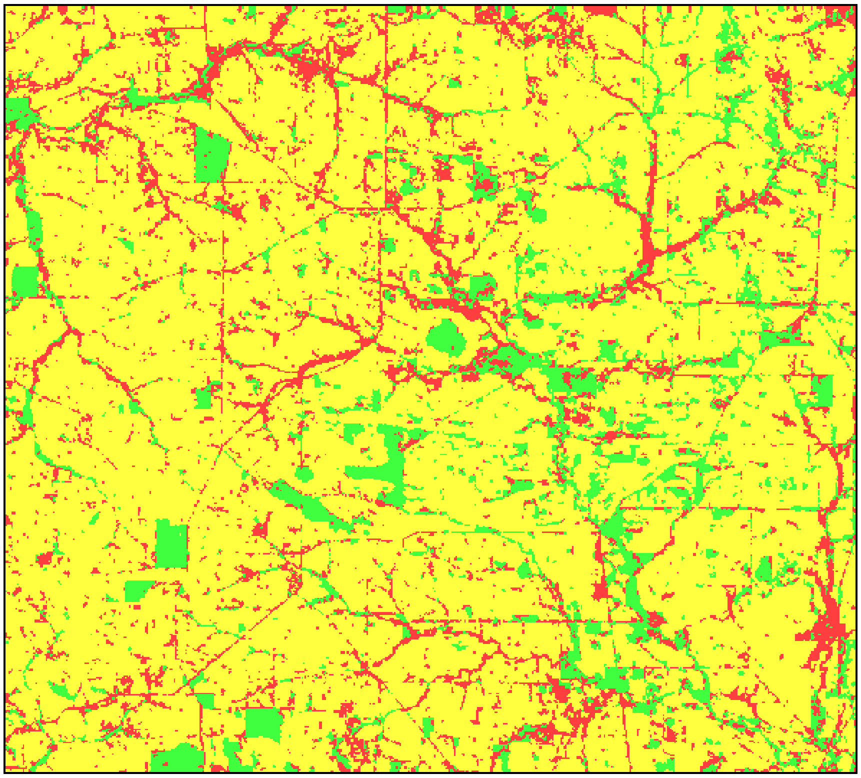

Figure 4: 1993 Landsat classification - yellow shows non-salt, green shows remnant vegetation and red shows salt

4.2 DEM-Derived Variables

4.2.1 Slope, Aspect, Curvatures

Slope, aspect, profile curvature, tangential curvature and mean curvature were derived from the DEM, on a per-pixel basis. Curvature attributes for large flat regions were also derived.

4.2.2 Water Accumulation / Upslope Contributing Area

Water accumulation algorithms simulate a rainfall event and measure the subsequent flow of water across the landscape. The algorithms make use of the DEM and work on the simple principle that water flows downhill. In the resulting map, each pixel is assigned a value which represents the amount of water which flowed through it. Since this value includes all of the water passing through areas upslope of a pixel, water accumulation maps also provide a measure of upslope area.

The simplest model assumes that all of the water flows in the steepest downhill direction. Multiple-direction water accumulation models distribute the flow amongst all downhill locations, according to the relative drop in elevation. These models are more realistic than the single flow path model, especially in areas with low relief and when the DEM has been derived from relatively coarse contour data. A multiple-direction water accumulation map has been produced for the study area.

The water accumulation map is shown in Figure 5 (see over).

4.2.3 Flow Slope

The slope map derived from the DEM using conventional methods consists of a map showing the steepest slope in any direction for each pixel, irrespective of whether the steepest slope pixel is above or below the current location. Since salinity at any pixel is influenced by its drainage, a map showing the local downhill slope was generated. This slope has been termed *flow slope* as it represents slope in the direction of flow.

The flow slope map is shown in Figure 6 (see over).

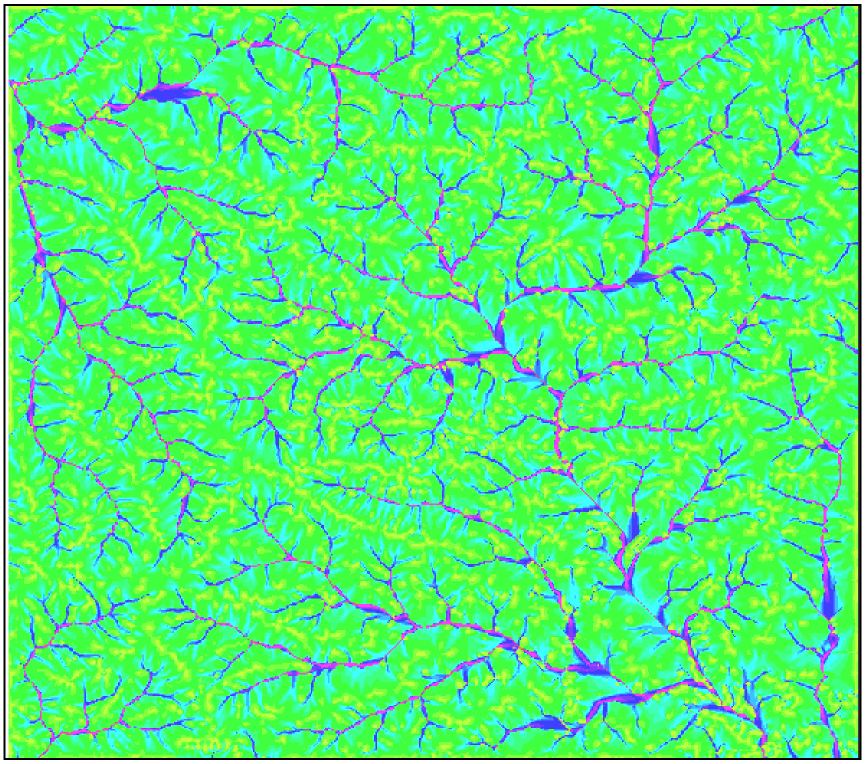

Figure 5: The water accumulation map - from low accumulation in yellow to high in red

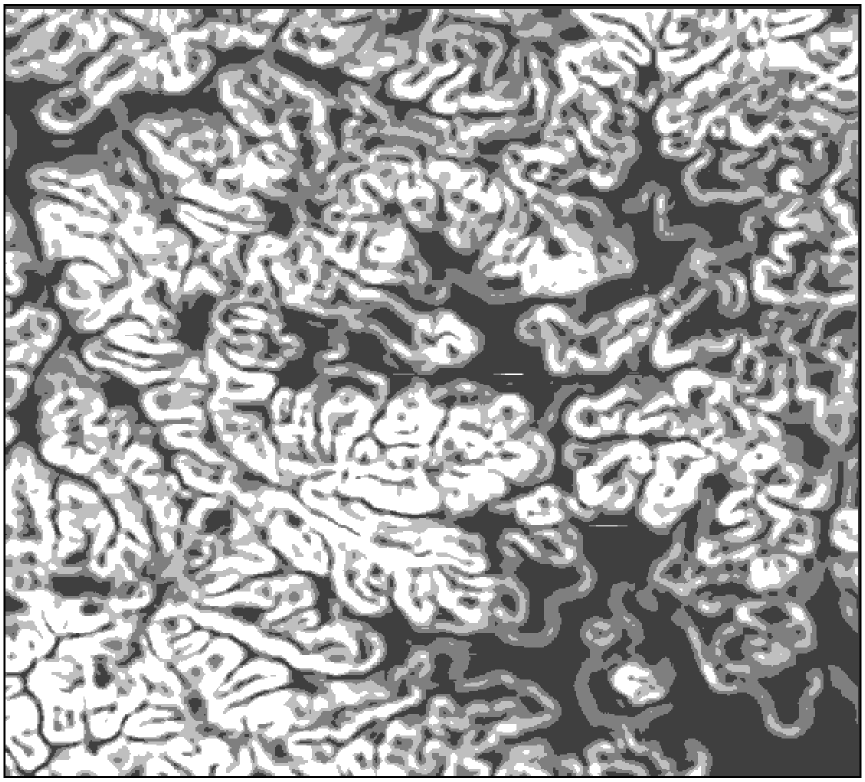

Figure 6: The flowslope map - from high slopes in white to low slopes in black

4.2.4 Upslope Clearing Maps

The Landsat TM classifications provide remnant vegetation maps for the different years. These have been incorporated into the water accumulation algorithms to produce maps of total upslope cleared area and percentage upslope cleared area for the years 1988 and 1994. In this way, the clearing of remnant vegetation and the effect of tree plantations can be considered.

5 Predicting Salinity

Previous work in the Upper Kent River catchment showed that area at risk from future salinity could be predicted with 76% accuracy (92% accuracy over non-risk areas), using only data derived from Landsat TM images and the digital elevation model. The contour data used to produce the Kent River DEM were at 5m intervals.

The same methods applied to the Wadjekanup and Byenup Hill catchments did not achieve the same results. The `best' predictions over-estimated the areas at risk from future salinity by more than 20%. This over-estimation of salinity risk results from the coarseness of the contour data available over the region. Because the contour data were available at only 10 m intervals, the DEM does not accurately model the terrain. In particular, the valleys and streamlines are smoothed so that the model over-estimates the extent of valley floors and stream-line bottoms, and hence over-estimates the areas at risk from salinity.

The DEM was then modified to better identify the streamlines and valleys. The modifications involved using the DEM to identify the location of rivers, streamlines and gullies, and then extracting the heights at these locations. The watercourses were then `lowered' by one metre, and the DEM was re-gridded. The DEM-derived variables were produced using the modified DEM, and the salinity prediction was perfomed again. The prediction was much improved, and showed accuracies approaching those achieved in the Kent. The accuracies are shown in Table 2, on the following page.

Table 2: Salinity Prediction Accuracies over the Test Data

	salt accuracy	non-salt accuracy
prediction	78%	88%

The modification of the DEM has improved salinity prediction where the available contour data caused initially poor results. However, this method is not ideal. Better contour data would produce a DEM which more accurately models the terrain and improve salinity prediction.

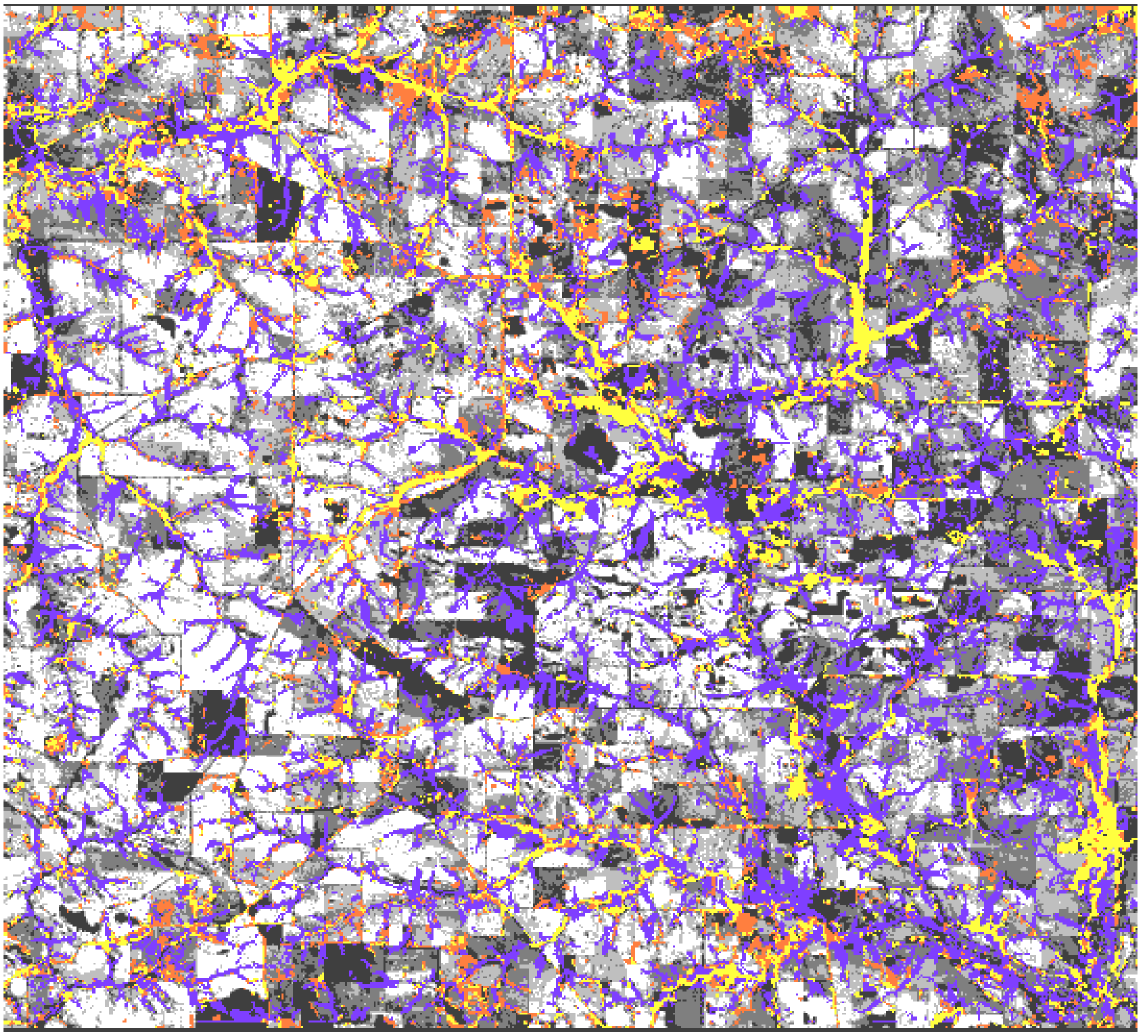

Figure 7: The salinity change map - yellow areas were saline in 1988, orange areas became saline by 1994, pruple areas are predicted to be at risk from future salinity

8 References

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Note: The figures contained in this report are of necessity either a large scale, or show only a small area in detail. Full digital versions of the original files are available.