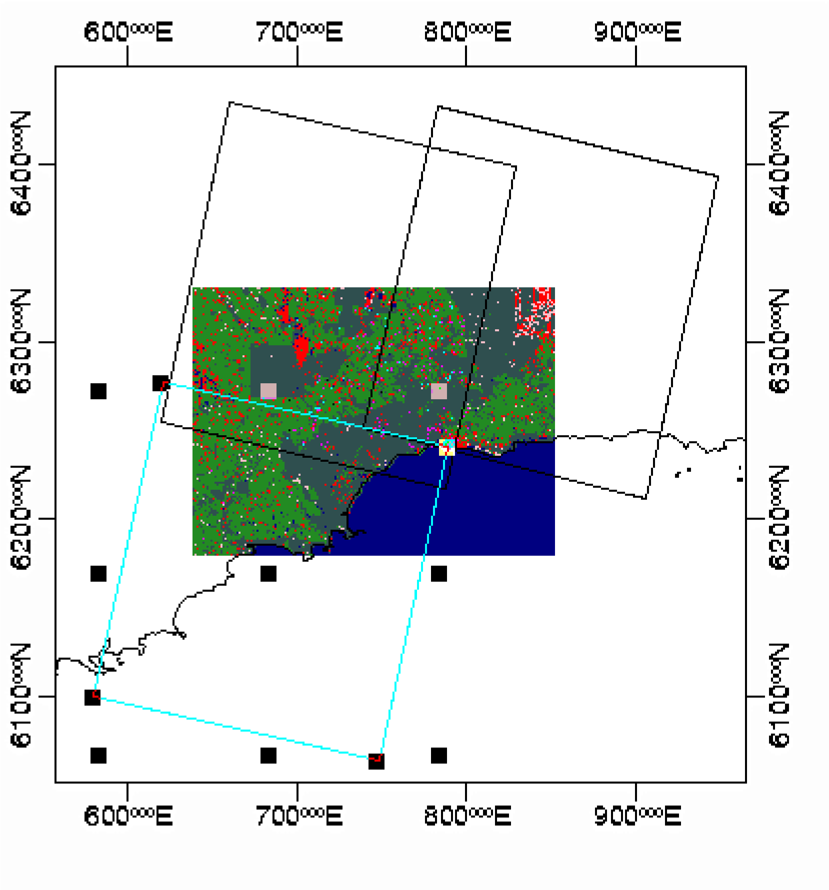
Mapping Salinity in the Fitzgerald Biosphere Region

A report from the NHT-funded project
Land Monitor



S. Furby

CSIRO Mathematical and Information Sciences

Summary

This report summarises the salinity mapping and monitoring work in the Fitzgerald Biosphere region as at December 1998. The aims are to describe

- the current salinity maps and their accuracy and limitations;
- the salinity change maps; and
- sufficient detail of the processing steps to allow a further update of the maps when better DEM data are available.

Copies of the latest maps have been sent to Ruhi Ferdowsian (Agriculture WA in Albany) and John Simons (Agriculture WA in Esperance) for their feedback on whether these maps can be released pending a Land Monitor DEM for the region.

I strongly recommend that the processing for this region be revisited when a better DEM is available, particularly for the Upper Gairdner region. I have effectively promised Ruhi Ferdowsian that this reprocessing will be performed, perhaps in conjunction with salinity prediction work.

1. The Study Area

The Fitzgerald Biosphere region is a 216km by 160km area located on the south coast of Western Australia, between Albany and Esperance as shown in figure 1. The region includes the Fitzgerald River National Park and a crescent of farmland approximately fifty kilometres wide surrounding it. The region supports a static rural community of around 2000 people, with 560 000 hectares of cleared farmland producing about $80 million per year from cropping and grazing (draft South Coast Regional Land and Water Care Strategy).

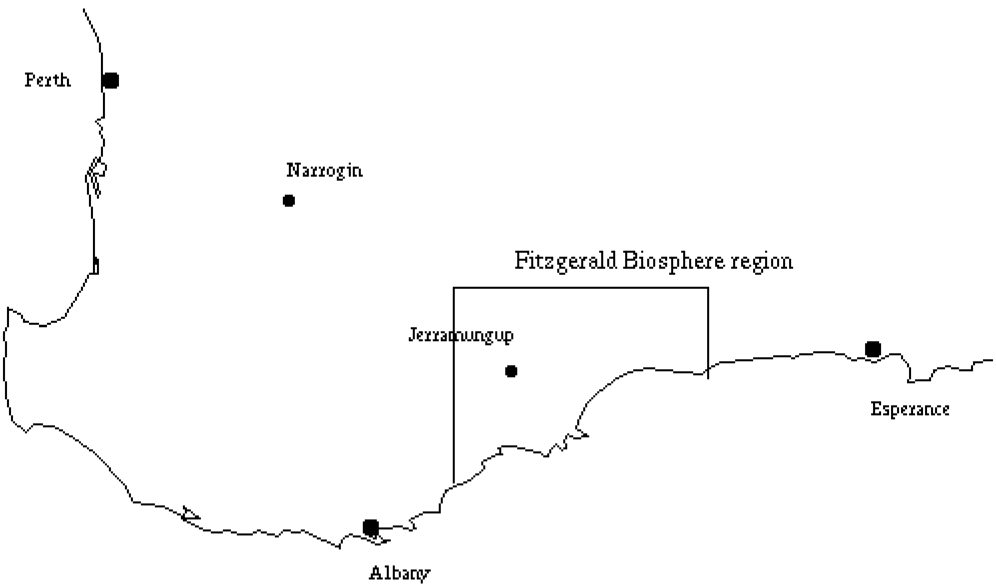


Figure 1: Location map showing the Fitzgerald Biosphere region

It is estimated that about 12% of the farmland is already affected by salinity, with the possibility that this may increase to 25% over the next 15 years unless appropriate action is taken (draft South Coast Regional Land and Water Care Strategy). Waterlogging, wind and soil erosion also affect substantial percentages of farmland in some catchments (Robinson, 1997).

The bounding coordinates of the region processed are (in extended zone 50 coordinates):

North = 6 330 000
West = 638 000   East = 852 000
South = 6 170 000

Parts of three Landsat TM scenes are required to cover the study area. The Bremer Bay scene (110-084) covers the south-western portion of the region. Its northern boundary is about the Jerramungup townsite. The study area accounts for approximately ¾ of the Bremer Bay scene. The Newdegate scene (110-083) covers the northern portion of the study area. The processed area includes the northern boundary of the Lake Magenta Reserve, approximately 1/3 of the Newdegate scene. The eastern edge of the Newdegate scene is just west of the Ravensthorpe townsite. The eastern extreme of the study area is covered by the Ravensthorpe scene (109-083).

Four test regions have been identified within the study area for which detailed ground information is available. These regions are:

- the Upper Gairdner catchment
- the Bremer Bay region
- the Fitzgerald corridor region
- the West River catchment

Ruhi Ferdowsian (Agriculture WA in Albany) and Carol Daniels (Jerramungup Landcare) are the contacts for the first three regions. John Simons (Agriculture WA in Esperance) and Rick Farrell (Ravensthorpe Landcare) are contacts for the West River catchment.

The coordinates of the study regions are:

Upper Gairdner Catchment:

North = 6 270 000
West = 655 000 East = 680 000
South = 6 245 000

Bremer Bay region:

North = 6 220 000
West = 675 500 East = 705 500
South = 6 182 500

Fitzgerald River corridor:

North = 6 270 000
West = 695 500 East = 720 500
South = 6 245 000

West River Catchment:

North = 6 289 000
West = 738 000 East = 763 000
South = 6 264 000

For the purposes of the classifications, the region was divided into two zones, west and east. The western zone includes the Upper Gairdner catchment and the Bremer Bay region. The eastern zone includes the Fitzgerald River corridor and the West River catchment. In the 1994 single-date classifications, the Bremer Bay region was processed separately from the Gairdner River region.

2. The Data

2.1 The Satellite Image Data

The Landsat TM scenes listed in table 1 have been used in the processing for this region. The 1997 scenes were only used in the 3rd-pass processing. Cloud-cover prevented a full sequence of 6 image dates being processed.

The images from 1994 and 1996 are from quite early in late growing seasons. Numerous bare paddocks can be seen that correspond to crops that haven't developed sufficiently for the satellite to "see" anything other than a lot of bare soil. The other seasons are more typical of the region and the image dates are adequate. There are some cloud patches in the 1992, 1994 and 1996 images.

Bremer Bay	Newdegate	Ravensthorpe
22 August 1990	22 August 1990	31 August 1990
12 September 1992	10 September 1991	13 September 1989
1 August 1994	1 August 1994	26 August 1994
22 August 1996	22 August 1996	14 September 1995
25 August 1997	25 August 1997	

The images have not been rectified to the new state base, although some GCPs based on the roads database were used in the rectification. Unfortunately few major roads pass through this region. The rectification of the August 1997 Newdegate scene is suspect and has only been corrected locally. The study area has been extracted from a mosaic of the three scenes.

The images have not been calibrated to the state spring calibration base. This base did not exist at the time of initial processing. Instead, the Newdegate August 1994 scene was used as the calibration base. Images from each year were cross-calibrated to each other using targets in the overlap regions. A single set of targets covering all three scenes was then used to calibrate each year to the August 1994 base. The 1997 images have subsequently been calibrated to the state spring base.

2.2 The DEM data

A DEM was formed by gridding contour data from DOLA. The contours were available at five metre intervals for most of the region. The exception is the Jerramungup 1: 100 000 mapsheet (2630), for which only ten metre contours were available. The region covered by this mapsheet (north and west of the Jerramungup townsite) is relatively flat and the contours are quite sparse. These are obvious deficiencies in the DEM in this region.

The DEM, water accumulation map and landform map are available on CD.

2.3 Ground-Truth Data

Ground data has been provided in three stages.

Initial ground data was provided by farmers in the region and marked on image prints at the JERAC show in October 1996. These data identified severely salt-affected areas, but did not identify any marginally saline areas. The data covered properties scattered across the whole study area.

The second stage ground data was provided by Nikki Runciman (Agriculture WA, formerly in Jerramungup but now in Mt Barker), Carol Daniels and John Simons. It consists of detailed mapping of representative regions in the Upper Gairdner and West River catchments on air photos. The data includes marginally saline areas with a cover of barley grass. A digital salinity map was also provided for the Mills Lake region. This region is at the extreme western edge of the study area and ideally would be included in the same calculations as the North Stirlings / Pallinup regions further west. The map includes salinity prediction data.

The third stage ground data was provided by Ruhi Ferdowsian and John Simons for each of the four test regions identified in the previous section. The data were again provided in the form of annotated air photos. In the case of the West River data (John Simons) detailed cover descriptions were provided. In the case of the other three regions (Ruhi Ferdowsian) no cover descriptions were provided. This final ground dataset has been reserved as an independent validation set.

3. Salinity Mapping Methodology

The steps used to produce the salinity maps are listed below. This is the standard methodology being used for Land Monitor salinity mapping and monitoring.

1. Co-register the images to a common map base. This allows ground sites to be traced through time and the satellite data to be compared with the ancillary map data, such as the DEM.

2. Calibrate the image data from different dates to a reference image so that digital counts from different image dates can be compared (Furby et al, 1996).

3. Locate ground sites of all the major cover types in each of the images.

4. Stratify the study area into zones within which there are no marked regional variations in rainfall, land-use types or rotations, geology, predominant soil types or visible patterns in the image. If there are strong differences between these zones, they should be processed separately.

5. Apply discriminant analysis procedures, in particular canonical variate analyses (Campbell and Atchley, 1981), to the training data to examine the separation of ground cover types in the TM spectral data, determine which image dates are most appropriate and define sensible spectral groupings of ground cover types.

6. Apply neighbourhood-modified maximum likelihood classification techniques (Campbell and Wallace, 1989) to the best individual image dates. This produces probabilities of belonging to each of the major cover classes on each date for each pixel in the images.

7. Combine the cover class probabilities from each date with position in the landscape – hill, slope, valley floor – to calculate the probability of each pixel being salt-affected. A conditional probability network is used for these calculations (Caccetta et al 1995).

8. Post-processing to remove obvious errors in the final salinity maps, such as roads, edges of bush blocks, dams and some hilltops being labelled as salt-affected.

4. Current Salinity Maps: Accuracy and Limitations

The current salinity maps are a result of the 3rd processing iteration. These 3rd-pass maps will be described in detail in section 4.2. Section 4.1 provides a brief description of the first two iterations. Detailed task reports describe each of the processing steps; only summary information is provided here. The task reports can be found in files in three boxes labelled “Fitzgerald Biosphere Project” in Suzanne’s office.

4.1 Previous Iterations

The initial salinity maps for this region were produced using only the first stage of ground data (farmer provided) and image data from 1989 to 1996. Although not formally assessed, the maps were perceived to identify most of the severely salt-affected land but none of the marginally salt-affected land. This prompted the collection of additional ground data to include marginally saline sites.

The second-pass salinity maps were based on the second stage ground data and the same image data as the first-pass. The single-date classifications for 1994 and 1996 were repeated using the new ground data and new CPNs were used to combine the classifications from the four years. The salinity maps were judged to be a significant improvement on the initial maps, but the commission errors were too high. As well as the usual road verges and gravel pits etc, a number of paddock-shaped areas were being labelled as salt-affected. These all corresponded to areas of late and/or failed crops in both 1994 and 1996. Data from 1997 was purchased for incorporation in the 3rd-pass processing to address this problem.

For both the first two passes, the study area was considered as a single zone for the single-date classifications and as two zones (west and east) for the CPN runs. Neighbour-modified processing was performed in all single-date classifications and no neighbour smoothing was performed at the CPN stage.

4.2 The Third Pass Salinity Maps

The third stage ground data was provided at the beginning of this processing run. This new ground data was compared to the 2nd-pass salinity maps as it was being digitised. My summary of this comparison was that all the salt-affected areas were detected, although the extents were wrong in some cases. In most cases the missed areas were far too small or narrow for homogeneous training sites to be selected, so the sites were digitised as potentially non-homogeneous sites which were reserved for validation purposes. A severe or marginal label was attached to most sites based on my subjective assessment of the 1996 and 1997 image data.

For the third iteration

- the Mills Lake training sites were omitted (they are atypical of the rest of the salt-affected sites).
- the remainder of the combined first and second pass training sites were divided into east (Fitzgerald and West Rivers) and west (Upper Gairdner and Bremer Bay) zones.
- the 1990 and 1991/92 classifications were repeated without neighbourhood-modified processing
- further iterations of the 1994 and 1996 single-date classifications were performed based on the two zones. An additional Bremer Bay zone was added for the 1994 classifications. Neighbour-modified processing was not performed.
- single-date classifications of the 1997 data were performed based on the two zones
- CPN runs were performed on the four test areas, but it was found that only the two east and west zones were required. In each case neighbour-smoothing was applied.
- a formal post-processing step was introduced to remove the obvious commission errors.

Table 2 summarises the accuracy assessment of the final 1994/1996/1997 salinity map for each of the test regions.

Table 2: Assessment of the Salinity Maps for Each Test Region Against Independent Ground Data

Catchment	Severely salt-affected land detected	Severely salt-affected land detected	Non-saline land labelled as salt-affected
Upper Gairdner catchment	80%	50%	8%
Bremer Bay region	86%	70%	7%
Fitzgerald River corridor	85%	67%	4%
West River catchment	85%	50%	6%

The biggest sources of commission errors in the West River catchment are:

- newly cleared land (since ~1990)
- properties on which there is little or no “super” (fertiliser) applied

In both cases, the fertiliser load is very low and the yield is correspondingly lower, significantly lower than any other crop or pasture paddocks in the area. In all cases this management regime has persisted for the entire time period of this study. Low areas in such paddocks are routinely being labelled as salt-affected in every single-date classification. Higher areas are usually correctly labelled.

The biggest source of commission errors found on a visit to the Fitzgerald River corridor area are paddocks that have been largely cleared but appear to never have been cropped. Scattered bushes are found in each paddock, the surface is generally hugely uneven and the volunteer vegetation is scrappy and sparse. Such paddocks fall on the boundary between salt-affected and poor productivity in each season. With no “good crop” in their rotation, the weight of evidence calls them salt-affected. “Parkland” regions (scattered trees with grassy understory used for pasture) also tend to fall into this category.

Similar expectations are held for the Upper Gairdner and Bremer Bay regions.

Many of the commission errors could be corrected by a better DEM. Parts of known saline drainage lines (such as the Gairdner River, but also in creeklines in paddocks) are labelled as hilltops by the water accumulation map. This derives from errors in the DEM. Errors such as these mean that rules such as “no salt on hilltops” cannot be strictly applied without omitting too many known salt-affected sites. It is strongly recommended that the CPNs be rerun when the “Land Monitor” DEMs are available for this area. With more accurate DEMs, stricter landform rules can be applied.

The observed omission errors fall into two categories:

- sites where a saline area is detected, but the extent is underestimated (common for flat areas where the margins are still cropped).
- narrow areas (up to 1 pixel) that are only just becoming saline (since ~1994).

Given Ruhi’s definition of salt-affected as a 10% loss of productivity (or a handful of tufts of barley grass in a 1 hectare region), it is common to under-estimate the extent of many salt-affected regions. Inspection of the completely missed areas shows narrow regions, typically mixed, that have quite good cover in one or more of the 1994, 1996 or 1997 images. Additionally, their size and heterogeneous nature generally prevents them from being selected as training sites. Even on a property by property basis, many of these sites would be difficult to accurately map.

5. A Description of the Class Labels Files

This section describes the final salinity maps that have been written to a CD. The maps for the eastern and western zones have been mosaiced into a single file for the whole study area.

5.1 Current Salinity Map (1994/1996/1997)

Filename: FTZcursalt(.ers):

1. Water
2. Bush
3. Salt-affected
4. Bare
5. Non-saline
6. Persistently poor bush (may be saline, but also just sparse)
7. Non-saline (areas mapped as salt but masked as dams or high in catchment (east zone only)).

5.2 Historical Salinity Map (1990/1991)

Filename: FTZoldsalt(.ers)

1. Water
2. Bush
3. Salt-affected
4. Bare
5. Non-saline
6. Persistently poor bush (may be saline, but also just sparse)
7. Non-saline (areas mapped as salt but masked as dams)

5.3 Salinity Change Map (Formed from Current and Historical Salinity Maps)

Filename: FTZsaltchg(.ers)

1. Water
2. Bush (in 1990/91 and 1994/96/97)
3. Salt-affected in both 1990/91 and 1994/96/97
4. Non-saline in both maps
5. Poor bush in both maps
6. Became salt in current map (non-saline in 90/91, saline in 94/96/97)
7. 'Recovered' in current map (saline in 90/91, non-saline in 94/96/97)
8. Decline / clearing (bush in 90/91, not bush and not salt in 94/96/97)
9. Improve / reveg (bush in 94/96/97, not bush and not salt in 90/91)

7. References

Caccetta, P., Campbell, N.A., West, G., Kiverii, H. K. and Gahegan, M. (1995). Aspects of reasoning with uncertainty in an agricultural GIS environment. The New Review of Applied Expert Systems, 1, 161-178.

Campbell, N. A. and Atchley, W. R. (1981). The geometry of canonical variate analysis. Syst. Zool., 30, 268-280.

Campbell, N. A. and Wallace, J. F., (1989). Statistical methods for cover class mapping using remotely sensed data. Proc. Int. Geosci. Remote Sensing Symp: 493-496.

Furby, S. L., Palmer, M. J. and Campbell, N. A. (1996). Image calibration to like values. Proceedings of 8th Australasian Remote Sensing Conference, Canberra, Australia.