Australian Government

Bureau of Rural Sciences

Land Use Data Integration Case Study: the Lower Murray NAP Region

A Report to the National Land and Water Resources Audit

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Executive summary

ACLUMP coordinates and promotes nationally consistent land use and land management information for Australia – a key interest is the detection and reporting of change.

Land use and land management practices have a profound impact on Australia's natural resources, the environment and agricultural production. The Bureau of Rural Sciences and its Australian and State government partners in the Australian Collaborative Land Use Mapping Program (ACLUMP) are promoting the development of nationally consistent land use and land management practices information for Australia. A current focus for the ACLUMP consortium is development of protocols for detecting and reporting land use change.

Land use data was integrated for the Lower Murray region across three state jurisdictions

This project integrated land use data for the Lower Murray region of New South Wales, Victoria and South Australia. State and Australian Government project partners collated land use data across the three jurisdictions and worked together on the development of integrated land use datasets using nationally agreed protocols.

Land use change was investigated for irrigated horticulture, dryland cropping and vegetation clearance and reservation

A capacity for detecting and reporting change in land use is critical for evaluating and monitoring trends in natural resource condition and the effectiveness of regional investments. Aspects of land use change were addressed in relation to (a) irrigated horticulture, (b) dryland cropping, and (c) vegetation clearing and areas reserved for nature conservation. Regional and catchment scale data were compared.

The area of irrigated horticulture and dryland cropping has increased significantly since 1990

Land use change analysis shows that the area under irrigated horticulture and dryland cropping has been increasing in the last decade in key locations. Areas under irrigated horticulture are most likely to be transformed from and return to grazing or dryland cropping. Dryland cropping is subject to seasonal fluctuation and has an apparent pattern of cycling between cropping and grazing.

A capacity to report change depends on the availability of consistent time series data capable of providing insights into aspects of change that are relevant to target interests

A capacity to report change depends on the availability of consistent time series data capable of providing insights into aspects of change that are relevant to target interests. The dimensions of land use change in an agricultural context depend upon farming systems, seasonal variability, and longer-term industry and regional trends. Four broad approaches to reporting land use change are identified:

- Simple areal change: loss or gain in the areal extent
- Transformation: transitions between different land uses
- Dynamics: temporal change (areal extent or transformations) in terms of rates of change and periodicity
- Prediction: modelling spatial or temporal patterns of change.

Land use information was integrated with vegetation information

This project sought to integrate land use with other natural resource information to address aspects of natural resource sustainability in the region. Preliminary regional profiling of vegetation and land use and aspects of land use and the region's water balance was completed.

Acknowledgements

Data collection for this project was a collaborative effort of the Bureau of Rural Sciences and State agencies. This report would not have been possible without the significant contributions from Stuart Lucas, Paul Spiers and Keith Emery from the NSW Department of Infrastructure, Planning and Natural Resources; Sandra Keane and Caroline Michalski from the SA Department of Water, Land and Biodiversity Conservation; and John Weber and Andy McAllister from the Victorian Department of Primary Industries.

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Financial support for work contributing to this project has been provided by the National Land and Water Resources Audit, the National Action Plan for Salinity and Water Quality, the National Landcare Program, the Bureau of Rural Sciences, the Victorian Department of Primary Industries, the NSW Department of Infrastructure, Planning and Natural Resources and the SA Department of Water, Land and Biodiversity Conservation.

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1. Introduction

1.1 Aims and objectives of the project

The Bureau of Rural Sciences (BRS) and its Australian and State government partners in the Australian Collaborative Land Use Mapping Program (ACLUMP) are promoting the development of nationally consistent land use and land management practices information for Australia. Land use in Australia has been mapped at a broad ‘regional’ or ‘national’ scale (1:2,500,000) and at a more detailed ‘catchment’ scale (1:25,000 to 1:250,000) through this program. Over 90 percent of the continent has been mapped at catchment scale with this work being carried out at a State level by State agency partners in the program.

The focus on work in ACLUMP is turning now to the application of land use information to support assessments of natural resource condition and trend, both at the regional and national level. Several issues are critical in this respect: the integration of data across jurisdictions, the capacity to report change over time, and the integration of land use information with other natural resource information to address natural resource sustainability questions.

A primary aim of the project has been to develop integrated cross-jurisdictional land use data for the Lower Murray region of New South Wales, Victoria and South Australia (as defined for the National Action Plan for Salinity and Water Quality (NAP) (Figure 1)). This region extends across nearly 200,000 km^2 of south-eastern Australia, centred on the lower reaches of the River Murray. It includes a diverse array of land uses with large areas under nature conservation uses, dryland agriculture and irrigated horticulture along the Murray. A collaborative effort between State and Australian government project partners was involved in the collation of land use data across the three jurisdictions, and the development of integrated land use datasets using nationally agreed protocols.

A second aim of this project has been to address the reporting of land use change. Over the past few years ACLUMP’s focus has been on mapping static land use and has only recently shifted to investigating ways to measure and report changes in land use over time. A capacity for detecting and reporting change in land use is critical for evaluating and monitoring trends in natural resource condition and the effectiveness of regional investments. This report considers methods of reporting land use change and addresses aspects of land use change in relation to (a) irrigated agriculture and horticulture, (b) dryland cropping, and (c) vegetation clearing and areas reserved for nature conservation. Regional and catchment scale data are compared.

Finally, this project has sought to integrate land use with other natural resource information to address aspects of natural resource sustainability in the region. Preliminary regional profiling of vegetation and land use and aspects of land use and the region’s water balance was completed.

This study represents a stepping-stone between the collation of natural resource data and information, regional and national assessments of natural resources condition and trend, and integrated analyses of biophysical, social and economic factors that will underpin moves to sustainable development. In this respect, project outputs support the ‘*Lower Murray Landscape Futures’* initiative, a collaboration between the Department of Water, Land and Biodiversity Conservation (SA), Department of Primary Industries (Vic), CSIRO Land and Water, the University of Adelaide and the SA Research and Development Corporation with financial support from the National Action Plan program in South Australia and Victoria and the CSIRO's Health Country which seeks to develop an integrated planning framework for this region.

This report is developed in three theme areas. The first theme (section 2) presents an integrated picture of land use in the Lower Murray NAP region at both catchment and regional scale. Information sources, integration and conversion processes, and scale comparisons are considered. The second theme of the report considers land use change. Section 3 addresses the analysis and reporting of change, including a review of alternative reporting approaches. Trial analyses using available data are reported for irrigated horticulture, dryland cropping and vegetation clearance and reservation, differentiating between catchment and regional scale data (sections 4, 5 and 6). The third theme of the report considers the integrated analysis of land use and natural resource information, focusing on vegetation and water balance. The report concludes by discussing project limitations and possible ways to overcome these with broader conclusions regarding land use and land use change in the Lower Murray region.

1.2 Agencies involved in the project

This project has been conducted as a collaborative partnership between four ACLUMP partner agencies:

- Bureau of Rural Sciences (BRS)
- New South Wales Department of Infrastructure, Planning and Natural Resources (DIPNR)
- South Australia Department of Water, Land and Biodiversity Conservation (DWLBC)
- Victoria Department of Primary Industries (DPI)

State agency partners were responsible for the compilation of catchment scale land use datasets, including the technical expertise required for the assembly of the data, field mapping and final data editing. State agencies were also responsible for compiling time-series data for detailed irrigated horticulture, dryland cropping and vegetation clearance and reservation and providing explanations and background information to help with the analysis of change.

BRS' role included coordinating technical aspects of mapping, ensuring consistency in analysis and outputs across jurisdictions, including compliance with nationally agreed standards for land use mapping. BRS was also responsible for conducting data integration and the analysis of land use change, including change detection analysis for irrigated horticulture and dryland cropping.

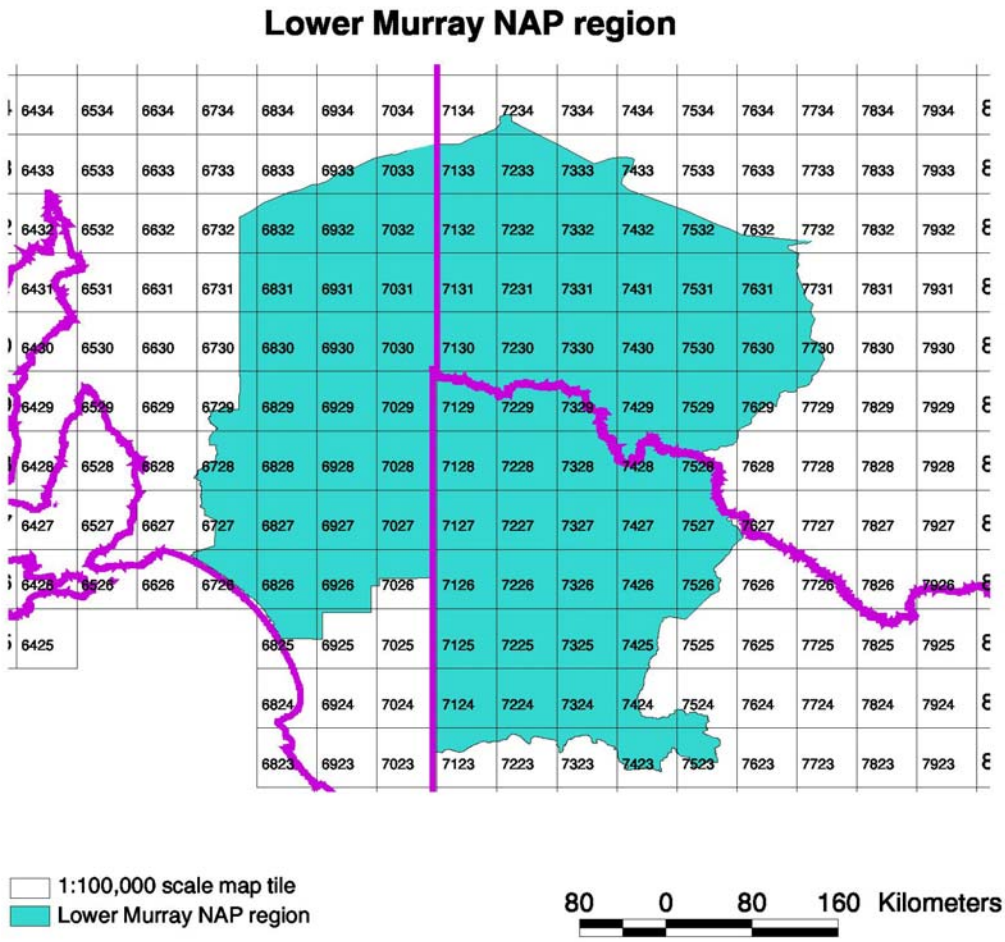
1.3 The Lower Murray Region

The Lower Murray NAP region spans three states, New South Wales, South Australia and Victoria, and is used as the boundary for this study (see Figure 1). It includes the Lower Murray Darling Catchment in New South Wales, the Mallee and Wimmera Catchments in Victoria and the South Australian Murray-Darling Basin region.

Major towns in the region are Broken Hill in New South Wales, Mildura, Horsham and Stawell in Victoria and Renmark and Murray Bridge in South Australia. This region is part of an area called the 'Murray Mallee' extending over 190,000km^2 with a population of over 200,000 people.

In the New South Wales part of the Lower Murray region major land uses include irrigated and dryland cropping, horticulture, wool and meat production, water storage (Menindee Lakes and Lake Victoria), mining, tourism, recreational fishing, forestry and nature conservation.

Figure 1. Lower Murray NAP region



Land use in the Victorian section is diverse with the major uses being irrigated agriculture, dryland cropping and grazing. The region accounts for more than 50 percent of Victoria's wheat production, 90 percent of its dried fruits, 30 percent of Australia's wine grapes and also has large quantities of citrus, avocado, olives and vegetable crops. The region also has salinity problems with highly saline groundwater close to the surface. Soils also have poor fertility and are prone to degradation.

Within the South Australian part of the region, major industries include irrigated viticulture and horticulture, broadacre dryland agriculture, fishing, recreation and manufacturing.

In the Lower Murray region as a whole, most of the remaining area that is not dedicated to cropping, grazing or irrigated agriculture is protected within public and private conservation reserves. Key reserves include:

- The World Heritage listed Willandra Lakes Region (which includes Mungo National Park)
- Bookmark Biosphere Reserve (incorporating Danggali Conservation Park) and Hattah-Kulkyne Biosphere Reserves
- Kinchega, Murray-Sunset, Wyperfeld and Little Desert National Parks

As a Priority Region of the National Action Plan for Salinity and Water Quality, regional bodies within the Lower Murray region have developed resource condition targets to help focus funding investments. Targets relate to:

- Land salinity
- Soil condition
- Native vegetation communities' integrity
- Inland aquatic ecosystems integrity
- Nutrients in aquatic environments
- Turbidity / suspended particulate matter in aquatic environments
- Surface water salinity in freshwater aquatic environments

In total the Lower Murray region has received over $4 million in foundation NAP funding, over $26.5 million in Priority Action funding and over $20 million in Regional Investments up to February 2004 (DAFF/DEH 2004).

2. Land Use in the Lower Murray

One of the principal objectives of this project was to compile integrated land use data across the three State jurisdictions comprising the Lower Murray region. Land use data were compiled at two mapping scales - catchment scale and regional scale.

Land use mapping at catchment scale focuses on the spatial representation of land use at a scale generally relevant to the landscape processes impacting on natural resources such as soil and water. Mapping scale varies according to the intensity of land use activities and landscape context, ranging from 1:25,000 for irrigated and peri-urban areas, to 1:100,000 scale for broadacre cropping regions and 1:250,000 for the semi-arid and arid pastoral zone. The full range of land use intensities and relevant mapping scales are present within the region.

Regional scale land use mapping provides a strategic-level overview of land use at a scale of approximately 1:2,500,000. Regional scale mapping has been completed nationally by BRS (for the year 1996/97) for the National Land and Water Resources Audit (NLWRA), and across the Murray-Darling Basin (for the years 1993, 1996, 1998 and 2000) for the Murray-Darling Basin Commission (MDBC).

Detailed catchment scale land use data were compiled by DIPNR, DWLBC and DPI at a single time period in each jurisdiction. Regional scale time series land use data produced by the BRS for the Murray-Darling Basin were clipped to the Lower Murray region.

This section of the report outlines the data sources for each of the land use mapping scales and provides a comparison of the mapping at different scales.

2.1 Catchment scale mapping

Catchment scale land use mapping was completed in all three jurisdictions consistent with the procedures and specifications included in the BRS Handbook *Land Use Mapping at Catchment Scale: Principles, Procedures and Definitions (Edition 2)*. Land uses were classified according to the Australian Land Use and Management (ALUM) classification system which is the Australian Spatial Data Infrastructure (ASDI) standard for land use datasets, see Appendix 1. All jurisdictions were mapped to ALUM version 5, introduced in November 2001.

The mapping was undertaken in a three staged process. The first step of mapping involved the collation of existing land use information, remotely sensed information (satellite imagery and aerial photography) and cadastre. Other important information sources were reserve estate data, land cover, local government zoning information and other land management data.

The second stage in the mapping process involved interpretation and assignment of land use classes according to the ALUM classification to create an initial draft land use map. The final stages of mapping included field verification, the editing of draft land use maps and validation.

For Victoria, catchment scale mapping was compiled for the Wimmera and Mallee catchments and the Glenelg-Hopkins & Corangamite region by DPI with additional financial support from the NHT, Victorian NAP and DPI. Mapping for the Wimmera and Mallee was completed in February 2005 with mapping at scales of 1:25,000 and 1:100,000. Mapping for the Glenelg-Hopkins & Corangamite region was completed in 2002.

In South Australia, mapping was completed for the Lower Murray region with financial support from the NLWRA (through the current project), the NHT, National Landcare Program (NLP) and DWLBC. Mapping for the Murray-Darling Basin and the south-east of South Australia was completed for 2003 and 2002 respectively, at scales of 1:25,000 and 1:100,000. Baseline irrigation 2002-2003 data provided by the River Murray Catchment Water Management Board and maintained by the South Australian Department for Environment and Heritage was combined with the land use data to provide more detailed and accurate uses in the irrigation areas (Keane 2005: 2). Land management information collected during this stage was not available to this project.

In New South Wales, mapping was completed for the Lower Murray region by DIPNR as part of ACLUMP with support from the National Landcare Program (2003-2004) and the NLWRA through the current project. The mapping is dated at June 2002 and is produced at scales of 1:25,000 and 1:100,000. Metadata for each of the catchment scale land use datasets is presented in Appendix 2.

The resulting integrated catchment scale land use dataset (Figure 2) is the most recent accurate land use mapping available for the region. This mapping shows that land use in the northern section of the Lower Murray region is predominantly grazing natural vegetation with some national parks and water features. Irrigated and residential land uses are mainly confined to the areas surrounding the Murray River. The southern section of the region is dominated by national parks and cropping in Victoria and grazing natural vegetation, cropping and nature reserves in South Australia.

Appendix 3 provides a summary of each of the land uses mapped in the Lower Murray region based on the detailed land use data provided by the project partners. Land uses are broken into ALUM 5 tertiary classes (Appendix 1) with the area and percentage of the total for each land use shown. These statistics have been developed for the Murray-Darling Basin component of the region to enable comparison of catchment scale and regional scale datasets. This accounts for 176,242 km^2 or almost 93 percent of the region.

Appendix 3 shows that approximately 46 percent of the area is attributed to grazing natural vegetation. Figure 2 shows that most of this grazing is concentrated in the northern parts of the region. Grazing modified pastures is the next dominant land use accounting for just over 15 percent of the area, located mainly south of the Murray River. Cropping classes account for 16 percent, nature conservation approximately 14 percent and production forestry two percent with remaining area spread among other land uses.

2.2 Regional scale mapping

Regional scale land uses for the Lower Murray region were derived from a baseline study of land use in the Murray-Darling Basin completed for the MDBC by BRS in collaboration with ACLUMP partners (BRS 2004). This involved the application of satellite imagery coupled with ABS' agricultural commodity statistics. Project outputs include a series of land use time-slices for the Basin (1993, 1996, 1998 and 2000), see Figure 3. The summary maps for each of the years show the non-agricultural uses and the likely spatial location of the agricultural uses based on probability maps that use simple spatial allocation rules to develop a maximum likelihood land use map. Metadata for the regional scale mapping is presented in Appendix 2.

Figure 2. Catchment Scale Land Use Map of the Lower Murray NAP Region 2002/2003

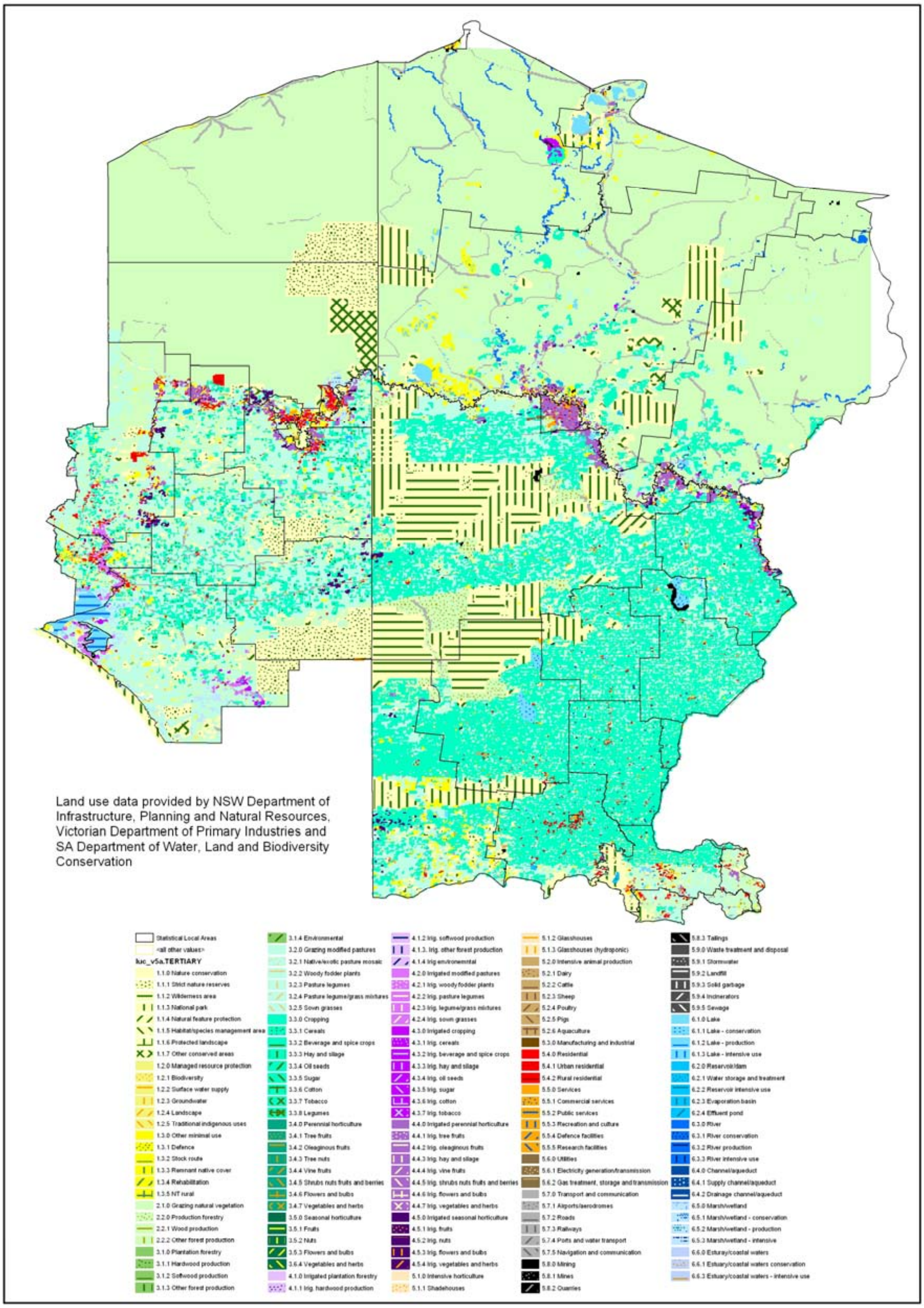
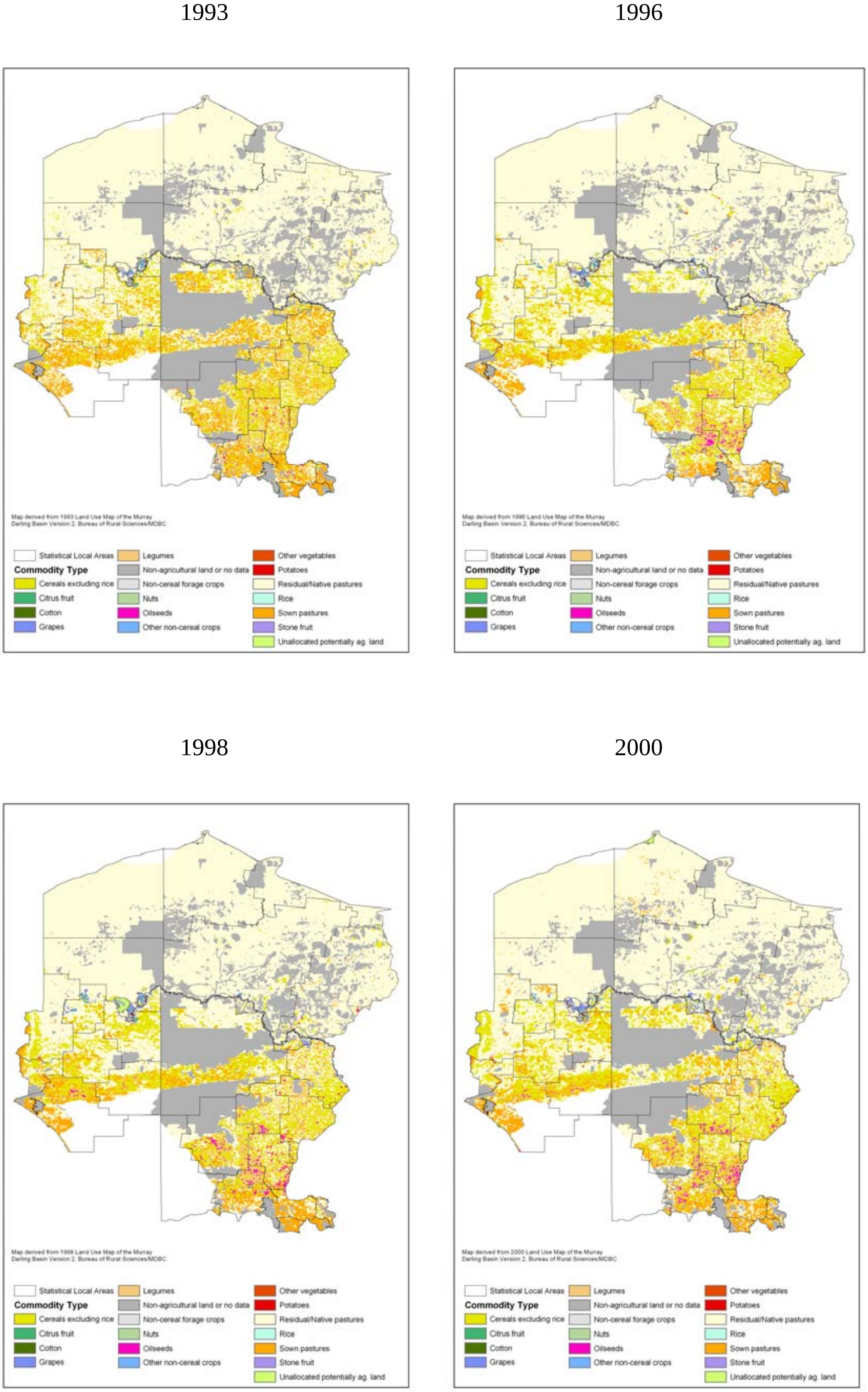


Figure 3. Regional Scale Land Use Maps of the Lower Murray NAP Region



These land use maps were created using SPREAD II, a modelling program that spatially interpolates Australian Bureau of Statistics agricultural commodity data using Advanced Very High Resolution Radiometer (AVHRR) satellite imagery. SPREAD (SPatial REallocation of Aggregated Data) II relies on the different growth characteristics of various crops and pastures over a one year period, which are characterised by the Normalised Difference Vegetation Index (NDVI) series over that period. Algorithms allocate land use in accordance with these profiles, subject to the area constraints provided by the agricultural commodity statistics generated by the Australian Bureau of Statistics and an irrigation constraint (BRS 2004).

Land uses originally mapped to ALUM Version 4 were converted to Version 5 for this project, including tertiary level commodity classes. This mapping was confined to the Murray-Darling Basin boundary, and as a consequence some land use information is missing for some northern and southern parts of the Lower Murray region. The regional scale land use maps are shown in Figure 3. Each of these maps shows the most likely agricultural use for the area based on a spatial probability assessment. Agricultural uses are dominated by residual/native pastures in the north and cereal growing, sown pastures and oilseeds in the south.

Land uses detected by the regional scale land use mapping are presented in Appendix 3. The dominant land use is grazing natural vegetation which accounts for over 55 percent of the area, mostly concentrated in the north. The next most abundant land use is cereals (cropping) at 12 percent. Grazing modified pastures and remnant vegetation each account for 5-6 percent of the area and conserved areas are also prominent combining to over 11 percent of the total area. Lakes and production forestry also have an impact on the landscape, each comprising two percent of the region according to the regional scale map.

2.3 A comparison of catchment scale and regional scale mapping

The following discussion briefly reviews differences in area allocations evident in catchment scale and regional scale land use mapping for the Lower Murray region. As indicated, the two mapping scales use different methods to map land use. Catchment scale mapping relies mainly on cadastral and remotely sensed data which is then field verified while the regional scale mapping utilises ABS agricultural statistics coupled to satellite imagery. Catchment scale land use mapping is more current, with dates ranging from 2002-2003 while the most recent regional scale land use mapping has been produced for the year 2000/01.

Differences in the areas of land uses identified in catchment scale and regional scale mapping are shown in Table 1. The common boundary between the two datasets has been used to ensure that the comparisons are not misleading on the basis of regional boundary configuration. Some of the major differences that can be observed apply to ‘1.2 Managed resource protection’ and ‘1.3 Other minimal use’ classes. It is probable that regional scale mapping underestimates ‘1.1 Nature conservation’ and that consequently some areas classed as 1.2 and 1.3 should instead fall under this former class.

The area under ‘2.1 Grazing natural vegetation’ is similar at each of the scales, as is ‘2.2 Production forestry’, ‘3.3 Cropping’ and ‘4.2 Irrigated modified pastures’. However, regional scale land use mapping only estimates a third of the area mapped at catchment scale for ‘3.2 Grazing modified pastures’ and even less for ‘4.3 Irrigated cropping’ and ‘4.5 Irrigated seasonal horticulture’ although the areas involved a relatively small. Large differences between the two datasets are evident for ‘3.4 Perennial horticulture’ although again the areas involved are relatively small. Regional scale mapping also allocates a much larger area to lakes.

Table 1. Catchment scale vs. regional scale land use areas for the Lower Murray

Primary Land Use	Secondary Land Use	Catchment scale area (sqkm)	Regional scale area (sqkm)
1. Conservation and natural environments	1.1 Nature conservation	24,933.8	19,611.5
	1.2 Managed resource protection	70.9	1,056.3
	1.3 Other minimal use	1,249.4	11,505.0
	TOTAL CLASS 1	**26,254.1**	**32,172.8**
2. Production from relatively natural environments	2.1 Grazing natural vegetation	81,091.3	96,558.8
	2.2 Production forestry	3,587.5	3,993.4
	TOTAL CLASS 2	**84,678.8**	**100,552.2**
3. Production from dryland agriculture and plantations	3.1 Plantation forestry	18.3	36.1
	3.2 Grazing modified pastures	28,750.8	10,322.8
	3.3 Cropping	28,092.8	25,205.0
	3.4 Perennial horticulture	0.5	65.2
	TOTAL CLASS 3	**56,862.5**	**35,629.0**
4. Production from irrigated agriculture and plantations	4.1 Irrigated plantation forestry	3.9	0.0
	4.2 Irrigated modified pastures	161.0	205.8
	4.3 Irrigated cropping	211.8	36.5
	4.4 Irrigated perennial horticulture	1,034.4	791.3
	4.5 Irrigated seasonal horticulture	225.4	102.6
	TOTAL CLASS 4	**1,636.5**	**1,136.2**
5. Intensive uses	5.0 Intensive uses	73.9	223.8
	5.1 Intensive horticulture	2.5	0.0
	5.2 Intensive animal production	30.2	0.0
	5.3 Manufacturing and industrial	24.5	0.0
	5.4 Residential	357.6	56.5
	5.5 Services	163.2	0.0
	5.6 Utilities	28.9	0.0
	5.7 Transport and communication	1,772.8	24.1
	5.8 Mining	119.7	0.0
	5.9 Waste treatment and disposal	15.6	0.0
	TOTAL CLASS 5	**2,588.8**	**304.4**
6. Water	6.1 Lake	1,550.6	4,544.0
	6.2 Reservoir/dam	64.7	42.5
	6.3 River	405.7	40.0
	6.4 Channel/aqueduct	32.7	0.0
	6.5 Marsh/wetland	524.9	130.6
	TOTAL CLASS 6	**2,578.5**	**4,757.0**
No Data		1.0	48.7
Total		**174,600**	**174,600**

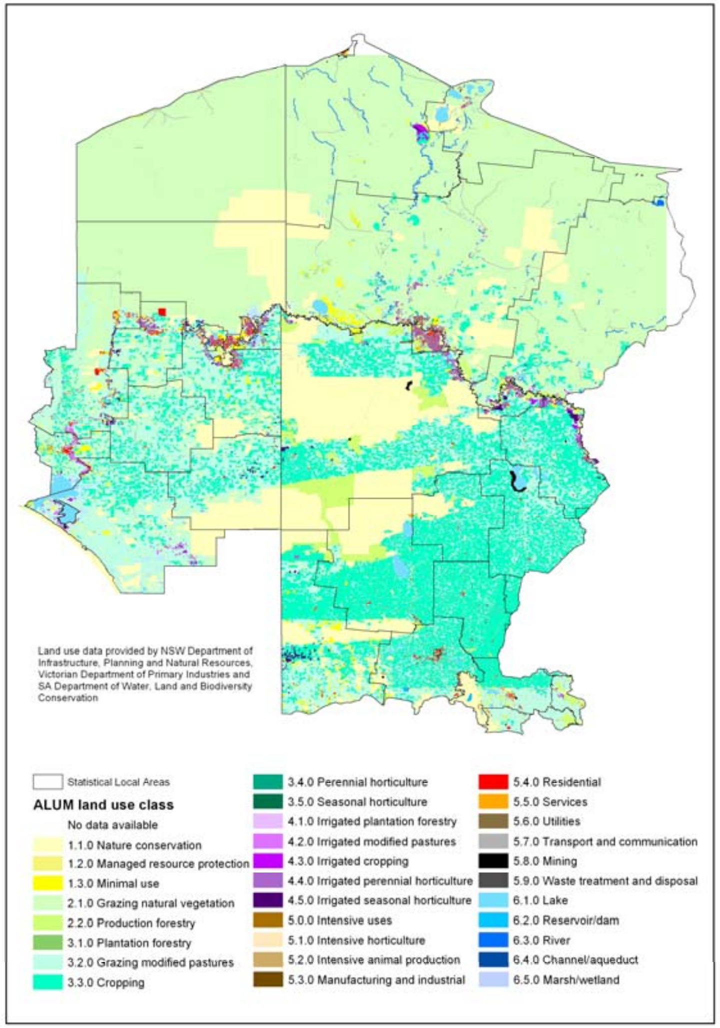
Data derived from land use data produced by NSW DIPNR, Vic DPI, SA DWLBC and BRS/MDBC

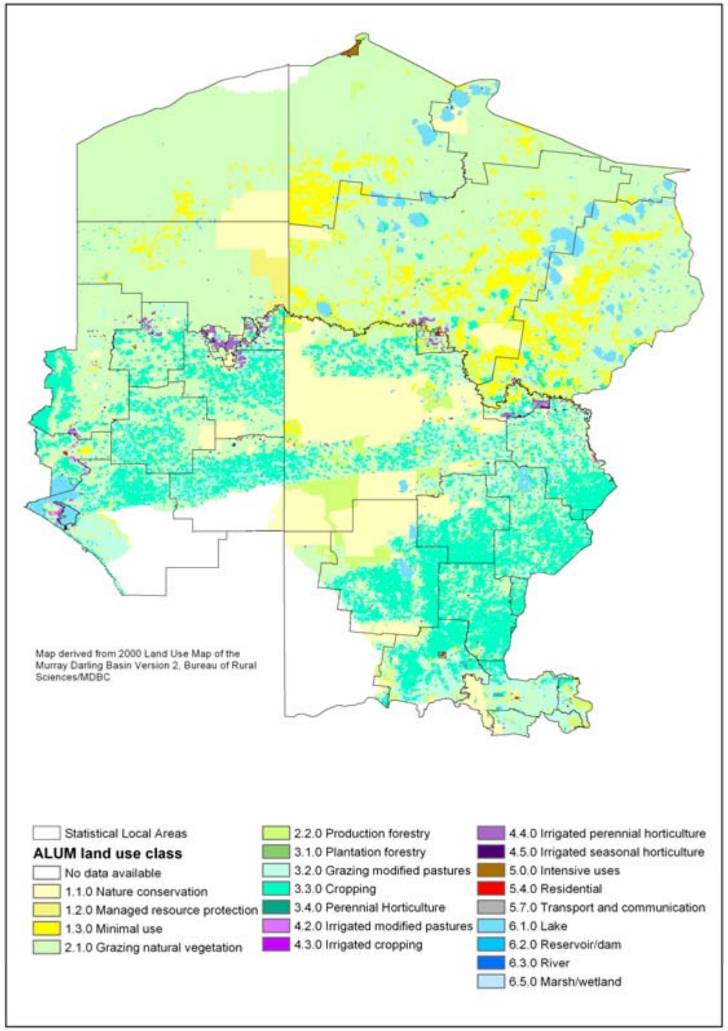
A spatial comparison between the catchment scale and regional scale land use mapping is presented in Figure 4. It is evident, especially in New South Wales, that many areas shown as lakes in regional scale mapping were once lakes but are now dry and used for grazing and other purposes. The Darling River is present in catchment scale mapping but not the regional scale.

Catchment scale mapping assigns the majority of the northern part of the region to grazing natural vegetation and nature conservation while regional mapping allocated larger areas to minimal use and water. Catchment scale mapping also identifies a substantially larger area of irrigated land uses along the Murray and Darling Rivers compared to regional scale mapping. The catchment scale mapping identifies a larger area of residential land uses long the Murray River, especially in South Australia.

The area identified under cropping is fairly similar for each scale of mapping in South Australia. However, significant differences are evident between scales in the mapping produced in Victoria. This may indicate technical differences in class allocation between the two states in mapping at catchment scale.

Figure 4. Comparison between catchment scale land use in 2002/2003 (left) and regional scale land use in 2000 (right)





3. Reporting Land Use Change

3.1 Introduction

This section of the report discusses recent approaches to reporting land use change and how these methods can be applied to measure land use change in the Lower Murray region.

Change in land use strongly relates to change in natural resource conditions (including soil, water and biodiversity), agricultural production, economic performance and the social well-being and sustainability of communities. An understanding of how land uses are changing is therefore critical to natural resource managers and policy-makers, helping to better inform agriculture, conservation and development policies and investment (Verburg et. al. 2000, Müller & Zeller 2002, Cardille & Foley 2003).

Spatial representations of land use drawn from different time periods coupled with a consistent classification system and information sources can help to identify ‘hot-spots’ of land use change.

Some recent changes in understanding of the characteristics and drivers of land use change and the implications that flow from this are shown in Table 2. This table shows that land use change and its implications are more complex, dynamic, and ubiquitous than previously appreciated (Lambin & Geist 2001).

Table 2. Changes in our understanding of land-cover/land-use changes

Previous understanding	Current understanding
characterised by land-cover conversion	characterised by land cover modification
affecting mostly forest landscapes	affecting all cover types, including rangelands, open forests, peri-urban areas, wetlands
assumed pristine benchmark	landscapes altered by human use for a millennia
permanent change	complex trajectories of change; land cover in a constant state of flux
spatially homogenous	high spatial heterogeneity; landscape fragmentation
driven by population growth	driven by response to change in economic opportunities and policies, with biophysical and socio-economic trigger events
local impact	influences from remote urban centres, amplified or attenuated by globalisation, with strong local-global interplay
characterised by expansion of agriculture	characterised by land use intensification and diversification
key impact on carbon cycle	key impact on human health, biodiversity, albedo, water cycle, emissions of carbon, methane, NO_x, etc.
intensity of impact depending on magnitude of biophysical change	intensity of impact depending mostly on vulnerability of people and places
change everywhere	spatial concentration in “hot spots” of change

Adapted from: Lambin & Geist 2001: 29

3.2 Land use change assessment in Australia

A number of projects analysing land use change have recently been completed in Australia. The report of most relevance to this project is *Irrigated Horticulture of the Lower Murray-Darling 1997 to 2003* produced by SunRISE Mapping in NSW and Victoria (SunRISE Inc 21 2004). This study reports on change in irrigation development in the Lower Murray-Darling region spanning irrigated areas from Balranald, NSW and Koraleigh, Victoria in the west to the South Australian border. SunRISE 21 Inc has three fine-scale (finer than 1:20,000 scale) crop databases of the region for the years 1997, 2001 and 2003. Irrigated crop information in the SunRISE study was collected using:

1. Orthophoto imagery (area, crop type)
2. Detailed property surveys (crop variety rootstock, irrigation method, use, year planted)
3. Visual interpretation of orthophotos and drive-by surveys (crop type, irrigation method, grape use, year planted)
4. Collaboration with related projects and programs (SunRISE Inc 21 2004)

SunRISE 21 uses a number of techniques to report change in irrigated horticulture. Changes are recorded for the region as a whole and for each irrigation district. Maps show the change in area by crop type, irrigation method and grape use. Changes in wine grapes and citrus are also studied in detail. Irrigation development status between 1997 and 2003 is measured for each of the districts and the region as either retired, no change, replanting or new area.

In August 2001, the NLWRA released a report that investigated changes in land use, productivity and diversification across Australia. The main aim of the project was to determine how land use is changing across Australia, and where production potential is declining or improving (NLWRA 2001: 1). The project focused on intensive agricultural land uses, ordered by degree of land use intensity for:

- Extensive grazing
- Sown pastures
- Broadacre crops
- Semi-intensive crops
- Horticulture (NLWRA 2001: 2)

The report provides a historical background to land use change in Australia and discusses the major cause of this change. Trends in land use change, productivity and enterprise diversification between 1983 and 1997 are presented as graphs and maps. As the data used for this project is sourced from the Australian Bureau of Statistics Agricultural Census (AgStats), change maps are presented at the Statistical Local Area level. Trend projections were also made to predict how agriculture will change over the next 20 years. Major findings from the land use change analysis included:

- An increase in the area of irrigated land from 1.6 million hectares in 1983-84 to 2.06 million hectares in 1996-97. This mainly occurred in New South Wales and Queensland
- Increasing diversity of agricultural species within broadacre cropping or within farms, especially in the grain cropping regions of southern Australia
- Increasing overall productivity across most areas

- The greatest rate of land use change in eastern and south-eastern Australia, the south west coast of Australia and Tasmania.
- Varied increase in productivity between regions, with the irrigation areas along the Murray and Murrumbidgee areas having consistently high productivity rates (NLWRA 2001: 3)

Within the Murray-Darling Basin, Bryan and Marvanek (2004) conducted a study of the distribution and dynamics of agricultural land use and the economic returns to agricultural use of land and water resources from 1996/07 to 2000/01. This study was conducted at broad regional scale and aimed to provide baseline data to inform integrated catchment management in the Basin. Land use maps created by BRS were combined with ABS agricultural statistics to map the distribution of agricultural commodities for the two time periods. Land use change was assessed at the Catchment Management Region level using pixel level land use data (see Stewart et. al 2001 for land use mapping methodology). Land use change was presented in terms of percentage change in area for broad land use types and specific agricultural commodities for the Basin and for each of the Catchment Management Regions. Water requirements for irrigated agriculture and economic returns were also measured.

In Queensland, a project conducted by the Department of Natural Resources and Mines with support of the NLWRA is underway to detect and map land use change in the Fitzroy Basin. The aim is to develop a set of procedures that will be broadly applicable to land use change detection for a number of agricultural uses (Witte pers. comm. 2004). Several analytical techniques are being explored which involve the use of Landsat TM imagery, MODIS imagery and ABS agricultural statistics data. It is planned to measure change in land use area over time using an integration of these datasets.

In South Australia in 2000, the DWLBC completed a study entitled *Evaluating Regional Change* that examined land use differences within the Mount Lofty Ranges between 1993 and 1999 (Flavel & Ratcliff 2000). This project used three methods to report on land use change in the region:

- Percentage area of land use area lost or gained
- Spatial change in single land uses
- Switches in land uses

Land use matrices were used to compare individual land uses between the two years. Change in land use was also used to derive change in erosion potential and residual nutrients.

Annett (2003) investigated change in agricultural land uses in Victoria from 1904-2000. Data for the project was sourced from the ABS agricultural statistics. Change analysis was based on change in area of farmland and number of farms for the State as a whole and also six regions. The project aimed to identify trends in the data and considered their significance on biodiversity and other land management policy issues.

3.3 Approaches to reporting change

Many methods may be employed to report land use change, the choice generally dependent on the problem being addressed, the scale and accuracy of the data and the available time series. A simple comparison of area may be determined with relatively broad-scale land use data and reporting can be straightforward. Conversely, predictive reporting using modelling can be complex with specific data requirements. Current approaches to reporting land use change tend to fall into one or more of the following categories:

- **Simple areal change**: loss or gain in the areal extent of a particular land use
- **Transformation**: transitions between different land uses
- **Dynamics**: temporal dimensions of change (areal extent or transformations) in terms of rates of change and periodicity
- **Prediction**: modelling expected spatial or temporal patterns of land use change

Simple areal change is the simplest way of reporting land use change. Change may be reported by calculating the area under a particular land use for two or more different time periods and comparing the difference. This gives an indication of whether target land uses are increasing or decreasing in area over time. Changes can be presented statistically in simple tables or graphs or spatially, where change in areal extent is demonstrated by mapping the location of land uses in one or more time periods. Simple maps can be produced for each time period and identified changes compared and trends observed (see Cardille & Foley 2003, Tanrivermis 2003 and Haines-Young & Watkins 1996).

Transformation investigates the patterns of transition from one land use to another over time in addition to observing how the area of a particular use has changed. For example, a particular area may be cropped one year, grazed the next year and then cropped again the year after. Alternatively, land under improved pasture for dairy may be converted to vineyards. A simple way to express land use transformations is using a change matrix that compares land uses between different years so that it is possible to see what land uses are changing into/from (see Müller & Zeller 2002, Velázquez et. al. 2003 and Pavón et. al. 2003). Change matrices also show change in area for each land use (simple areal change approach). Flavel & Ratcliff (2000) demonstrated spatially the transformation of a single land use between 1993 and 1999 by mapping the extent of the selected use in 1999 and 1993 and showing whether it still existed in 1999, had changed into something else or did not exist in 1993.

Reporting on the **dynamics** of land use change can provide a more detailed picture of land use change (either simple areal changes or transformations) over time. It may, for instance, be possible to obtain a more informative picture of how land uses are changing by examining the temporal nature of change over years or seasons; whether rates of change are increasing or decreasing, are long term or short-term trends, or cyclic (for example changes as a result of differences in growing seasons, structural adjustment, farming systems, or rotation regimes). This approach may identify key trends in land use (and land management) not evident in assessments of simple areal change or transformations (see Annett 2003). Rates of expansion for land uses or new developments can give different values for growth and decline than total area comparisons. However, to successfully analyse land use change using a dynamics approach, a large amount of consistent, high quality time-series data is required. Often it is not possible to obtain consistent data for consecutive years, seasons, etc.

The final common approach used to report land use change is **prediction**. This approach uses models to predict past, present and future land uses based on certain rules, relationships and input data. This approach helps identify how changes in certain parameters may affect future land use, information that may be particularly important as an input into scenario planning. It may also help fill gaps in data availability (Verburg et. al. 2000, Taillefumier & Piégay 2003 and Velázquez et. al. 2003).

The most appropriate approach for reporting change depends on particular questions posed, the accuracy and spatial precision of the data and the availability of a time-series. Fine-scaled analysis can be carried out where there is a high level of confidence in the reliability and accuracy of the source data, especially its spatial accuracy. Data with a lower level of confidence can be aggregated to regions or broad classes to provide a more reliable analysis

(Bryan & Marvanek 2004). The end use of the land use change analysis and the data available should determine the scale at which the analysis should be carried out.

The most common sources of data used for change analysis are aerial photographs, remote sensing, agricultural statistics/farm surveys and other region-specific surveys. Advantages of aerial photographs and remote sensing include being able to collect data at the regional scale for specific time periods for broad land use classes. A disadvantage of this data is that there are often misclassifications, especially when trying to map past land use, resulting in under or overestimation (see for example, Pavón et. al. 2003). The use of agricultural statistics may overcome this problem as they provide spatially aggregated information. However, since agricultural statistics are often aggregated to large spatial units (for example, at the Statistical Local Area level in Australia), the spatial precision is often insufficient to carry out local change analysis (Bryan & Marvanek).

3.4 How this applies to the Lower Murray region

This short review of land use change analysis has shown that there are a variety of methods that can be used to measure land use change depending on the purpose of the analysis and the data available. These methods can range from a simple comparison of change in area between different time periods to the prediction of land use changes into the future.

Since one of the purposes of this report is to explore ways to report land use change, it would be desirable to apply land use reporting analyses using methods from each of the categories identified and discussed. Such analyses would make use of the most reliable data available and would be conducted at an appropriate scale for each dataset. Results would then be compared in order to investigate changes between the data and the effect of scale on the changes observed.

For this study of the Lower Murray NAP region, data has been supplied from a number of different sources (both Australian and State government agencies) at a range of different scales. A distinction is made between data sourced at the catchment scale and data sourced at the regional scale. Change reporting for irrigated horticulture land uses considers change in area over time, change in spatial distribution and replacement and substitution for both catchment scale and regional scale data. These analyses draw from the simple areal change and transformation approach to reporting land use change. Comparisons are made between the results from different scales to determine the major contrasts and possible errors in the land use mapping. Similar methods are used to detect changes in dryland cropping and reference is also made to vegetation clearance and reservation over time.

Originally it was hoped that land management practices information for the Lower Murray region would be able available to this project to investigate change over time. Unfortunately this information was not available to the study.

4. Irrigated Horticulture

The Lower Murray region, which takes in the Riverland and Sunraysia irrigation areas of southern Australia, is one of the pre-eminent regions for irrigated horticulture in Australia. Irrigated horticulture land uses extend along much of the length of the River Murray, with major centres of activity around Renmark, Loxton and Waikerie in South Australia, and Wentworth, Mildura, and Swan Hill in New South Wales and Victoria. The total area under irrigated horticulture in the region in 2003 was 101,860 hectares. Fifty-two percent (53,065 hectares) was located in South Australia, 36 percent (36,869 hectares) in Victoria and the remaining 12 percent (11,926 hectares) in New South Wales. Irrigated horticulture is a critical regional land use, both in terms of its economic and social importance for the region, and its implications for natural resource management, particularly soil and water. The location of irrigated horticulture for the Lower Murray region in 2003 based on land use mapping completed at catchment scale is shown in Figure 5.

This section of the report investigates change in irrigated horticulture over time using two different scales of land use data – catchment and regional scale. The catchment scale data are drawn primarily from two organisations conducting irrigation mapping in the Lower Murray region (the private firm SunRISE 21 Inc (Sunraysia Regional Initiative for a Sustainable Economy into the 21st Century), and the River Murray Catchment Water Management Board) while the regional scale data are based largely on ABS AgStats and satellite imagery. Change evident in irrigated horticulture at each scale is considered in turn.

4.1 Irrigated horticulture at catchment scale

4.1.1 Data integration for change reporting

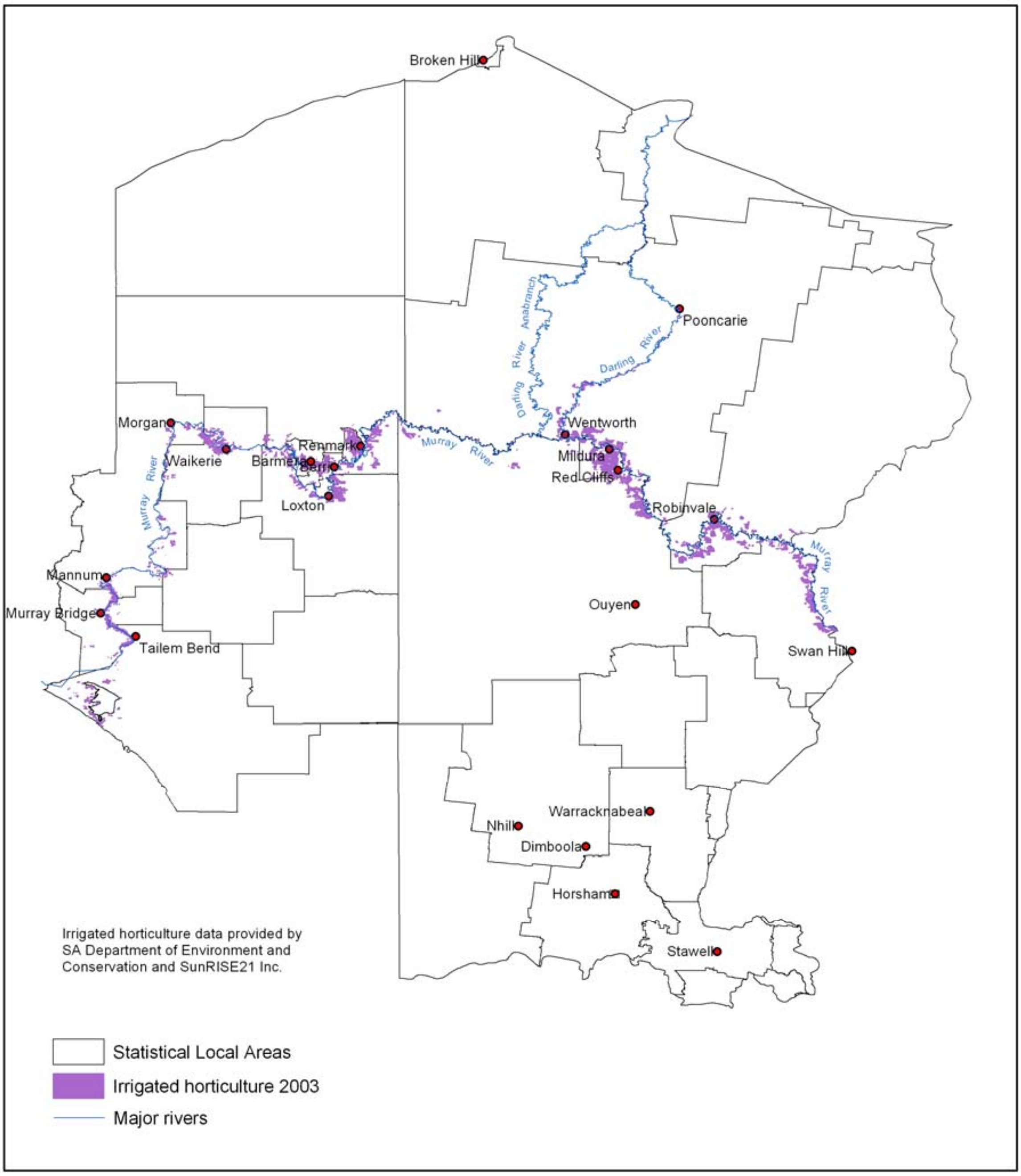
Change in irrigated horticulture in the Lower Murray region could be distinguished using catchment scale land use data of relatively high spatial precision and attribute accuracy from sources in each State jurisdiction collated over a number of years (1988-2003).

In New South Wales and Victoria, DIPNR and DPI obtained detailed spatial irrigation data from SunRISE 21 Inc. These data show the location of irrigated horticulture within the Lower Murray-Darling region and provide information on area, crop type, year planted and whether it had been reworked. Other information such as crop variety, rootstock and irrigation method are also collected but were not available to this project. Irrigated horticulture was mapped for 2003 using aerial and orthophoto imagery, detailed property surveys and drive-by surveys. The information on the year planted was broken into the following time periods: before 1989, 1989, 1990-1994, 1995-1999, 2000, 2001, 2002, 2003 and 2004.

In South Australia DWLBC provided detailed spatial irrigation horticulture data developed by the SA Department for Environment and Heritage (SA DEH). These data show the location, type and area of irrigated horticulture along the South Australian section of the River Murray. Data are available for the years 1988, 1995, 1997, 1999, 2001 and 2003. These data were collected using 1:20,000 aerial photographs for January of those years with additional checks using 1:40,000 photography for areas not covered by the finer scale photography.

State-based data for irrigated horticulture were extracted from primary mapping sources with different levels of detail and currency. The New South Wales and Victorian data both produced by SunRISE 21 had attributes for area, crop type (eg. Valencia, almond, grape, etc), year planted and year last reworked. These data were only available for irrigated horticulture present in 2003, with the relevant year of establishment attributed to each crop. Crops established prior to this time but not present in 2003 were not recorded. Therefore, area figures are only accurate for 2003. However, some area figures (non-spatial) for change in irrigated horticulture were available for the region as a whole.

Figure 5. Irrigated horticulture in the Lower Murray NAP Region 2003



South Australian irrigated horticulture mapping available to this study simply mapped the location of irrigated horticulture, without details of the type of horticulture. However, individual datasets were available for a number of years between 1989 and 2003 showing the spatial distribution and area of irrigated horticulture for each year. This meant that it was possible to map and compare areas between different years.

In order to carry out analyses on the data for the region as a whole, the South Australian data were merged for the different years to mirror the New South Wales and Victorian data. Each of the datasets were clipped to the 2003 irrigated horticulture extent so that it was possible to determine the year that the crops present in 2003 were first planted. South Australian data from the years 1988, 1995, 1997, 1999 and 2001 were included if they were still present in 2003. Once these datasets were combined, individual polygons were attributed with the date they first appeared in the datasets even if they were not irrigated for a number of years in between establishment and 2003. These data were then combined with the New South Wales and Victorian data to carry out analyses for the entire region.

4.1.2 Simple areal change

As discussed, New South Wales and Victorian SunRISE 21 data and the South Australian irrigated horticulture were obtained in different formats. The South Australian data were combined to match the attribute format of SunRISE 21 data which provided the year planted for irrigated horticulture present in 2003. Year planted data were only available for particular time periods, not all dates matching between the South Australian and SunRISE 21 data (some had to be combined).

Table 3. Area of 2003 irrigated horticulture in the Lower Murray by year planted

		Irrigated horitulture year planted						
	State	< 1989	1990-1994	1995-1999	2000	2001	2002	2003/4
Area (Ha)	South Australia	34,298	-	10,276	-	3,404	-	5,087
	New South Wales	3,671	1,557	4,175	602	781	766	374
	Victoria	10,609	2,919	9,976	2,672	4,480	4,301	1,912
	Total	48,578	4,475	24,427	3,274	8,665	5,067	7,373

Sources: SunRISE 21 Inc, South Australia Dept of Environment and Heritage

Table 3 shows the year planted for areas of irrigated horticulture present in 2003 in the Lower Murray region. South Australian data were not available for all time periods present in the table but are sufficiently accurate to allow useful conclusions to be drawn. For all of the jurisdictions, 48 percent of the irrigated horticulture present in 2003 was first planted in 1989 or earlier. The years 1995 to 1999 also account for significant planting amounting to 24 percent of 2003's total horticulture. A larger area of irrigated horticulture was developed from 2000 to 2003/4 in South Australia and Victoria but the rates for New South Wales declined to 374 hectares in 2003/4. The area newly planted in Victoria in 2003/4 also dropped to less than half of that planted in 2001 and 2002. In South Australia, the area of newly planted irrigated horticulture in 2003 was 10 percent or 5,087 hectares.

'Year planted' data for irrigated horticulture in the Lower Murray region shows most of the current horticulture originates from areas that were first irrigated prior to 1989. These areas may have not been irrigated or cropped every single year since establishment but were irrigated again in 2003/4. The irrigated horticulture data collected by SunRISE 21 in New South Wales and Victoria also included information on re-working since first planting. For Victoria, 860 hectares or 2 percent of the irrigated horticulture had been re-worked between first planting and 2003/04 and in New South Wales the figure was 316 hectares or 3 percent.

The *Irrigated Horticulture of the Lower Murray-Darling 1997 to 2003* report produced by SunRISE 21 provides some useful information on development of irrigated horticulture in the Lower Murray-Darling. The region discussed in the report contains areas outside the Lower Murray NAP region but gives an indication of change in location.

The change in area in irrigation development for pumped and non-pumped districts in the Lower Murray-Darling from 1997 to 2003 is shown in Table 4. In 1997 there were 62,735 hectares of irrigated crops and in 2003 this had risen to 77,750 at an increase of 4 percent per annum. Of the crops present in 1997, 360 hectares had been retired by 2003 with the majority occurring in pumped districts. Over 77 percent of the crops planted in 1997 remained unchanged in 2003 while 22 percent were either re-worked, replaced or undergoing redevelopment. The pumped districts had a high proportion of replanting with over a third of crops redeveloped. The majority of new plantings occurred in non-pumped districts at a rate of double the area replanted. In pumped districts, new plantings were significantly lower with redevelopment five times more likely than new plantings.

Table 4. Lower Murray-Darling irrigation development 1997-2003 (NSW & Vic)

	Area (Ha)		
Irrigation Development	**Pumped District**	**Other**	**Total**
Retired - change in land use since 1997	315	75	390
No Change - no change to planting between 1997 & 2003	13,950	34,460	48,410
Replanting - planting reworked, replaced or in redevelopment	6,265	7,670	13,935
New Area Planting - planting in an area not irrigated in 1997	1,310	14,095	15,405

Source: SunRISE 21 Inc 2004: 30

SA DEH has conducted land use change analyses of irrigated horticulture along the Murray River in South Australia (pers. comm. Matt Miles 2004). These analyses are based on the irrigated horticulture data made available for this project by SA DEH. The analyses conducted by SA DEH include the River Murray Prescribed Watercourse and so therefore also include some areas outside Lower Murray NAP region.

Irrigation development for the River Murray Prescribed Watercourse from 1988 to 2003 is shown in Table 5. The SA DEH irrigated areas were clipped to the Lower Murray NAP region for comparison with irrigation development figures shown in Table 6. These tables show that the majority of irrigated horticulture occurring in the River Murray Prescribed Watercourse falls within the Lower Murray NAP region. They also show that for both regions, the growth in new irrigation areas is greater than rate of growth for the total irrigated area. Focusing only on the growth in total irrigated area can mask internal changes. For example, between 1997 and 1999 the overall irrigation area decreased but there was a net increase in areas under new irrigation. The main cause of the total loss was due to almost 7,000 ha present in 1997 being retired in 1999.

Table 5. South Australia irrigation development 1988 to 2003 – River Murray Prescribed Watercourse

	Area (Ha)					
Irrigation Development	**1988**	**1995**	**1997**	**1999**	**2001**	**2003**
Irrigation loss from previous year		2,918	2,042	6,851	4,772	2,929
Fromer irrigation returning		0	1,032	680	1,839	3,586
New irrigation developments		7,310	3,744	3,962	4,364	4,805
Rate of new development (ha/year)		1,044	1,872	1,981	2,182	2,402
Total area irrigated	**40,976**	**45,368**	**48,101**	**45,892**	**47,323**	**52,785**
Growth in total irrigated area (ha/year)		627	1,367	-1,105	716	2,731
Development west of lakes						9,675
New development outside 01 extent						1,145
Grand total area irrigated						**63,604**

Source: pers. comm. Matt Miles 2004

The data for the River Murray Prescribed Watercourse shows that approximately 40 percent of the irrigated land retired in the period 1988-1995 was returned to use in the period 1995-

1999 at a rate of 9.8 percent per year (pers. comm. Matt Miles 2004). During this same period (1995-1999) the total irrigated area only increased by 524 hectates while the Lower Murray region increased by 4,005 hectates.

Table 6. South Australia irrigation development 1988 to 2003 – Lower Murray NAP region

	Area (Ha)					
Irrigation Development	**1988**	**1995**	**1997**	**1999**	**2001**	**2003***
New irrigation developments		4,526	2,524	3,314	3,424	5,087
Rate of new development (ha/year)		647	1,262	1,657	1,712	2,544
Total area irrigated	**34,711**	**37,862**	**40,644**	**41,867**	**44,636**	**53,065**
Growth in total irrigated area (ha/year)		450	1,391	611	1,385	4,216

Source: South Australia Dept of Environment and Heritage

*Note: these values include the new development west of the Murray River Mouth lakes & outside 2001 extent

Focusing on the Lower Murray region, Table 6 shows that from 1988 to 2003 the irrigated areas increased at an average of 4.1 percent per year. This compares to an average growth rate of 4.0 percent per year from 1997 to 2003 in New South Wales and Victorian sectors. The period between 2001 and 2003 saw the biggest increase in South Australia with irrigated areas growing at 9.5 percent per year. The rate of new irrigation development per year has continued to increase since 1995 with the greatest growth between 2001 and 2003.

Irrigated horticulture in the Lower Murray region in 2003 based on the year planted is shown in Figure 6. Years recorded range from pre-1989 to 2003. As is clear in the area figures described previously, the majority of horticulture present in 2003 was planted in 1989 or earlier. This is true for the entire region and for all jurisdictions. The next biggest planting period was between 1995 and 1999, mainly concentrated in areas around Renmark in South Australia and between Wentworth and Robinvale in Victoria and New South Wales. These two regions had new horticulture planted for each of the time periods from 1989 to 2003. However, the amount planted in 2003 was very small in New South Wales and Victoria. South Australia appears to be more consistent in the amount and spatial location of new horticulture planted in the Renmark region from 1990 to 2003.

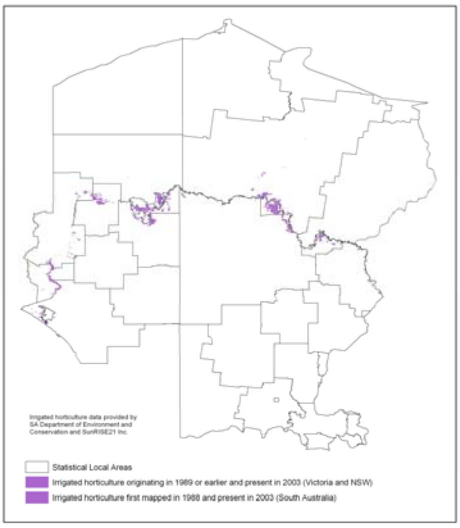
The area between Mannum and Tailem Bend in South Australia appears to have undergone the least change over the time period. Almost all of the irrigated horticulture present for this region in 2003 was first planted in 1989 or earlier.

Figure 7 combines the maps in Figure 6 to give a clearer indication of the age of irrigated horticulture in the Lower Murray region. This map shows that South Australia has some of the older crops with most of the region being first mapped in 1988. These tend to be large areas concentrated around the major towns. In New South Wales, the horticulture crops are also concentrated around the major towns although in more recent years irrigated horticulture has started to spread along the Murray River from Swan Hill to past Robinvale. Downstream of Robinvale a number of large irrigated horticulture areas were established in 2001.

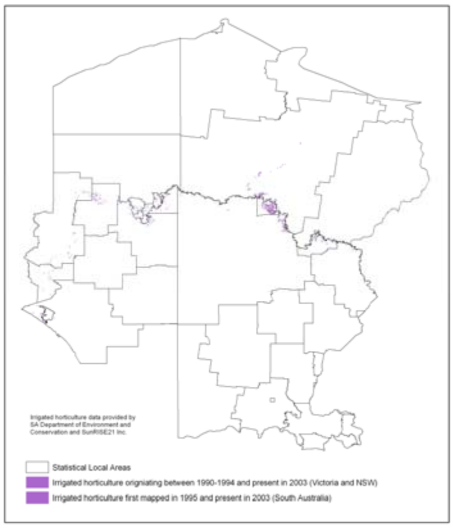
A more detailed map of the irrigated horticulture by year planted in the region surrounding Berri in South Australia is shown in Figure 8. The map shows that most of the irrigated horticulture was established before 1989 in large areas surrounding the major towns. After this time irrigated horticulture was either established in small areas adjacent to the pre 1989 plantings or in larger areas further away from the towns. In later years, central pivot irrigation is quite obvious in the mapping especially in 2003 as shown in the circular features in purple to the west of Barmera.

Figure 6. Lower Murray NAP region 2003 irrigated horticulture by year planted

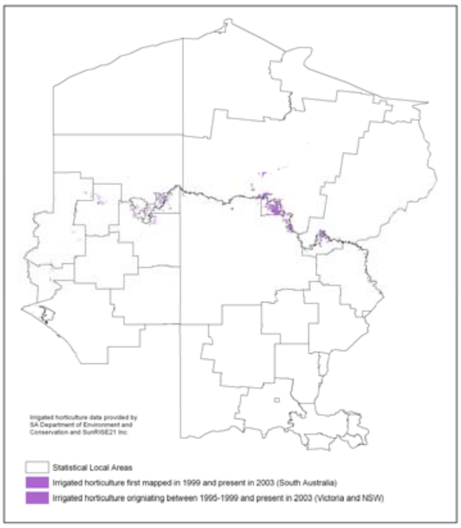
Pre 1989



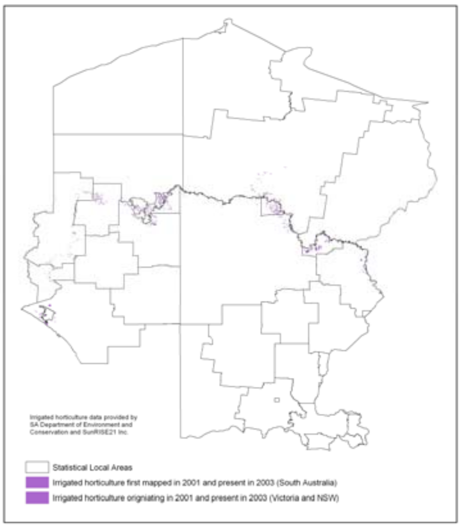
1990-1995



1995-1999



2001



2003

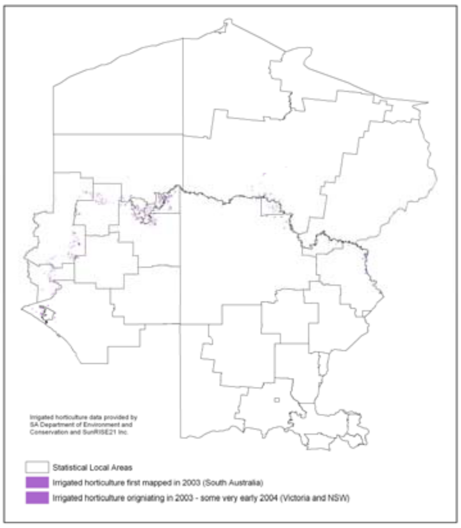


Figure 7. **Lower Murray NAP region 2003 irrigated horticulture by year planted**

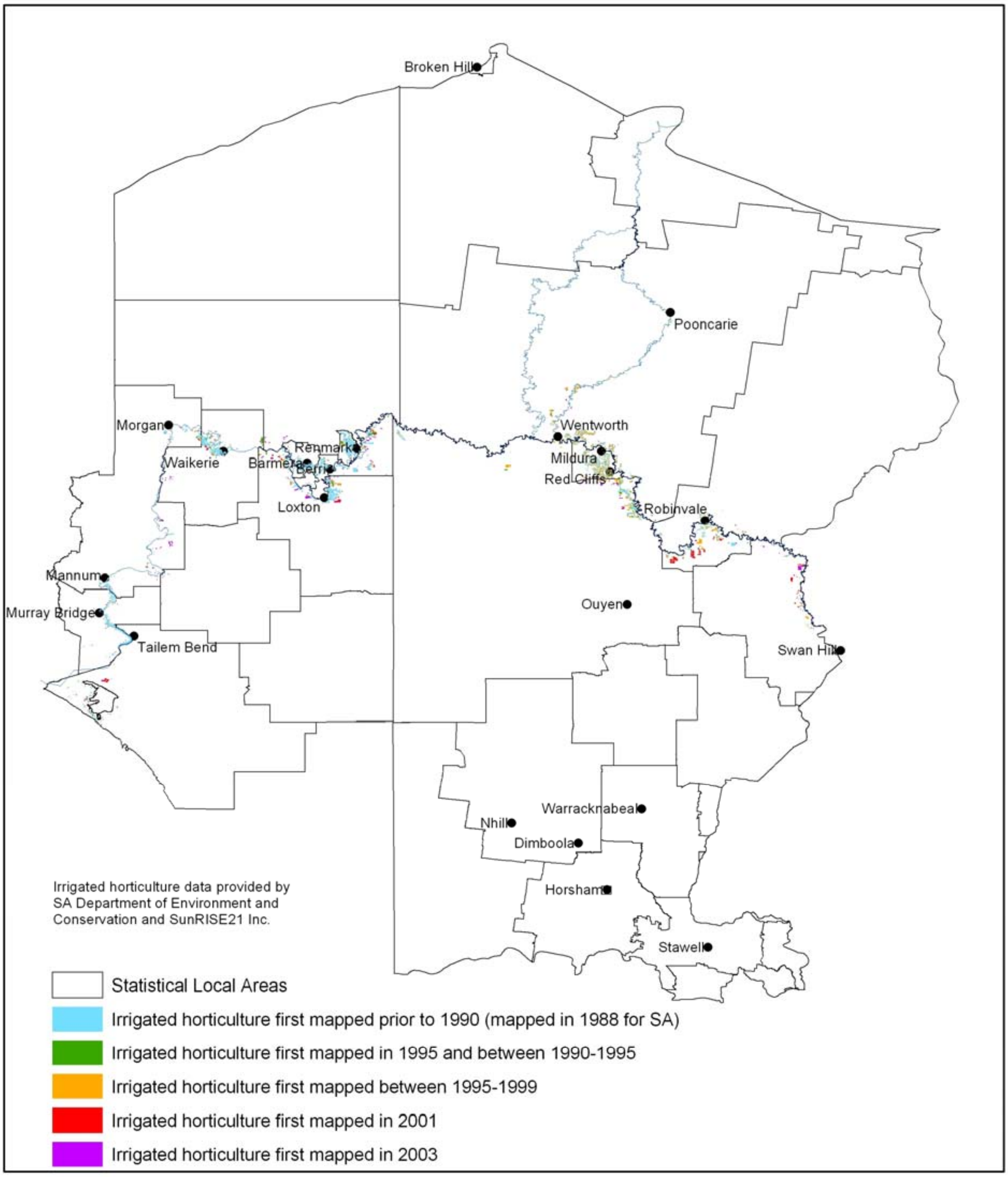


Figure 8. **2003 irrigated horticulture by year planted – Barmera, Berri & Renmark, SA**

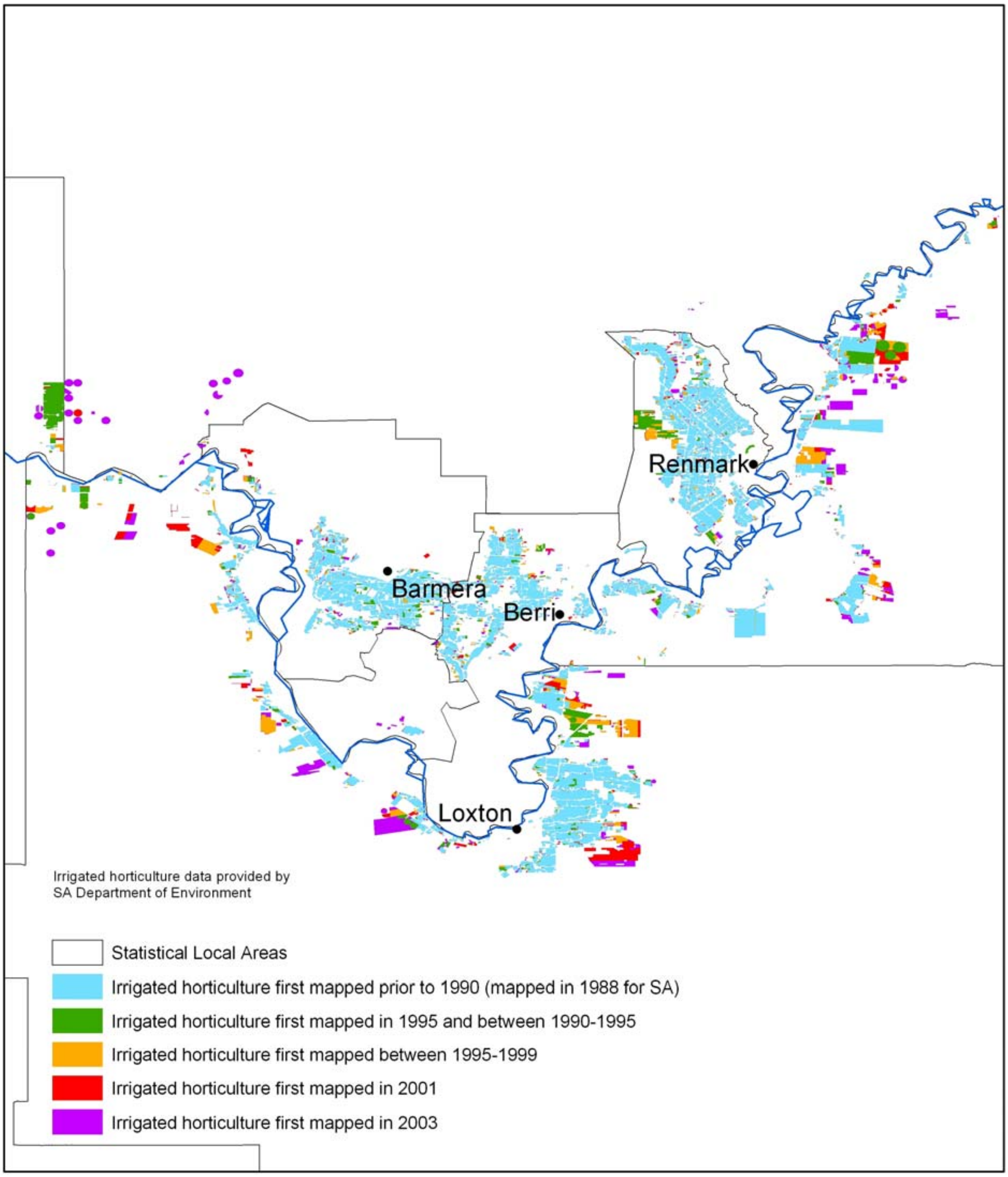


Figure 9. **2003 irrigated horticulture by year planted – Wentworth, Mildura & Red Cliffs, NSW**

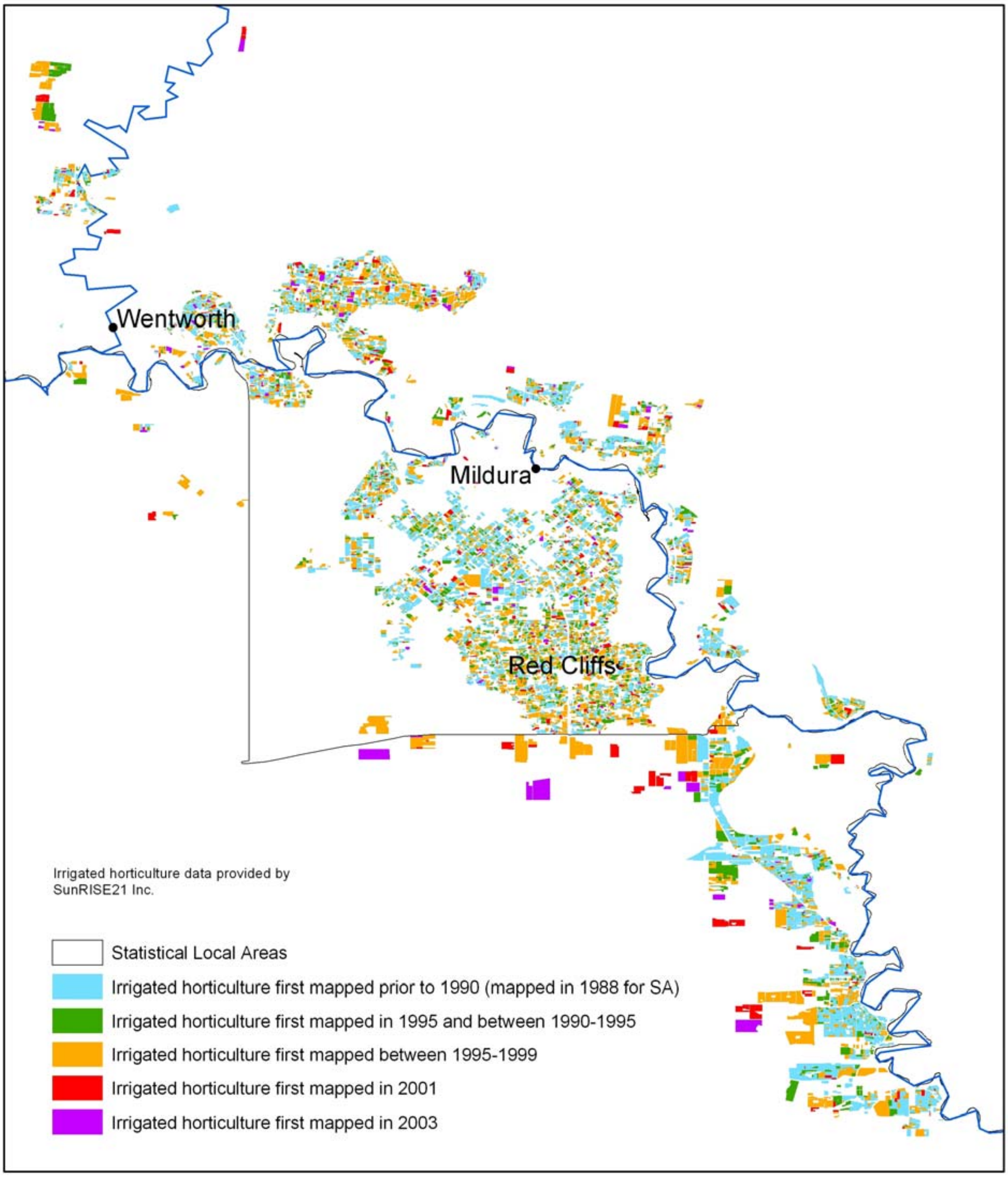


Figure 9 is a map of irrigated horticulture by year planted for the region surrounding Wentworth, Mildura and Red Cliff in New South Wales. The pattern for this area is very different to that in the previous South Australia map. In this region it appears as though irrigated horticulture has expanded each year surrounding the areas from the previous year. In the later years, some larger crops are apparent such as those to the south of Red Cliffs.

4.1.3 Land use transformations

The catchment scale irrigated horticulture data available to this project showed either the extent of horticulture at different years (South Australia) or the year current horticulture was first planted (NSW and Victoria). This made it difficult to determine the replacement and substitution land use taking place in the irrigated horticulture regions. The South Australian data provided in Table 5 shows that areas that have been set aside for irrigated horticulture are not necessarily used every year. They may be left fallow for one or more years and then replanted. This was a similar pattern in New South Wales and Victoria as seen in Table 4.

Table 7. Irrigated crop types Lower Murray NAP Region – NSW & Victoria

	Area (Ha)				Area (Ha)		
Type of horiticulture	**Victoria**	**NSW**	**Total**	**Type of horiticulture (cont)**	**Victoria**	**NSW**	**Total**
Almond	4,059	23	4,082	Oats/Rye	1	8	9
Apple	1	0	1	Okra	1	0	1
Apricot	22	14	36	Olive	705	5	710
Aquaculture	1	0	1	Orange	18	10	28
Asparagus	358	101	458	Orchard	1	0	1
Avocado	266	63	329	Other	1	2	3
Beans	4	7	11	Pasture	133	66	199
Blood Orange	8	12	19	Peach	0	1	1
Capsicum	0	5	5	Peacherine	1	0	1
Cereal	41	0	41	Persimmon	23	0	23
Citrus/Citrus Mix	28	116	144	Pistachio	157	0	157
Clover/Rye	1	0	1	Plum	21	8	29
Currant	0	75	75	Pomegranate	1	0	1
Eggplant	0	1	1	Potato	964	0	964
Field Crop	1,960	69	2,030	Proteace	1	0	1
Fig	1	1	3	Pummelo	1	0	1
Flower	13	2	15	Pumpkin	0	12	12
Fodder	0	138	138	Rockmelon	25	28	53
Fruit Tree/Fruit Tree Mix	47	11	58	Spinach	1	0	1
Grape	21,325	7,857	29,182	Stonefruit	168	57	225
Grapefruit (inc red & white)	68	117	184	Tangelo	32	39	71
Lemon	96	56	153	Tree/Tree Mix	2	0	2
Lime	1	7	8	Tropical	1	0	1
Lucerne	12	54	66	Turf	0	7	7
Mandarin	294	200	494	Vacant	0	28	28
Mango	1	0	1	Valencia	885	791	1,676
Melon	105	10	115	Vegetable	2,546	98	2,644
Native Shrub	1	1	2	Walnut	3	0	3
Navel	2,175	1,793	3,969	Watermelon	18	13	31
Nectarine	4	0	4	Wheat	0	6	6
Not Surveyed	0	1	1	Woodlot	167	6	173
Nursery	100	6	105	Zucchini	1	0	2
				Total	**36,869**	**11,925**	**48,795**

Source: SunRISE 21 Inc

Land uses surrounding the irrigated horticulture regions along the Murray River mainly consist of grazing natural vegetation, grazing modified pastures, dryland cropping and residential areas (Figure 2). It is therefore likely that new irrigated horticulture is established on areas under these uses. It is also likely that these areas under irrigated horticulture are converted to grazing or dryland agriculture land uses, if relinquished. This pattern in borne out by studies carried out in South Australia that show the expansion of irrigated lands into areas not previously irrigated are comparable to the reductions in non-irrigated croplands (pers. comm. Matt Miles 2004).

Within irrigated areas growth of the wine industry has caused many farmers to convert from growing citrus or table grapes to wine grapes (pers. comm. Matt Miles 2004). This same pattern appears to occur in New South Wales and Victoria. Between 1997 and 2003 the area of citrus production in the Lower Murray-Darling region decreased by 6.2 percent (SunRISE 21 2004: 33). For the same period, the area of dried and other grapes decreased by 22.7 percent, table grapes increased by 41.3 percent and wine grapes increased by 50.3 percent (SunRISE 21 2004: 30).

The breakdown of horticulture present in the Lower Murray for New South Wales and Victoria in 2003 based on the SunRISE 21 data is shown in Table 7. Over the region as a whole, grapes (all uses) account for almost 60 percent of the total area while citrus varieties only make up 13.8 percent. Other major crops irrigated in the region are nuts at 8.7 percent of the area, vegetables (including asparagus, zucchini, etc) at 8.4 percent, field crops at 4.2 percent and other fruits at 3.4 percent.

An indication of the change in irrigated grapes and citrus in the New South Wales and Victorian part of the Lower Murray region is provided in Table 8 . This shows the year that grapes and citrus present in 2003 were planted. On average for the region, the amount of new grapes planted each year has been increasing. This trend is more pronounced in Victoria which accounted for 74 percent of grapes present in 2003. Since 1995, the area of new grapes planted in Victoria has remained over 1,000 ha with 2001 and 2002 being the biggest years. Overall for New South Wales, the amount of new grapes planted each year since 1995 has been decreasing. For the same time period, the amount of new citrus being planted each year has remained steady at an average of about 150 hectares across both jurisdictions.

Table 8. Irrigated grapes & citrus Lower Murray NAP Region – NSW & Victoria

	2003 irrigated area by year planted								
Crop type	**< 1989**	**1989**	**1990-1994**	**1995-1999**	**2000**	**2001**	**2002**	**2003/4**	**Total present in 2003**
New grapes planted - NSW	1,519	79	823	3,614	464	611	537	211	7,857
New grapes planted - Vic	6,172	238	2,289	7,637	1,216	1,182	2,225	1,477	22,437
New grapes planted total	**7,691**	**318**	**3,113**	**11,251**	**1,679**	**1,793**	**2,762**	**1,688**	**30,294**
Rate of new grape development (ha/yr)		318	623	2,250	1,679	1,793	2,762	1,688	-
New citrus planted - NSW	1,890	77	459	338	84	94	97	103	3,142
New citrus planted - Vic	2,386	146	435	413	56	71	62	35	3,605
New citrus planted total	**4,277**	**223**	**894**	**751**	**140**	**165**	**158**	**138**	**6,747**
Rate of new citrus development (ha/yr)		223	179	150	140	165	158	138	-

Source: SunRISE 21 Inc

4.2 Irrigated horticulture at regional scale

This section of the report describes the reporting of change in irrigated horticulture in the Lower Murray region using regional scale land use mapping based largely on statistics from the ABS' Agricultural census and surveys (AgStats) coupled with satellite image analysis. The change evident from these data and change evident at catchment scale is compared.

Irrigated horticulture data have been extracted from the 1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin time series previously discussed in section 2.2.

4.2.1 Simple areal change

The changes evident in the total area under irrigated horticulture in regional scale mapping are shown in Table 9. In common with the catchment scale irrigated horticulture data, the regional scale data shows that irrigated horticulture has increased over time. The major period of growth was between 1996 and 1998 when the area of irrigated horticulture increased by over a third. The area of fruit and nuts fluctuated from 1993 to 1998 but remained around 25,000 hectares. The major growth trends were in vine fruits and vegetables and herbs which contributed to the overall increase in irrigated horticulture.

Table 9. Change in regional scale irrigated horticulture for the Lower Murray

	Area (Ha)			
Crop Type	**1993**	**1996**	**1998**	**2000**
Fruit and nuts	23,693	20,817	27,137	25,271
Vine fruits	29,490	34,050	47,137	53,889
Vegetables and herbs	1,470	4,880	7,728	10,264
Total	**54,653**	**59,747**	**82,002**	**89,424**

Table 10. Regional scale vs. catchment scale irrigated areas Lower Murray NAP region

State	Regional scale 2000 MDB land use total irrigated area (ha)	Catchment scale 2003 total irrigated horticulture area (ha)
New South Wales	7,490	11,926
Victoria	30,070	36,869
South Australia	51,864	53,065
Total	**89,424**	**101,860**

Catchment scale irrigated horticulture sources: SunRISE Inc and SA Dept. Environment and Heritage

The SPREAD-based regional scale mapping produced similar values to the catchment scale mapping. Differences in the total area under irrigated horticulture recorded by the SPREAD-based regional scale and catchment scale land use mapping are presented in Table 10. Total area recorded is similar with the main differences being the larger area recorded under irrigation by catchment scale mapping in New South Wales and Victoria. Comparing the year 2000 regional scale map in Figure 10 and the 2003 catchment scale map in Figure 7 it appears that the catchment scale mapping shows a greater concentration of irrigated horticulture around the Red Cliffs and Mildura region. The lesser area of irrigated horticulture in this area could explain the lower regional scale figures for New South Wales and Victoria.

The location of irrigated land uses in the Lower Murray region identified using the SPREAD-based regional scale land use mapping approach is shown in Figure 10 for 1993, 1996, 1998 and 2000. Each map shows the total distribution of irrigated land uses for that year. All years show a large concentration of irrigated land uses around the Renmark and Barmera regions of South Australia.

In contrast, there is limited capacity to show the spatial distribution of irrigated land uses using the raw AgStats data as they are based on Statistical Local Areas (SLAs) for each commodity. Figure 11 shows the change in spatial distribution of irrigated grapevines over time by SLA. These maps use the raw AgStats data to show the area of grapevines for particular years. The time series shows that over the years the Victorian and New South Wales SLAs surrounding the Murray River have increased in the area of irrigated grapevines while most other SLAs have remained fairly constant. The SLA with the greatest area of grapevines is the small SLA surrounding Mildura (Mildura (RC) – Pt A) and given the small size of this SLA it will also have the greatest concentration.

Figure 10. Regional Scale MDB irrigated horticulture 1993 to 2000

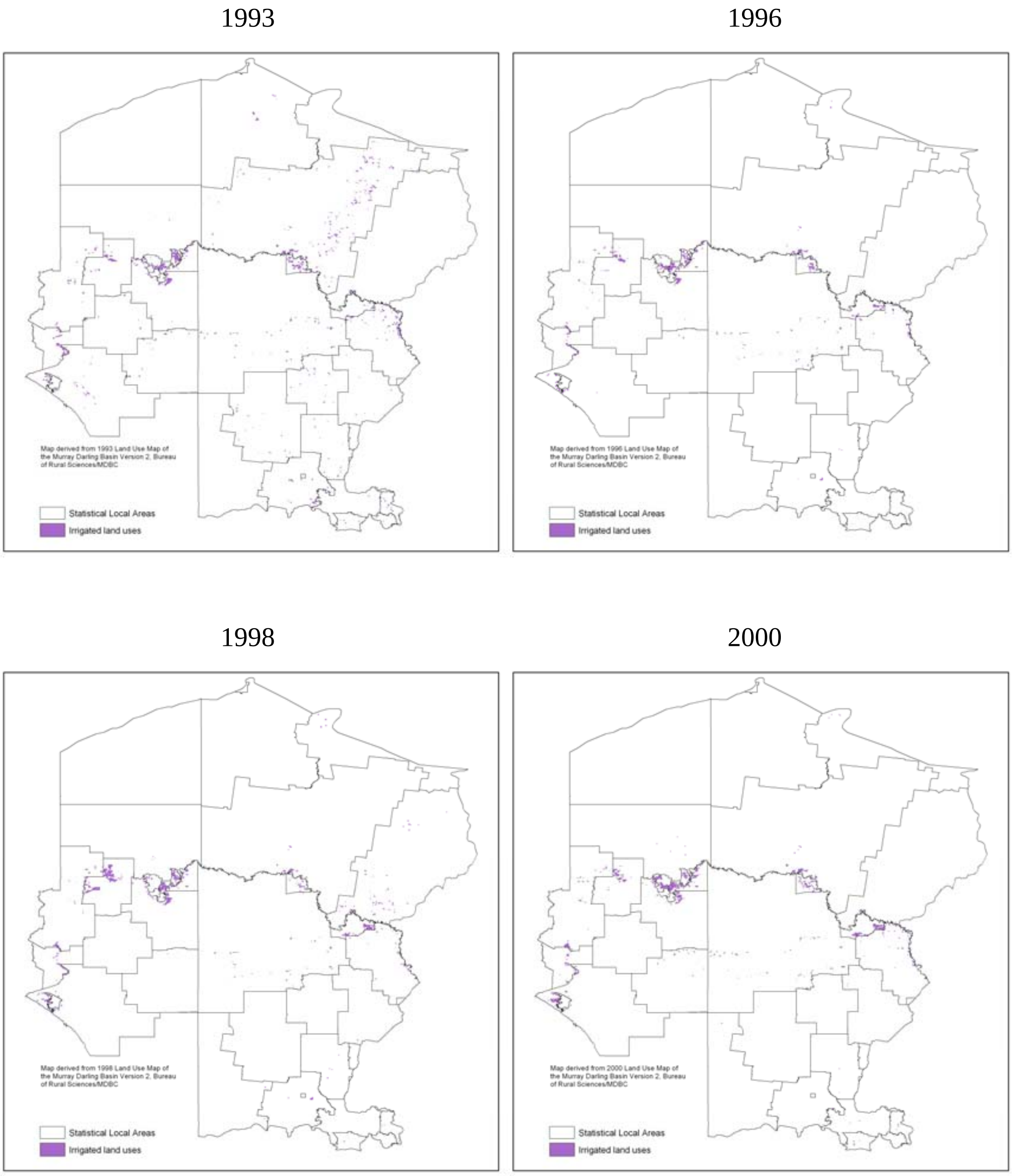


Figure 11. Irrigated grapevines by SLA in the Lower Murray NAP region – AgStats data

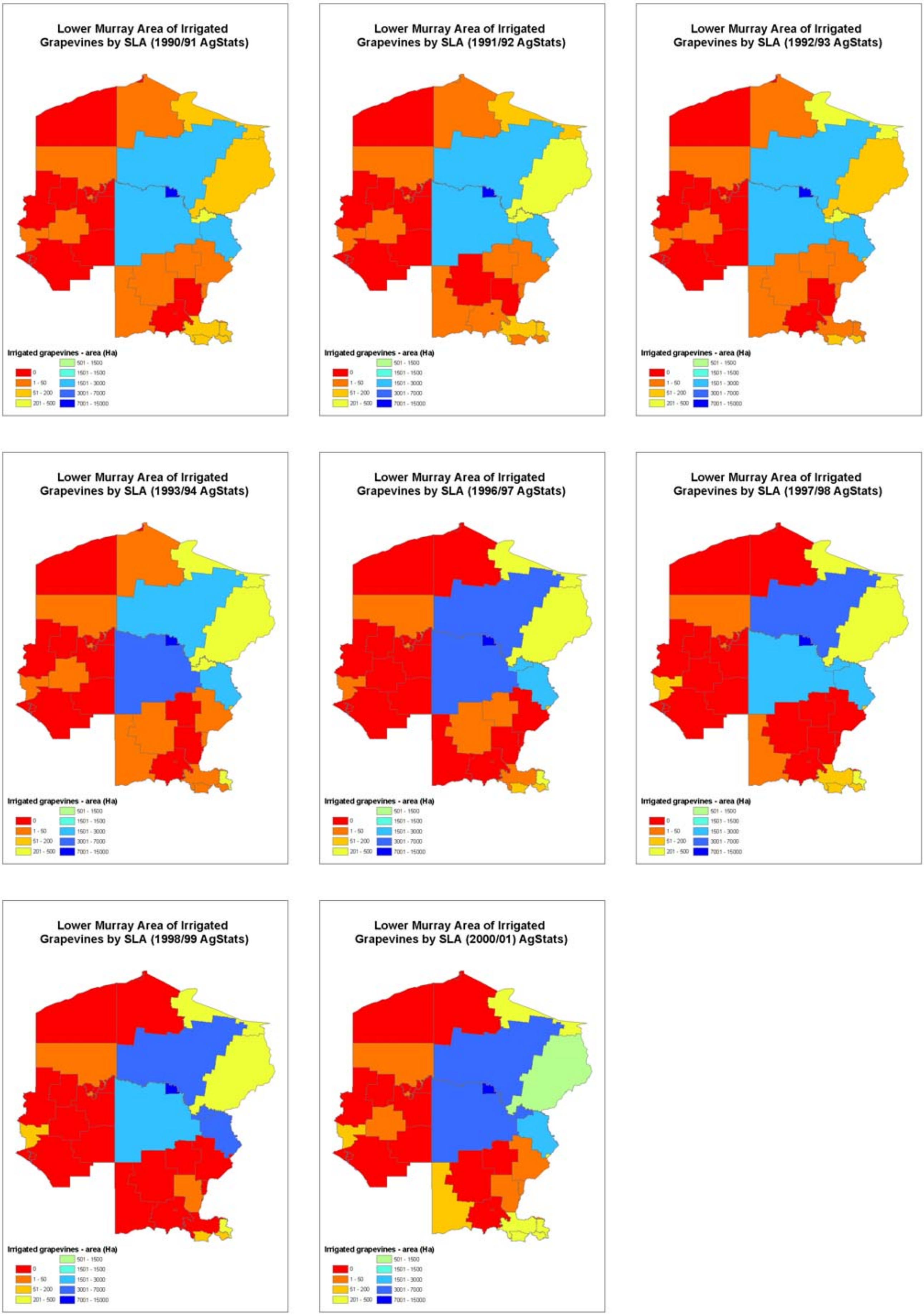


Figure 12 and Figure 13 indicate the spatial overlap of irrigated horticulture for the catchment scale and regional scale mapping. This shows the co-located area of irrigated horticulture mapped at each scales. The figures show that while the total area of irrigated horticulture mapped at each scale is similar, there is not a high degree of spatial overlap, especially for irrigated seasonal horticulture.

Figure 12. Spatial overlap of ALUM class 4.4 Irrigated perennial horticulture

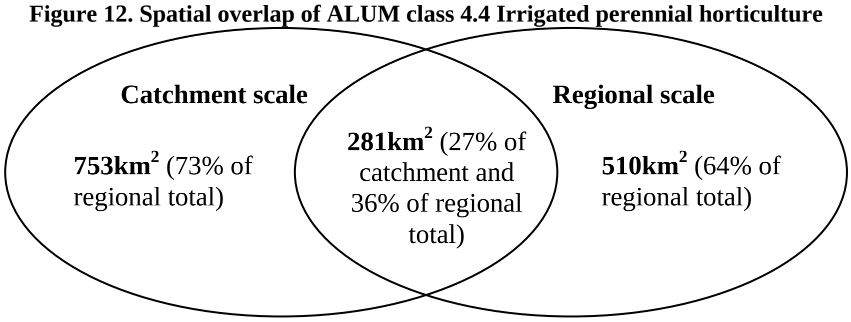
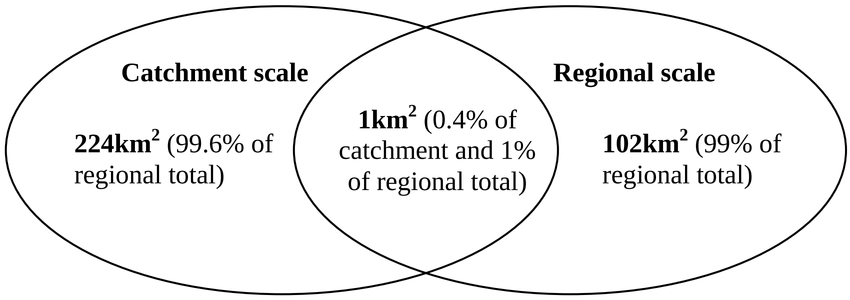
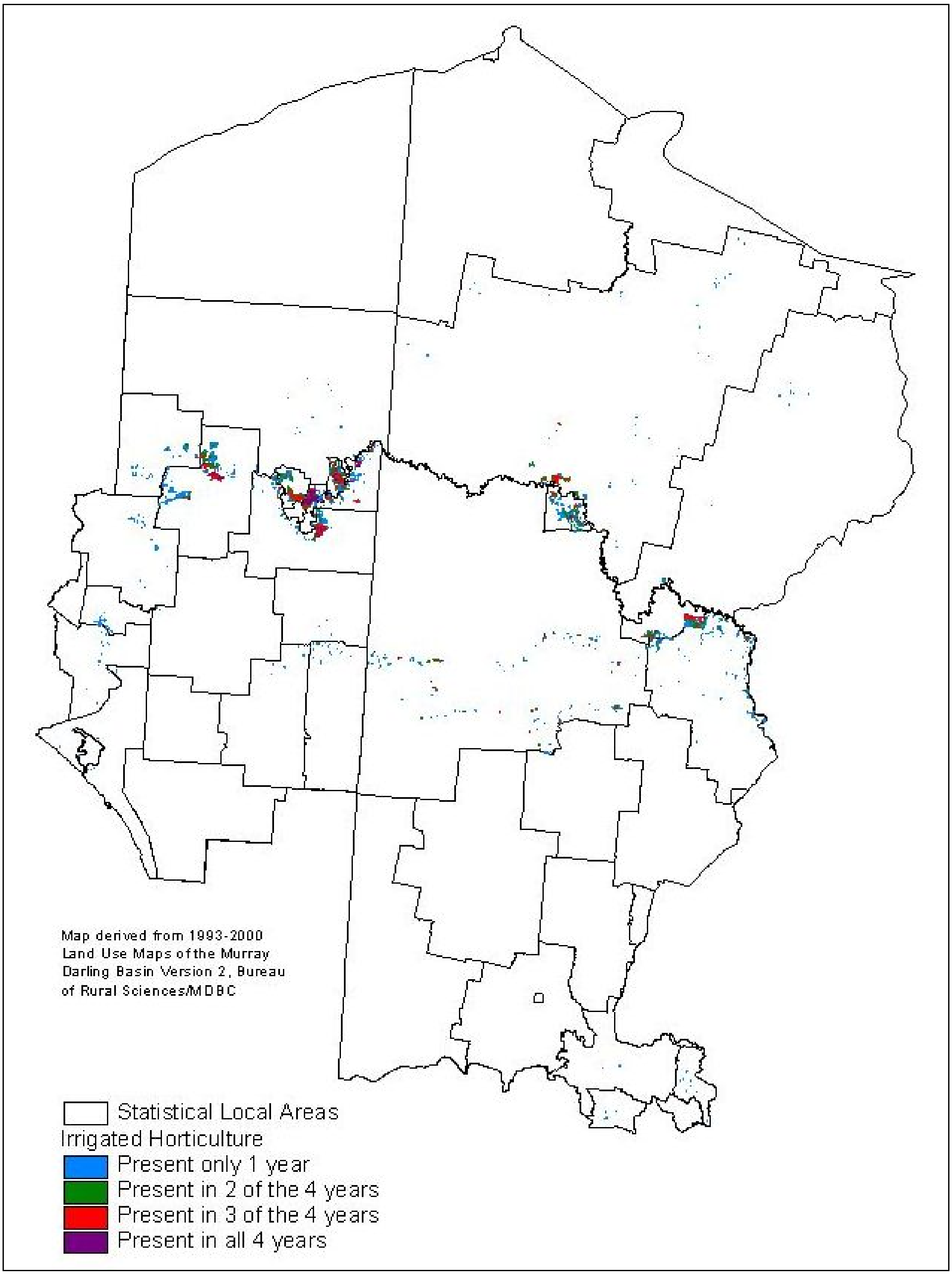


Figure 13. Spatial overlap of ALUM class 4.5 Irrigated seasonal horticulture



Spatial change has also been investigated by determining how many years a particular area was mapped as irrigated horticulture at regional scale. Figure 14 shows that irrigated horticulture was present in most years in the areas surrounding the towns of Waikerie, Barmera/Berri, Loxton and Renmark in South Australia and Wentworth in New South Wales. Interestingly, for most of the irrigated horticulture regions in New South Wales and Victoria, horticulture was only mapped on average for one or two years. Also, the further away from the river, the less likely that irrigated horticulture will be mapped for more than one year.

Figure 14. Number of years irrigated horticulture present in regional scale mapping



4.2.2 Land use transformations

Land use transformations for irrigated land use in the Lower Murray region have been investigated using regional scale land use data derived by the SPREAD-based mapping procedure. It is emphasised that this mapping is based on probabilities of land use, with significant uncertainty as to the spatial precision of attribution at any given location. Because detection of transformations is very sensitive to spatial precision and attribute accuracy, this considerably limits confidence in observed patterns. The following maps should therefore be regarded as illustrative of a process, rather than indicative of particular patterns of change. The remainder of this section assumes that the regional scale mapping of land uses is correct in order highlight how land use transformations can be used to measure land use change.

Figure 15 and Figure 16 show the land uses that irrigated horticulture has changed into and changed from during the period 1993 to 2000 for the Barmera region in South Australia. The first map shows that the majority of irrigated horticulture present in 1993 remained as irrigated horticulture in 2000, especially around the towns of Barmera and Berri. The area around Renmark is characterised by a substantial amount of change with shifts to dryland uses such as grazing and cereals. The area around Loxton also exhibits a significant transformation from irrigated to dryland uses.

The second map (Figure 16) shows for areas of irrigated horticulture present in 2000 the land use that existed in 1993. Again, the static area around Barmera and is prominent. The map also shows that grazing areas and land used for cereal cropping near Waikerie, Barmera, Loxton and Renmark had been converted to irrigated horticulture by 2000. Other major 1993 land use transformations to irrigated horticulture were intensive uses and irrigated modified pastures.

Figure 17 and Figure 18 show irrigated horticulture transformations between 1993 and 200 for the region surrounding the Red Cliffs area in Victoria. The first map shows that there was limited irrigated horticulture in 1993 and that a very small proportion of this land use was still present in 2000. The majority of areas under irrigated horticulture were transformed to grazing land uses by 2000.

The second map shows an increase in area under irrigated horticulture in 2000 compared to 1993. These increases occurred around Wentworth and to the south of Robinvale. Near Wentworth and Mildura, the majority of irrigated horticulture was transformed from irrigated modified pastures and irrigated cereals. South of Robinvale most of the new irrigated horticulture in 2000 had been under dryland agriculture in 1993, uses such as grazing, cereals and legumes.

Figure 15. 1993 irrigated horticulture in 2000, Barmera region, South Australia

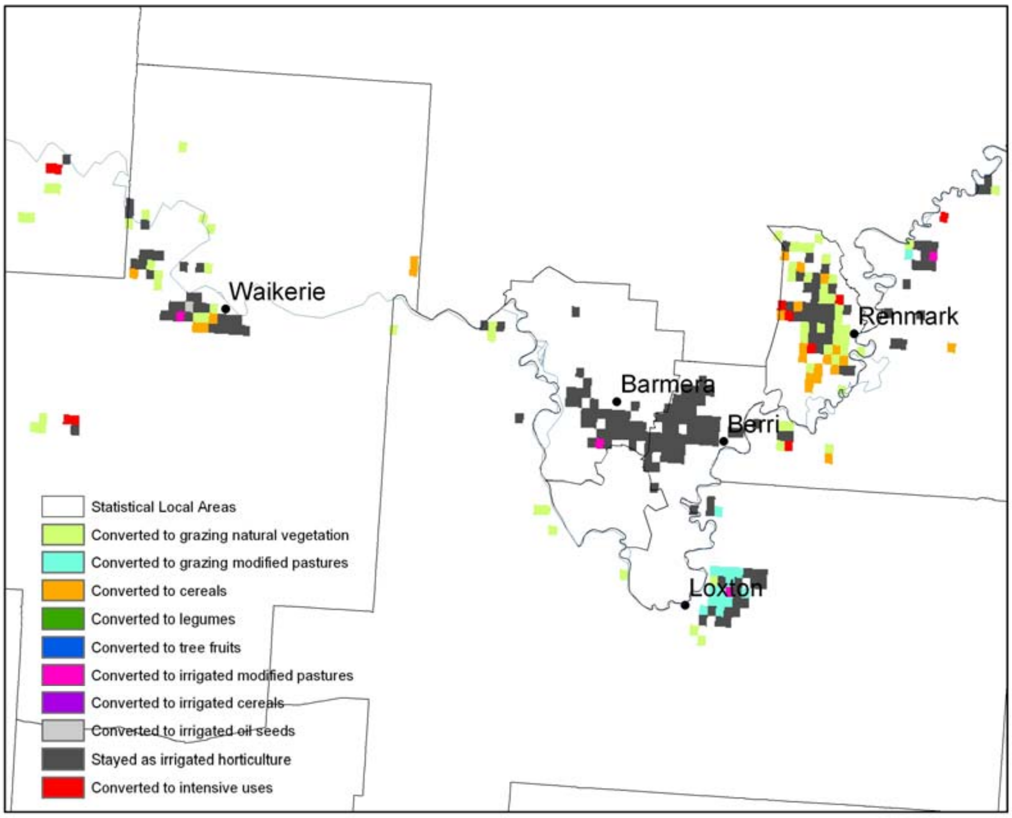


Figure 16. 2000 irrigated horticulture in 1993, Barmera region South Australia

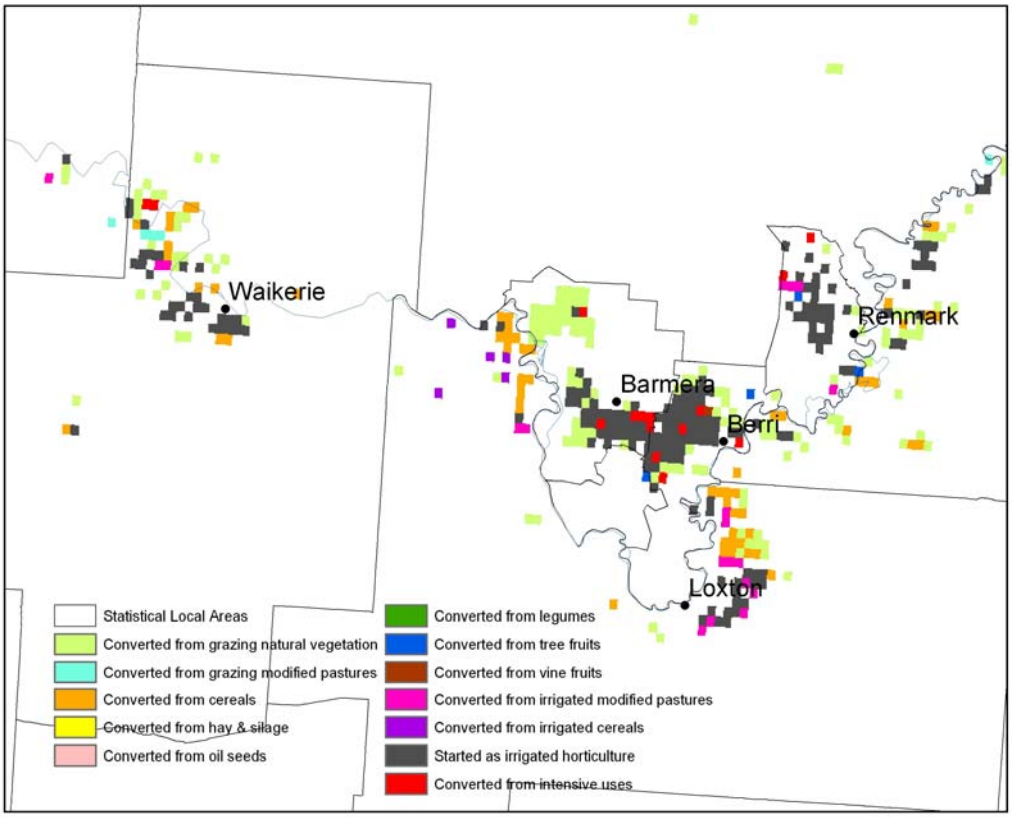


Figure 17. 1993 irrigated horticulture in 2000, Red Cliffs region, Victoria

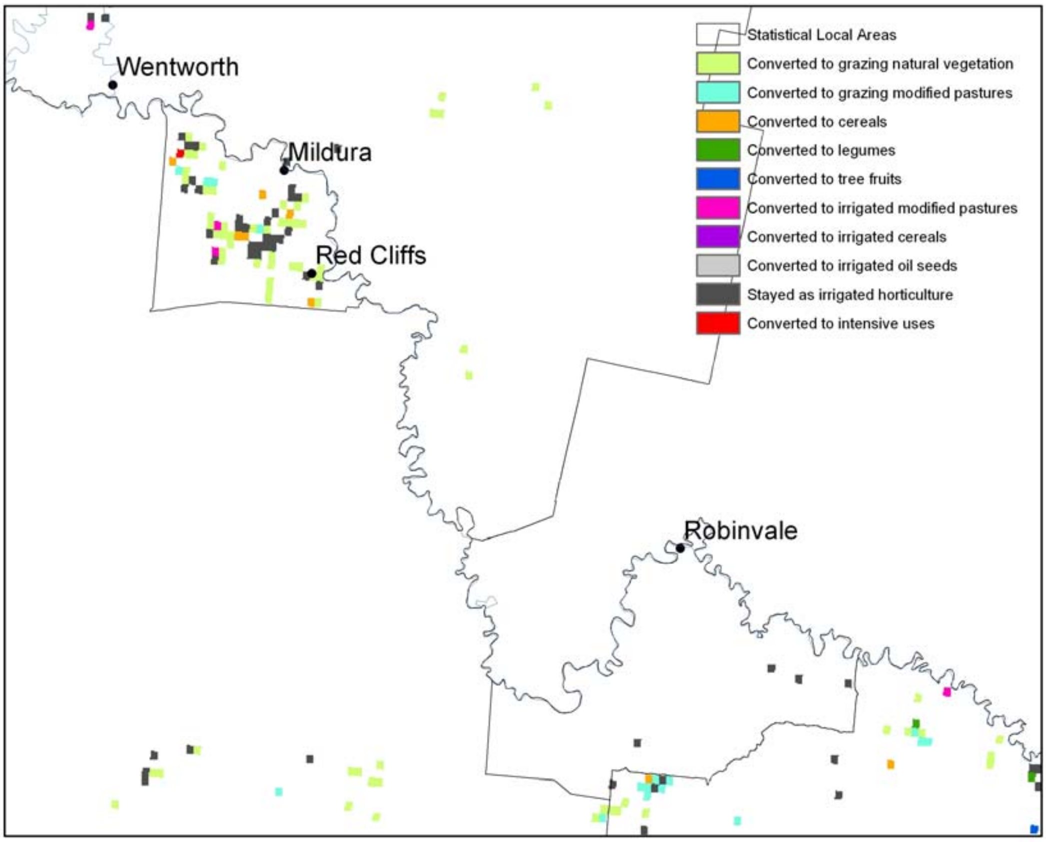
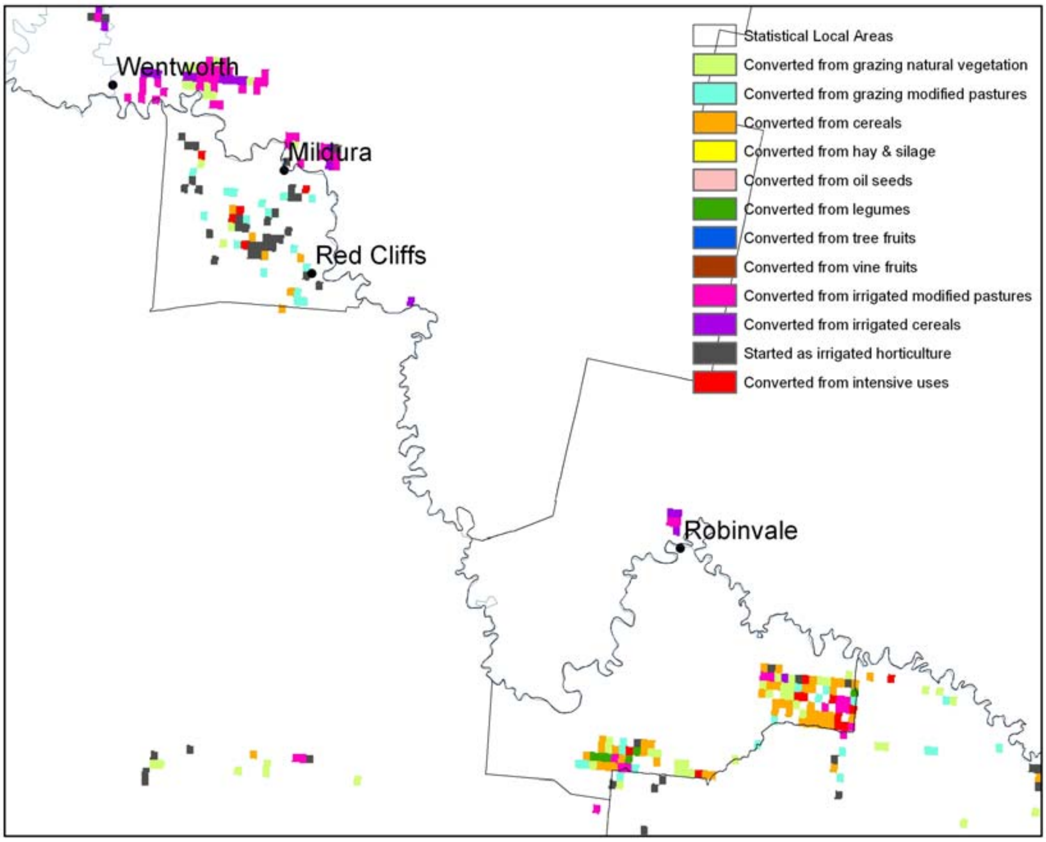


Figure 18. 2000 irrigated horticulture in 1993, Red Cliffs region, Victoria



5. Dryland Cropping

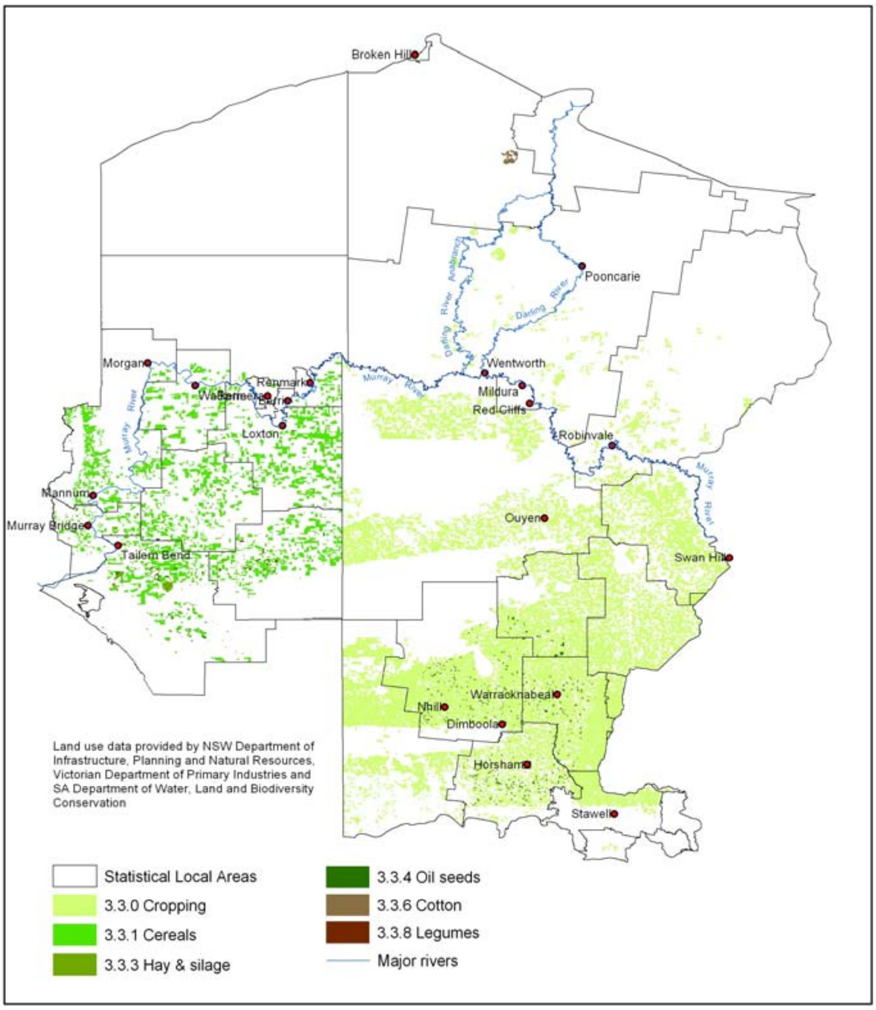
Dryland cereal cropping is a dominant land use in the southern part of the Lower Murray region, south of the River Murray where rainfall is sufficiently reliable to support regular cereal production. The Lower Murray region falls within a zone of transition in south-eastern Australia between the winter broadacre cropping belt and the semi-arid rangelands (generally less than 250mm annual rainfall). This means that the areal extent of sowing in this region in any season is highly dependent on seasonal conditions. Cropping is also in many instances undertaken as part of a rotational regime of sheep grazing on improved pasture.

The extent to which changes in the spatial distribution and areal extent of dryland cropping in the Lower Murray region could be ascertained was investigated as a part of this study using land use mapping at both catchment and regional scale.

5.1 Dryland cropping at catchment scale

The spatial distribution of dryland cropping in the Lower Murray region in 2002/2003 developed using the catchment scale land use data collected by the State agency partners is shown in Figure 19.

Figure 19. Dryland cropping in the Lower Murray NAP region 2002/2003



A total of 3,069,262 hectares of the region was identified as under dryland cropping. Of this total, a majority of 2,392,866 hectares (78 percent) is located in Victoria, 560,452 hectares (18 percent) is in South Australia, and a relatively minor 115,944 hectares (4 percent) in New South Wales.

The apparent discontinuity in the distribution of cropped land between South Australia and Victoria in Figure 19 largely relates to the level to which cropping was attributed to the ALUM classification by project partners. Most dryland cropping in New South Wales and Victoria is mapped to the secondary level of the ALUM classification (the minimum expected level of attribution) except for oil seed crops to the south-west of Swan Hill and cotton crops at Menindee Lakes, south-east of Broken Hill. In contrast, cropping in South Australia is attributed to the tertiary level, distinguishing mainly cereals and some areas of hay and silage.

Some additional variability arises also from the seasonal conditions at the time of mapping (2002 in South Australia and New South Wales and 2003 in Victoria) and technical difficulties in interpreting cropping from improved pasture at key stages in rotational cropping/pasture systems. These issues are an inevitable feature of the catchment scale land use mapping process which is dependent on fine-scaled data sources and technical capacity particular to State and regional jurisdictions.

5.1.1 Reporting of change

The capacity to identify and report change in dryland cropping across the Lower Murray region at catchment scale using existing State and regional sources of information was investigated. Each jurisdiction had difficulty in obtaining consistent and consecutive datasets appropriate for catchment scale mapping for the region and, as a consequence, an integrated spatial assessment of change in land under cropping was not practicable. This section discusses the nature of the information available at the state and regional level, and the issues arising in attempting to draw information at this level together.

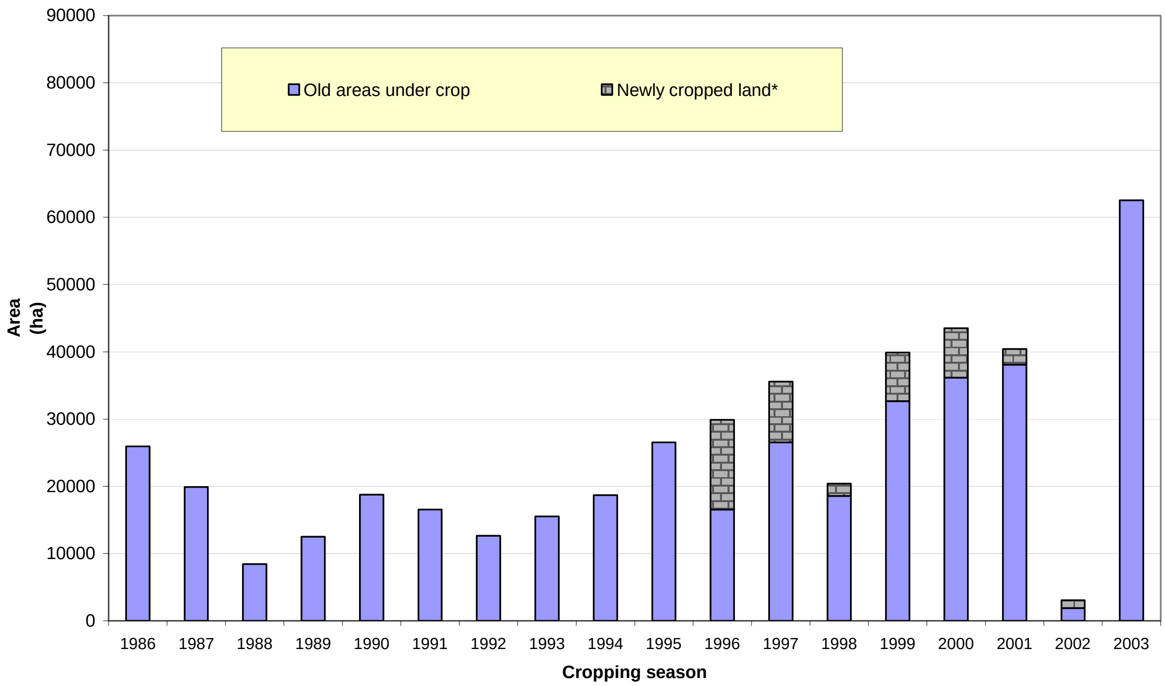
Overall, the available data suggest an increase in the area of land cropped from 1990 to 2001 in the region, with the area under cropping in any particular year changing in response to seasonal conditions. The largest fluctuations are evident in areas where cropping is most marginal (most notably a 2002 drought-induced crop failure in New South Wales).

Over the last decade the marginal return for sheep grazing has been deteriorating. Conversely marginal returns for cropping have become generally more favourable in relatively marginal cropping areas such as the Lower Murray region of New South Wales. As a result there has been strong interest in cropping from graziers. Initially cropping occurred in lakebeds, without the need for clearing. In more recent years large areas of the mallee country have been cleared and developed for cropping enterprises. Landholders have also invested in machinery, committing to cropping for a number of years and moving from rotational cropping with periods of long fallow to short rotations with back to back cropping or continuous cropping (DIPNR 2005; McIntosh; pers. comm).

Data on the extent of cropping in the Lower Murray region in New South Wales is collected by the Resource Assessment and Monitoring System (RAMS) associated with Western Lands compliance monitoring. It has been in operation since 1986 and uses (October) satellite imagery and vehicle transects to annually map the spatial extent of seasonal cropping. A major limitation of the methodology is that crops that have been grazed out, failed or re-cultivated by October are likely not to be identified. In addition, licensees on Crown leasehold land require a special licence to commence cropping in New South Wales. Information on cropping applications and approvals is maintained by Western Lands Commission and DIPNR. However, approvals do not show if the land has been cropped.

RAMS project data for cropped areas in the NSW Lower Murray region between 1986 and 2003 is presented in Figure 20. The long term trend shows a steady increase over time with large plantings over the last seven to eight years. Total areas vary according to seasonal conditions, particularly the suitable soil moisture at the time of sowing. Figure 20 also shows the component that was land being cropped for the first time (from 1995 to 2004 only). Data from 1996 shows relatively large amounts of new land being brought into cropping, approximately 42,000 ha. Even in 2002 when only 1,877 ha were cropped, 64 percent was virgin cropping land.

Figure 20. Area under crop in the Lower Murray Region NSW (ha)



Source: Rams project (DIPNR Dubbo office)   *land cropped for the first time that season (post 1995 only)

An appreciation of trends in growth in cropping and its seasonable variability in more established cereal growing parts of the region is provided by ABS' AgStats in the South Australian part of the Lower Murray region. The only individual crop type data available as a full time-series from 1990-1991 to 2000-2001 is wheat (see Figure 21), where there was an overall increase of 75 percent in area planted over that period from 200,000 to 350,000 hectares.

The relationship between fluctuations in yield and seasonal conditions is illustrated in Figure 22, showing the yield (tonnes/hectare) of combined wheat and barley for 1965-2000 for the SLA of Southern Mallee compared to mid-year rainfall. There is a general increase in yield from 1965 to 2000, although there are years where yields decrease during drought periods. Comparing this data to Figure 21, the increase in the quantity the wheat produced appears linked to the increase in the area under wheat.

Figure 21. Area of wheat crops in Lower Murray Region SA (ha) – AgStats data

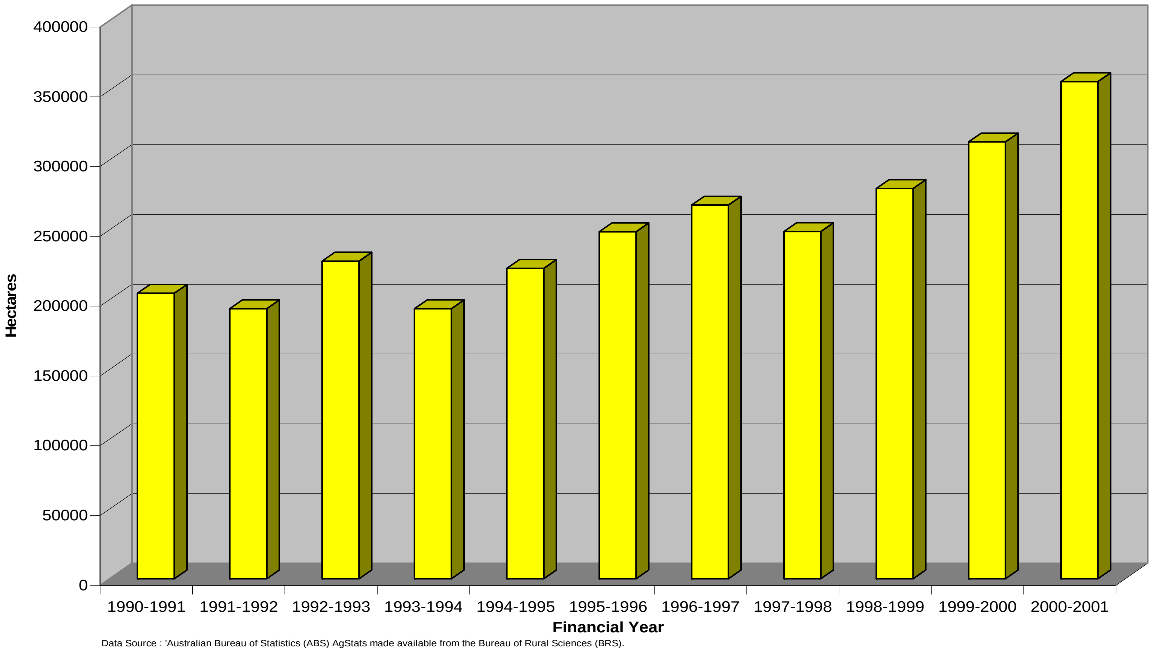
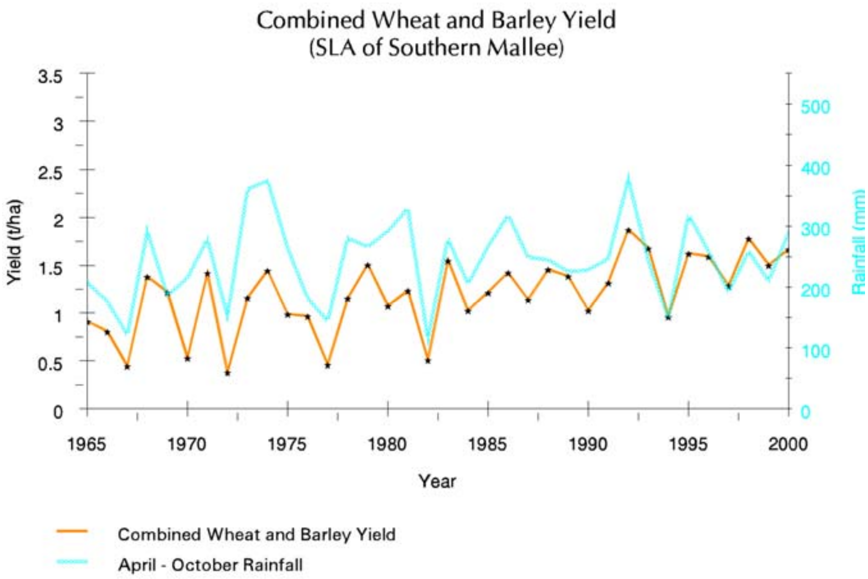


Figure 22. Mean combined Wheat and Barley yield for the Loxton Waikerie – East SLA (1998 SLA boundary) (1996 SLA boundaries of Browns Well and Loxton), calculated from production data provided by the ABS agricultural census.

Source: A selected set developed by DWLBC Land Condition Monitoring. McCord and Payne (2005) "Report on the Condition of Agricultural Land in South Australia".



5.2 Dryland cropping at regional scale

The remainder of this section describes aspects of change in dryland cropping at regional scale across the Lower Murray region. The discussion draws on the SPREAD-based time series of available regional scale land use mapping (1993, 1996, 1998 and 2000) from the recently completed BRS study of land use in the Murray-Darling Basin (BRS 2004). As described previously, this mapping is based on ABS AgStats data coupled to AVHRR satellite imagery and ground control data to determine the most probable land use.

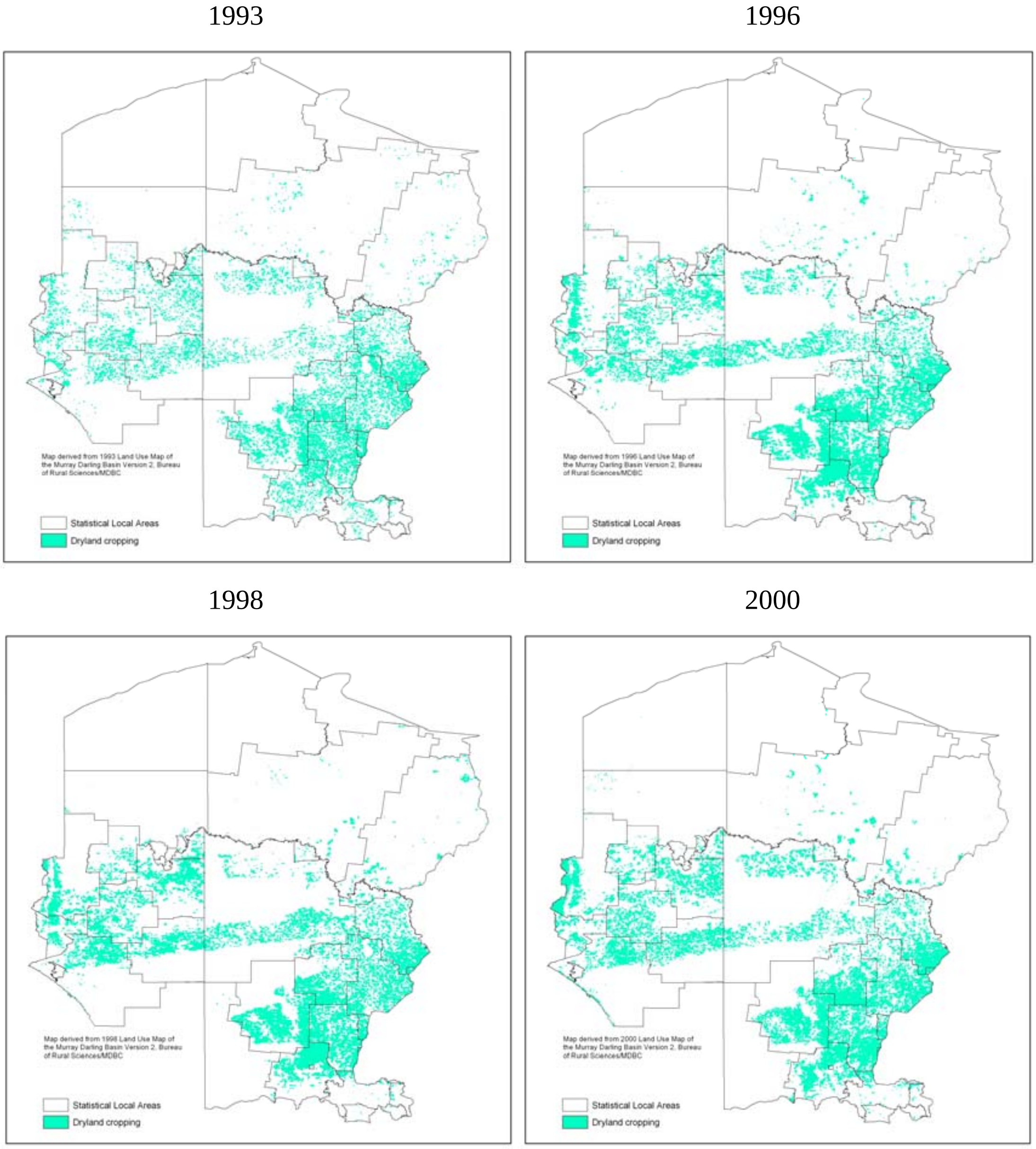
The extent of available ABS census and survey data on cropping land uses that can support mapping at the SLA level is shown in Table 11. While data is available for 1997-1998 and 1998-1999, most commodities have zero values (except wheat and rice) and not all commodities are available for 1999-2000. This is due to sample surveys being conducted in these years.

Table 11. Availability and Frequency of AgStats Dryland Cropping Data in the Lower Murray Region

		FINANCIAL YEAR										
CROP TYPE	ALUM v5	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
All cereals for other purposes	3.3.0	-	✓	✓	✓	-	-	-	-	-	-	✓
Barley For Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Cereal rye for grain	3.3.1	✓	✓	✓	✓	-	-	-	-	-	-	-
Grain Sorghum	3.3.1	-	✓	-	-	-	-	-	-	-	-	-
Maize for Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Millet & Panicum for Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oats For Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Rice for Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Triticale For Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Wheat For Grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cereals cut for hay	3.3.3	-	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Crops (excl Cereals) for hay	3.3.3	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Crops feed off or silage	3.3.3	✓	✓	✓	✓	-	-	-	-	-	-	-
Lucerne (pure)	3.3.3	✓	✓	✓	✓	-	✓	✓	-	-	-	✓
Canola	3.3.4	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Mustard Seed	3.3.4	-	-	✓	-	-	-	-	-	-	-	-
Linseed - Linola	3.3.4	-	-	✓	-	-	-	-	-	-	-	-
Peanuts	3.3.4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Popcorn	3.3.4	✓	✓	✓	✓	-	-	✓	✓	✓	✓	✓
Safflower	3.3.4	-	✓	✓	✓	✓	✓	✓	-	-	-	✓
Soybeans	3.3.4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sunflower	3.3.4	-	-	✓	✓	-	✓	✓	-	-	-	-
Tobacco	3.3.7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chick peas	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Field peas for grain	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Lentils	3.3.8	✓	✓	✓	✓	-	-	-	-	-	-	-
Lupins for grain	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Vetches For Seed	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓

The extent of the Lower Murray region under dryland cropping estimated using the SPREAD-based regional scale mapping procedure for the years 1993, 1996, 1998 and 2000 is presented in Figure 23.

Figure 23. Regional Scale MDB dryland cropping land uses 1993 to 2000



A comparison of the area under dryland cropping recorded at regional scale in 2000 and at catchment scale in 2002/2003 is presented in Table 12. Overall, the catchment scale mapping identifies a larger total area under dryland cropping.

Table 12. Regional scale vs. catchment scale dyland cropping areas Lower Murray NAP region

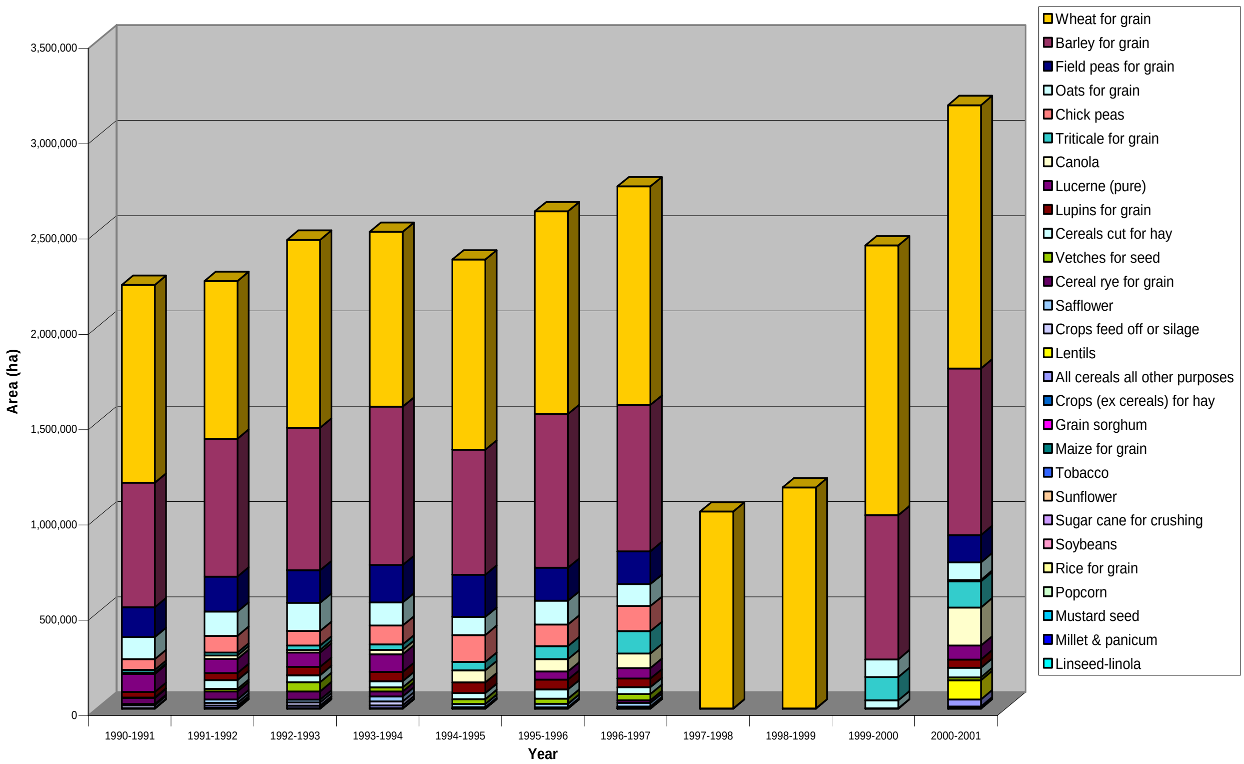
State	Regional scale 2000 MDB land use total dryland crops (ha)	Catchment scale 2003 total dryland crops (ha)
New South Wales	82,527	115,944
Victoria	1,592,727	2,392,866
South Australia	848,216	560,452
Total	**2,523,470**	**3,069,262**

While patterns in the spatial distribution of cropping revealed at both scales of mapping are generally similar, regional scale mapping suggests a greater concentration in South Australia to the east of the Murray River. In this district, catchment scale mapping attributes a significantly greater area to grazing on modified pastures. This could point to technical differences in the approach used to distinguish cropping from improved pasture in catchment scale mapping in the two jurisdictions (South Australia and Victoria). North of the Murray River the catchment scale land use data shows limited and scattered dryland cropping in South Australia and dense cropping in Victoria. Again, regional scale mapping shows a similar density of dryland cropping across the two jurisdictions.

5.2.1 Simple areal change

Aggregate changes in cropping in the Lower Murray Region are revealed in the 1990-2001 time series of ABS Agstats presented in Figure 24 showing the area of dryland cropping in the Lower Murray region by crop type. As mentioned previously, data is unavailable for most crop types in 1997 to 1998 and several again in 1998 to 1999. Overall, from 1990 to 2001, the area of dryland cropping in the region has increased. Major crops present in the Lower Murray region are wheat and barely. For years when information for most crops types was available, wheat made up over 40 percent of the total dryland crops while barley made up 30 percent. Only two commodities show significant proportional increases in area over 1990s. These are canola, which increased from around 8,000ha to almost 200,000 hectares and triticale for grain which increased from 13,500 hectares to 136,500 hectares.

Figure 24. Lower Murray NAP region change in dryland cropping – AgStats data



The regional scale map series (1993, 1996, 1998 and 2000) presented in Figure 23 reveals that the spatial pattern of areas under dryland cropping have been relatively consistent over time with no substantial shift over this time period. The distribution of dryland cropping in 1993 appears more dispersed than the following years - from 1996 onwards the dryland cropping is concentrated in key locations south of the Murray River. North of the Murray dryland cropping is concentrated in particular locations over time.

Overall, the figures in Table 13 suggest that the total area under crop in the Lower Murray region is increasing over time at an average rate of increase of 3.5 percent per annum from 1993 to 2000. However, some variability is evident with the rate of growth decreasing from 5.5 percent per year between 1993 and 1996 to 1.9 percent between 1998 and 2000. This matches the New South Wales catchment scale RAMS data (see Figure 20) which shows a general trend of growth but also shows years when the area under crop has decreased.

Table 13. Comparison of region scale dryland crops Lower Murray NAP region

	Area (Ha)			
Crop type (ALUM code)	**MDB 1993**	**MDB 1996**	**MDB 1998**	**MDB 2000**
3.3.0 Cropping	396	2,694	2,294	4,293
3.3.1 Cereals	1,605,096	1,872,609	1,959,151	2,114,512
3.3.3 Hay & silage	4,422	2,304	3,298	2,897
3.3.4 Oil seeds	28,190	59,163	110,799	117,325
3.3.8 Legumes	321,616	348,120	358,706	286,655
Total	**1,959,720**	**2,284,890**	**2,434,248**	**2,525,682**

Figure 25 shows the spatial co-location of dryland cropping identified in mapping at catchment scale and regional scale. This diagram shows that the two scales of mapping co-locate about half of their dryland cropping. This diagram can be compared with Figure 26 which shows the spatial overlap of areas mapped under ALUM class 3 'Dryland agriculture and plantations'. This shows a greater spatial coincidence between scales of mapping and suggests that there will be more spatial overlap for the broader land use classes.

Figure 25. Spatial overlap of ALUM class 3.3 Cropping

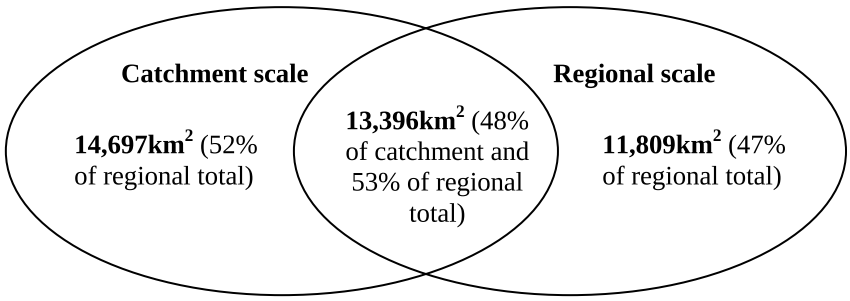
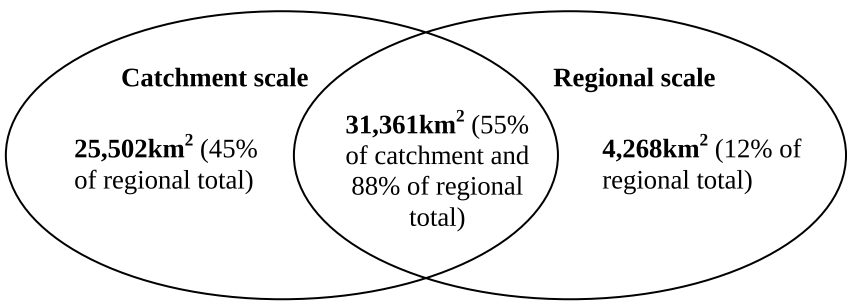
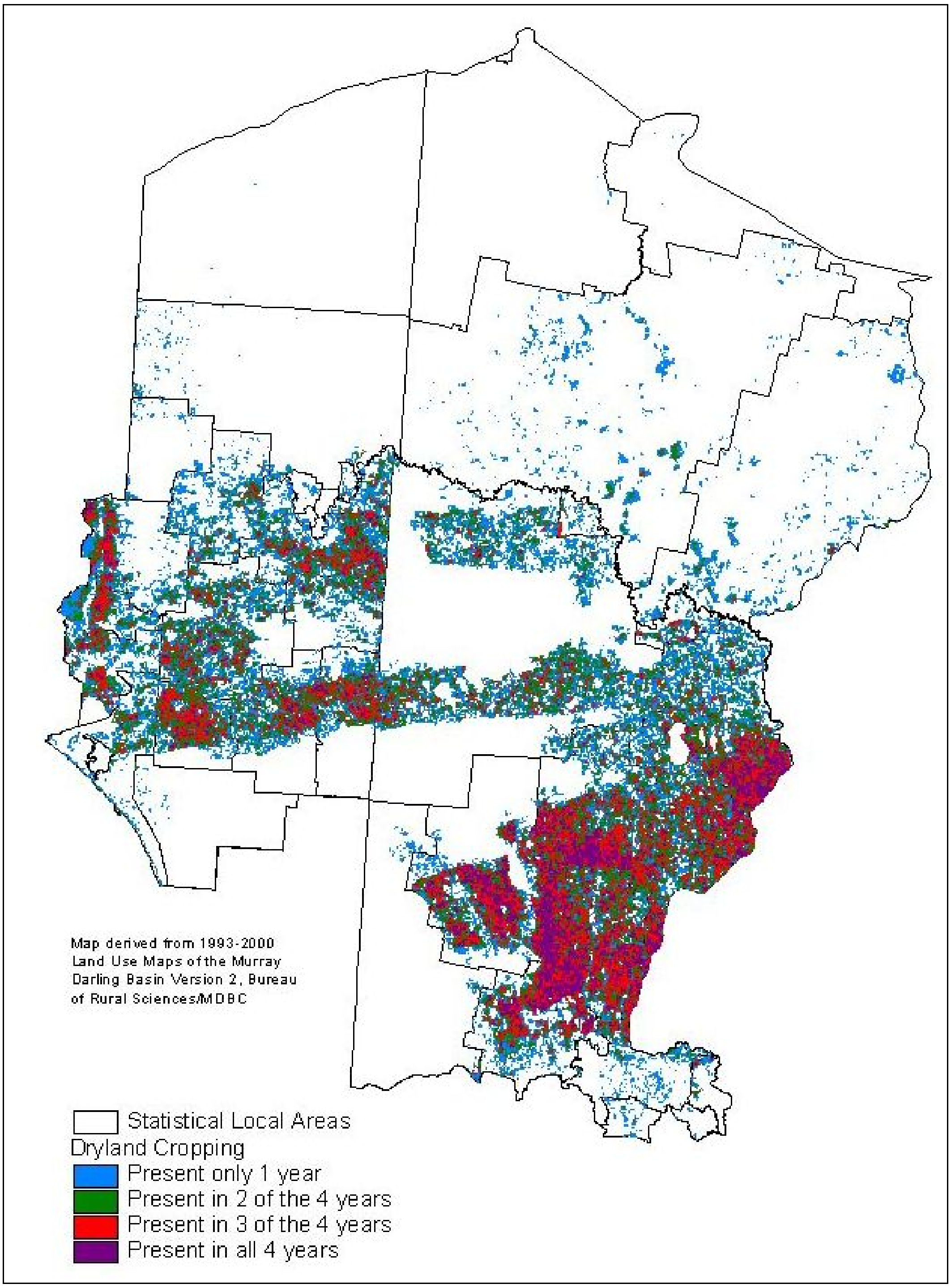


Figure 26. Spatial overlap of ALUM class 3 Dryland Agriculture and Plantations



Temporal consistency in the spatial location of dryland cropping across the Lower Murray region identified using the regional scale techniques is presented in Figure 27. This figure shows the number of times that dryland cropping was found to be the probable land use at a location (mapped grid cell) in the four time periods (1993, 1996, 1998 or 2000).The greatest consistency in the likely presence of dryland cropping throughout the region is in south-east Victoria and central South Australia. There is a low consistency in dryland cropping north of the Murray River. To the south of the Murray River, apart from areas under nature conservation, the time series indicated that there is potential for cropping to be widely present.

Figure 27. Number of years dryland cropping identified in regional scale mapping



5.2.2 Land use transformations

Bearing in mind the limitations of regional scale mapping discussed in section 4.2.2, the pattern of transformation of dryland cropping has been investigated for two areas in the Lower Murray region. This discussion assumes that the land uses identified at particular locations using the SPREAD-based regional scale method are accurate for those years. As previously indicated, the following maps should be regarded as illustrative of a process, rather than indicative of particular patterns of change.

Figure 28 and Figure 29 show transformations of dryland cropping (what dryland cropping has changed into and changed from) between 1993 and 2000 for the Barmera region in South Australia. The first map shows the 2000 land use of areas that were under dryland cropping in 1993. Most of the area either remained as dryland cropping or was converted to some form of grazing by 2000. Only small areas close to the Murray River had substantially different land uses such as irrigated or intensive uses. Similarly, most of the areas that were dryland cropping in 2000 were cropped or grazed in 1993. Both maps indicate cropping confined to south of the river.

Land use transformations surrounding the Red Cliffs region in Victoria are shown in Figure 30 and Figure 31. In common with the Barmera map, the majority of the areas under cropping in 1993 that did not remain dryland cropping converted to some type of grazing. The second map also shows dryland cropping establishing to the north of the river in areas that were grazing natural vegetation in 1993.

Figure 28. 1993 dryland cropping in 2000, Barmera region, South Australia

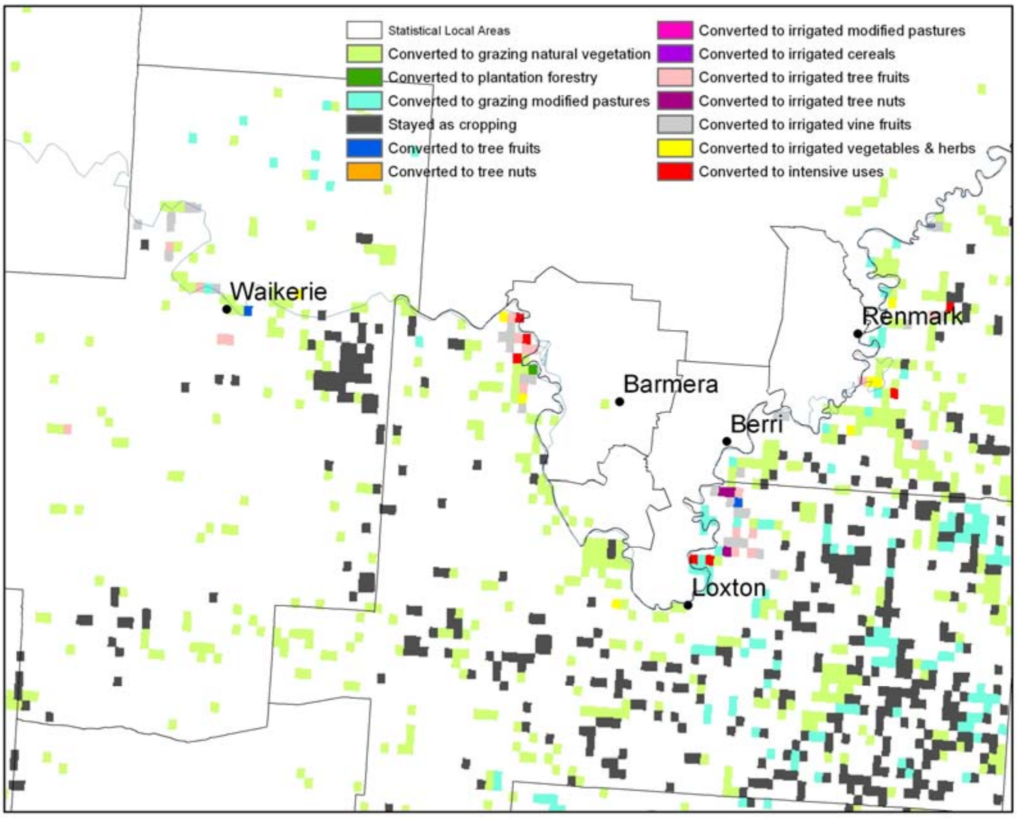


Figure 29. 2000 dryland cropping in 1993, Barmera region South Australia

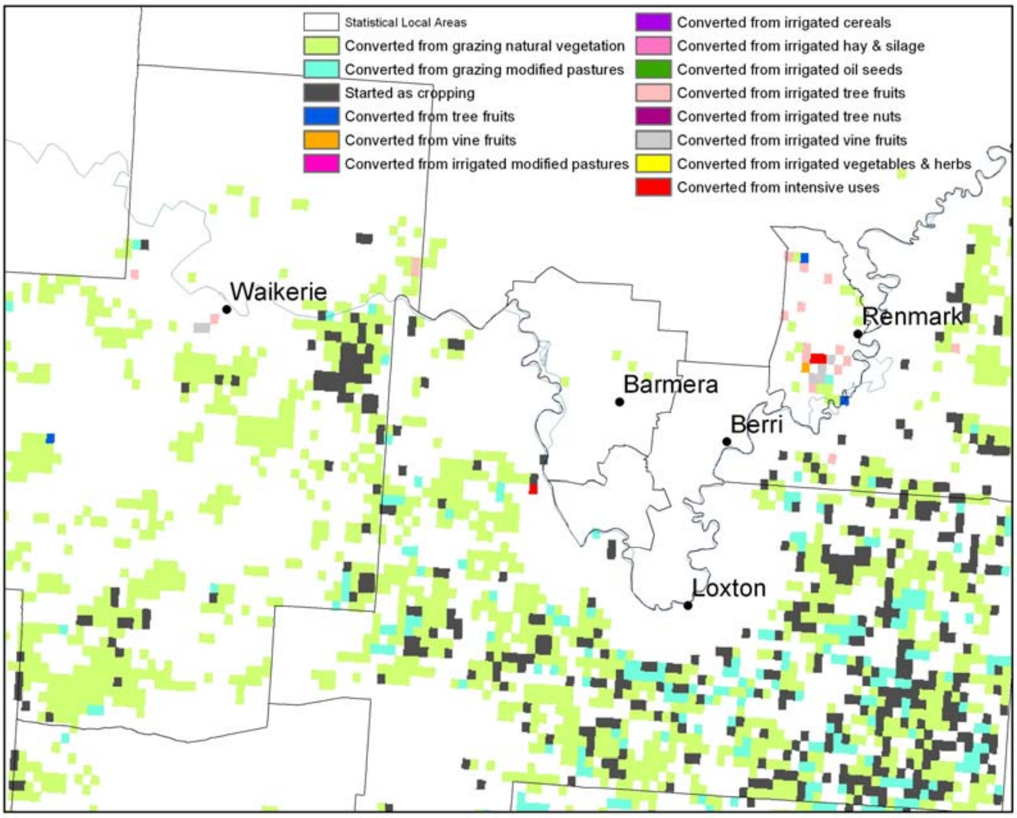


Figure 30. 1993 dryland cropping in 2000, Red Cliffs region, Victoria

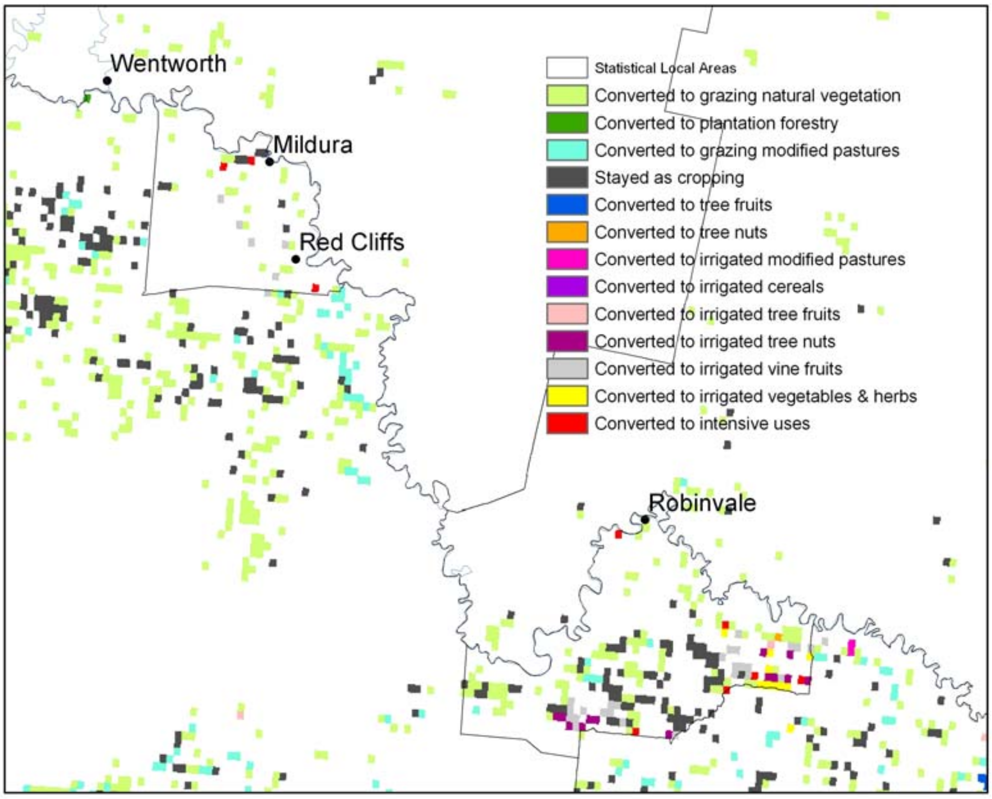
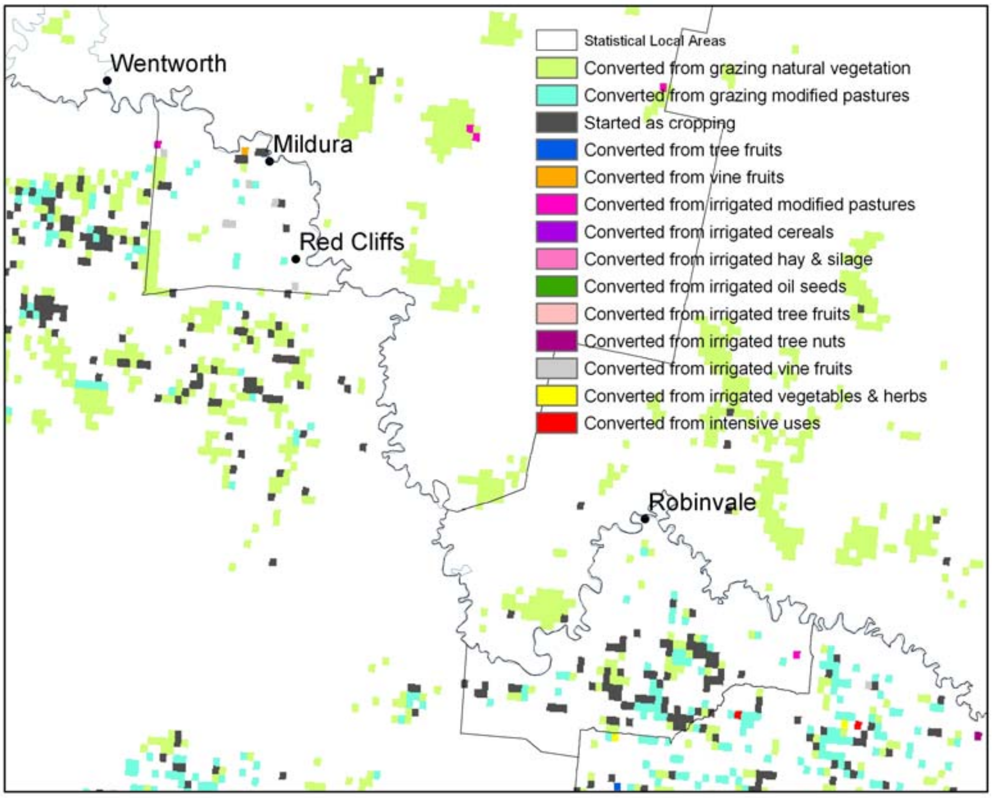


Figure 31. 2000 dryland cropping in 1993, Red Cliffs region, Victoria

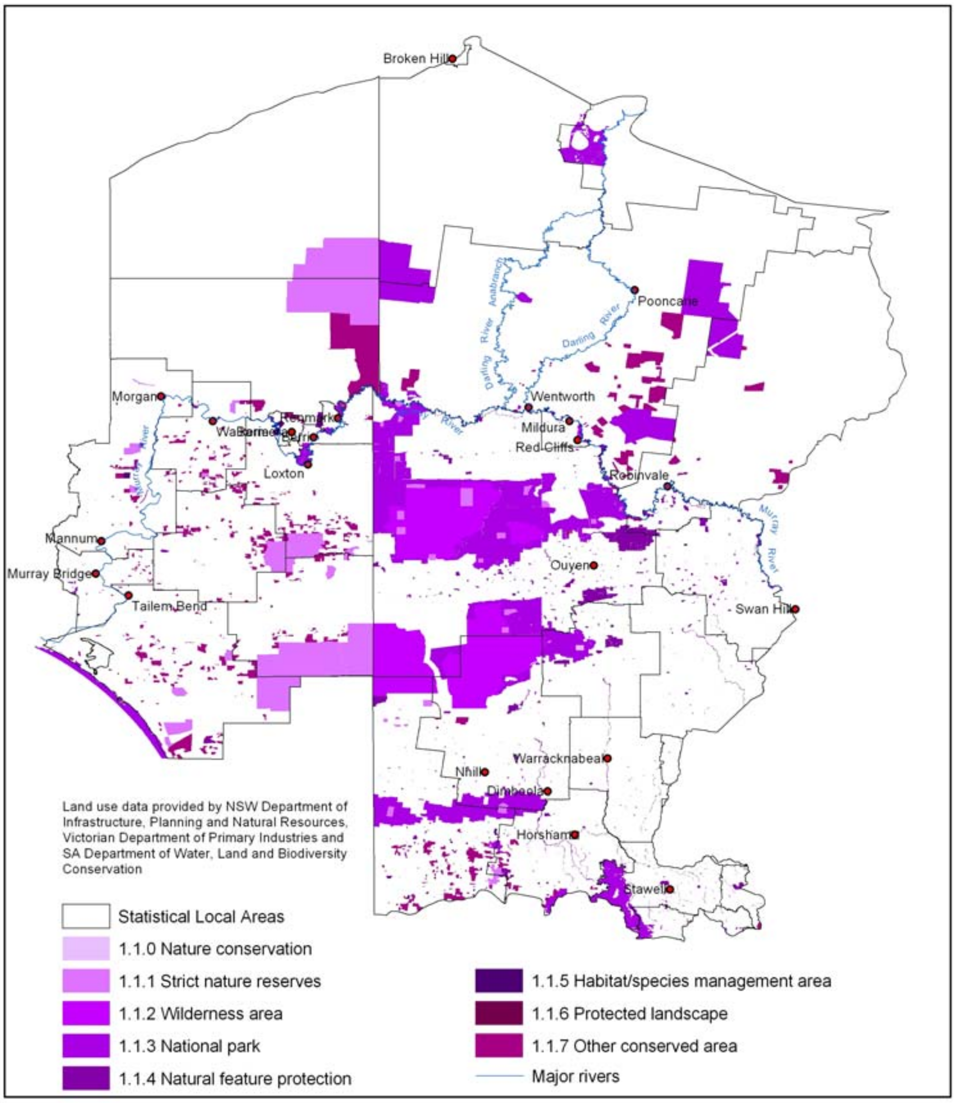


6. Native Vegetation Clearance and Reservation

Conservation of native vegetation has emerged as one of several dominant land uses in the Lower Murray Region over the last 20 years. The development of conservation as a major land use over this period has resulted from concern over the implications of the loss of native vegetation for the sustainability of natural resources, particularly salinity and water quality, and the loss of biodiversity.

This study reviewed the availability of existing regional and state level information capable of tracking changes in native vegetation clearance and reservation in the region. The location of nature conservation areas in the Lower Murray region based on the catchment scale land use mapping compiled for this project is shown in Figure 32.

Figure 32. Nature conservation in the Lower Murray NAP region 2002/2003



The region contains a number nationally significant mallee reserves, including the complex of reserves making up the Bookmark Biosphere Reserve, Ngarkat and Billiat Conservation Parks in South Australia, the Big Desert, Wyperfeld and Murray Sunset National Parks in Victoria. Key reserves are listed below:

National Parks

- Kinchega National Park (NSW)
- Mungo National Park (NSW)
- Mallee Cliffs National Park (NSW)
- Murray Sunset National Park (Vic)
- Wyperfeld National Park (Vic)
- Hattah-Kulkyne National Park (Vic)
- Little Desert National Park (Vic)
- Grampians National Park (Vic) – only in part
- Coorong National Park (SA)
- Murray River National Park (SA)

Other major conservation areas

- Tarawi Nature Reserve (NSW)
- Scotia Sanctuary (NSW)
- Willandra Lakes Region World Heritage Area (NSW)
- Annuello Reserve (Vic)
- Big Desert Wilderness Park (Vic)
- Ngarkat Conservation Park (SA)
- Billiatt Conservation Park (SA)
- Chowilla Regional Reserve (SA)
- Danggali Conservation Park (SA)

Figure 32 also shows other smaller conservation areas scattered throughout the region that are not a part of formal reserve systems, many of which are private land under conservation covenants. Most of these areas fall under ALUM class 1.1.7 'Other conserved area'. Table 14 shows the breakdown of the nature conservation classes based on information compiled for catchment scale land use mapping.

Table 14. Nature conservation types in Lower Murray NAP region

ALUM Class	Victoria	New South Wales	South Australia	Total conservation
1.1.0 Nature conservation	1,642	0	0	1,642
1.1.1 Strict nature reserves	50,765	0	553,973	604,738
1.1.2 Wilderness area	606,594	0	0	606,594
1.1.3 National park	733,248	340,448	52,566	1,126,261
1.1.4 Natural feature protection	138,933	0	8,923	147,855
1.1.5 Habitat/species management area	4,066	0	4,888	8,954
1.1.6 Protected landscape	220	0	0	220
1.1.7 Other conserved area	54,411	93,128	246,878	394,418
Total conservation	1,589,878	433,576	867,227	**2,890,681**

Data sourced from land use mapping produced by: NSW DIPNR, Vic DPI, SA DWLBC

According to the catchment scale land use data a total of 2,890,681 hectares are set aside for nature conservation in the Lower Murray region. Of this, over half is located in Victoria at 1,589,878 hectares, 867,277 hectares is in South Australia and 433,576 hectares in New South Wales.

6.1 Data

The lack of spatial and temporal consistency in available regional and state level data made it difficult to collate a coherent picture of change in the Lower Murray region across the three state jurisdictions. Lack of consistency largely results from each jurisdiction having quite different legislative and administrative arrangements governing the reservation and management of native vegetation. Nevertheless, the available data do suggest similar trends (reductions) in area cleared following the tightening of native vegetation management legislation and clearance approvals processes.

Much of the land in the New South Wales part of the Lower Murray region is leasehold, and license holders require a permit or license to clearing, cropping or irrigation (DIPNR 2005). Licence applications and approvals data are collected and maintained by DIPNR. However, this systems does not track clearing *per se* or include data on illegal clearing which has been significant at times (DIPNR 2005). Other sources of clearance data in New South Wales included the Southern Mallee Sustainable Farming Project (Wentworth and Balranald Shires). Data on private conservation agreements were available from DIPNR and the Southern Mallee Farming Project. Data on gazetted reserves apart from the conservation agreements were not obtained by the NSW partners.

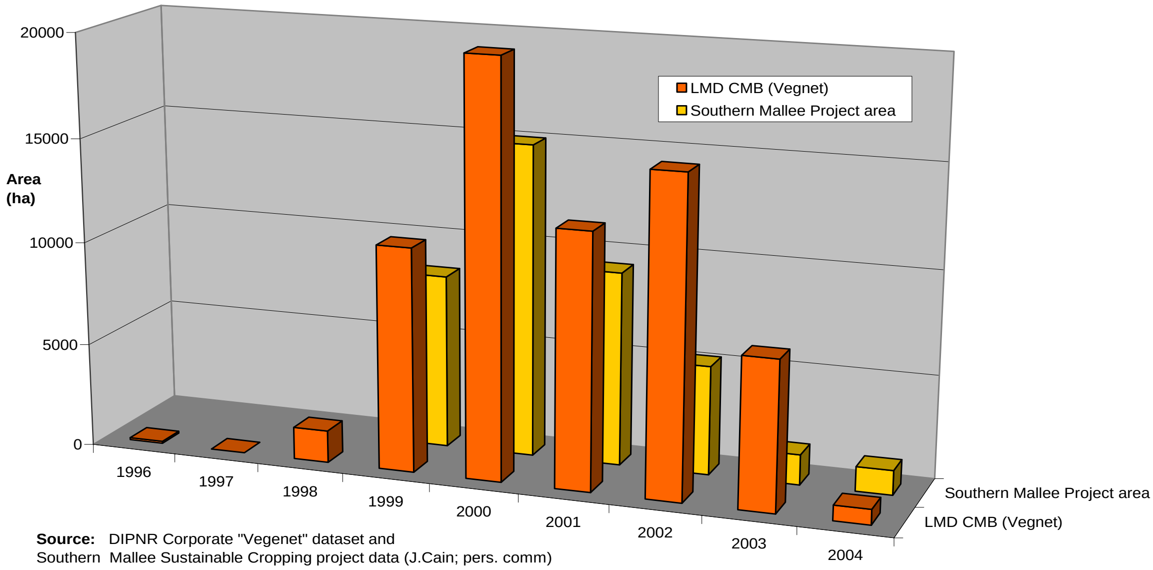
In South Australia vegetation reservation data were obtained for Vegetation Heritage Agreement Areas and National Parks and Wildlife Services SA Reserves (maintained by the Department for Environment and Heritage, South Australia). The Heritage Agreement Scheme was established in 1980 to combat over-clearance of bushland in the agricultural region of South Australia by assisting landholders conserve native vegetation. A state-wide dataset containing Heritage Agreement areas and date of establishment was available for analysis. Vegetation clearance data in South Australia were obtained from the Native Vegetation Database, DWLBC. This dataset contained information on clearance applications, including the area cleared and the type of consent given (Keane 2005).

6.2 Analysis

New South Wales trends in the clearance of native vegetation in the Lower Murray region is shown in Figure 33 using clearance approval data from two local sources (DIPNR Buronga office and Southern Mallee Sustainable Farming Project). The data indicates that prior to 1999 approvals for only small areas were granted, less than 100 hectares per year. Over the following four years (1999-2002) total clearance approvals averaged almost 15,000 hectares per year, reducing to an expected 2,000 hectares in 2004.

An indication of likely land use transformations in this region is provided by the ‘purpose for clearing’ information presented in Figure 34 as recorded in the Vegnet database. The majority of land has been cleared for cropping, although there is ambiguity between ‘cropping’ and ‘cropping/grazing’ definitions.

Figure 33. Clearing approvals 1996 to November 2004: Lower Murray region and Southern Mallee project area (NSW)



South Australian trends in native vegetation clearing and reservation for the years 1983 to 2001are presented in Figure 35 (Heritage Agreements and gazetted reserves). The time series reveals that from 1983-1987 large areas of native vegetation were cleared with little native vegetation assigned to conservation use. From 1998-1995 the amount of clearance was broadly counter-balanced with an equal amount of reservation through the establishment of Heritage Agreements on private land.

Figure 34. Proposed land use for clearing approval areas in Lower Murray Region NSW

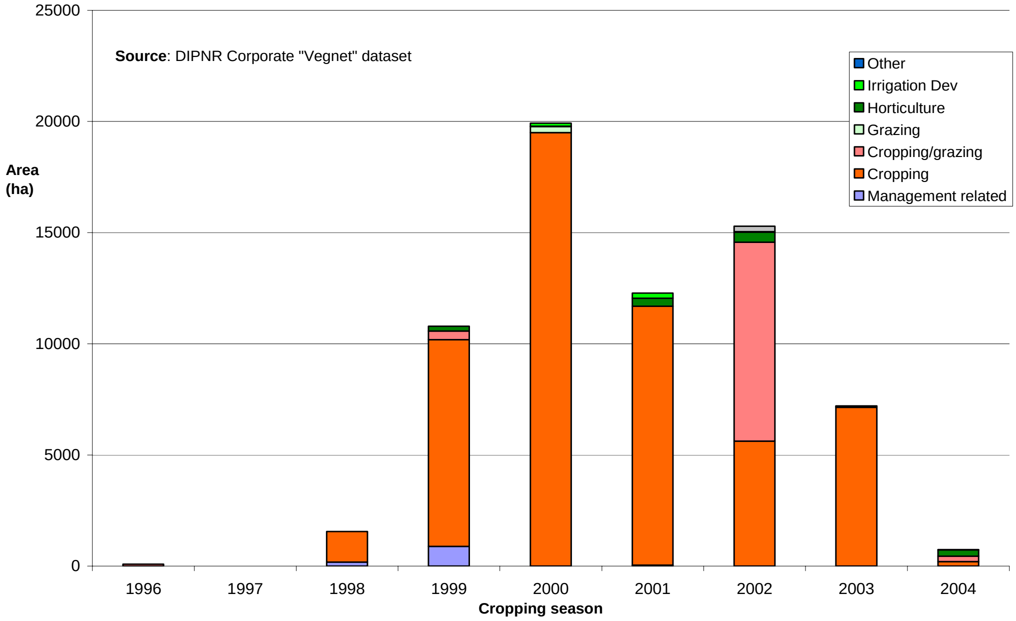
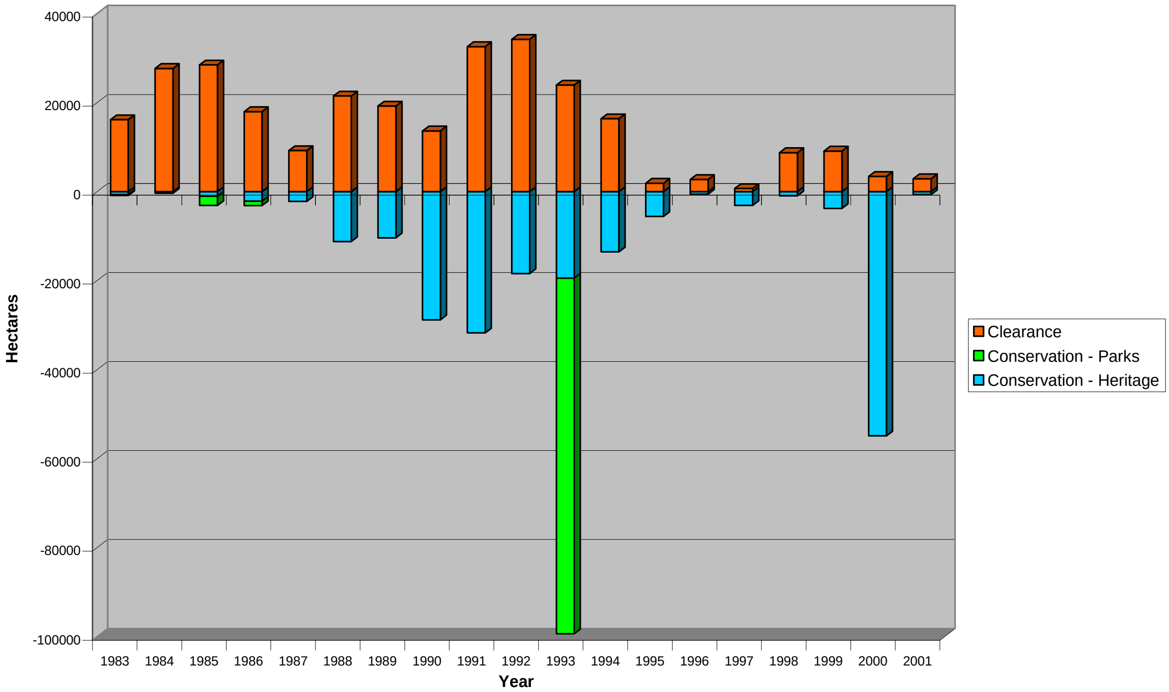
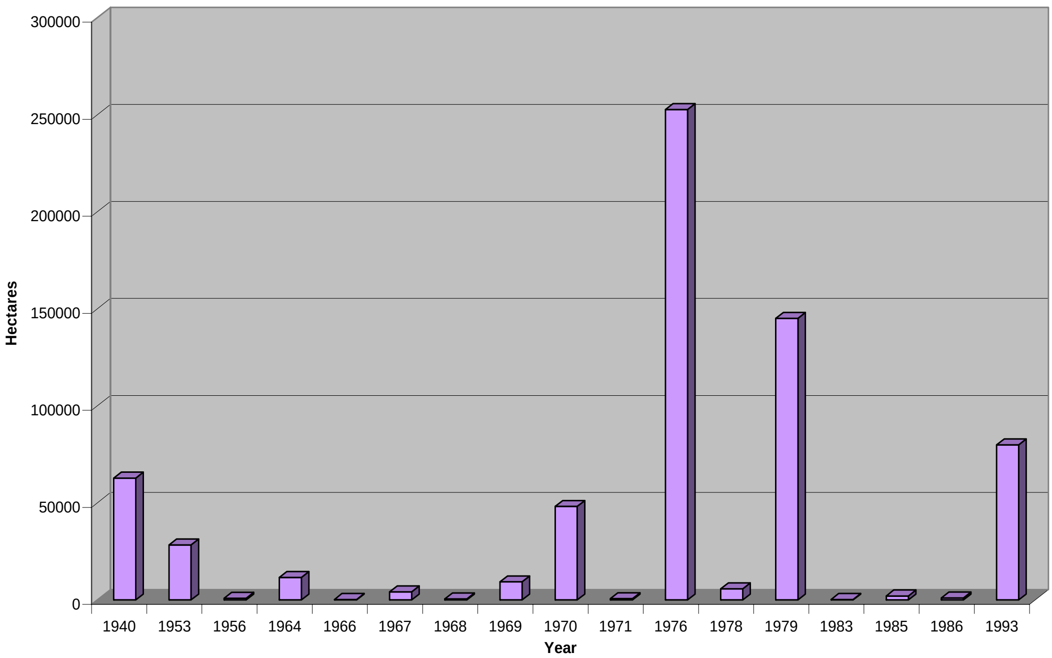


Figure 35. Native vegetation clearing and reservation 1983-2001 (SA)



The more sporadic nature of protection through the formal reserve system in this region over the last sixty years is revealed in Figure 36 which shows areas constituted as reserves under the *National Parks and Wildlife Service Act*. The first constituted reserve was established in the region in 1940 and the most recent was in 1993. In most years, less than 10,000 hectares was set aside.

Figure 36. Parks gazetted under the NPWS Act 1940-1993 (SA)



Source Dataset : 'National Parks and Wildlife Services SA Reserves', Department of Environment and Heritage, SA

7. Integration of Land Use Data

Policy makers and land managers increasingly appreciate the complex nature of the landscape processes affecting the status of Australia's natural resource base. Our capacity to examine complex biophysical systems and their interactions with economic and social environments is improving and this will be central to developing an effective basis for monitoring and managing our land, water and vegetation resources. The key to this is the integration of appropriately scaled topography, soils, climate, hydrogeology, land cover, land uses and land management practices information. While there is room for improvement in most of the data sets and models, the increasing availability of land use and land management practice data is an important step toward realising this capacity.

This section of the report provides proof-of-concept illustrations of the integration of land use data with other information to assist in addressing natural resources sustainability issues – in this case regional profiling of vegetation and land use and aspects of land use and the region's water balance. This illustration represents a stepping-stone between the collation of natural resource data and information, and integrated regional and national assessments of natural resources condition and trend.

7.1 Vegetation and Land Use Profile

Land use and vegetation have a major influence on the way Australian landscapes function – including their soils, water and biodiversity resources. Information about land use and vegetation can therefore help inform decisions affecting natural resource condition and sustainable production. A simple illustration of the integration of land use and vegetation information is provided on the following page as a profile showing the relationship between land use and vegetation types for the Lower Murray NAP region.

Profiles of this kind can assist natural resources planning, management, monitoring and reporting at the regional level, complementing more detailed regional and local information. The type, extent and use of vegetation provide insights into complex management issues such as salinity, water quality and availability, the maintenance of biodiversity and healthy landscapes. This information also helps inform socio-economic issues such as the diversification of land use and community development. This vegetation/land use profile provides summary regional statistics on:

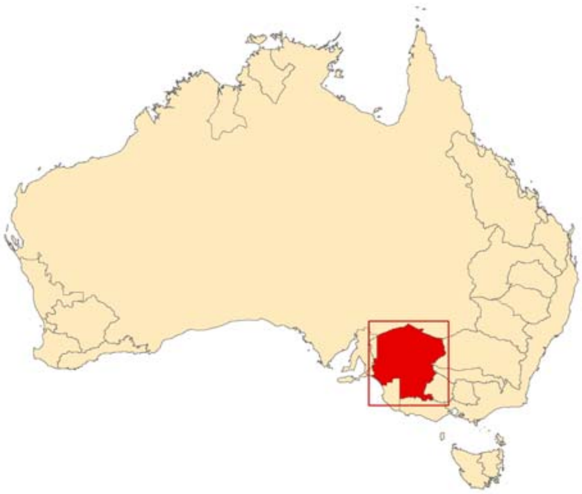
- Area and climate
- Major population centres
- Regional population
- Value of production by land use
- Relative area of land use
- Relationships between land use and vegetation

Data was integrated from the sources outlined in Appendix 6.

Lower Murray NAP Region

National Action Plan for Salinity and Water Quality Region

land_management@brs.gov.au



Population (2001): 200,700 (approx)

Annual average percentage change: (geometric growth) 1996-2001): +0.1 %

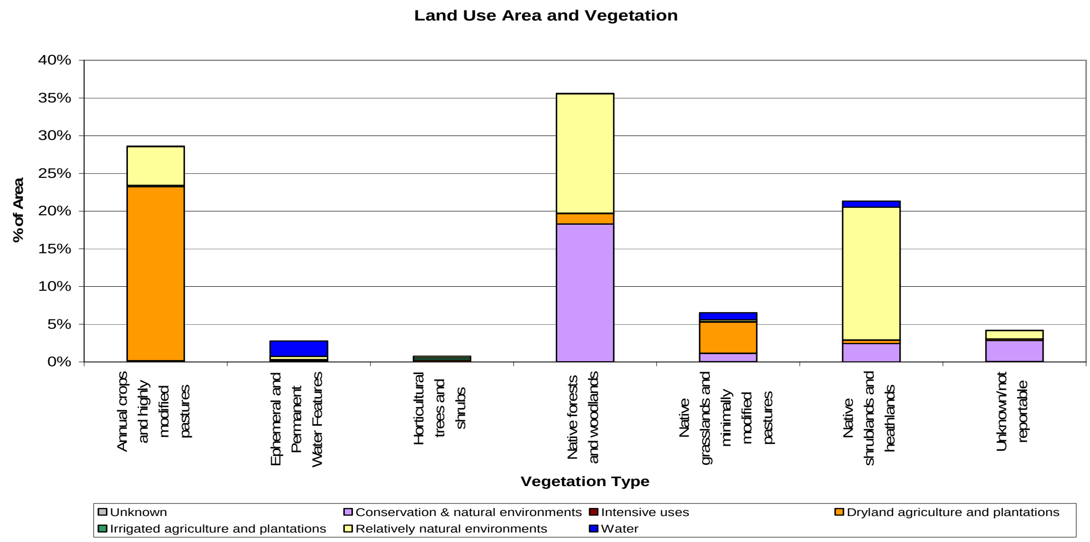
Major Towns: Mildura, Vic (28,062), Broken Hill, NSW (19,834), Horsham, Vic (13,241), Murray Bridge, SA (13,017) Stawell

Area: 190,010 km^2

BOM Climate Zones: Temperate distinctly dry (and warm) summer, Temperate no dry season (warm summer), Grassland warm (persistently dry), Grassland hot (persistently dry), Desert warm (persistently dry), Desert hot (persistently dry)

Land use area and agricultural production value (1996/97):

Land use	Area (%)	Area (km^2)	Total gross revenue ($000)	Gross revenue ($ per km^2)
Unclassified	0.1	223	2,197	986
Nature conservation	11.8	22,490	n/a	n/a
Other protected areas (incl. indigenous uses)	0.6	1,094	n/a	n/a
Minimal use	4.1	7,760	n/a	n/a
Grazing natural vegetation	58.4	110,995	258,201	233
Production forestry	2.3	4,377	n/a	n/a
Plantation forestry	0.0	3	n/a	n/a
Grazing modified pastures	6.5	12,444	196,238	1,577
Dryland cropping	12.9	24,586	736,680	2,996
Dryland horticulture	0.1	123	185,665	151,131
Irrigated pastures and cropping	0.1	273	42,293	15,475
Irrigated horticulture	0.3	576	911,298	158,162
Urban intensive uses	0.0	87	n/a	n/a
Water	2.6	4,979	n/a	n/a
TOTAL	**100**	**190,009**	**2,332,572**	



Data Sources: NHT population figures generated from ABS 1996 & 2001 Census of Population and Housing. Major Towns – Geoscience Australia, GEODATA TOPO-250K. Land Use Areas – 1996/97 Land Use of Australia Version 2, NLWRA. BOM Climate Zones – BOM Climate Classification of Australia. Agricultural Revenue – CSIRO 1996/97 National 1km Grid of Agricultural Profit Surfaces. Vegetation – Integrated Vegetation Cover 2003: BRS. NHT Boundaries – NHT Interim Boundaries: DEH 2004.

Australian Government
Bureau of Rural Sciences

7.2 Water Balance

Land use can have an important effect on the quality and availability of water resources by altering surface infiltration, runoff, turbidity and chemistry. A wide range of landscape processes and natural resources are affected by changes in these characteristics leading to impacts on, for example, salinity, biodiversity and agricultural capacity.

One key aspect of hydrology affected by land use is the water balance. The Water2010 project being conducted by the Bureau of Rural Sciences is adopting a land-use-mapping-based approach to analysing the dynamic water balance, particularly with respect to run-off, transpiration and irrigation. Work is focusing on four main components, namely:

- Capturing information on the water balance (water availability, reliability and use) at the finest scale possible for the continent (incl. groundwater);
- Constructing a national dynamic water balance to help identify catchments of concern;
- Investigating the impact of likely or desired changes in land use, demography, climate and policies/practices on water resources;
- Identifying the challenges (risks and opportunities) for communities, industries and regions, to underpin policy development.

The project is primarily designed to address the information needs of the National Water Commission with respect to specific components of the National Water Initiative, and also to provide information needed by the Australian Department of Agriculture, Fisheries and Forestry to develop sound water reform policy in a changing physical and social environment in Australia.

The water balance model was used to calculate values for land use area, evapotranspiration, deep drainage, runoff, precipitation and supplemental water demand (irrigation) for drainage basins in the Lower Murray region over four separate years (1993, 1996, 1998 and 2000). Water balance values were derived as follows (further information in Appendix 7):

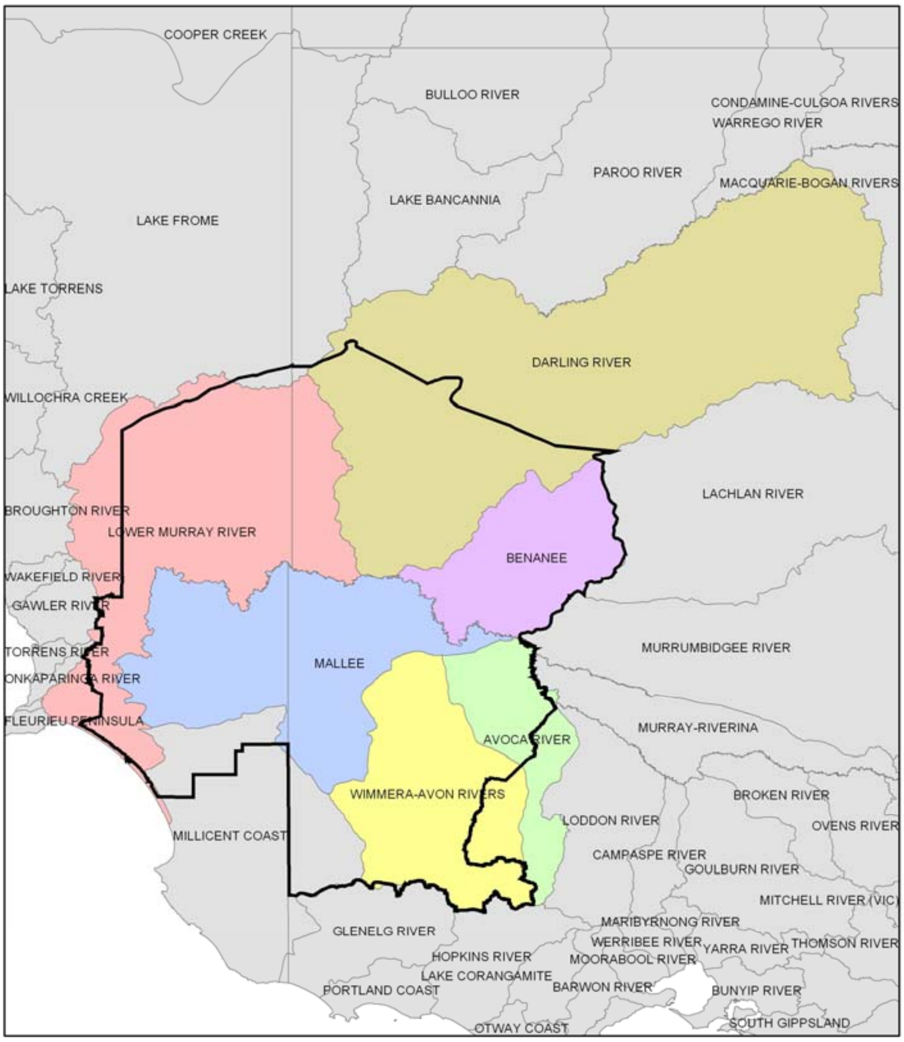
1. Compiled regional scale mapping for selected basins in the Lower Murray region for four years)
2. Assigned water use coefficients to land use classes
3. Modelled monthly and annual outputs using Bureau of Meteorology precipitation and CSIRO Earth Observation Centre potential evaporation grids
4. Separated ‘runoff’ component into surface runoff and deep drainage (Runoff = rainfall – evapotranspiration – deep drainage)
5. On cells that are irrigated, irrigation = potential evaporation – evapotranspiration

Results were calculated for the following basins within the Lower Murray region (see Figure 37):

- Avoca River
- Benanee
- Darling River
- Lower Murray River
- Mallee

- Wimmera-Avon Rivers

Figure 37. Basins used in calculating the water balance for the Lower Murray region



For each contributing basin evapotranspiration, deep drainage, runoff, precipitation and supplemental water demand (irrigation) were calculated for key land use categories in terms of potential impact on water balance. Some of the attributes are calculated as averages for land uses (mm) while others are sums (ML). Details on how these figures were calculated can be found in Appendix 7. The selected land use categories were:

- Pasture
- Irrigated pasture
- Cropping
- Irrigated cropping
- Horticulture
- Irrigated horticulture
- Built-up areas

To accommodate concerns over the spatial accuracy of regional scale mapping and scale issues in relation to water balance calculations, results for the six contributing basins were aggregated. This aggregated view estimates change across the Lower Murray region from 1993 to 2000. Change in each water balance attribute has been expressed as a percentage at the regional level. Figure 38, Figure 39 and Figure 40 show the changes for each selected land use from 1993 to 1996, 1996 to 1998 and 1998 to 2000 respectively.

Figure 38 shows the pattern of change in land use and modelled water balance characteristics (runoff and irrigation) between 1993 and 1996. Dryland and irrigated pastures and irrigated cropping decreased from 1993 to 1996. During this time the area of pastures decreased by almost 50 percent, irrigated pastures decreased by over 60 percent and irrigated cropping decreased by over 80 per cent. Cropping and horticulture did not follow the same pattern. Cropping increased in area while horticulture showed the greatest increase between 1993 and 1996, increasing by about 75 percent. Irrigated horticulture also showed an increase, though more marginal. The area of land classified as ‘built-up’ decreased slightly.

As a result of these changes, the water balance model estimated average annual runoff would have decreased by around 20 percent, while irrigation demand would have decreased by over 40 percent.

Changes between 1996 and 1998 were quite different, with the majority of the land uses increasing in area (Figure 39). Pastures increased during this period after having decreased over the prior period, while irrigated pastures continued to decrease. Irrigated cropping had the greatest overall increase in area at around 120 percent. Horticultural area decreased after increasing between 1993 and 1996.

The water balance model indicated both runoff and irrigation demand would have increased by around 20-25% between 1996 and 1998 as a consequence of these land use changes.

Figure 38. Land use and modelled water balance percentage change from 1993 to 1996

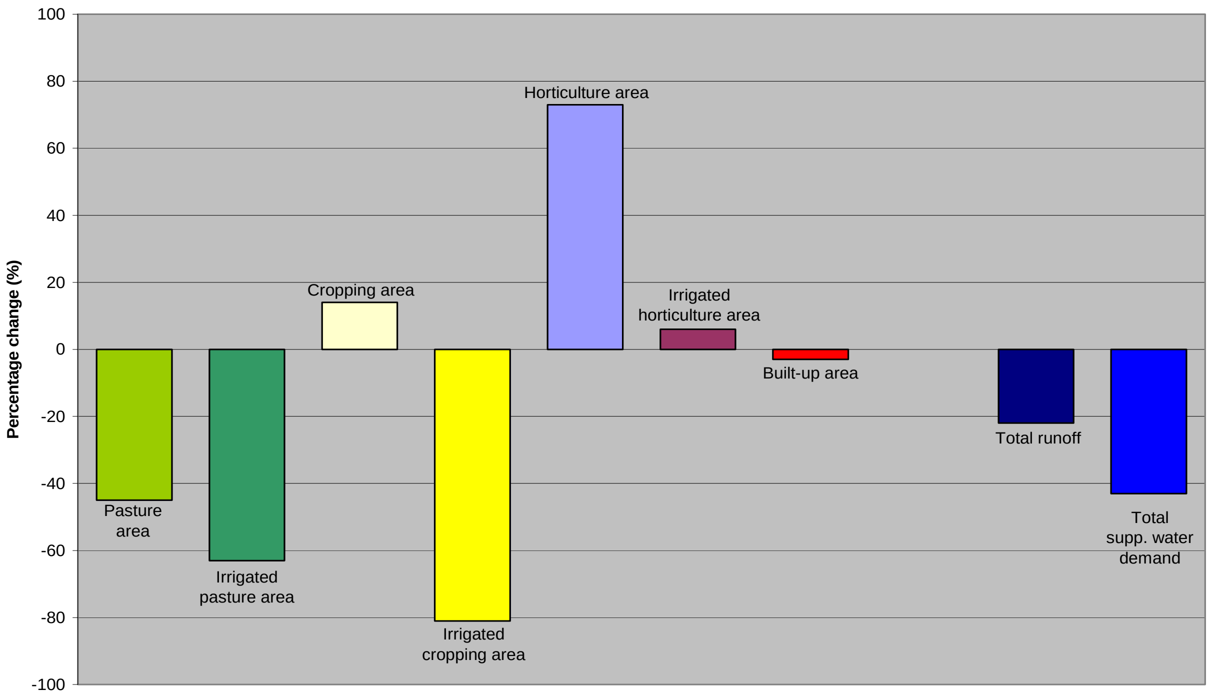


Figure 40 shows changes observed from 1998 to 2000. Again, changes differ to those between 1993 and 1996 and 1996 and 1998, with irrigated pastures and irrigated cropping reversing the trend from the previous time period. Horticulture continued to decrease but at a greater rate while irrigated horticulture continued to increase. The water balance model estimated runoff would have remained fairly stable over this time period, while irrigation demand would have continued to increase, but at a slower rate than during the previous period.

Figure 39. Land use and modelled water balance percentage change from 1996 to 1998

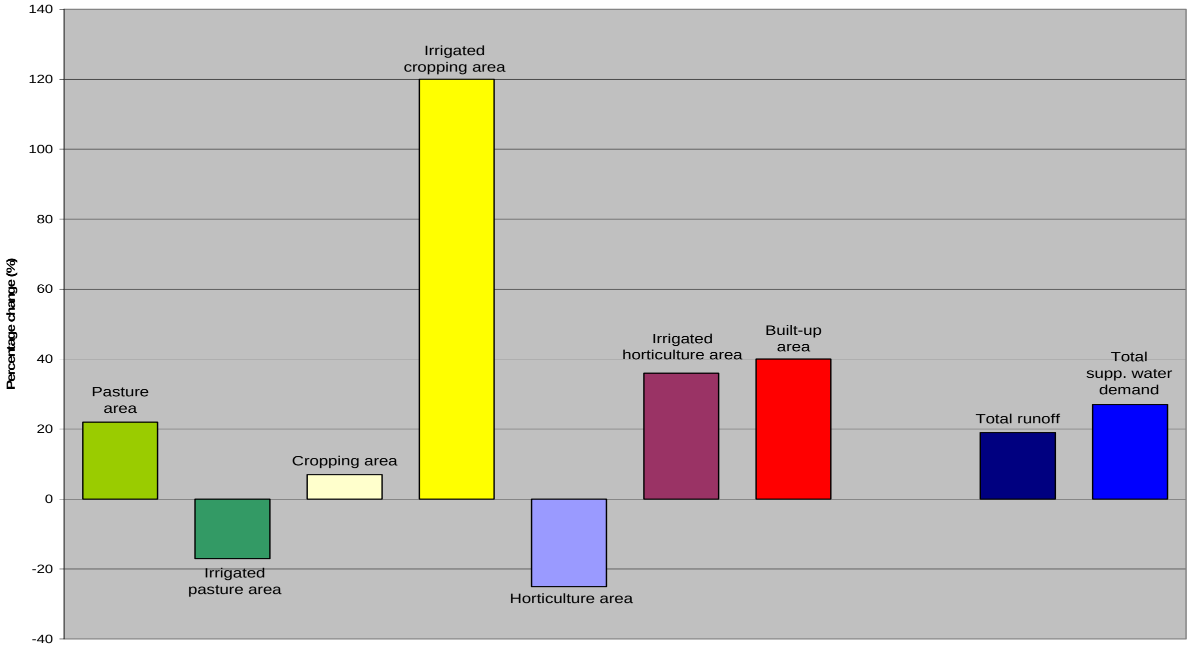
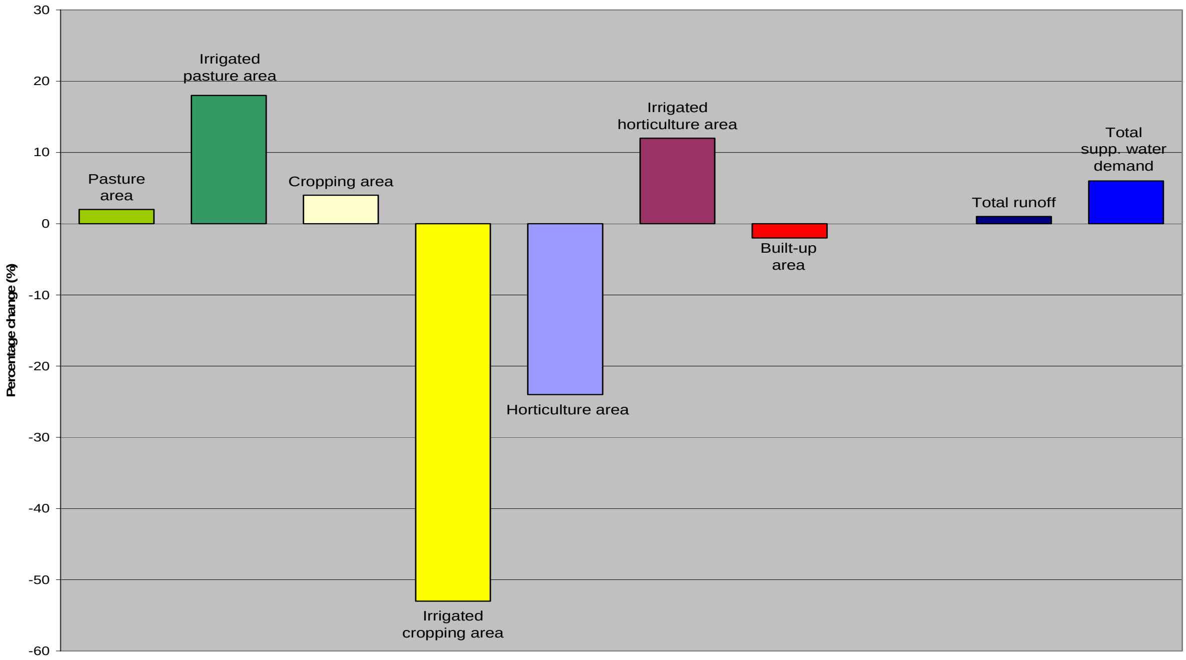


Figure 40. Land use and modelled water balance percentage change from 1998 to 2000



8. Conclusions

This study was prompted by ACLUMP's recognition of the need to consider the application of land use information to support assessments of natural resource condition and trend, both at the regional and national level. This report assists in this process by examining the Lower Murray region of New South Wales, Victoria and South Australia and demonstrating the:

- integration of land use data across jurisdictions,
- capacity to report change over time, and
- integration of land use information with other natural resource information.

In approaching these objectives this study completed a mapping effort involving the collation of land use data across the three state jurisdictions and the development of an integrated land use dataset using nationally agreed protocols. The study also considered methods of reporting land use change, addressing aspects of land use change in relation to (a) irrigated agriculture and horticulture, (b) dryland cropping, and (c) vegetation clearing and areas reserved for nature conservation. Catchment scale land use data were also compared with available regional scale data. Finally, this project completed a preliminary regional profiling of vegetation and land use to illustrate the concept of integrating land use data with other natural resource information to assist in addressing natural resource sustainability in the region.

The land use data integration exercise demonstrated the importance of developing and maintaining consistent mapping procedures and technical specifications across jurisdictions. Consistent mapping standards and specifications developed through ACLUMP processes proved essential to data integration and the development of a coherent and meaningful 'whole-of-region' land use picture. Some differences in the interpretation of standards and protocols between mapping teams were identified and the exercise pointed to the need for further attention to standards and their interpretation.

The results of this work also pointed to the issue of resolving a single integrated land use picture from multi-temporal information sources. For regions like the Lower Murray, where important land uses are subject to seasonal influence, the integration of multi-temporal information is problematic. Discriminating cropping from grazing modified pastures at catchment scale was a particular concern in this region owing to the sensitivity to seasonal conditions and the prevalence of rotational pasture /cropping systems. Significant differences in patterns were apparent in 2002 and 2003 mapping. The methods employed in regional scale mapping largely address this issue, but there are concerns here in relation to spatial precision and accuracy. Significant differences were also evident in the total area and spatial location of land uses mapped at catchment and regional scale.

A key finding of the project is that the capacity to report change depends on the availability of consistent time series data capable of providing insights into aspects of change that are relevant to target interests. A particular difficulty with change detection and reporting for land use is distinguishing the various dimensions of change. In an agricultural context this includes farming systems (eg rotations), seasonal variability, and longer-term industry and regional trends. Protocols for reporting change must be capable of distinguishing and providing insight into these change characteristics. The study identified four broad approaches to reporting land use change:

- Simple areal change: loss or gain in the areal extent of a particular land use,
- Transformation: transitions between different land uses,

- Dynamics: temporal dimensions of change (areal extent or transformations) in terms of rates of change and periodicity, and
- Prediction: modelling expected spatial or temporal patterns of land use change

The study highlighted practical limitations in the availability of consistent time-series land use data at catchment scale across jurisdictions. Data of sufficient consistency across all jurisdictions did enable simple areal change reporting for irrigated horticulture. However, the form of possible change analyses is directly dependent on the type, amount and quality of available data. Catchment scale mapping is generally assembled from information collected by a variety of state and regional agencies in order to satisfy particular state and regional information requirements. Catchment scale mapping is necessarily reliant on these sources and as a result there will inevitably be problems developing and maintaining consistent time-series data, even within state jurisdictions. The relative expense of repeating catchment scale mapping on a regular basis is additionally problematic. It is key issue for the ACLUMP to identify consistent time series data suitable for mapping at catchment scale. Opportunities to utilise high spatial and temporal resolution imagery (eg MODIS) and also cadastre-based Valuer Generals data appear at this stage to be prospective.

Regional scale land use mapping derived using SPREAD-based methods and ABS AgStats, while of limited spatial accuracy and precision, is based on a relatively consistent time series of input data (ABS Agricultural census and survey data and AVHRR imagery). This provides scope for time series analyses, providing that limitations in spatial accuracy can be accommodated. There is scope too for improvement in this aspect of mapping, if higher resolution satellite imagery (e.g. MODIS) can be applied successfully. The results of the simple regional-scale change analysis for irrigated horticulture and cropping presented in this report appear to be of value in characterising the spatial and temporal dynamics of particular uses subject to expansion or contraction, or periodic cycling.

The study provided only a limited opportunity to demonstrate an integrated analysis of land use and natural resource information. The land use and vegetation profile for the Lower Murray region derived for this study was created using regional-scale land use data and a national integrated vegetation dataset, along with a range of ancillary information. The profile is based on data that is regularly collated providing the opportunity for periodic re-analysis and updating.

APPENDIX 1: ALUM Classification Summary

Australian Land Use and Management Classification (ALUM) Version 5 summary

AUSTRALIAN LAND USE AND MANAGEMENT CLASSIFICATION version 5 (November 2001)

I Conservation and Natural Environments

1.1.0 Nature conservation
- 1.1.1 Strict nature reserves
- 1.1.2 Wilderness area
- 1.1.3 National park
- 1.1.4 Natural feature protection
- 1.1.5 Habitat/species management area
- 1.1.6 Protected landscape
- 1.1.7 Other conserved area

1.2.0 Managed resource protection
- 1.2.1 Biodiversity
- 1.2.2 Surface water supply
- 1.2.3 Groundwater
- 1.2.4 Landscape
- 1.2.5 Traditional indigenous uses

1.3.0 Other minimal use
- 1.3.1 Defence
- 1.3.2 Stock route
- 1.3.3 Remnant native cover
- 1.3.4 Rehabilitation

2 Production from Relatively Natural Environments

2.1.0 Grazing natural vegetation

2.2.0 Production forestry
- 2.2.1 Wood production
- 2.2.2 Other forest production

3 Production from Dryland Agriculture and Plantations

3.1.0 Plantation forestry
- 3.1.1 Hardwood production
- 3.1.2 Softwood production
- 3.1.3 Other forest production
- 3.1.4 Environmental

3.2.0 Grazing modified pastures
- 3.2.1 Native/exotic pasture mosaic
- 3.2.2 Woody fodder plants
- 3.2.3 Pasture legumes
- 3.2.4 Pasture legume/grass mixtures
- 3.2.5 Sown grasses

3.3.0 Cropping
- 3.3.1 Cereals
- 3.3.2 Beverage & spice crops
- 3.3.3 Hay & silage
- 3.3.4 Oil seeds
- 3.3.5 Sugar
- 3.3.6 Cotton
- 3.3.7 Tobacco
- 3.3.8 Legumes

3.4.0 Perennial horticulture
- 3.4.1 Tree fruits
- 3.4.2 Oleaginous fruits
- 3.4.3 Tree nuts
- 3.4.4 Vine fruits
- 3.4.5 Shrub nuts fruits & berries
- 3.4.6 Flowers & bulbs
- 3.4.7 Vegetables & herbs

3.5.0 Seasonal horticulture
- 3.5.1 Fruits
- 3.5.2 Nuts
- 3.5.3 Flowers & bulbs
- 3.5.4 Vegetables & herbs

4 Production from Irrigated Agriculture and Plantations

4.1.0 Irrigated plantation forestry
- 4.1.1 Irrigated hardwood production
- 4.1.2 Irrigated softwood production
- 4.1.3 Irrigated other forest production
- 4.1.4 Irrigated environmental

4.2.0 Irrigated modified pastures
- 4.2.1 Irrigated woody fodder plants
- 4.2.2 Irrigated pasture legumes
- 4.2.3 Irrigated legume/grass mixtures
- 4.2.4 Irrigated sown grasses

4.3.0 Irrigated cropping
- 4.3.1 Irrigated cereals
- 4.3.2 Irrigated beverage & spice crops
- 4.3.3 Irrigated hay & silage
- 4.3.4 Irrigated oil seeds
- 4.3.5 Irrigated sugar
- 4.3.6 Irrigated cotton
- 4.3.7 Irrigated tobacco
- 4.3.8 Irrigated legumes

4.4.0 Irrigated perennial horticulture
- 4.4.1 Irrigated tree fruits
- 4.4.2 Irrigated oleaginous fruits
- 4.4.3 Irrigated tree nuts
- 4.4.4 Irrigated vine fruits
- 4.4.5 Irrigated shrub nuts fruits & berries
- 4.4.6 Irrigated flowers & bulbs
- 4.4.7 Irrigated vegetables & herbs

4.5.0 Irrigated seasonal horticulture
- 4.5.1 Irrigated fruits
- 4.5.2 Irrigated nuts
- 4.5.3 Irrigated flowers & bulbs
- 4.5.4 Irrigated vegetables & herbs

5 Intensive Uses

5.1.0 Intensive horticulture
- 5.1.1 Shadehouses
- 5.1.2 Glasshouses
- 5.1.3 Glasshouses (hydroponic)

5.2.0 Intensive animal production
- 5.2.1 Dairy
- 5.2.2 Cattle
- 5.2.3 Sheep
- 5.2.4 Poultry
- 5.2.5 Pigs
- 5.2.6 Aquaculture

5.3.0 Manufacturing and industrial

5.4.0 Residential
- 5.4.1 Urban residential
- 5.4.2 Rural residential

5.5.0 Services
- 5.5.1 Commercial services
- 5.5.2 Public services
- 5.5.3 Recreation and culture
- 5.5.4 Defence facilities
- 5.5.5 Research facilities

5.6.0 Utilities
- 5.6.1 Electricity generation/transmission
- 5.6.2 Gas treatment, storage and transmission

5.7.0 Transport and communication
- 5.7.1 Airports/aerodromes
- 5.7.2 Roads
- 5.7.3 Railways
- 5.7.4 Ports and water transport
- 5.7.5 Navigation and communication

5.8.0 Mining
- 5.8.1 Mines
- 5.8.2 Quarries
- 5.8.3 Tailings

5.9.0 Waste treatment and disposal
- 5.9.1 Stormwater
- 5.9.2 Landfill
- 5.9.3 Solid garbage
- 5.9.4 Incinerators
- 5.9.5 Sewage

6 Water

6.1.0 Lake
- 6.1.1 Lake - conservation
- 6.1.2 Lake - production
- 6.1.3 Lake - intensive use

6.2.0 Reservoir/dam
- 6.2.1 Water storage and treatment
- 6.2.2 Reservoir - intensive use
- 6.2.3 Evaporation basin
- 6.2.4 Effluent pond

6.3.0 River
- 6.3.1 River - conservation
- 6.3.2 River - production
- 6.3.3 River - intensive use

6.4.0 Channel/aqueduct
- 6.4.1 Supply channel/aqueduct
- 6.4.2 Drainage channel/aqueduct

6.5.0 Marsh/wetland
- 6.5.1 Marsh/wetland - conservation
- 6.5.2 Marsh/wetland - production
- 6.5.3 Marsh/wetland - intensive use

6.6.0 Estuary/coastal waters
- 6.6.1 Estuary/coastal waters - conservation
- 6.6.2 Estuary/coastal waters - production
- 6.6.3 Estuary/coastal waters - intensive use

minimum level of attribution

APPENDIX 2: Metadata Statements

Metadata Statement: Land Use Mapping – Lower Murray Darling

Category	Element	Description
Data set	Title	Draft Land Use: Lower Murray Darling
Custodian	Custodian	Group General Manager, Natural Resource Products Division, NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), 23-33 Bridge Street SYDNEY NSW AUSTRALIA 2000
	Jurisdiction	New South Wales, Australia
Description	Abstract	A data set of land use as at June 2002 for Lower Murray Darling. Land use is classified to three separate classification schemes. These classification schemes are: - NSW Land Use Mapping Program (LUMAP). - NSW SCALD (Standard Classification for Attributes of Land) Classification - ALUM (Australian Land Use and Management) Classification. The LUMAP Classification is DIPNR's most recent classification for mapping of land use classes for NSW. It is a simple numeric classification, open-ended to enable additional classes to be added. Prior to LUMAP, the SCALD classification was the standard for mapping of land use in NSW. It is a combined alpha-numeric classification system. The ALUM classification is based upon the modified Baxter & Russell classification and presented according to the specifications contained in www.LUCs.gov.au/land&water/landuse. Versions 4 and 5 of the classification are used to describe the land use classes. The mapping was commenced in November 2003 and is on-going. The date of the data set is set as the land use occurring at the time the satellite imagery was acquired in between 2000 and 2002.
	Search Word	Land use, land use mapping
	Geographical Extent Name	Lower Murray Darling extending from the coast to the start of the western plains.
	GEN Category	Covers the following 1:100 000 map sheets (listed by map sheet number: 7129, 7130, 7131, 7132, 7133, 7134, 7229, 7230, 7231, 7232, 7233, 7328, 7329, 7330, 7331, 7332, 7333, 7428, 7429, 7430, 7431, 7432, 7433, 7528, 7529, 7530, 7531, 7532, 7533, 7628, 7629, 7630, 7631, 7632 Includes parts or all of the following Local Government areas: Wentworth Shire, Central Darling Shire, Balranald Shire, Wakool Shire, Hay Broken Hill City and the Unincorporated area.
	GEN Custodial Jurisdiction	New South Wales Western Division
	GEN Name	
	Geographical Extent Polygon	
	Geographic Bounding Box	
	North Bounding Latitude	31°30'S

	South Bounding Latitude	35°30'S
	East Bounding Longitude	144°0'E
	West Bounding Longitude	141°0'E
Data Currency	Beginning Date	1.12.2003
	Ending Date	1.11.2004
Dataset Status	Progress	On going
	Maintenance & Update Frequency	On going as required. There are no proposals to update the land use data at this stage.
Access	Stored Data Format	ArcGIS PGDB
	Available Format Type	ArcGIS PGDB, (UTM, AGD66)
	Access Constraint	Unrestricted
Data Quality	Lineage	The data set is a new series of land use maps prepared by DIPNR for the Lower Murray Darling area of NSW. Data sets were input into ArcGIS workstations and used to build a composite polygon layer. Where new linework was required this was direct digitised on screen within the Arc GIS Environment. Information compiled prior to mapping comprises: - the cadastral layer from the NSW Digital Cadastral Database - boundaries of State Forests, National Parks and Nature Reserves from each agency. - Property Agreements and Management Contracts funded under the NSW State Government's Native Vegetation Management Fund - Western Division clearing consents - land use information prepared as part of the mapping of native vegetation. - SunRISE Irrigated cropping - RAMS cropping The ALUM classification defines three levels of land use description – primary, secondary and tertiary. For the majority of the land use descriptions is down to the tertiary level. Satellite imagery, aerial photography, existing data sets, local knowledge and field checking were used as the main data sources. Patterns and spectral signatures in the Landsat 7 imagery, which comprise band combinations of 453 RGB multispectral merged with 12.5 metre pixel panchromatic provide specific recognition of a range of agricultural activities, namely cereal and fodder cropping, vegetable production and grazing. For other land use features such as newly established plantation (softwood, hardwood, tea-tree), intensive animal industries, farm dams, fish farms, extractive industries and features including previously mined areas, swamps. The main data sources are the aerial photographs, supplemented by field checking and local knowledge.
		The Aerial photographs were mostly contact prints produced at 1:50,000 scale and were viewed with an optical sterioscope to produce a three dimensional image. This information was then drawn as lines on hard copy maps in the initial stages of the program, and directly to digital layers via on-screen digitising for the later and majority of the program. Other imagery providing high resolution detail over specific sections of the

		project area, mainly river corridors, was used This was in the form of scanned digital images that were used as a backdrop for the on screen digitising process. The DIPNR spatial database for Property Agreements and Management Contracts was used to identify the class 'other conserved areas' which are primarily private conservation agreements (Class 1.1.7). The same database for Clearing Consents was used to identify areas recently cleared and planted to softwood, hardwood or tea-tree in a well-defined plantation. The spectral signatures in the satellite imagery for these areas is the same as cultivated areas (if completely bare), grassland or young woody vegetation. Aerial photographs taken in 2000 or thereafter are used to confirm a satellite pattern that indicated the plantation is established. Irrigation developments were identified from the SunRISE Irrigation Development dataset produced by SunRISE Mildura Local knowledge isused for specific commodity types in orchards or on cultivated lands, specialised industries such as plant nurseries, local urban features and crops grown under irrigation. Local information is obtained from the following sources: - district DIPNR and Landcare officers - local landholders - officers of NSW Agriculture - rural extension officers and/or managers with private stock and station agencies - internet advertising for specific industries and districts. Field verification is carried out after the interpretation of the satellite imagery and aerial photographs. This is designed to confirm specific land uses such as: - rural residential lands - effluent disposal systems - vineyards, orchards, and olive groves and if they are irrigated on a permanent basis - specific commodity types in orchards - dairies and poultry sheds - eucalyptus oil plantations - fish and yabby farms - evidence of previous cropping activities using the presence of stubble as an indicator - pasture improvement activities. As part of the checking process a number of landholders are interviewed to provide further checks on the land use classification.
	Positional Accuracy	50 metres for the original DIPNR mapping.
	Attribute Accuracy	Independent officers of DIPNR validated the original mapping and classification of polygons. These officers have more than 20 years experience in land use classification techniques. Data were verified by checks of the satellite imagery and aerial photographs Once the data was converted into digital format, additional checks are undertaken to validate the data.
	Logical Consistency	All lines and polygons are tagged. Topological consistency is performed as part of the quality assurance procedures using ArcGIS.
	Completeness	The majority of land uses are described to the tertiary level with some description at secondary level for approximately 25 percent of the total survey area
Contact	Contact Organisation	New South Wales Department of Infrastructure, Planning and Natural Resources

Information		
	Contact Position	Project Manager – Keith Emery Natural Resource Officer (Landuse)
	Mail Address 1	P.O. Box 3720 PARRAMATTA 2124
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	Suburb or Place or Locality	PARRAMATTA
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Metadata Date	Metadata Date	28 July 2004

Metadata Statement: South Australia Lower Murray NAP Irrigation Data Integration

Category	Element	Description
Data set	Title	South Australia Lower Murray NAP Irrigation Data Integration
Custodian	Custodian	SA Department of Water, Land and Biodiversity Conservation (DWLBC)
	Jurisdiction	South Australia
Description	Abstract	This dataset forms part of the ‘Land Use Integration Case Study – Lower Murray NAP Region’, for the Bureau of Rural Sciences, Australian Government Department of Agriculture, Fisheries and Forestry. This is a joint project between South Australia, New South Wales and Victoria. The ‘Baseline Information 02-03’ data (Department for Environment and Heritage, SA), which was mapped at the specific crop level, was added to the land use data as some areas were only mapped to the secondary level (broad crop level) of the Australian Land Use Management (ALUM) classification. This dataset contains the ‘2003 Murray Darling Basin Land Use’ and ‘2002 South East Land Use’. These have been converted to ALUM classification v5, unioned together and clipped to the Lower Murray NAP Region boundary. The Baseline Information 02-03 contains crop and irrigation information for licensed areas of the River Murray. It does not include areas covered by the Cental Irrigation Trust mapping. The land use classifications used in this dataset were converted to ALUM v5. The Baseline data was unioned with the combined land use data.
	Search Word	AGRICULTURE Mapping, LAND Use Mapping
	Geographical Extent Name	South Australia, SA, Lower Murray NAP Region
	GEN Category	Lower Murray NAP Region (South Australia)
	GEN Custodial Jurisdiction	SA Department of Water, Land and Biodiversity Conservation (DWLBC)
	GEN Name	
	Geographical Extent Polygon	
	Geographic Bounding Box	
	North Bounding Latitude	-32.074364
	South Bounding Latitude	-36.253639
	East Bounding Longitude	141.000000
	West Bounding Longitude	138.893341
Data Currency	Beginning Date	2002
	Ending Date	2004
Dataset Status	Progress	Complete
	Maintenance & Update Frequency	Not Planned
Access	Stored Data Format	ArcInfo 8.3, Vector Data, geographicals, 30810 polygons
	Available Format Type	ESRI Shapefile

	Access Constraint	The data is copyright to the Government of South Australia. This data is NOT to be used for any other purpose except for inclusion in the 'Land Use Data Integration Case Study – Lower Murray NAP Region' project, Bureau of Rural Sciences, Australian Government Department of Agriculture, Fisheries and Forestry.
Data Quality	Lineage	The 2003 Murray Darling Basin land use dataset and 2002 South East land use dataset were unioned and updates with Baseline Information 02-03 data, to improve the detail of the land use classifications. The Baseline data is more detailed in its land use classes and was used to update the land use datasets to tertiary level land use classes, as a lot of the irrigation polygons in the combined land use dataset were only mapped to the secondary level. He Baseline data is also more spatially correct as the land use boundaries were mapped with more accurate imagery (1:2 000 aerial photographs), and individual crop groupings outlined. The Baseline data was collected in land use categories determined by the Local Action Planning (LAP) Officers. Only 12 of the available 20 land use categories were useable. They were: Berries, Citrus, Fruit, Nuts, Pasture, Pome fruit, Stone fruit, Tree Mix, Tropical fruit, Vegetables, Vines and Woodlot. The other available land use categories were not used, as they were too broad in their descriptions, and could not be allocated a tertiary level ALUM classification. They were: Miscellaneous, Miscellaneous agriculture, Mixed crop, Not surveyed, Other, Unknown, Vacant horticulture and Vacant non-productive. The land use classes used were converted to ALUM v5. The Murray Darling Basin land use dataset was collected in ALUM v5 and the South East land use dataset was collected in ALUM v4, which was converted to ALUM v5. The land use datasets were unioned and then the Baseline Information dataset after it was converted to ALUM v5 classes was unioned on top of the combined land use datasets. Where more detailed tertiary Baseline Information data overlaid land use data mapped to the secondary level, the Baseline data was used in the final dataset. As data of varying spatial accuracies were overlaid together, the resultant dataset had a lot of slithers in it where data overlapped. To remove some of these slithers, the 'Eliminate' command was used in ArcInfo to dissolve Area < $200m^2$. Some changes made after the union were: - Where data from the two datasets overlapped, the more detailed (tertiary level) and spatially accurate Baseline data overwrote the underlying land use dataset class and polygon boundaries. However, where the Baseline codes = '4.2.4', the underlying land use polygon, if it was labelled with '4.3.3' or '4.2.2' was used. This was done as the '4.2.4' class in the Baseline data included both pastures and hay/silage classes, as opposed to being separated in the land use dataset. - If polygons from the Baseline data looked as if they were meant to line up with the polygons of the land use data, the lines in the final dataset were adjusted to the more spatially accurate Baseline boundaries. - Where more spatially accurate data was in the Baseline dataset, such as vineyards where individual blocks were mapped, any areas classified in the land use data that were not mapped to the Baseline boundaries were re-labelled with the general classes of '3.2.0' or '1.3.0'. This represented farm infrastructure/roads. - Where the Baseline boundaries overlaid roads/railways classes from the combined dataset, the roads and railways codes were used in the final dataset.
	Positional Accuracy	For both the land use datasets, positional accuracy of the datasets was to the DCDB parcels and land use boundaries accurate to Landsat ETM+ imagery (dryland cropping areas) and aerial photography (riverine areas) (unknown scale, either 1:20 000 or 1:10 000). For the Baseline dataset, positional accuracy to the ortho-rectified imagery (1:2 000).
	Attribute Accuracy	For the Murray Darling Basin land use dataset, the attribute accuracy was 84% and for the South East land use dataset, the attribute accuracy was 95%. The attribute accuracy of the Baseline dataset was per survey responses filled out by

		landholders.
	Logical Consistency	ArcInfo was used to check for non-labelled polygons. The dataset is topologically correct.
	Completeness	Complete.
Contact Information	Contact Organisation	DWLBC Information Management
	Contact Position	Principal GIS Officer
	Mail Address 1	GPO Box 2834
	Mail Address 2	
	Suburb or Place or Locality	Adelaide
	State or Locality 2	South Australia
	Country	Australia
	Postcode	5001
	Telephone	08 8303 9310
	Facsimile	08 8303 9320
	Electronic Mail Address	tonkin.david@saugov.sa.gov.au
Metadata Date	Metadata Date	10/03/2005

Metadata Statement: Lower Murray, Victoria Land Use

Category	Element	Description
Data set	Title	Draft Land Use Classification of North-West Lower Murray NAP - Mallee and Wimmera Regions
Custodian	Custodian	Department of Primary Industries (DPI)
	Jurisdiction	Victoria
Description	Abstract	This land use map has been prepared under contract for the Lower Murray NAP. The classification scheme followed here was the Australia Land Use Mapping (ALUM) classification version 5 (BRS, 2001). ALUM version 5 was developed by BRS as a modification of Baxter – Russell Classification, in coordination with State agencies. This product is based on information from a number of sources: Corporate Geospatial Data Library (CGDL), DPI regional data sets, VGV Shire Valuation Datasets, SunRise 21 Inc. datasets, satellite imagery, aerial photography, tree cover and field survey information.
	Search Word	Land use, Mallee Catchment, Wimmera Catchment, Lower Murray, land management
	Geographical Extent Name	Lower Murray - Victoria, North-west Victoria, Mallee and Wimmera Catchments.
	GEN Category	
	GEN Custodial Jurisdiction	
	GEN Name	
	Geographical Extent Polygon	Minimum latitude: 33.960 S Maximum latitude: 37.374 S Minimum longitude: 140.947 E Maximum longitude: 143.695 E
	Geographic Bounding Box	
	North Bounding Latitude	
	South Bounding Latitude	
	East Bounding Longitude	
	West Bounding Longitude	
Data Currency	Beginning Date	2000
	Ending Date	2005
Dataset Status	Progress	In Progress - **Complete**
	Maintenance & Update Frequency	Not known
Access	Stored Data Format	Arc/Info coverage
	Available Format Type	Arc/Info coverage
	Access Constraint	Access will be provided by DPI, Mallee CMA, Wimmera CMA, BRS or AFFA

Data Quality	Lineage	Created from (1) CGDL layers (DPI corporate geospatial data library) *Topographic and cadastral data layers* - Digital cadastre 1:25,000 - VicMap Property (July 2003) - Transport - Roads and Rail 1:25,000 - VicMap Transport - Hydrologic features; line & point 1:25,000 - VicMap Hydrology (Sep. 2003) *State-wide/Regional land data and mapping layers* - Public Land Management - current legal status of land 1:100,000 – plmmt100 (Sep. 2003) - Tree Cover - 1:25,000 - tree25 (June 2003) (2) SunRise21 Inc. 1:25,000 Irrigated Horticulture Dataset (Dec. 2003) (3) Valuer-General of Victoria (VGV) Shire Valuation Datasets (Dec. 2002). (4) Fieldwork carried out in November 2004 (5) Aerial Photography: - Irrigated Horticulture - 1:15,000 & 1:25,000 flown in February & March 2000 - Mallee Dryland Agriculture - 1:50,000 flown in March 2003 (6) Satellite Imagery: - Landsat 5 ETM - 30m Captured 20/09/2004 - Landsat 5 ETM - 30m Captured 27/08/2004 **Inputs and Processes - Draft Landuse Layer** *Classification by Shire:* The draft classification was first performed on each of the shires that made up the catchment. The VicMap digital cadastre of each shire was first clipped to the catchment boundary before the classification was undertaken. These clipped shires would eventually be merged to form the one whole dataset. *VGV Shire Valuation Dataset:* The first step in the draft classification process was to use the Land Classification Codes (LCC) that were surveyed by the Valuers for each Shire. The Valuers assign an LCC code to each Property Number (PROPNUM) of a Shire's Vicmap Property cadastre. Using these Property Numbers, the Valuer's Landuse Dataset could then be linked to the corresponding shire's Vicmap Digital Property Cadastre. A Lookup Table was created that assigned an ALUM Classification Code to each of the 265 LCC codes. This Lookup table was then linked to the digital cadastre to provide a base landuse dataset for each shire. As the Valuer's dataset also contained other relevant information pertaining to landuse, this helped with the classification of the anomalies that were present within the LCC Codes (Eg. LCC Code 666 = Mixed Use Farming). Information regarding landuse such as the amount of land that is dryland, irrigated, horticulture, cropping or grazing may also be provided within the dataset, which could then be used to assign an ALUM code to the property. It must be noted that the quality of this information varied from shire to shire. The product of this Valuer's information made up the base of the draft landuse dataset for each shire. *SunRISE 21 Inc. - 2003 Mallee Irrigated Horticulture:* After obtaining this dataset, ALUM codes were first assigned to entries in the CATEGORY field. With this information, the dataset was then intersected into the above draft landuse cadastre. *Public Land Management Layer:* The next step in the process was to classify the public land (i.e. Conservation and

		natural environments) within each shire. The latest 1:100,000 Public Land Management Layer from the CGDL (September 2003) was overlayed on the digital cadastre and an appropriate ALUM code was then assigned to each corresponding polygon. **Inputs and Processes - Final Landuse Layer** *Refinement of Draft Landuse Layer:* Building upon the Draft Landuse layer, cadastre parcels that remained unclassified or incorrectly classified in the intensive used areas of towns and irrigated horticulture were classified based upon aerial photography and satellite imagery. *Classification of Dryland Agriculture:* The software package Ecognition, in conjunction with the satellite imagery and fieldwork was used to produce a raster layer that identified cropped and grazed land within the Lower Murray. This process was then checked in the field to verify results and fix anomalies. *Implementation of Dryland Agriculture Raster Layer:* The refined landuse layer was converted to a raster layer so that the dryland agriculture and tree cover information could be incorporated. Then by utilising a methodology applied by Queensland DPI, the raster layer was converted back into a vector coverage format. This vector version was then further refined into a more traditional product to allow for better compatibility between other state's data. *Merging Datasets:* The completed landuse datasets of each shire were then merged together to produce the overall coverage of the catchment extent.
	Positional Accuracy	25 – 100 m
	Attribute Accuracy	The accuracy of the land use attributes has been determined through a validation procedure. Validation was carried out for each shire, shortly after the completion of the land use data layer. 50 random sample sites were generated for every 245,000Ha. The number of sample sites allocated to each land use was proportional to the area of each land use class in each validation area. Land uses at sample sites were recorded by independent observers. An error matrix was constructed for each validation area, comparing mapped land use to independently observed land use classes. The validation results produce an attribute accuracy of **??.?%**. **(Validation is still in progress)**
	Logical Consistency	***Data Collation*** Integration of existing datasets containing information relating to landuse including remotely sensed Landsat 5 ETM, aerial photography, DPI/DSE Corporate datasets including cadastre, public land, infrastructure and tree cover, VGV Shire Valuation Datasets and SunRise21 dataset. ***Interpretation*** This stage involved interpreting landuse, by assigning appropriate landuse codes to the source datasets and preparing draft landuse maps for verification and field checking. ***Verification*** Field verification of draft landuse maps included the annotation of field maps on the basis of expert advice and field checking. The primary focus of this activity was to capture agricultural landuse and incorporated extensive windscreen surveys, utilising mobile mapping technology and local knowledge of DPI/DSE and CMA staff. ***Final Editing*** Final editing was carried out using ArcGIS and Ecognition software (remote sensing interpretation) and incorporating field survey datasets, aerial photographic interpretation, and ancillary datasets prepared in Step 1.
	Completeness	Land Use has been mapped across the full extent of the study area down to a minimum secondary ALUM Version 5 level.
Contact Information	Contact Organisation	Department of Primary Industries, PIRVic - Tatura Centre

	Contact Position	Spatial Sciences Group
	Mail Address 1	Private Bag 1
	Mail Address 2	Ferguson Rd
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	State or Locality 2	Victoria
	Country	Australia
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	Telephone	5833 5293
	Facsimile	5833 5377
	Electronic Mail Address	GIS.Tatura@dpi.vic.gov.au
Metadata Date	Metadata Date	8th July 2005
Additional Metadata	Additional Metadata	DPI/DSE CGDL Catalogue, 17th Edition, September 2003.
Additional Information	Additional Information	Key Reference: Bureau of Rural Sciences (BRS), 2002, Land Use Mapping at Catchment Scale: Principles, Procedures and Definitions, Edition 2, February 2002, BRS Document, Canberra.
File Transfer Details	Files name(s) and size(s)	lm_lum94geo: 80.70 MB
	Number of Records	lm_lum94geo: 107404 (Dissolved version)
	File Format	Arc/Info
	Field Name Definitions	Main item: lu_code, lu_description, source_scale, source_date, source_desc, luc_date Look-up Tables: multiple_uses.lut, working_lucode_v5, source_lut Reliability definitions (source.lut): 1 = Field Mapping/Local Knowledge 2 = Ancillary Dataset 3 = Aerial Photography & VG Validation Dataset 4 = SPOT imagery and Landsat 5 ETM/TM 5 = Other
	Fields Names	Fields names in each file
	Update	Full or partial
	Date of Creation	June 2005

Metadata Statement: 1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin, Version 2

Category	Element	Description
Data set	Title	1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin, Version 2
Custodian	Custodian	Bureau of Rural Sciences
	Jurisdiction	Australia
Description	Abstract	The 1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin, Version 2, is a time series of land use maps of the Murray-Darling Basin for the years 1993, 1996, 1998 and 2000. Temporal variation is shown for agricultural land uses only. The non-agricultural land uses are based on existing digital maps. The agricultural land uses shown in each map are based on the Australian Bureau of Statistics' agricultural census or survey collection with appropriate reference period. The spatial distribution of agricultural land uses is interpretive and has been determined using AVHRR satellite imagery with ground control data. The maps are supplied as a set of ARC/INFO grids with geographical coordinates referred to WGS84 and 0.01 degree cell size. For each year there is a set of probability maps, one for each agricultural land use, and a single summary map showing the non-agricultural land uses and a likely arrangement of the agricultural land uses. The arrangement of agricultural land uses in the summary map was determined from the probability maps using some simple rules to make an approximation to a maximum likelihood land use map. As supplied the probability maps are floating point grids with cell value between 0 and 1 and no value attribute table while the summary map is an integer grid with a value attribute table with attributes defining the agricultural commodity group, irrigation status and land use according to the Australian Land Use and Management Classification (ALUMC), Version 4 (http://www.affa.gov.au).
	Search Word	AGRICULTURE, AGRICULTURE Crops, AGRICULTURE Horticulture, AGRICULTURE Irrigation, BOUNDARIES, BOUNDARIES Administrative, BOUNDARIES Biophysical, BOUNDARIES Cultural, FLORA, FLORA Exotic, FLORA Native, FORESTS, FORESTS Agroforestry, FORESTS Natural, FORESTS Plantation, HUMAN ENVIRONMENT, LAND, LAND Conservation, LAND Conservation Reserve, LAND Cover, LAND Ownership, LAND Use, VEGETATION, VEGETATION Structural, WATER, WATER Lakes, WATER Surface, WATER Wetlands
	Geographical Extent Name	
	GEN Category	
	GEN Custodial Jurisdiction	
	GEN Name	
	Geographical Extent Polygon	
	Geographic Bounding Box	
	North Bounding Latitude	-24.485
	South Bounding Latitude	-37.785
	East Bounding Longitude	152.585
	West Bounding Longitude	138.475

Data Currency	Beginning Date	1993-04
	Ending Date	2003-08
Dataset Status	Progress	Complete
	Maintenance & Update Frequency	As required
Access	Stored Data Format	DIGITAL ARC/INFO 8.2 under SunOS
	Available Format Type	DIGITAL - ARC/INFO raster
	Access Constraint	Access is unrestricted. There are two conditions of use: 1. Users of the data should acknowledge the following in any visual or published material: the data set was derived and compiled by the Bureau of Rural Sciences and land uses were derived using the Collaborative Australian Protected Areas Database 2000 (Dept of Environment and Heritage), TOPO-250K Version 1 (Geoscience Australia, Division of National Mapping), Australian Tenure and Forests of Australia 2003 (Bureau of Rural Sciences, National Forest Inventory), Normalised Difference Vegetation Index data (Dept of Environment and Heritage), agricultural census and survey data collected in 1994, 1997, 1999 and 2001 (Australian Bureau of Statistics) and control site data (compiled for the National Land and Water Resources Audit by NSW Agriculture, Victorian Dept of Natural Resources and Environment, Queensland Dept of Natural Resources and Mines, Primary Industries and Resources SA, Agriculture Western Australia, Tasmanian Dept of Primary Industries, Water and Environment and Northern Territory Dept of Lands, Planning and Environment). 2. Any errors, omissions or suggestions for improvement should be made known directly to BRS (by e-mail to dataman@brs.gov.au or by mail to the Data Manager, Bureau of Rural Sciences).
Data Quality	Lineage	I. The following existing digital maps were overlaid to determine the non-agricultural land uses and the distribution of agricultural land: 1. TOPO-250K (Version 1), 1:250,000 scale vector topographic data, published by Geoscience Australia, Division of National Mapping, February 1999 update. Line and point features were buffered prior to conversion to raster format. 2. Collaborative Australian Protected Areas Database (CAPAD 2000), 1:250,000 scale vector protected areas data, published by the Department for Environment and Heritage. 3. Australian Tenure, 250m raster tenure data, compiled by the Bureau of Rural Sciences, National Forest Inventory, in 1997. Information compiled by state and territory agencies in 1997 was used to classify aboriginal freehold and aboriginal leasehold land as agricultural or non-agricultural. 4. Forests of Australia 2003, 250m raster native and plantation forest data, compiled by the Bureau of Rural Sciences, National Forest Inventory, in 2003. II. The spatial distribution of specific agricultural land uses for each of the four years was determined using SPREAD II, a modified version of the SPREAD (SPatial REallocation of Aggregated Data) algorithm of Walker and Mallawaarachchi (1998). The method requires 3 inputs relating to a particular time period. These are a time sequence of NDVI images, a set of control sites (known location and agricultural land use) and agricultural census or survey data (reported on small regions and giving the area devoted to each agricultural land use). A computer program embodying an adaptation of SPREAD II was implemented by the Bureau of Rural Sciences. NDVI images were obtained from Advanced Very High Resolution Radiometer (AVHRR) data processed to correct for cloud cover by ERIN, Department for Environment and Heritage. Control site data were collected by State and Territory agencies. The irrigation status of most control sites is known and the method was used to determine the distribution, not only of commodity groups, but also of their irrigation status. Agricultural census and survey data reported on Statistical Local Areas (SLAs) were obtained from

		the Australian Bureau of Statistics. Modifications made to the agricultural census and survey data are documented in the Final Project Report. The SPREAD II methodology is statistically based, using a Bayesian technique - a Markov chain Monte Carlo (MCMC) algorithm. An irrigation area boundaries data set supplied by the Murray-Darling Basin Commission showing designated irrigation areas in the southern Murray-Darling Basin and actual irrigation areas in the northern Murray-Darling Basin was used to refine the prior probabilities used in the MCMC algorithm. The irrigation constraint was set so that 100% of irrigated land uses would fall within the designated irrigation areas (to the extent that the area inside the irrigation areas was sufficient to accommodate them). For each of the four years, SPREAD II generated outputs comprising the 42 probability maps described in the abstract and a summary agricultural land use map (which constitutes the agricultural component of the summary map described in the abstract). III. Land uses were assigned to pixels in the summary grids by using a macro to construct lookup tables which were then permanently joined to the value attribute tables of the summary grids. Non-agricultural land uses were assigned according to the attributes of the four layers overlaid in step I. Agricultural land uses were assigned according to the attributes of the summary agricultural land use map produced in step II. The land use classification used is the Australian Land Use Management Classification V4 (http://www.affa.gov.au).
	Positional Accuracy	The data type and stated positional accuracy of the major existing data sets used to determine the non-agricultural land uses and the distribution of agricultural land (as discussed in the lineage section) are as follows: CAPAD 2000 - vector data, spatial errors are in the range 1m to 500m. TOPO-250K (Version 1) - vector data, error less than 160m for at least 90% of well-defined points. Australian Tenure - 250m raster data, spatial errors, in the main, do not exceed 125m. Forests of Australia 2003 - 250m raster data; source data has variable pixel size ranging up to 500m. The input NDVI imagery and the output probability and summary grids have 0.01 degree pixel size. Therefore, the positional accuracy of the outputs is approximately 1 - 2 km.
	Attribute Accuracy	Non-agricultural land uses were assigned, initially, on the basis of existing data sets showing protected areas, tenure, forest type and topographic features. Specific agricultural land uses were then assigned by automated interpretation of NDVI images. Accuracy of assignments based on existing data sets depends mainly on the attribute accuracy of the underlying data sets but also on the validity of the rules used for land use assignment. The attribute accuracy of the underlying data sets has not been tested except for the topographic features data set (TOPO-250K, Version 1 of Geoscience Australia) for which the range of allowable attribute errors is from 0.5% to 5% at a 99% confidence level. However, the attribute accuracy of the other three underlying data sets is expected to be high, with consequent high accuracy in non-agricultural land use assignments. The accuracy of the specific agricultural land use allocations based on automated interpretation of NDVI images is variable. The probability grids give an indication of the accuracy of the agricultural land use allocations. The final report shows how attribute accuracy varies as a function of probability for certain agricultural land uses.
	Logical Consistency	The attribute combination corresponding to each land use assignment in the summary grid was tested by inspection to verify that these automated assignments were as intended and were logically consistent.
	Completeness	Coverage and classification are complete. Verification of spatial and attribute data is discussed in the final report. In brief, the grids constituting the 2000 map were compared against catchment scale land use mapping (CLUM) data currently being compiled by the Bureau of Rural Sciences (Bureau of Rural Sciences, 2002). This analysis was confined to 17 SLAs. The relationship between attribute accuracy and probability was established for various agricultural land uses and the extent of agreement on a pixel to pixel basis was also assessed. Difficulties with this approach include the fact that the currency of the CLUM data is variable, the fact that the CLUM land use categories do not align well with the commodity groups mapped by SPREAD II and the fact that the level of attribute detail in the CLUM data is variable. Analysis of spatial and attribute accuracy

		was supplemented using Landsat imagery for the year 2000.
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Metadata Date	Metadata Date	2004-06-11
Additional Metadata	Additional Metadata	Bureau of Rural Sciences, 2002, Land use mapping at catchment scale: principles, procedures and definitions, Edition 2, Bureau of Rural Sciences, Canberra. Bureau of Rural Sciences, 2004, Caveats: 1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin, Version 2. Bureau of Rural Sciences, 2004, Final Report: 1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin, Version 2. Bureau of Rural Sciences, 2004, User Guide: 1993, 1996, 1998 and 2000 Land Use of the Murray-Darling Basin, Version 2. Walker, P.A. & Mallawaarachchi, T. 1998, 'Disaggregating agricultural statistics using NOAA-AVHRR NDVI', Remote Sens. Environ., vol. 63, pp. 112-125.

APPENDIX 3: Land Use Summary Statistics

Catchment scale land use summary statistics

Note that these statistics have been clipped to the boundary of the Murray-Darling Basin Regional Scale land use data and therefore do not cover the entire region (see Figure 4 for extents).

Primary Land Use	Secondary Land Use	Tertiary land use	Area (sqkm)	% Total
1. Conservation and natural environments	1.1 Nature conservation	1.1.0 Nature conservation	16.4	0.01%
		1.1.1 Strict nature reserves	4,023.9	2.30%
		1.1.2 Wilderness area	6,060.8	3.47%
		1.1.3 National park	10,146.6	5.81%
		1.1.4 Natural feature protection	1,409.2	0.81%
		1.1.5 Habitat/species management area	62.2	0.04%
		1.1.7 Other conserved areas	3,214.7	1.84%
	TOTAL 1.1		**24,933.8**	**14.28%**
	1.2 Managed resource protection	1.2.0 Managed resource protection	20.2	0.01%
		1.2.4 Landscape	0.3	0.00%
		1.2.5 Traditional indigenous uses	50.4	0.03%
	TOTAL 1.2		**70.9**	**0.04%**
	1.3 Other minimal use	1.3.0 Other minimal use	486.7	0.28%
		1.3.1 Defence	46.7	0.03%
		1.3.2 Stock route	0.5	0.00%
		1.3.3 Remnant native cover	278.1	0.16%
		1.3.4 Rehabilitation	437.4	0.25%
	TOTAL 1.3		**1,249.4**	**0.72%**
2. Production from relatively natural environments	2.1 Grazing natural vegetation	2.1.0 Grazing natural vegetation	**81,091.3**	**46.44%**
	2.2 Production forestry	2.2.0 Production forestry	**3,587.5**	**2.05%**
3. Production from dryland agriculture and plantations	3.1 Plantation forestry	3.1.0 Plantation forestry	7.8	0.00%
		3.1.1 Hardwood production	1.3	0.00%
		3.1.2 Softwood production	3.3	0.00%
		3.1.3 Other forest production	4.2	0.00%
		3.1.4 Environmental	1.7	0.00%
	TOTAL 3.1		**18.3**	**0.01%**
	3.2 Grazing modified pastures	3.2.0 Grazing modified pastures	27,194.7	15.58%
		3.2.1 Native/exotic pasture mosaic	1,452.1	0.83%
		3.2.2 Woody fodder plants	12.1	0.01%
		3.2.3 Pasture legumes	16.4	0.01%
		3.2.4 Pasture legume/grass mixtures	73.6	0.04%
		3.2.5 Sown grasses	1.9	0.00%
	TOTAL 3.2		**28,750.8**	**16.47%**
	3.3 Cropping	3.3.0 Cropping	22,402.3	12.83%
		3.3.1 Cereals	5,165.1	2.96%
		3.3.3 Hay & silage	95.7	0.05%
		3.3.4 Oil seeds	349.5	0.20%
		3.3.6 Cotton	53.8	0.03%
		3.3.8 Legumes	26.3	0.02%
	TOTAL 3.3		**28,092.8**	**16.09%**
	3.4 Perennial horticulture	3.4.1 Tree fruits	0.1	0.00%
		3.4.2 Oleaginous fruits	0.2	0.00%
		3.4.3 Tree nuts	0.2	0.00%
	TOTAL 3.4		**0.5**	**0.00%**
4. Production from irrigated agriculture and plantations	4.1 Irrigated plantation forestry	4.1.0 Irrigated plantation forestry	1.3	0.00%
		4.1.1 Irrigated hardwood production	2.0	0.00%
		4.1.3 Irrigated other forest production	0.1	0.00%
		4.1.4 Irrigated environmental	0.5	0.00%
	TOTAL 4.1		**3.9**	**0.00%**
	4.2 Irrigated modified pastures	4.2.0 Irrigated modified pastures	40.5	0.02%
		4.2.2 Irrigated pasture legumes	5.8	0.00%
		4.2.3 Irrigated legume/grass mixtures	2.6	0.00%
		4.2.4 Irrigated sown grasses	112.1	0.06%
	TOTAL 4.2		**161.0**	**0.09%**
	4.3 Irrigated cropping	4.3.0 Irrigated cropping	187.8	0.11%
		4.3.1 Irrigated cereals	3.5	0.00%
		4.3.3 Irrigated hay & silage	20.3	0.01%
		4.3.4 Irrigated oil seeds	0.1	0.00%
		4.3.8 Irrigated legumes	0.2	0.00%
	TOTAL 4.3		**211.8**	**0.12%**
	4.4 Irrigated perennial horticulture	4.4.0 Irrigated perennial horticulture	277.4	0.16%
		4.4.1 Irrigated tree fruits	178.6	0.10%
		4.4.2 Irrigated oleaginous fruits	18.1	0.01%
		4.4.3 Irrigated tree nuts	69.6	0.04%
		4.4.4 Irrigated vine fruits	487.1	0.28%
		4.4.6 Irrigated flowers & bulbs	1.0	0.00%
		4.4.7 Irrigated vegetables & herbs	2.8	0.00%
	TOTAL 4.4		**1,034.4**	**0.59%**
	4.5 Irrigated seasonal horticulture	4.5.0 Irrigated seasonal horticulture	8.3	0.00%
		4.5.3 Irrigated flowers & bulbs	9.5	0.01%
		4.5.4 Irrigated vegetables & herbs	207.6	0.12%
	TOTAL 4.5		**225.4**	**0.13%**

Primary Land Use	Secondary Land Use	Tertiary land use	Area (sqkm)	% Total
5. Intensive uses	5.0 Intensive uses	5.0.0 Intensive uses	**73.9**	**0.04%**
	5.1 Intensive horticulture	5.1.0 Intensive horticulture	0.3	0.00%
		5.1.1 Shadehouses	0.5	0.00%
		5.1.2 Glasshouses	1.7	0.00%
	TOTAL 5.1		**2.5**	**0.00%**
	5.2 Intensive animal production	5.2.0 Intensive animal production	8.9	0.01%
		5.2.1 Dairy	2.2	0.00%
		5.2.2 Cattle	0.1	0.00%
		5.2.4 Poultry	11.4	0.01%
		5.2.5 Pigs	7.2	0.00%
		5.2.6 Aquaculture	0.4	0.00%
	TOTAL 5.2		**30.2**	**0.02%**
	5.3 Manufacturing and industrial	5.3.0 Manufacturing and industrial	**24.5**	**0.01%**
	5.4 Residential	5.4.0 Residential	0.7	0.00%
		5.4.1 Urban residential	117.9	0.07%
		5.4.2 Rural residential	239.0	0.14%
	TOTAL 5.4		**357.6**	**0.20%**
	5.5 Services	5.5.0 Services	0.8	0.00%
		5.5.1 Commercial services	19.8	0.01%
		5.5.2 Public services	32.2	0.02%
		5.5.3 Recreation and culture	108.0	0.06%
		5.5.5 Research facilities	2.4	0.00%
	TOTAL 5.5		**163.2**	**0.09%**
	5.6 Utilities	5.6.0 Utilities	28.2	0.02%
		5.6.1 Electricity generation/transmission	0.7	0.00%
	TOTAL 5.6		**28.9**	**0.02%**
	5.7 Transport and communication	5.7.0 Transport and communication	2.2	0.00%
		5.7.1 Airports/aerodromes	24.4	0.01%
		5.7.2 Roads	1,633.3	0.94%
		5.7.3 Railways	112.2	0.06%
		5.7.4 Ports and water transport	0.3	0.00%
		5.7.5 Navigation and communication	0.4	0.00%
	TOTAL 5.7		**1,772.8**	**1.02%**
	5.8 Mining	5.8.0 Mining	27.0	0.02%
		5.8.1 Mines	8.1	0.00%
		5.8.2 Quarries	81.6	0.05%
		5.8.3 Tailings	3.1	0.00%
	TOTAL 5.8		**119.7**	**0.07%**
	5.9 Waste treatment and disposal	5.9.0 Waste treatment and disposal	3.6	0.00%
		5.9.2 Landfill	0.8	0.00%
		5.9.3 Soild garbage	2.7	0.00%
		5.9.5 Sewage	8.4	0.00%
	TOTAL 5.9		**15.6**	**0.01%**
6. Water	6.1 Lake	6.1.0 Lake	439.3	0.25%
		6.1.1 Lake - conservation	515.0	0.29%
		6.1.2 Lake - production	593.8	0.34%
		6.1.3 Lake - intensive use	2.5	0.00%
	TOTAL 6.1		**1,550.6**	**0.89%**
	6.2 Reservoir/dam	6.2.0 Reservoir/dam	2.3	0.00%
		6.2.1 Water storage and treatment	35.1	0.02%
		6.2.2 Reservoir - intensive use	2.6	0.00%
		6.2.3 Evaporation basin	24.4	0.01%
		6.2.4 Effluent pond	0.4	0.00%
	TOTAL 6.2		**64.7**	**0.04%**
	6.3 River	6.3.0 River	232.7	0.13%
		6.3.3 River - intensive uses	173.0	0.10%
	TOTAL 6.3		**405.7**	**0.23%**
	6.4 Channel/aqueduct	6.4.0 Channel/aqueduct	23.4	0.01%
		6.4.1 Supply channel/aqueduct	9.0	0.01%
		6.4.2 Drainage channel/aqueduct	0.2	0.00%
	TOTAL 6.4		**32.7**	**0.02%**
	6.5 Marsh/wetland	6.5.0 Marsh/wetland	406.6	0.23%
		6.5.1 Marsh/wetland - conservation	25.1	0.01%
		6.5.2 Marsh/wetland - production	92.7	0.05%
		6.5.3 Marsh/wetland - intensive use	0.5	0.00%
	TOTAL 6.5		**524.9**	**0.30%**
No Data			**1.0**	**0.00%**
Total			**174,600**	**100.00%**

Regional scale land use summary statistics

Note that these statistics have been clipped to the boundary of the Catchment Scale land use data and therefore do not cover the entire region (see Figure 4 for extents).

Primary Land Use	Secondary Land Use	Tertiary land use	Area (sqkm)	% Total
1. Conservation and natural environments	1.1 Nature conservation	1.1.1 Strict nature reserves	5,795.8	3.32%
		1.1.2 Wilderness area	5,410.8	3.10%
		1.1.3 National park	7,914.9	4.53%
		1.1.4 Natural feature protection	100.4	0.06%
		1.1.5 Habitat/species management area	143.9	0.08%
		1.1.7 Other conserved areas	245.8	0.14%
	TOTAL 1.1		**19,611.5**	**11.23%**
	1.2 Managed resource protection	1.2.0 Managed resource protection	**1,056.3**	**0.61%**
	1.3 Other minimal use	1.3.0 Other minimal use	1,883.6	1.08%
		1.3.1 Defence	41.5	0.02%
		1.3.3 Remnant native cover	9,579.9	5.49%
	TOTAL 1.3		**11,505.0**	**6.59%**
2. Production from relatively natural environments	2.1 Grazing natural vegetation	2.1.0 Grazing natural vegetation	**96,558.8**	**55.30%**
	2.2 Production forestry	2.2.0 Production forestry	**3,993.4**	**2.29%**
3. Production from dryland agriculture and plantations	3.1 Plantation forestry	3.1.0 Plantation forestry	**36.1**	**0.02%**
	3.2 Grazing modified pastures	3.2.0 Grazing modified pastures	**10,322.8**	**5.91%**
	3.3 Cropping	3.3.0 Cropping	42.7	0.02%
		3.3.1 Cereals	21,101.4	12.09%
		3.3.3 Hay & silage	29.0	0.02%
		3.3.4 Oil seeds	1,169.3	0.67%
		3.3.8 Legumes	2,862.5	1.64%
	TOTAL 3.3		**25,205.0**	**14.44%**
	3.4 Perennial horticulture	3.4.1 Tree fruits	27.4	0.02%
		3.4.3 Tree nuts	5.1	0.00%
		3.4.4 Vine fruits	32.7	0.02%
	TOTAL 3.4		**65.2**	**0.04%**
4. Production from irrigated agriculture and plantations	4.2 Irrigated modified pastures	4.2.0 Irrigated modified pastures	**205.8**	0.12%
	4.3 Irrigated cropping	4.3.0 Irrigated cropping	12.1	0.01%
		4.3.1 Irrigated cereals	22.4	0.01%
		4.3.4 Irrigated oil seeds	1.0	0.00%
		4.3.8 Irrigated legumes	1.0	0.00%
	TOTAL 4.3		**242.2**	**0.14%**
	4.4 Irrigated perennial horticulture	4.4.1 Irrigated tree fruits	180.5	0.10%
		4.4.3 Irrigated tree nuts	72.2	0.04%
		4.4.4 Irrigated vine fruits	538.6	0.31%
	TOTAL 4.4		**791.3**	**0.45%**
	4.5 Irrigated seasonal horticulture	4.5.4 Irrigated vegetables & herbs	**102.6**	**0.06%**
5. Intensive uses	5.0 Intensive uses	5.0.0 Intensive uses	**223.8**	**0.13%**
	5.4 Residential	5.4.1 Urban residential	**56.5**	**0.03%**
	5.7 Transport and communication	5.7.1 Airports/aerodromes	**24.1**	**0.01%**
6. Water	6.1 Lake	6.1.0 Lake	3,405.7	1.95%
		6.1.1 Lake - conservation	1,138.3	0.65%
	TOTAL 6.1		**4,544.0**	**2.60%**
	6.2 Reservoir/dam	6.2.0 Reservoir/dam	**42.5**	**0.02%**
	6.3 River	6.3.0 River	25.5	0.01%
		6.3.1 River - conservation	14.5	0.01%
	TOTAL 6.3		**40.0**	**0.02%**
	6.5 Marsh/wetland	6.5.0 Marsh/wetland	117.5	0.07%
		6.5.1 Marsh/wetland - conservation	13.1	0.01%
	TOTAL 6.5		**130.6**	**0.07%**
No Data			**48.7**	**0.03%**
Total			**174,600**	**100.00%**

APPENDIX 4: New South Wales State Report

NSW Report: Projects detecting land use change in the Lower Murray Darling

(Supplied to BRS as part of contract requirement and contribution to Tri-State project report)

Change detection analysis:

Some of the objectives of the project set to explore what methods were already in place to monitor and detect change in the main land use/land management issues in the LMD area. Those identified were:

- vegetation clearing,
- land use after clearing,
- reservation for conservation,
- dryland cropping, and
- irrigated horticulture

The NSW partners in this project were to report on the first three with BRS reporting on the latter.

Much of the land in the NSW LMD catchment in Crown leasehold and license holders require a permit or special license to undertake activities such as clearing, cropping or irrigation. Consequently data for these land use activities is collected and maintained for reporting needs.

Vegetation clearing in the LMD

Introduction to analysis – method

Clearing of native vegetation in the LMD is detected and monitored under the administration of compliance with NSW legislation. Information relating to clearing application and approvals in NSW is systematically entered and maintained in a DIPNR (Department of Infrastructure Planning and Natural Resources) State "Vegnet" database. However it does not track actual clearing or incorporate data on illegal clearing which has been significant at times. This associated operating system has a range of set queries used for reporting. One of them is on the basis of catchment.

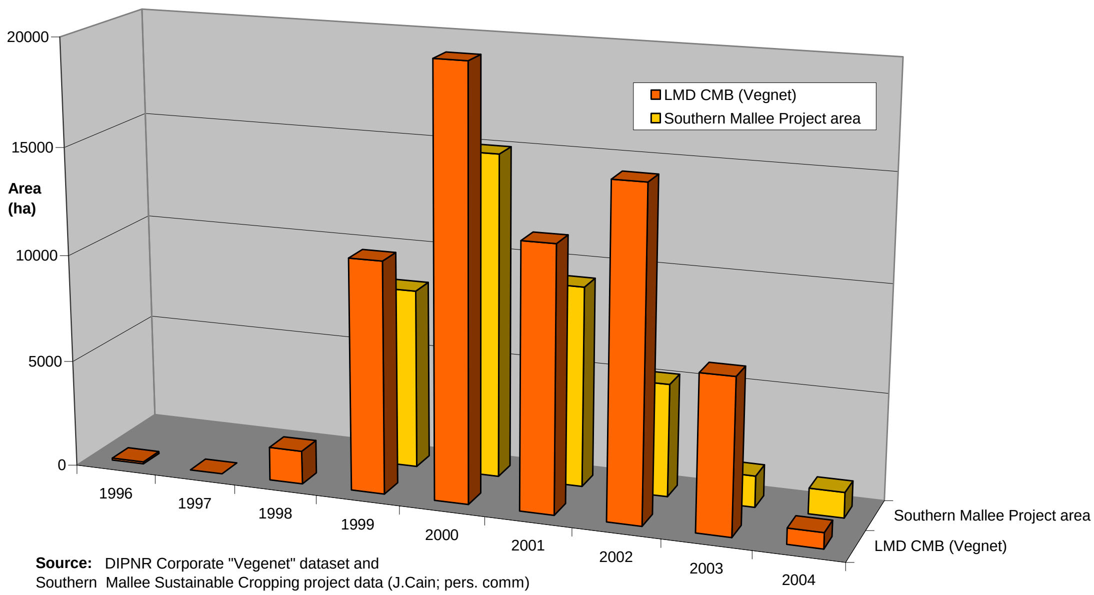
The DIPNR Vegnet dataset was used to obtain information for clearing applications approved in the LMD catchment area, by calender years between 1996 to the date of the query (October 2004).

Change over time – histograms of vegetation clearance

A plot of the DIPNR Vegenet clearing permit data is shown in Figure 1.

This data set was verified against local data held by the DIPNR Buronga office associated with the "Southern Mallee Sustainable Farming Project" (see Figure 1). It should be noted both these datasets identify areas approved for clearing, not the areas actually cleared, and that landholders have up to 25 years to undertake the clearing after approval.

Figure 1 : Clearing approvals 1996 to date: LMD catchment and Southern Mallee project area (NSW)



Source: DIPNR Corporate "Vegenet" dataset and Southern Mallee Sustainable Cropping project data (J.Cain; pers. comm)

Trends and rates of change in the data are obvious. Only approvals for small areas were occurring prior to 1999 (less than 100 ha/annually). Over the following four years (1999-2002) approvals for clearing averaged almost 15,000 ha annually. This has recently reduced to an expected 2,000 ha in 2004, mainly due to clearing applications over 500 ha being required to provide a higher level of information and more demanding assessment. With the end of the Southern Mallee Sustainable Farming Project, apparently clearing applications over 500 ha will not be accepted (K. Markotis, pers. comm).

Possible reasons for change

Over the last decade or so in Australia the marginal return for sheep grazing has been deteriorating. Conversely, with new technologies, marginal returns for cropping have become more favourable and potentially viable in traditionally considered marginal areas. Consequently there has been strong interest in cropping from graziers. Initially this was in the form of opportunistic lakebed cropping utlilizing flooding from the Darling Anabranch system and the treeless lakebeds.

The reasons for the rapid increase in clearing approvals between 1998 and 2003 has been primary due to a policy change, and the establishment of the "Southern Mallee Sustainable Farming Project". This allowed authorised clearing on leasehold land, if it was compensated for with reservation of suitable areas of native vegetation as a biodiversity trade.

Limiting factors and needs

A process is in place to administer applications to clear native vegetation. The main additions required to accurately determine changes in native vegetation due to clearing are:

- data for actual clearing, rather than the approved amounts for clearing open into the future,
- data for illegal (no application/approval) to be included as part of the database, and

- support of the corporate vegetation clearing dataset to ensure data capture and access is ongoing for many years, particularly when some native vegetation responsibilities transfer to CMA's.

These could be facilitated by communicating information back to stakeholders and decision makers on a regular basis. For example, presentation in the annual relevant annual reports, AGM's, and regional forums.

Reservation for conservation

Introduction to analysis – method

The project was to document trends in native vegetation reservation. Areas of native vegetation can be reserved for conservation in several ways. These include gazetted/formal agreement, such as:

- National Park,
- State Forest,
- Nature Reserves,
- private conservation agreements with DIPNR.

Others areas managed primarily for vegetation conservation are less formal and ungazetted including:

- private park/research reserves,
- indigenous lands,
- elapsed wildlife reserves,
- landcare activities,
- landholder private management activities.

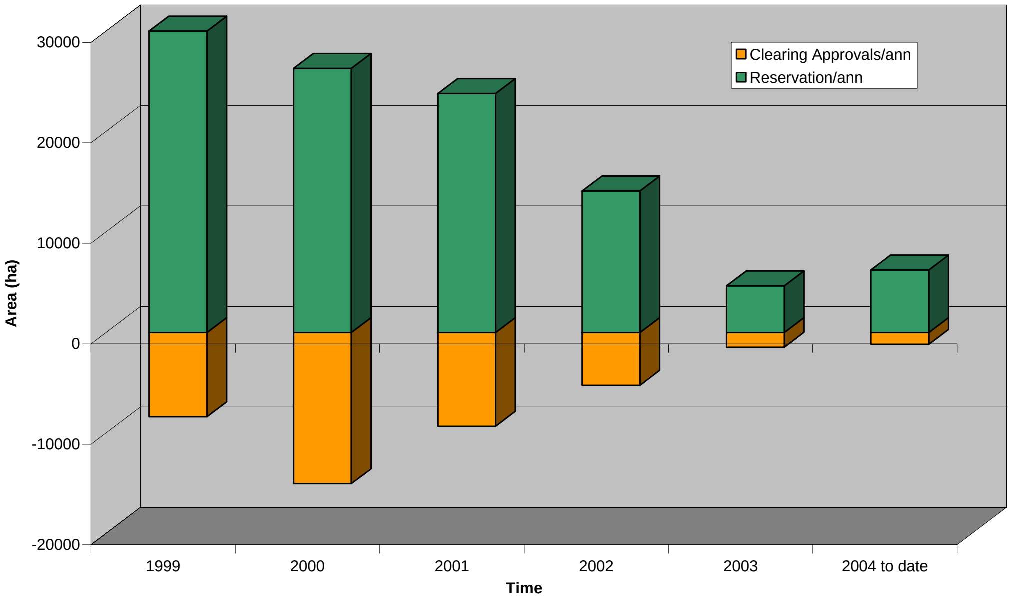
In the NSW LMD area processes are in place and datasets exist for the gazetted/formal reserved areas and DIPNR office maintained information on indigenous reserves and private conservation agreements. The rest are either not documented or collated in any systematic way.

Change over time – histograms of reservation

Despite several approaches to the appropriate Agencies we have not been able to obtain any data on gazetted reserves apart from the conservation agreements. Lands under Indigenous ownership and managed primarily for conservation uses have not been formally reserved.

Consequently, we have used the "Private Conservation agreements (17.11.2004), as the surrogate for land reservation in this area as this is expected to be the dominant force. Figure 2 shows the private conservation agreements associated with the Southern Mallee Sustainable Farming Project area (Wentworth and Balranald Shires). It also shows the areas cleared which the agreements are to compensate.

Figure 2: Clearing and Reservation Approvals in the NSW Southern Mallee Project area: 1999 to date



Source: Southern Mallee Sustainable Mallee Project (J. Cain; pers. comm)

The project has "reserved" over 100,000 ha of native vegetation to compensate for approximately 40,000 ha of clearing. The ratio has generally been over 2.5:1; reservation:clearing, respectively, but this has apparently been falling on most properties in recent time, only kept up by some one-off large reservations (J.Cain; pers. comm).

Three properties have been purposed and under indigenous management for primarily conservation, but have not reserved to date.

Limiting factors and needs

Clearly it would be desirable to have better access to State Forest and National Parks reservation data. The Southern Mallee Farming Project has kept good records to show the results of its "reservation" activities. A similar system needs to be maintained in the future with the transition to CMA responsibility for these activities.

Land use after clearing (native vegetation)

Introduction to analysis – method

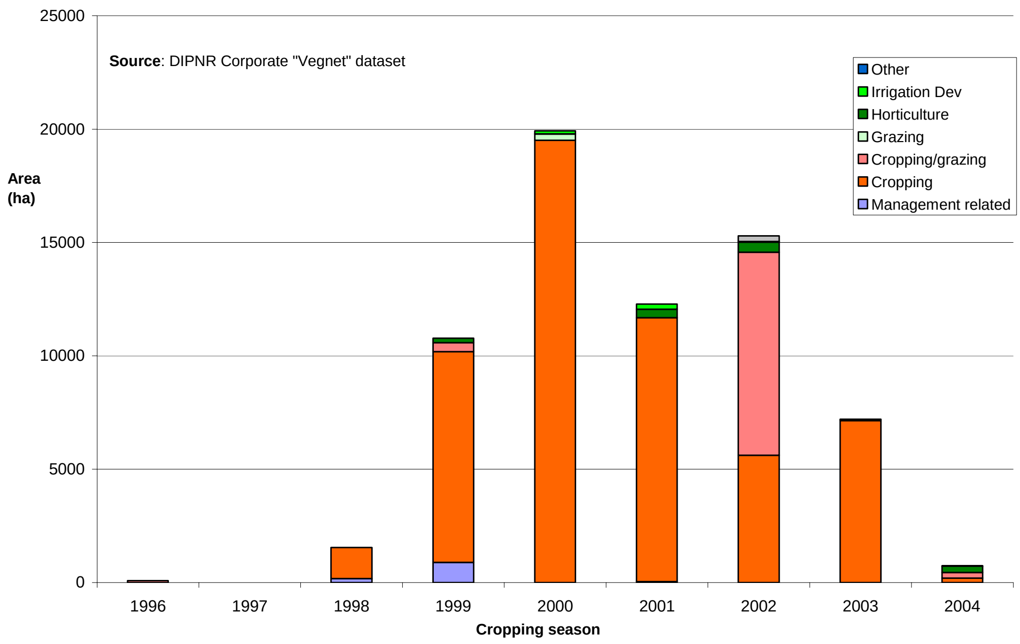
Documentation relating to applications to clear native vegetation (maintained on the DIPNR Vegnet system) also record the proposed land use for each application. The Vegnet dataset was used to obtain information on the proposed purpose for approved clearing applications. This was grouped into calendar years for the period from 1996 to the date of the query (October, 2004).

Change over time – histograms of purpose for clearing

Plots of the Vegnet "purpose for clearing" data for the NSW LMD catchment are shown in Figure 3. By far the majority has been nominated as cropping, with the remainder being relatively constant at around 2-300 ha for each purpose/annum.

Limiting factors and needs

Figure 3: Proposed land use for clearing approval areas in the NSW LMD (ha)



The data was easy to access and in this case showed a strong trend. Speaking to officers who complete the forms revealed that the general data could be improved by more clarity in definitions. For example the "cropping" v's "cropping/grazing" classes (see 2002 data in Figure 3).

Dryland cropping

Introduction to analysis – method

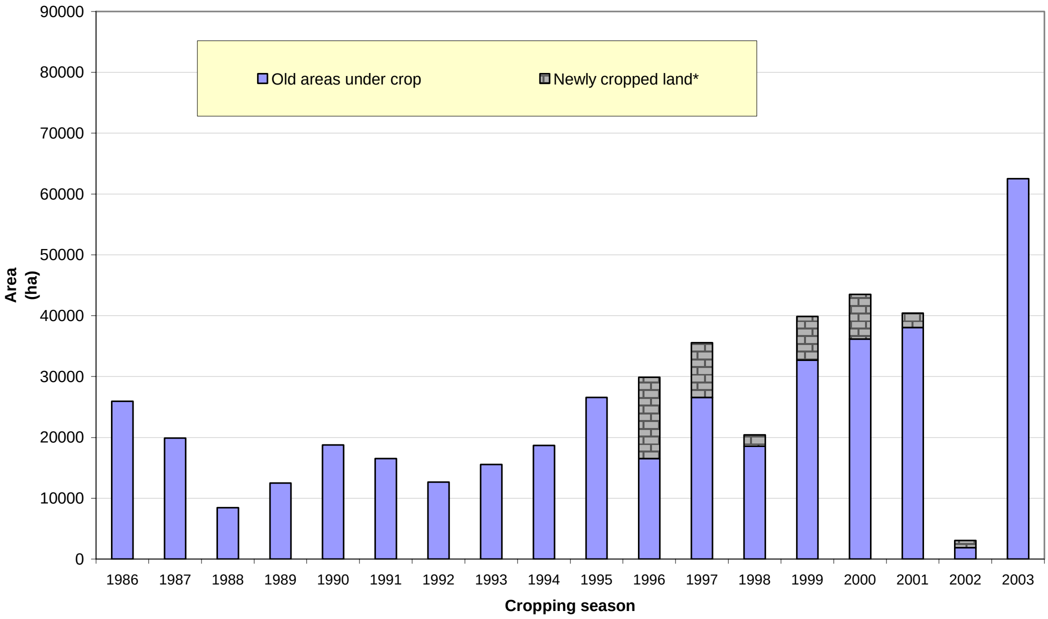
Much of the land in the NSW LMD catchment is Crown leasehold and licensees require a special license to commence cropping. Information relating to cropping application and approvals is systematically entered and maintained by Western Lands and DIPNR compliance project staff. However this does not necessarily mean this land is cropped nor does this process collect information on when or how often land is cropped.

Spatial and temporal data for cropping in the NSW LMD area is collected as part of the RAMS (Resource Assessment and Monitoring System) project. RAMS is an ongoing project associated with Western Lands compliance monitoring, but has other useful side benefits. It has been continually operating since 1986 using a similar methodology. Using (October) satellite imagery and vehicle transects it annually accurately maps the spatial extent of seasonal cropping across much of the Western Lands area. The project area was expanded in about 2000 prior to which only one (1) Landsat image was assessed. The only limitation being paddocks that have been grazed out or where crops have failed by October, are likely not to be identified on the imagery. If they have been recultivated before field-ckecking is undertaken they are definitely missed.

Change over time – histograms of cropping

Figure 4 shows the RAMS data for areas cropped in the NSW LMD Landsat assessment image area between 1986 and 2003. It also shows the component that was new land being cropped for the first time (from 1995 to 2002 only). Please be aware these figures are not the complete LMD area. For the purpose of showing trends only the figures for the initial single scene have been presented.

Figure 4: Dryland cropping in the LMD CMA area (ha) (Source: RAMS project)



At the start of the project, we were aware that 2002 had been a bad cropping season, and local staff recommended the project use Year 2000 data for dryland cropping rather than 2002, the date of the base imagery. However the RAMS value for 2002 seemed dramatically low. When queried, it was found that the RAMS methodology is based on October imagery and hence is vulnerable to seasons with major crop failures (eg 2002). It was measuring the successful crops that made it through to harvest and had missed the areas that had been grazed off, or simply failed because of the poor season. As fieldwork is undertaken post harvest, some areas may also be missed if they have been cultivated or prickle chained between harvest and ground truthing (A. Colbran and D. Gee; pers. comm).

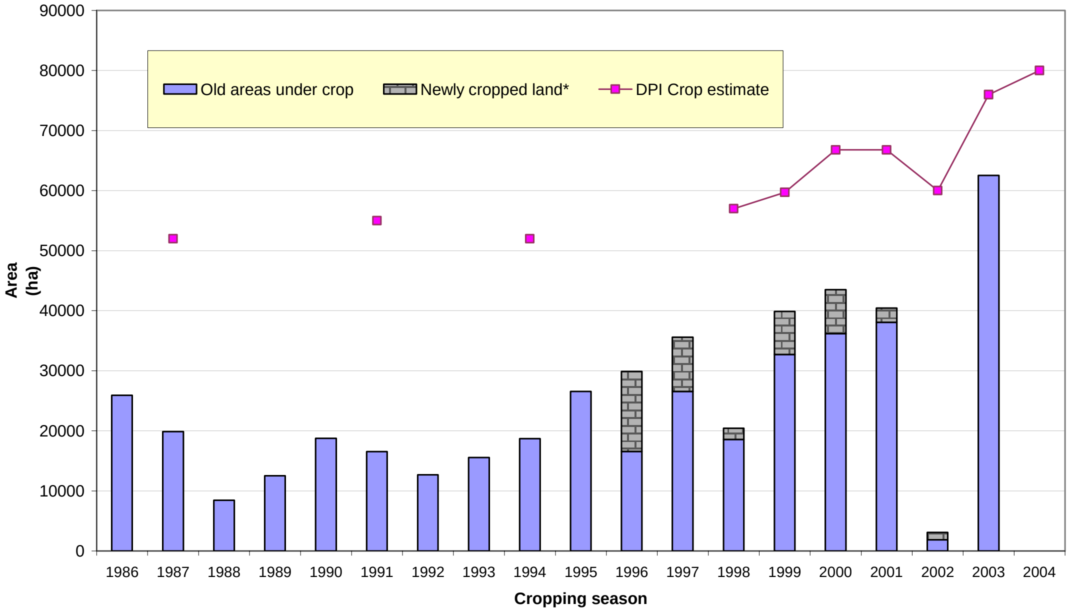
To fill this data gap local knowledge was sought. Across the cropping belt of NSW each year Government District Agronomists provide an estimate for the amount of land cropped and the average yields in their district. These figure were requested and supplied by the Dareton DPI office for an area thought to be fairly close to LMD CMA study area (see Figure 5). Local field staff have been aware of anomalies between these figures and RAMS data for some time. Apart from the DPI figures being "guesstimates" (G.McIntosh, pers. comm), there is variation in the boundaries, and DPI include freehold tenure. These differences aside, from Figure 5 we can see:

- a steady increase in the area in the area being prepared for crop/cropped,
- relatively large amounts of new land being brought into cropping (approximately 42,000 ha) providing a much larger land bank of cropping land in the LMD CMA area than 10 years ago.
- a massive crop failure in 2002, (and probably to some extent also in 1998),

- a further big increase in the cropping area in 2003 (following the failed cropping season), and a further estimated increase the following year, 2004 (no RAMS data available as yet).

DIPNR has recently supplied data from our land use mapping project to assist collating a figure for the total area cleared and available for cropping.

Figure 5: Dryland cropping in the LMD CMA area (ha)



Possible reasons for change

The changing economics of grazing and cropping was mentioned above under section 1.1: Vegetation clearing. Initially cropping occurred in the lakebeds, without the need for tree clearing, and utilising external contractors and sharefarmers. In more recent times these lakes have not had water and large areas of mallee country have been cleared and developed as the basis for enterprises on their own right on many properties. Furthermore landholders have invested in machinery committing them to cropping for a number of years.

The Southern Mallee Sustainable Farming Project has facilitated a large increase in the bank of land available to be cropped. Landholders have invested and inplemented best management practices and moved from rotational cropping with periods of long fallow, to short rotations with back to back cropping or continuous cropping (McIntosh; pers. comm). So not only is more land no being cropped but it is apparently being cropped more intensely.

Limiting factors and needs

A process is in place to annually monitor cropping across the Western Lands area. Other estimates are being made by DPI and these are available back to the 1930's. RAMS is a very good project but analysis for our particular purpose has shown a significant flaw. The main additions required to accurately determine the areas cropped each year are:

- need to map the area sown to crop, rather than the areas of successful cereal grain crops, to account for heavy grazing and crops failures,

- project needs to be better resourced, so it can report more timely to stakeholders and data users,
- an analysis of the frequency of cropping could prove valuable, perhaps linked to site specific yield data.

With the increase in cropping activity the RAMS project has been strained and been barely able to meet its objective requirements with the resources available. Relevant CMA's need to ensure support for this project. These could be facilitated by information feeding back to CMA's and other land management decision makers on a regular basis. For example, presentation in the annual relevant annual reports, AGM's, and regional forums.

Stuart Lucas

22 April 2005

I wish to acknowledge the wide range of support provided which has assisted the preparation of this brief. This includes:

- numerous staff from the Buronga DIPNR office, but particularly James Val, Jacinta Cain, Bill Tapnell and David Gee
- Graeme McIntosh, DPI Dareton office
- RAMS project staff , Dubbo DIPNR office.

APPENDIX 5: South Australia Report

Government of South Australia

Department of Water, Land and Biodiversity Conservation

SOUTH AUSTRALIAN REPORT

LAND USE DATA INTEGRATION CASE STUDY
- LOWER MURRAY NAP REGION –

REPORT FOR:

BUREAU OF RURAL SCIENCES

AUSTRALIAN GOVERNMENT DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

SANDRA KEANE

GIS OFFICER

SOIL AND LAND INFORMATION

KNOWLEDGE AND INFORMATION

DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

MARCH 2005

1. IRRIGATION LAND USE DATA INTEGRATION

Previous land use mapping exercises in the Lower Murray NAP region have been '2003 Murray Darling Basin Land Use' and '2002 South East Land Use'. When the 2003 MDB land use was undertaken, due to financial and time restrictions, a lot of the intensive horticultural areas were only mapped to the secondary level of the Australian Land Use and Management (ALUM) classification, and not to the tertiary level like the rest of the project area. For this project, we have been given the opportunity to update the MDB land use with high detailed irrigation mapping (Baseline Information 2002/03) organised by the River Murray Catchment Water Management Board (RMCWMB) and collected by River Murray Local Action Planning Project Officers (spatial data maintained by Department for Environment and Heritage (DEH), SA). This data was collected from landholder surveys and boundaries obtained from 1:2 000 aerial photographs. Land management information was also obtained, but is not accessible for this project.

DEH Crop Type	Used in Data Integration	ALUM v5 Conversion
Berries	✓	4.4.5
Citrus	✓	4.4.1
Fruit	✓	4.4.1
Miscellaneous	×	NA
Miscellaneous Agriculture	×	NA
Mixed Crop	×	NA
Not Surveyed	×	NA
Nuts	✓	4.4.3
Other	×	NA
Pasture	✓	4.2.4
Pomefruit	✓	4.4.1
Stonefruit	✓	4.4.1
Tree Mix	✓	4.4.1
Tropical Fruit	✓	4.4.1
Unknown	×	NA
Vacant Horticulture	×	NA
Vacant Non-Productive	×	NA
Vegetables	✓	4.5.4
Vines	✓	4.4.4
Wood Lot	✓	4.1.3

Figure 1 : DEH irrigation data

As seen in Figure 1, not all the crop types are used for this project. This is because their definitions are too broad and may cover multiple secondary ALUM classes, resulting in degradation of the data. The crop types that were used were converted to ALUM version 5 tertiary classes.

The Murray Darling Basin Land Use and South East Land Use were unioned together in ArcMap to create a land use dataset for the NAP region. The Baseline data was unioned onto the combined land use to improve the detail of the land use classes as well as improve the spatial accuracy of the land use boundaries. Some changes made after the union were:

1. Where data from the two datasets overlapped, the more detailed (tertiary level) and spatially accurate baseline data overwrote the underlying land use dataset class and polygon boundaries. However, where the Baseline codes = '4.2.4', the underlying land use polygon, if it was labelled with '4.3.3' or '4.2.2' was used. This was done as the '4.2.4' class in the Baseline data included both pastures and hay/silage classes, as opposed to being separated in the land use dataset.
2. If polygons from the Baseline data looked as if they were meant to line up with the polygons of the land use data, the lines in the final dataset were adjusted to the more spatially accurate Baseline boundaries.
3. Where more spatially accurate data was in the Baseline dataset, such as vineyards where individual blocks were mapped, any areas classified in the land use data that were not mapped to the baseline boundaries were re-labelled with the general classes of '3.2.0' or 1.3.0'. This represented farm infrastructure/roads.
4. Where the Baseline boundaries overlaid roads/railways classes from the combined land use dataset, the roads and railways codes were used in the final dataset.

2. CHANGE DETECTION

A. RESERVATION & CONSERVATION DATA

Spatial data available for this part of the project was Vegetation Heritage Agreement Areas and National Parks and Wildlife Services SA Reserves (maintained by Department for Environment and Heritage (DEH), South Australia).

i. VEGETATION HERITAGE AGREEMENT AREAS

“The Heritage Agreement Scheme has been in operation since 1980. It was introduced because of concern about over-clearance of bushland in the agricultural region of the State, the Heritage Agreement Scheme and over 1,200 Heritage Agreement landholders have ensured the long-term protection of over 565,000 ha of the State's original vegetation. The Heritage Agreement Scheme is a program to encourage and assist landholders to conserve native vegetation on their properties. A 'Heritage Agreement' is a contract between a landholder and the State Government for the protection in perpetuity of a particular area of native vegetation. In signing the Agreement the landowner becomes eligible to receive financial assistance for the management of the land, a rate rebate on the Heritage Agreement land and fencing assistance if required”.

Source: ‘Ecosystem Conservation: Conserving Biodiversity - The Heritage Agreement Scheme’.
http://www.environment.sa.gov.au/biodiversity/heritage_education.html

The statewide cover of Vegetation Heritage Agreement Areas was clipped to the NAP boundary. The dataset contains polygons for each Heritage Agreement and any additional blocks that are contained under each Agreement. There is a date of establishment for when a new Agreement was signed but not when each unique block was established and added to the Agreement. The dates therefore may over-estimate the date of protection of vegetation in South Australia, and would only be accurate for the block that is defined as the first if there are multiple blocks.

No. of Blocks	No. of Agreements
1	193
2	72
3	54
4	15
5	4
7	5
8	1
14	1
16	1

Figure 2 : Number of multiple blocks in Heritage Agreements.

As shown in Figure 2, multiple blocks are contained in some Heritage Agreements. In summary, 193 Agreements have only one block and 153 Agreements have more than one block. The dates of the Agreements are from 1982-2001, and there is one Agreement that does not have a date available and will be excluded from any further calculations.

Figure 3 shows a chart of each year of Agreement approvals for the years 1982-2001 with the sum of hectares per year, differentiating between the area for single block and multiple blocks Agreements. It can be seen that the distribution of single and multiple blocks vary over the years. If we look at single block Agreements, which are the most accurate of dates to conservation, there was an increase in Agreements between 1988 and 1995, with the biggest area of conservation in 2000. The increase in Agreements between 1988 and 1995 can also be seen with the inclusion of multiple block Agreements.

Year of Agreement	Number of Single Block Agreements
1982	3
1983	4
1984	3
1985	1
1986	5
1987	6
1988	15
1989	13

1990	24
1991	24
1992	21
1993	25
1994	18
1995	7
1996	3
1997	2
1998	1
1999	9
2000	4
2001	4

Figure 4 : Number of single blocks in Heritage Agreements for 1982-2001.

Figure 4 shows the number of single block Agreements for 1982-2001. This explains the reasons for the increase in hectares during 1988-1995, as there were more Agreements signed during this time. It also shows that in 2000, when the hectares covered by Agreements was almost double the second highest hectares figure, it was not due to there being a lot of Agreements signed that year, but to one or more of the Agreements covering an extensive area.

ii. NATIONAL PARKS AND WILDLIFE SERVICES SA RESERVES

"Formal protection of a proportion of structural groups and plant communities appears to have occurred by default, rather than by design, in that many NPWSA parks were deemed to have limited economic value for agricultural or pastoral purposes and their dedication was seen as a land management strategy rather than a biodiversity conservation issue. This is clearly the means whereby a number of the large mallee NPWSA parks were gazetted in the SA MDB.

Only recently has the need for a comprehensive, adequate and representative reserve system (CARRS) been highlighted. Through this system the acquisition of land with threatened or unrepresented plant communities has become targeted and strategic. Future land acquisition in the SA MDB can be undertaken through the CARRS approach, using the information in this plan as a basis for decision making"

Source: Kahrimanis, MJ, Carruthers, S., Opperman, A and Inns, R (2001) *Biodiversity Plan for the South Australian Murray-Darling Basin.* Department for Environment and Heritage, South Australia.

The statewide cover of National Parks and Wildlife Services SA Reserves was clipped to the NAP boundary. The dataset contains polygons for areas gazetted under the *NPWS Act*. The categories and number of each Park contained in the clipped data are:

- Conservation Parks (34) - Areas that are protected for the purpose of conserving wildlife or the natural or historic features of the land.
- Conservation Reserves (1) - Land currently set aside for conservation of natural and cultural features under the *Crown Lands Act 1929*.
- Game Reserves (5) - Areas set aside for the conservation of wildlife and the management of game for seasonal hunting.
- National Parks (2) - Areas considered to be of national significance due to wildlife, natural features of the land or Aboriginal or European heritage.
- Recreation Park (1) - Areas managed for public recreation and enjoyment in a natural setting.
- Regional Reserves (1) - Areas proclaimed for the purpose of conserving wildlife or natural or historical features while allowing responsible use of the area's natural resources.

Source: 'Parks & Reserves - Park Categories'.
http://www.environment.sa.gov.au/parks/parks.html

Examining the data, three parks (Chowilla Game Reserve, Poonthie Ruwi-Riverdale Conservation Park and Coorong National Park) do not have a date attached, so will not be included in further analysis. Figure 5 shows the areas gazetted to Parks under the *NPWS Act*. From DEH records, the first area gazetted to Park was in 1940 and the most recent was in 1993. There are 15 other years between these two dates when Parks were gazetted. There is more than 1 Park gazetted for some years. For most years, less than 10,000 hectares were gazetted to Parks. Comparing the Parks data to the Heritage Agreement data, there are only 4 years (1983, 1985, 1986 and 1993) that overlap.

The hectare data from the NPWS SA Reserves data will be added to the Heritage Agreement hectare data to determine the area of reservation/conservation between 1983 and 2001. This data will be compared to the clearance data to see the trends in clearance and conservation for an approximate 20 year period.

- There are other ways that native vegetation can be conserved/protected that is not included under Heritage Agreements or gazetted Parks.
- "There are a number of privately owned sanctuaries dedicated to conserving biodiversity within the SA MDB. For example, Moorundie Wildlife Sanctuary near Swan Reach and the Yookamurra Sanctuary near Sedan. These types of conservation reserves are important for Regional biodiversity conservation as they can provide important habitat for a diversity of plants, animals and ecosystem types. They are not listed under any acts.
- Forestry SA manages a few areas of native vegetation in the SA MDB under the *Forestry Act 1950*. Some Forestry SA reserves contain significant populations of plant and animal species, and plant species of high conservation significance at the State and Regional level.
- Significant portions of native vegetation in the SA MDB occur on Crown Land under the care of Local Government (eg. Cemetery reserves, water reserves, stone reserves, parklands surrounding surveyed towns). These areas often contain rare and threatened plant communities and species. Councils are

responsible for the management of the native vegetation in these reserves. These areas are covered by the *Crown Lands Act 1929"*.

Source: Kahrimanis, MJ, Carruthers, S., Opperman, A and Inns, R (2001) *Biodiversity Plan for the South Australian Murray-Darling Basin.* Department for Environment and Heritage, South Australia.

B. NATIVE VEGETATION CLEARANCE DATA

"In the agricultural region, extensive areas of native vegetation were cleared for farming purposes before the introduction of the *Native Vegetation Management Act* in 1985. Today there is a total of 1,191,000ha or 28% native vegetation cover remaining in the agricultural region of which 42% is formally protected."

Source: Kahrimanis, MJ, Carruthers, S., Opperman, A and Inns, R (2001) *Biodiversity Plan for the South Australian Murray-Darling Basin.* Department for Environment and Heritage, South Australia.

Data available for this part of the project, in the form of an Excel spreadsheet, was obtained from the Native Vegetation Database, Native Vegetation Group, Department of Water, Land and Biodiversity Conservation (DWLBC), South Australia.

The vegetation clearance database had tabular data extracted for the Councils in the Lower Murray NAP. No spatial data (shapefiles/coverages) exist. Relevant fields in the tables were:

- Category description : the reason for the clearance application, i.e. the resultant land use.
- CI_decision_date : Date of whether the application was approved or rejected;
- Councils current : Council areas the applications are in.
- Decision : Conditional consent & Consent – consent based on inspections to check what vegetation is to be cleared, how is revegetation going to be managed, making sure planning approvals are obtained, water licences obtained for central pivot irrigation; Deferred; Exempt; Invalid; No decision made; Not stated/unknown; Partial consent (conditional) & Partial consent – consent to some clearance with conditions but refusal to clearance of other parts of the vegetation; Refused and Withdrawn.
- Area consent (bush): Hectares of bush consented to clearance.
- Area conditional consent (bush): Hectares of bush conditionally consented to clearance.
- Area consent (trees): Hectares of trees consented to clearance.
- Area conditional consent (trees): Hectares of trees conditionally consented to clearance.

From this list, the only data that is suitable for using are Conditional consent, Consent, Partial consent (conditional) and Partial consent. For each of these decision types, the areas of clearance are divided into a combination of the 4 area consent types for either areas of bush or areas of trees. However some landholders have not actually cleared the native vegetation yet, so some applications have no values against them. There were 90 records where the application date was listed but had no decision date, even though the applications were consented. The applications date was used for analysis as most decisions are made within a few months of the applications being received. The reasons for the clearance application will be analysed even though the clearance may not have yet occurred. The dates available for the clearance data were 1983 to 2004. It is important to note that the landholders have 5 years after the application approval to undertake the clearing so the data may misrepresent the actual year of clearance.

Reasons for Clearance Application	Grouping for Analysis	Area (ha)
Brush cutting	Brush cutting	88918
Clearing for research purposes	Clearing for research purposes	86
Farm management - Farm broadacre	Farm management	90328
Farm management - Salinity reveg	Farm management	834
Farm management - Unknown use	Farm management	1565
Farm management – Weed control	Farm management	354
Fire - Fire hazard reduction	Fire - Fire hazard reduction	105
Grazing - Increased Intensity	Grazing - Increased Intensity	36
Irrigation – Horticulture	Irrigation	2225
Irrigation – Pasture	Irrigation	0.4
Irrigation - Unknown use	Irrigation	15228
Miscellaneous development	Miscellaneous develop	3697
Miscellaneous development - Airstrip	Miscellaneous develop	641
Miscellaneous development - Access tracks	Miscellaneous develop	44
Miscellaneous development - Cut flowers, eucalypt oil, seed collection	Miscellaneous develop	508
Miscellaneous development - Drain maintenance	Miscellaneous develop	3
Miscellaneous development - House site/Farm buildings	Miscellaneous develop	1020
Miscellaneous development - River reeds	Miscellaneous develop	16
Miscellaneous development - Scattered trees	Miscellaneous develop	710
Miscellaneous development - Telecommunications/Power	Miscellaneous develop	1200
Miscellaneous development - Weed control	Miscellaneous develop	303
Not specified/Unknown	Not specified/Unknown	38811
Orchard - Fruit	Orchard - Fruit	294
Roadside - Maintenance	Roadside	117
Roadside - New roads	Roadside	12
Roadside - Realignment/safety	Roadside	8760
Vineyards	Vineyards	6183
Woodcutting	Woodcutting	40962

Figure 6 : Reasons for vegetation clearance and the hectares cleared with re-grouping of reasons into general groups for the analysis.

Figure 6 shows the list of reasons that are used on the clearance applications, grouped broadly into land management, agriculture crops and farm infrastructure. Figure 7 is a graphic display of the total hectares per year cleared and the distributions of the reasons for the clearance. Clearance rates vary from less than 1,000 hectares to around 34,000 hectares. The most common reasons are brush cutting, not specified/unknown, woodcutting and farm management. These tended to be the most common reasons for the first 10 years of approvals. The least common reasons are vineyards, orchards - fruit, grazing, fire - fire hazard reduction and clearing for research purposes. Since 1994, there is a greater mixture of reasons each year with less of the forestry based uses, plus less hectares have been cleared every year.

Reasons for the decrease in clearance from the early 1990s is the tougher restrictions in the *Native Vegetation Act 1991 (SA)*, which may have prevented a lot of applications from being approved. Trends in the changes of land use types is uncertain, such as whether agroforestry has made it easier to obtain wood for wood cutting and brush cutting and since *The Development Act (SA) 1993* developments have had to seek approval for native vegetation clearance. The *Native Vegetation (Miscellaneous) Amendment Act 2002* (the Amendment Act) was passed by the South Australian Parliament in November 2002. The Amendment Act amends the *Native Vegetation Act 1991* to formally end broadacre clearance in the State. This will lead to lower amounts of approvals to current and future applications.

Figure 8 shows the comparison of clearing of native vegetation with reservation of native vegetation (Heritage Agreements and gazetted Parks) for the years of 1983 to 2001. From 1983-1987 a lot of clearance occurred with little native vegetation being put to conservation. From 1988-1995, with the exception of Parks in 1993 (3 Parks were gazetted that year), the amount of clearance was counter-balanced with an equal amount of conservation. From 1996 there are no trends in clearance versus conservation.

C. DRYLAND CROPPING DATA

Data used was Australian Bureau of Statistics (ABS) AgStats made available from the Bureau of Rural Sciences (BRS). Dryland cropping land use data (in hectares) were extracted from the 1996 Concorded AgStats database for 1996 SLAs within the Lower Murray NAP region. There are two SLAs that are not completely contained within the Lower Murray NAP, however the dryland cropping extents of these SLAs do fall into the NAP boundary and they will be used in analysis. The selection of commodities was based on those that fell under ALUM v5 3.3.0 codes in the *Land Use Mapping at Catchment Scale: Principles, Procedures and Definitions, Edition 2*, pages 41-44.

		FINANCIAL YEAR										
CROP TYPE	ALUM v5	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
All cereals for other purposes	3.3.0	-	✓	✓	✓	-	-	-	-	-	-	✓
Barley for grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Cereal rye for grain	3.3.1	✓	✓	✓	✓	-	-	-	-	-	-	-
Grain sorghum	3.3.1	-	✓	-	-	-	-	-	-	-	-	-
Oats for grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Triticale for grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Wheat for grain	3.3.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Cereals cut for hay	3.3.3	-	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Crops (excl cereals) for hay	3.3.3	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Crops feed off or silage	3.3.3	✓	✓	✓	✓	-	-	-	-	-	-	-
Lucerne (pure)	3.3.3	✓	✓	✓	✓	-	✓	✓	-	-	-	✓
Canola	3.3.4	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Mustard seed	3.3.4	-	-	✓	-	-	-	-	-	-	-	-
Linseed - Linola	3.3.4	-	-	✓	-	-	-	-	-	-	-	-
Safflower	3.3.4	-	✓	✓	✓	✓	✓	✓	-	-	-	✓
Sunflower	3.3.4	-	-	✓	✓	·	✓	✓	-	-	-	·
Chick peas	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Field peas for grain	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Lentils	3.3.8	✓	✓	✓	✓	-	-	-	-	-	-	-
Lupins for grain	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓
Vetches for seed	3.3.8	✓	✓	✓	✓	✓	✓	✓	-	-	-	✓

Figure 9 : Dryland Cropping data available for South Australian Lower Murray NAP SLA (Statistical Local Area). The dates ticked are those years data is present. (Adapted from table received from Jodie Smith, BRS)

Figure 9 shows the availability and frequency of crop data. For the years 1997-1998 and 1998-1999 there is only data for Wheat, and for 1999-2000 there is limited data for most crops. Figure 10 shows the total hectares for each of the ALUM secondary classes. All secondary classes were a lot smaller or had values of zero during 1997-1998 and 1998-1999. Besides for '3.3.1 Cereals' there are no real trends seen due to unavailability of continuous data. The only individual crop type that has all its data available is Wheat (see Figure 11). From 1990-1991 to 2000-2001 there has been an overall increasing gain of 75% from 200,000 to 350,000 hectares.

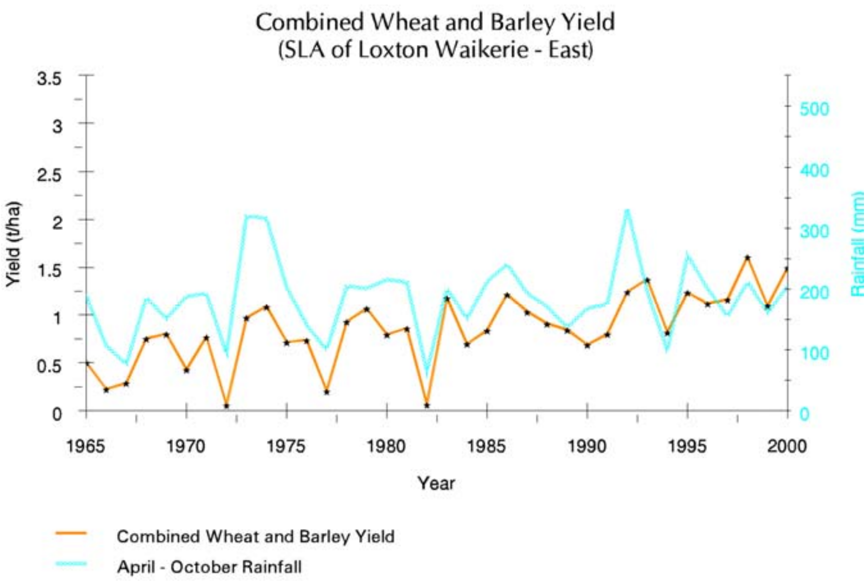


Figure 12 : Mean combined Wheat and Barley yield for the Loxton Waikerie – East SLA (1998 SLA boundary) (1996 SLA boundaries of Browns Well and Loxton), calculated from production data provided by the ABS agricultural census.

Source: A selected set developed by DWLBC Land Condition Monitoring. McCord and Payne (2005) "Report on the Condition of Agricultural Land in South Australia".

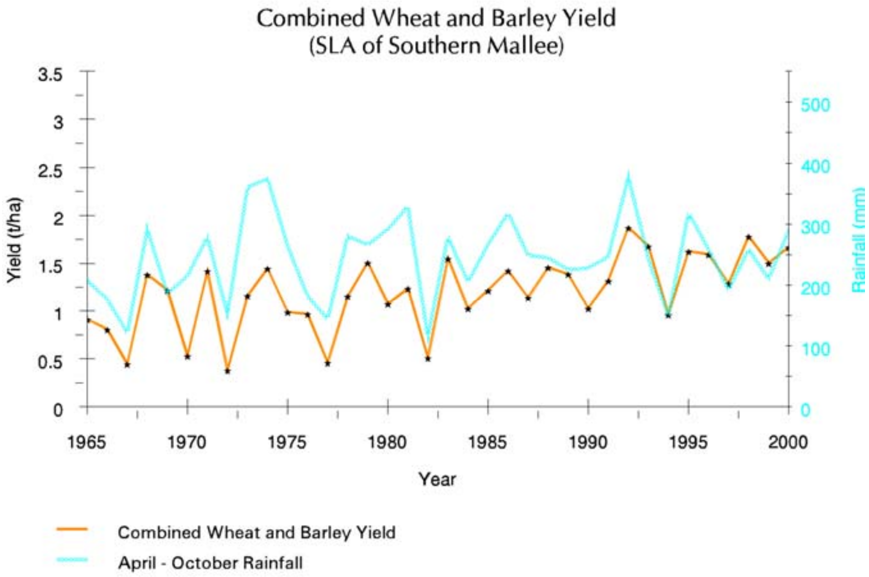


Figure 13 : Mean combined Wheat and Barley yield for the Southern Mallee SLA (1998 SLA boundary) (1996 SLA boundaries of Pinnaroo and Lameroo), calculated from production data provided by the ABS agricultural census.
Source: A selected set developed by DWLBC Land Condition Monitoring. McCord and Payne (2005) "Report on the Condition of Agricultural Land in South Australia".

Figure 12 and 13 shows yield (tonnes/hectare) of combined Wheat and Barley for 1965-2000 for two SLAs. These show yield compared to mid-year rainfall. For both SLAs there is a general increase in yield from 1965 to 2000. There are some years where yields decreased, but that was when rainfall was lower during drought years. Comparing this data to Figure 11, the increase in hectares of Wheat has coincided with an increase in the quantity of the Wheat produced.

3. DATA LIMITATIONS

A. IRRIGATION DATA

The major issue with data access for this project was with the Baseline Irrigation 02-03 data, which was used to update the combined 2002-2003 DWLBC Land Use dataset. It took a lot of negotiation with DEH and the LAP Officers to be granted permission to access this data. They were fearful that crop variety/rootstock data might be released and accessed by other landholders in the region for financial gain. It had to be enforced that the level of data required for this project could be gathered from driving along roadsides. Once it was confirmed that the data to the ALUM tertiary level was required, access was granted.

Data access permission forms were signed by each landholder allowing different levels of access to different Government departments. There may be some irrigation polygons that were not included in the provided dataset, as those landholders agreed to have their property information used only for annual reporting purposes. Due to problems accessing this data, BRS Land Use Mapping has been added to the 'Information Release Permit'. Landholders will identify what level of data DWLBC Land Use Mapping will be allowed to access from future irrigation surveys, such as crop type spatial data (see Figure 14). Levels of access on the form vary from district to irrigation and drainage information.

B. Reservation and Conservation Data

A limitation with the Heritage Agreement Area data is that the dates of additional blocks after the signing of the Agreement for the first block are not available. If 5 blocks were added to an Agreement over a 10 year period, they would all be dated the same year as the first block.

A limitation with the Parks data is that there were dates missing for three Parks. These Parks cover a combined area of 58,000 hectares. Data, either spatial or areal, for the other types of ways native vegetation is conserved (*Forestry Act 1950*, *Crown Lands Act 1929*, private sanctuaries) is unavailable.

C. Native Vegetation Clearance Data

A limitation to the clearance data is that there was no spatial data available. The Native Vegetation Group only started using GIS 2 years ago. A lot of the records did not have the area of native vegetation cleared, even though the application may have been over 20 years old. The graphs produced may not give an accurate representation of clearance hectares.

D. Dryland Cropping

Data for this analysis was not available from any State agencies. Most people use AgStats on a regional basis to report on cropping patterns. Cropping extents could have been mapped from aerial photography/satellite imagery, but consecutive years of images were unavailable, plus it would have been very time consuming to undertake this task. The AgStats data would have been more useful if crop data for all years were available.

4. Irrigation Data Collected By Agencies

A. RMCWMB / LAP

The data used in this project (Baseline Irrigation 02-03) was collected by the RMCWMB on behalf of the LAP Groups and in collaboration with DWLBC and DEH. They undertake a detailed survey of land use including crop types, varieties, rootstocks and more, as well as water supply information such as irrigation type (over head sprinkler, micro-jets), scheduling methods, use of soil moisture monitoring, etc (see Figure 15). Crop boundaries were digitised from aerial photographs. The landholders surveyed were private diverters. The data is collected for a range of purposes including:

- To assist on farm management (aerial photo property plans are delivered as an output);
- To assist local action and regional planning, eg education courses;
- To facilitate annual reporting under the Water Allocation Plan to DWLBC, including Water Use Efficiency calculations; and
- To provide an annual snapshot of the regional status of the irrigation industry for state and national datasets such as BRS.

The LAP groups are custodians of the databases, and any requests for data must go through them (via the RMCWMB). Individual growers can grant or deny access to their data, this is done through a permissions matrix that records which agencies can have access to what degrees of detail from the data for each irrigator, eg a state/regional data set only require crop type information and not the full array of detail to rootstock. The area was re-surveyed in 2003-2004 to only those landholders who had added new crops or removed existing crops. The survey will occur on an annual basis. The mapping work will be undertaken by a Riverland Resource Information Centre, which will open later this year.

Crop and Water Inventory 2003/2004

The following information represents the crops and irrigation systems that were present on your property from 1 July 2003 through to the 30 June 2004.

**Denotes mandatory information*

PROPERTY INFORMATION

*District:

*PropertyID:

PATCH INFORMATION						
*PatchID:						
*Grower Reference:						
*Ground Cover:						
CROP INFORMATION	Crop 1	Crop 1	Crop 1	Crop 1	Crop 1	Crop 1
*Crop Type:						
*Crop Category:						
*Crop Variety:						
*Crop Rootstock:						
*Year Planted:						
*Crop Use:						
Tree/Row Count:						
Rework Year						
WATER INFORMATION						
*Private Licence:						
*Meter Number (1):						
*Meter Number (2):						
*Drained:	Yes No	Yes No	Yes No	Yes No	Yes No	Yes No
Irrigation Systems (#)						
*System Type:						
*System Use:						
*Year Installed:						
Drainage System:						
Drainage Disposal:						
Drainage Hazard Type:						
Scheduling Method(s):						
SWM Devices-Installed:						
SWM Devices-Used:						
IDMP:	Yes No	Yes No	Yes No	Yes No	Yes No	Yes No
Number of Test Wells:						
Pumped:	Yes No	Yes No	Yes No	Yes No	Yes No	Yes No

Figure 15 : Information collected during RMCWMB crop surveys.

B. CENTRAL IRRIGATION TRUST

The Central Irrigation Trust (CIT) in Barmera collects the same information at the RMCWMB and LAP Officers for Water Use Efficiency calculations and reporting. The CIT manages 9 districts including the Riverland and Mypolonga with 1600 growers covering 13,000 hectares of horticultural properties. They supply River Murray water to parks/ovals, domestic users and irrigation users.

They undertook initial mapping in 2002, digitising from aerial photographs followed by detailed/landholder surveys, collecting the same management information as the LAP Officers. In following years they sent maps to landholders to see if there were any changes, but did not get a good response from the landholders. They now plan to obtain 2005 aerial photography and re-survey 20% of the landholders each year for the next 5 years. There is also the Renmark Irrigation Trust (RIT) who is also part of this mapping program. They map the irrigation around the Renmark township. They follow a similar procedure as the LAP Officers and CIT.

The CIT will only release collated data on a district basis due to the privacy of the information, see Figure 16:

CROPS and TYPES of IRRIGATION SYSTEMS in CIT districts

The following tables show the areas of crops in hectares (Ha) and the type of irrigation systems in use in 2003/04

	Berri		Cadell		Chaffey		Cobdogla		Kingston		Loxton		Moorook		Mypolonga		Waikerie		Total	
Crops	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Vines	2,638	81%	57	18%	787	71%	2,717	84%	131	72%	2,000	62%	238	65%	76	21%	944	54%	**9,590**	**69%**
Citrus	309	9%	98	30%	112	10%	64	2%	31	17%	586	18%	95	26%	162	44%	598	34%	**2,054**	**15%**
Stonefruit	158	5%	103	32%	101	9%	71	2%	6	3%	43	1%	23	6%	84	23%	100	6%	**688**	**5%**
Pasture	25	1%	11	3%	49	4%	91	3%	0	0%	101	3%	0	0%	36	10%	2	0%	**316**	**2%**
Pome fruit	4	0%	30	9%	3	0%	3	0%	0	0%	59	2%	0	0%	0	0%	9	1%	**108**	**1%**
Vegetables	12	0%	6	2%	7	1%	116	4%		0%	21	1%	7	2%		0%	9	1%	**177**	**1%**
Nuts	9	0%	1	0%	48	4%	2	0%	0	0%	105	3%		0%		0%	13	1%	**177**	**1%**
Tropical fruit	1	0%	0	0%		0%	2	0%	5	3%	1	0%		0%	0	0%	21	1%	**30**	**0%**
Other (e.g. Berries, Wood Lot)	77	2%	8	2%	2	0%	36	1%	1	0%	193	6%	1	0%	10	3%	44	2%	**371**	**3%**
Vacant (unplanted)	28	1%	12	4%	6	1%	149	5%	8	4%	94	3%	3	1%	1	0%	14	1%	**313**	**2%**
Total area	**3,259**	**100%**	**326**	**100%**	**1,115**	**100%**	**3,250**	**100%**	**182**	**100%**	**3,203**	**100%**	**368**	**100%**	**368**	**100%**	**1,753**	**100%**	**13,824**	**100%**

Irrigation System	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Under canopy	1315	40%	271	83%	487	44%	959	30%	112	62%	1188.09	37%	245	67%	248	67%	1013	58%	**5,839**	**42%**
Overhead	1253	38%	35	11%	36	3%	1682	52%	27	15%	1018.68	32%	35	9%	45	12%	251	14%	**4,382**	**32%**
Drip	352	11%	6	2%	466	42%	159	5%	35	19%	606.01	19%	61	17%	57	15%	192	11%	**1,934**	**14%**
Flood/furrow	210	6%	4	1%	111	10%	274	8%	2	1%	113.57	4%	9	2%	3	1%	15	1%	**741**	**5%**
Microsprinkler	62	2%	9	3%	1	0%	54	2%	6	3%	12.85	0%	13	4%	13	3%	274	16%	**444**	**3%**
Multiple systems	49	1%			13	1%	51	2%			23.6	1%	5	1%			3	0%	**143**	**1%**
Other (e.g. hose)	18	1%			2	0%	71	2%			240.37	8%			3	1%	7	0%	**340**	**2%**
Total area	**3,259**	**100%**	**326**	**100%**	**1,115**	**100%**	**3,250**	**100%**	**182**	**100%**	**3,203**	**100%**	**368**	**100%**	**368**	**100%**	**1,753**	**100%**	**13,824**	**100%**

Note
Loxton data excludes Century Orchards.

Figure 16 : Data available from the CIT.

APPENDIX 6: Land Use/Vegetation Profile Sources

This Appendix gives more detailed information on the data sources for the land use/vegetation Lower Murray NAP region profile and considerations that need to be taken into account when viewing the data.

Note that these profiles are simple representations of a limited number of social, economic and environmental attributes and represent a snapshot in time.

NAP region

There are 21 National Action Plan for Salinity and Water Quality (NAP) regions identified across Australia. For more information: http://www.napswq.gov.au/priority-regions.html.

Population (2001)

Australian Bureau of Statistics 2001 Census of Population and Housing; concorded to NAP regions by BRS.

Annual average percentage change

The average annual rate of growth is calculated from the *Australian Bureau of Statistics 1996 & the 2001, Census of Population and Housing*; concorded to NAP regions by BRS.

Major Towns

The major town population figures are derived from the *Australian Bureau of Statistics 2001 Census of Population and Housing.*

Spatial locations for the major towns were derived from *Geoscience Australia, GEODATA TOPO-250K.*

Area

Area figures have been derived from the *National Land and Water Audit, 1996/97 Land Use of Australia, Version 2* and rounded to the nearest 10 km^2. This dataset was used so that the area value matched that of the value in the land use area and agricultural production table.

BOM Climate Zones

The Bureau of Meteorology Australian climate zones are based on the Köppen classification system. (http://www.bom.gov.au/climate/environ/other/aus_clim_zones.shtml)

Land use area

Land use areas and percentages were derived from the *National Land and Water Audit, 1996/97 Land Use of Australia, Version 2*. Land uses have been grouped into the following classes:

- Nature conservation
- Other protected areas including indigenous uses
- Minimal use (such as defence, stock route, remnant vegetation)
- Grazing natural vegetation
- Production forestry
- Plantation forestry
- Grazing modified pastures
- Dryland cropping
- Dryland horticulture
- Irrigated pastures and cropping
- Irrigated horticulture
- Urban intensive uses
- Water
- Unclassified

Land uses are assigned based on the primary land use at the time of mapping (1996/97) and do not take into account multiple uses.

See http://www.daff.gov.au/corporate_docs/publications/pdf/rural_science/lms/brr5_rept.pdf for further details on how the 1996/97 Land Use of Australia map was created.

Agricultural revenue

Agricultural revenue is derived from *CSIRO 1996/97 National 1km Grid of Agricultural Profit Surfaces*. The production of this dataset involved the integration of land use data with ABS production data for all major agricultural activities. Detailed information on methods can be found in

Hajkowicz, S. A. and M.D. Young (eds) 2002. *Value of returns to land and water costs of degradation*, A consultancy report to the National Land and Water Resources Audit, CSIRO Land and Water, Canberra.

As the revenue grid created by CSIRO did not contain the same land use codes as used in the 1996/97 Land Use of Australia dataset, these two grids were combined spatially. Revenue values ($/ha) were then totalled for each of the land use classes and converted to gross revenue ($) and gross revenue per square kilometre ($\$/km^2$) for the financial year 1996-1997.

The CSIRO revenue grid only provides data for agricultural activities (commodities) and therefore does not have information on revenue generated from conservation areas, forestry or urban intensive uses. Revenue data for these classes would give a better indication of land use returns for each NAP region but was unavailable during production of these profiles. It is hoped that more information will become available when the profiles are next updated.

Vegetation (and land use)

Derived from the Bureau of Rural Sciences Integrated Vegetation Cover, (2003) and National Land and Water Audit, 1996/97 Land Use of Australia, Version 2.

APPENDIX 7: Water Balance Methodology

The Water 2010 water balance model calculates modelled outputs using the following steady-state water balance equation:

$$\frac{dW}{dt} = 0 = P - E_{act} - R_{surf} - DD$$

Where P = effective precipitation, E_{act}= actual evapotranspiration, R_{surf} = surface runoff, and DD = deep drainage. Further information on the water balance equation can be found in Raupach *et al*, 2001.

It can be seen that in order to alter runoff when precipitation remains constant, evapotranspiration or deep drainage must be modified. Deep drainage is generally a relatively small component of the water balance equation, suggesting that evapotranspiration has the most significant influence on the calculated runoff value. This also suggests that the significant errors in estimated runoff, identified during the model validation process, are most likely the result of inaccurate modelled actual evapotranspiration outputs. As the model is consistently overestimating runoff, it appears that actual evapotranspiration is generally being underestimated.

Unfortunately, there is currently limited observed data available to validate modelled evapotranspiration, but as this data becomes available, validation could be performed in the future to test this hypothesis.

Actual evapotranspiration has been calculated within the model using the following equation:

$$e = \left[\frac{p^{\alpha}}{1 + p^{\alpha}}\right]^{\frac{1}{\alpha}}$$

Where $e = \frac{E}{E_{PT}}$ and $p = \frac{P}{E_{PT}}$

And E represents actual evapotranspiration, E_{PT} represents potential evapotranspiration, and P represents effective precipitation.

The value of α describes the influence of land use on actual evapotranspiration. Zhang *et al* (1999) have determined three values for α. For pasture, α = 1.50, for mixed vegetation α = 1.64, and for forest α = 2.48.

Within the Water 2010 model, gridded national land use data have been categorised into 12 land uses. Individual α values have been estimated for these different land uses, ranging from 0.5 to 2.75, based on soil rooting depth and the α values determined by Zhang *et al* (1999).

References

Annett S. 2003. *Victorian agriculture 1904-2000: land use change or transition?* Proceedings of the Conference on Rural Land Use Change, Department of Sustainability and Environment: Victoria.

Australian Government Departments of Agriculture, Fisheries and Forestry and the Environment and Heritage (DAFF/DEH), April 2004. *National Action Plan for Salinity and Water Quality Annual Report 2002-2003,* Australian Government: Canberra.

Bryan B., Marvanek, S. 2004. *Quantifying and valuing land use change for Integrated Catchment Management evaluation in the Murray-Darling Basin 1996/97 – 2000/01: Stage 2 Report to the Murray-Darling Basin Commission*. CSIRO Land and Water Client Report: Adelaide.

Bureau of Rural Sciences 2002. *Land use mapping at catchment scales: Edition 2.* Agriculture, Fisheries and Forestry – Australia: Canberra.

Bureau of Rural Sciences 2004. *Land Use Mapping for the Murray-Darling Basin: 1993, 1996, 1998, 200 maps.* Department of Agriculture, Fisheries and Forestry: Canberra.

Cardille, J. A., Foley, J.A. 2003. Agricultural land-use in Brazilian Amazonia between 1980 and 1995: Evidence from integrated satellite and census data. *Remote Sensing of Environment,* 87(4): 551-562.

DIPNR (NSW Department of Infrastructure, Planning and Natural Resources) 2005 unpublished. *LMD land use report (NSW).*

Keane, S. 2005 unpublished. *South Australian Report: Land Use Data Integration Case Study – Lower Murray NAP Region, Report for Bureau of Rural Sciences.* South Australia Department of Water, Land and Biodiversity Conservation, Adelaide.

Flavel, R., Ratcliff, C. 2000. *Mount Lofty Ranges Implementation Project: Evaluating Regional Change.* Primary Industries and Resources South Australia: Adelaide.

Haines-Young, R., Watkins, C. 1996. The rural data infrastructure. *Geographical Information Systems,* 10(1): 26-46.

Hajkowicz, S. A., Youn, M. D. (eds) 2002. *Value of Returns to Land and Water and Costs of Degrasation,* A consultancy report to the National Land and Water Resources Audit, CSIRO Land and Water: Canberra.

Lambin, E.F., Geist, H.J. 2001. Global land-use and cover change: What have we learned so far? *Global Change Newsletter,* 46: 27-30.

National Land & Water Resources Audit (NLWRA). August 2001. *Land Use Change, Productivity and Diversification: Final Report of Theme 5.1 to the National Land & Water Resources Audit.* Commonwealth of Australia: Canberra.

McIntosh, G. (DPI Dareton office) 2005. pers. comm. As reported to Stuart Lucas at Albury DIPNR.

Miles, M. 2004. pers comm. Unpublished data held by the South Australian Department for Environment and Heritage, Environmental Information Branch: Adelaide.

Müller D., Zeller M. 2002. Land use dynamics in the central highlands of Vietnam: a spatial model combining village survey data with satellite imagery interpretation. *Agricultural Economics*, 27(3): 333-354.

Pavón, D., Ventura, M., Ribas, A., Serra, P., Sauri, D., Breton F. 2003. Land use change and socio-environmental conflict in the Alt Emporda county (Catalonia, Spain). *Journal of Arid Environments*, 54(3): 543-542.

Raupach, M.R., Kirby, J.M., Barrett, D.J., Briggs, P.R., Lu, H., Zhang, L., 2001. *Balances of Water, Carbon, Nitrogen and Phosphorus in Australian Landscapes: (2) Model Formulation and Testing*, CSIRO Land and Water, Technical Report 41/01.

Stewart, J.B., Smart, R.V., Barry, S.C. and Veitch S.M. 2001. *1996/97 Land Use of Australia. Final report for project BRR5, National Land and Water Resources Audi*t. Bureau of Rural Sciences, Australian Government, Canberra.

SunRISE Mapping. June 2004. *Irrigated Horticulture of the Lower Murray-Darling 1997 to 2003.* SunRISE 21 Inc, Mildura.

Taillefumier F., Piégay H. 2003. Contemporary land use changes in prealpine Mediterranean mountains: a mulitvariate GIS-based approach applied to two municipalities in the Southern French Prealps. *CATENA*, 51(3): 267-296.

Tanrivermis H. 2003. Agricultural land use change and sustainable use of land resources in the Mediterranean region of Turkey. *Journal of Arid Environments*, 54(3): 553-564.

Velázquez A., Durán E., Ramírez I., Mas J.-F., Bocco G., Ramírez G., Palacio J.-L. 2003. Land use-cover change processes in highly biodiverse areas: the case of Oaxaca, Mexico. *Global Environmental Change*, 13(3): 175-184.

Verburg P.H., Chen Y., Veldkamp T. 2000. Spatial explorations of land use change and grain production in China. Agriculture, *Ecosystems and Environment*, 82(1): 333-354.

Witte, C. 2004. pers. comm. *Developing methodology to map land use change in Fitzroy River catchment. Presentation at Technical Advisory Group for Australian Land Use Mapping (TAGALUM) Meeting and Workshop*, 12 October 2004: Adelaide.

Zhang, L., Dawes, W.R., Walker, G.R., 1999. *Predicting the effect of vegetation changes on catchment average water balance*, Cooperative Research Centre for Catchment Hydrology, Technical Report 99/12