1996/97 Land Use of Australia

Final report for project BRR5

J. B. Stewart, R. V. Smart, S. C. Barry, S. M. Veitch
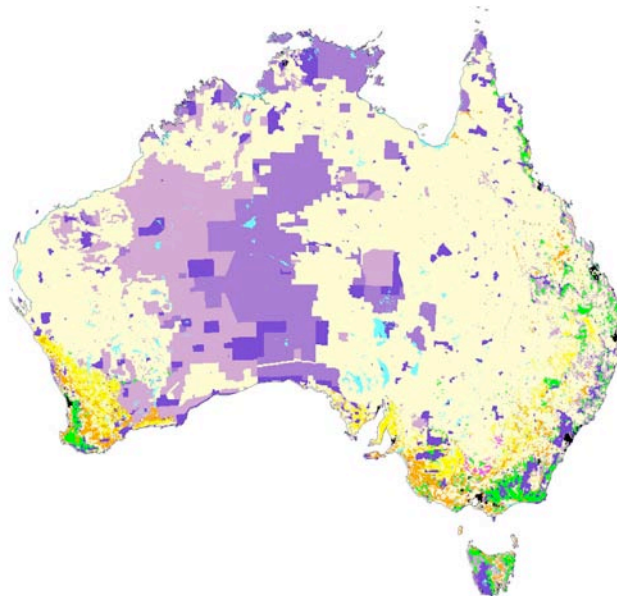
1996/97 Land
Use of Australia
– Final report for
project BRR5

*J.B. Stewart, R.V. Smart, S.C. Barry and S.M. Veitch**

National Land and Water Resources Audit

December 2001

* Authors can be contacted at:

Bureau of Rural Sciences, GPO Box 858, CANBERRA, ACT, 2601

Contents

Acknowledgements

Acronyms

Organisations

NRIC	National Resource Information Centre
BRS	Bureau of Rural Sciences
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ABS	Australian Bureau of Statistics
NHT	Natural Heritage Trust
ERIN	Environmental Resources Information Centre
EA	Environment Australia
AUSLIG	AUstralian Surveying and Land Information Group
NFI	National Forest Inventory
ABARE	Australian Bureau of Agricultural and Resource Economics
IUCN	International Union for Conservation of Nature and Natural Resources
PSMA	Public Sector Mapping Agency

Terminology

GIS	Geographical Information System
SRIAS	State Resource Information and Assessment System
AVHRR	Advanced Very High Resolution Radiometer
NDVI	Normalised Difference Vegetation Index
SPREAD	SPatial REallocation of Aggregated Data
SLA	Statistical Local Area
ASGC	Australian Standard Geographical Classification
CAPAD	Colloborative Australian Protected Areas Database
ALUMC	Australian Land Use and Management Classification
AGD66	Australian Geodetic Datum 1966
WGS84	World Geodetic System 1984

Summary

Introduction

The 1996/97 Land Use of Australia, Version 2 provides an area representation of dominant land use by level of intervention or intensity of land use. For agricultural land uses, the land use shown is that predicted to have occurred in 1996/97. The actual land use may differ from year-to-year reflecting crop and pasture rotations and use of irrigation.

Agricultural land uses were determined through an automated process to spatially allocate agricultural census data (AgStats 96/97, Australian Bureau of Statistics) using satellite imagery. Advanced very high resolution radiometer (AVHRR) data was processed to provide maximum NDVI (normalised difference vegetation index) composite images. A fortnightly sequence of NDVI images for the same period as the agricultural census was used to assign the agricultural land use. This was achieved by comparing the NDVI profile of a pixel with the NDVI profile of a known land use or control site. Those pixels with NDVI profiles most like the control site were assigned the control site's land use. The number of pixels assigned a particular land use was constrained to the area reported in the agricultural census for the region being solved. The method used is described in Walker & Mallawaarachchi (1998).

The control sites were provided by various state and territory agencies largely through field visits and farmer interviews. The participating agencies were: NSW Agriculture, Victorian Department of Natural Resources and Environment, Qld Department of Natural Resources, Primary Industries and Resources SA, Agriculture WA, Tasmanian Department of Primary Industries, Water and Environment and NT Department of Lands Planning and Environment.

Several available data sets were utilised to determine non-agricultural land uses. These were:

- Collaborative Australian Protected Areas Database - CAPAD97 for Tasmania and CAPAD99 for mainland Australia (Environment Australia, 1998 and 2000 respectively) for protected areas.

- GEODATA TOPO-250K, Series 1 (AUSLIG, 1999) for topographic features (water bodies, built-up areas and licensed airports).

- Australian Tenure (BRS, 1997) for distribution of public, private and aboriginal land in Australia.

- Native Forest and Plantations of Australia, 250m (BRS, 1999) for native and plantation forests and the 1995 Land Cover Theme: Queensland (BRS, 2000) to improve Queensland plantation data.

The data set is available for download from the Australian Natural Resources Data Library (http://adl.brs.gov.au/ADLsearch/).

Key findings

In conjunction with existing national data sets, the SPREAD (SPatial REallocation of Aggregated Data) method of Walker & Mallawaarachchi (1998) has enabled the compilation of the first national land use map in digital form. The features of the resulting 1996/97 Land Use of Australia data set are:

- It is a nationally consistent product.

- It is a spatial benchmark for land use in Australia circa 1996.

- It has a flexible data structure to enable users to modify the land use classification to suit their requirements.

- It has reliability indicators for the agricultural land uses mapped.

- It embodies a spatially corrected version of the commodity area data from the 1996/97 AgStats database.

Content of the data set

From the 1996/97 Land Use of Australia data set the following can be stated regarding Australia's land use:

- The most extensive land use is 'livestock grazing' covering 430 Mha or 56% of Australia.

- Agricultural land represents 473 Mha or 62% of the continent.

- About 2.2 Mha are irrigated for agriculture, representing 0.5% of all agricultural land or 5% of the area under crops, horticulture and modified pastures.

- Cropping (dryland and irrigated) covers 22 Mha or 3% of Australia with cereals representing 18 Mha.

- 73% of the 323 000 ha under horticulture (perennial and seasonal) are irrigated.

- Nearly 47 Mha or 6% of Australia has the land use, 'nature conservation', with 85% of this area having the gazetted IUCN categories strict nature reserve and national park.

- 'Water' occupies 13 Mha or nearly 2% of Australia, with 60% of this being water features with a conservation classification.

- 13% or 100 Mha of Australia is 'managed resource protection' with traditional indigenous uses being 89% of this area.

- 'Other minimal use' occupies 118 Mha or 15% of the continent. Reserved, vacant or institutional crown land represents 77% of this area and remnant native cover on private land occupies nearly 28 Mha.

- Forestry (production and plantation) covers 2% of the continent.

- 'Intensive uses' occupy about 2.4 Mha, or 0.3% of Australia. 'Intensive uses' includes urban and periurban areas and open-cut mines.

Limitations of the data set and future improvements

Limitations of the 1996/97 Land Use of Australia data set are listed below. These limitations offer opportunities for improvement in future implementations of the methodology used.

- A number of minor intensive land uses, most notably rural residential land and mining, proved difficult to distinguish from agricultural land.

- Fine-scale spatial heterogeneity of agricultural land use is not handled well by SPREAD (i.e. where the typical land use parcel size is significantly less than the pixel size).

- Fine-scale temporal heterogeneity of agricultural land use is not handled well by SPREAD (i.e. where the typical cropping period is six months rather than one year).

- The matching of AgStats area data to mapped areas of agricultural land requires assumptions and adjustments based on the assumptions.

- The ability of SPREAD to discriminate between the NDVI profiles of target zones limits the accuracy of the agricultural land use allocations.

- The performance of the heuristic implementation of SPREAD is poorly understood.

Applications

The 1996/97 Land Use of Australia has many applications relevant to national scale issues. At a spatial resolution of 1:1 000 000 to 1:2 500 000 the national land use map is one of the National Land and Water Resources' fundamental data sets. It has been widely used by other Audit projects as a key input or for context setting. The data set will be useful in:

- Providing primary attribute maps as background information products to inform decision-making and assist in the presentation of policy proposals (e.g. pair-wise comparisons – i.e. land use by soil type; combining appropriate tenure classes, protected areas, forests etc).

- Supporting information on diversity of environment and related patterns in economic use of land (e.g. risk assessment of land use with climate reliability projections; relating land use to social factors).

- Strategic industry-based planning to take advantage of increasingly deregulated domestic and global trading or to decide where to locate a new factory of office.

- Integrating with other data sets to allow multi-objective assessment on land use and land use change (e.g. ecological services design, trade-off and sensitivity analysis, land use competition futures).

Each product should be supplemented with explanatory notes. The suggested approaches require statistically and spatially relating the land use data to other data sets and/or the integration of Audit themes.

Where more detailed land use mapping is available this will be useful in decision-making at the regional to catchment scale.

Some primary attribute products derived from the 1996/97 Land Use of Australia data set are provided on the Australian Natural Resources Atlas at http://audit.ea.gov.au/ANRA/atlas_home.cfm

Recommendations

Implications for managing Australia's natural resources

In the management of Australia's natural resources:

- The national land use map should be used as a spatial benchmark for land use in Australia *circa* 1996.

- Users should make use of the data set's flexibilty to modify the land use classification to suit their purposes.

- Users should consider the agricultural land use reliability indicators provided.

- The data set should be recognised as a source of spatially corrected agricultural commodity area data derived from the 1996/97 AgStats and used as such when the opportunity arises.

- Use of the 1996/97 Land Use of Australia data set should be encouraged for appropriate purposes in government, industry, research and education.

- Possibilities for integration of the national land use map with other thematic data relevant to natural resource management should be explored.

Improvements to the national land use map

To ensure the success of future implementations of the methodology and to improve shortcomings of the current implementation, there is a need for:

- Better mapping approaches for non-agricultural rural land uses, particularly rural residential land and mining.

- A solution to mapping areas where land use parcel sizes are significantly smaller than the pixel size. A possible solution may be to use finer resolution imagery with smaller pixels or, at least, to do this in selected regions.

- A solution to mapping areas where the characteristic cropping period is only six months rather than one year. One possible solution might be, in the implementation of SPREAD, to characterise phenology over two consecutive six monthly periods, independently.

- Regular collection of agricultural census data. The potential release of geocoded agricultural census data should be encouraged. Geocoding offers a way to identify and quantify errors and facilitate spatial correction of the data and to facilitate the identification of ground control sites for the SPREAD method.

- A review of the agricultural census questions with the view to including supplementary questions to improve SPREAD's assignment of agricultural land uses.

- Investigate the possibility of Improving SPREAD's capacity to discriminate between the NDVI profiles of target zones. Options include increasing the number of control sites, using a better discriminating metric and grouping different commodities into more easily discriminated groups.

- A better understanding of the heuristic implementation of SPREAD and its limitations.

Choice of land use methods and suggestions for the future

Some considerations for future land use mapping are as follows:

- The investment of the NLWRA in the Land Use Mapping of the Continent Using AVHRR Data project, resulted in a land use map at a scale ranging from 1:1 million to 1:2.5 million, costing approximately 12.5 cents km^{-2}.

- To re-run the AVHRR-based method is estimated to cost between 3.3 and 13 cents km^{-2}.

- Detailed land use mapping done for the NLWRA, resulting in land use maps at scales ranging from 1:25 000 to 1:250 000, cost approximately 50 cents km^{-2}. The finer detail and potentially greater accuracy of ground-based and related methods has the benefit of being more reliable for decision making in small regions and catchments.

- New technologies will be beneficial, such as the global positioning system, to enable convenient new ways to conduct surveys.

- Geocoded agricultural census data would provide a source of ground control sites for the AVHRR method and enable it to be re-run with high levels of confidence, particularly in areas where land use parcel sizes are large compared with the 1 km AVHRR pixels. High resolution imagery, such as Landsat TM, would enable the same methodology to be used with improved results in areas where land use parcel sizes are small.

Introduction

Need for a national land use map

In 1980 and 1982 the Division of National Mapping published national land use and agricultural commodity maps for the Atlas of Australian Resources (Division of National Mapping, 1980, 1982). Its publications predated computer-based Geographic Information Systems (GIS) and were only available as hardcopy maps. During the early to mid 1990s many national datasets were converted to digital GIS databases by the National Resource Information Centre (NRIC). The land use maps were deemed to be too out-of-date for conversion. This decision was made while recognising the value of and need for a national land use map to support strategic land use and management decisions.

An interim response, in the absence of good land use information, was to use other data such as the Digital Atlas of Australian Soils (BRS after CSIRO, 1991) where the typical use made of a soil type was used as a surrogate for the actual land use. Other approaches used the Australian Bureau of Statistics (ABS) AgStats database to extract commodity and stock numbers to give a broad, Statistical Local Area (SLA)-based overview of prevailing land use. Examples were the Sheep and Cattle Stock Density maps (BRR, 1992). The interim products were useful in the absence of anything better but they did not provide a sufficiently rigorous basis for decision-making, especially where issues were contentious, such as for drought assistance or for managing outbreaks such as Anthrax or fruit flies.

During the 1980s and 1990s state and territory agencies prepared a variety of small area land use or related maps. The maps often incorporated or built upon earlier land systems mapping, especially that done by CSIRO during the 1960s and 1970s. These products suffered from their limited spatial extent, making broader context assessments, as needed for the Murray-Darling Basin, difficult, unreliable or impossible. Another problem of the small area maps was the variety of methods, conceptual models, techniques and classification schemes. Supporting documentation of the mapped information was often, at best, preserved only in 'grey' literature. Some small area mapping was captured or converted with GIS but the content differences made it inappropriate to meld the maps to larger areas.

During the 'Decade of Landcare Program' (Commonwealth of Australia, 1991) the difficulty of making strategic decisions for large regions and Australia as a whole was increased by the absence of reliable national land use data. Assessments of land degradation were only possible for the whole country at very coarse scales (1:20 000 000) due to the poor quality and unreliability of available data. Even the clear demarcation of agricultural land compared with other land uses was spurious. The question of land degradation severity, its extent and impact, was unclear because the crude mapping could not be matched reliably with land use and related production statistics.

In the period from the 1960s to 1990s Australia's approach to land use and management has moved from having a land development orientation to one where the objective is a combination of profitability, productivity and sustainability, recognising the interdependence of economy and ecology. This necessarily invokes a multi-disciplinary consideration (economics, management and ecology) of Australia's lands where the requirements of many interests need to be considered both in space and time. Fundamental is that we know what we are currently doing with our land and also, that we know its qualities and sensitivities; a national view of land use is therefore, a key component.

Selection of methodology

In 1991, the CSIRO began a project to review the land use and productivity for NSW named the State Resource Information and Assessment System (SRIAS). The project used Multi-spectral Scanner (MSS) satellite imagery, GIS-based cadastre and infrastructure data, together with ABS AgStats 89/90, to assign land uses to 100 metre dimension pixels (grid squares). The method (Walker and Mallawaarachchi, 1998) relied on the disaggregation of the AgStats (reported by SLA) to the appropriate pixels within the SLA. Twelve monthly MSS scenes were assembled, for the same period as the agricultural census, and processed to show relative greenness (NDVI) covering all NSW. The pattern of greenness change through the year (phenology) in each pixel was matched to the

characteristic growth (and greenness) pattern for a particular crop type. Its area was then subtracted from the SLA area statistic until the total area for the crop was accounted for by other matching pixels. In this way the SLA-based area of a crop was disaggregated and apportioned to small mapping areas (square pixels) to give a far more detailed representation of the crop's distribution.

The project results were sufficiently encouraging for the project leaders, Drs Walker and Young (CSIRO) to propose its extension to all of Australia as a means to regularly and rapidly update land resource information. The proposal for an Australia-wide land use and productivity assessment ultimately became a core component of a new initiative, the National Land and Water Resources Audit (NLWRA), to be funded by the Natural Heritage Trust (NHT).

A national application of the SRIAS method within the NLWRA timeframe was only possible by using large and fast computing systems such as those in the Bureau of Rural Sciences (BRS). The requirement for a good quality national-scale product led to the choice of Advanced Very High Resolution Radiometer (AVHRR) satellite data. AVHRR data were consistent with complete coverage, were readily and freely available (courtesy of the Department of Environment and Heritage - Australia), and provided fortnightly NDVI images for matching with the census period covered by the latest ABS agricultural census data, AgStats 96/97. AVHRR data has a nominal 1.1 km pixel dimension that indicates a spatial resolution for map production scales between 1:1 000 000 and 1:2 500 000.

Methodology

Background

Over the past decade there has been increased use of automated techniques for land use/land cover mapping. In 1994 CSIRO Wildlife and Ecology (now CSIRO Sustainable Ecosystems) developed a technique which significantly improved the ability to integrate land use mapping with economic production statistics. This work using 1989–1990 data was confined to New South Wales and established the SPREAD (Spatial Reallocation of Aggregated Data) methodology (Walker and Mallawaarachchi, 1998).

CSIRO and BRS have adapted this methodology to create a 1996–1997 land use map for Australia, which can be routinely updated when new agricultural census statistics are collected. This national land use map can be used as input to a range of continental and regional modelling exercises, and integrated with more detailed land use studies and with Australian Bureau of Statistics' agricultural production statistics.

The 1996/97 Land Use of Australia is a GIS-based data set identifying dominant land use within areas larger than 100 hectares. This was achieved using existing data sets (namely tenure, forestry, protected areas and topographical features) and the Australian Bureau of Statistics' (ABS) AgStats 96/97 with assistance from a time series of AVHRR remotely sensed imagery. The map has value for land use planning and for providing context for policies relating to sustainable agriculture. The land use map provides key input to the Audit's assessment of the productivity and sustainability of Australia's agriculture and forests.

The project has established:

1. a set of cloud corrected satellite data (AVHRR) suitable for land use mapping;

2. a geographically referenced set of land use control sites;

3. a spatially consistent data set based on the ABS' AgStats (by SLAs) which accounts for the area occupied by tree-based land use crops and has been adjusted for multiple counting of areas under production;

4. a semi-automated process for allocating any area in Australia to one of 20 agricultural commodities derived from the ABS' agricultural classification.

5. a process for updating the allocation process described above.

Limitations to method

1. Need to have ABS AgStats for the same time period as the AVHRR data

2. The resolution of AVHRR data is 1.1 km pixels which can cause problems with small acreages and in peri-urban areas

Strengths of Method

1. Methodology has been tested, evaluated and reviewed

2. Known input requirements

3. Provides a probability/uncertainty measure for each allocation

4. Rapid assessment which is repeatable as new agricultural statistics are collected

The procedure

The following products were produced and used in constructing the 1996/97 Land Use of Australia data set:

1. A time sequence of fortnightly georeferenced, cloud-corrected, national NDVI images covering the period 1 April 1996 to 31 March 1997.

2. A non-agricultural land use map derived from existing data sets. This map was used to mask those areas not to be processed by SPREAD.

3. An area constraints table for the agricultural commodity groups to be mapped. This table gives the areas in hectares for the commodity groups in each SLA. The table defines the maximum area which can be allocated to a particular agricultural land use in a SLA by SPREAD.

4. A database of agricultural land use control sites with known locations and agricultural land uses. The land uses for input to SPREAD applied to the period 1.4.1996 to 31.3.1997 although additional land use information relating to more recent years was also collected.

5. Allocation of a specific agricultural land use to each target zone or pixel using the SPREAD method. The SPREAD inputs were:

   - NDVI profiles for target zones;

   - NDVI profiles for control sites; and

   - area constraints table.

6. The final land use map was produced by combining the non-agricultural land use map and the agricultural land uses assigned by SPREAD. A number of additional outputs were derived from the procedure and are described below.

The outputs

The outputs are shown diagrammatically in Figure 1. All themes are ARC/INFO grids with the exception of the Control Site Locations Theme which is a point coverage. The Control Site Database is a Microsoft Access database.
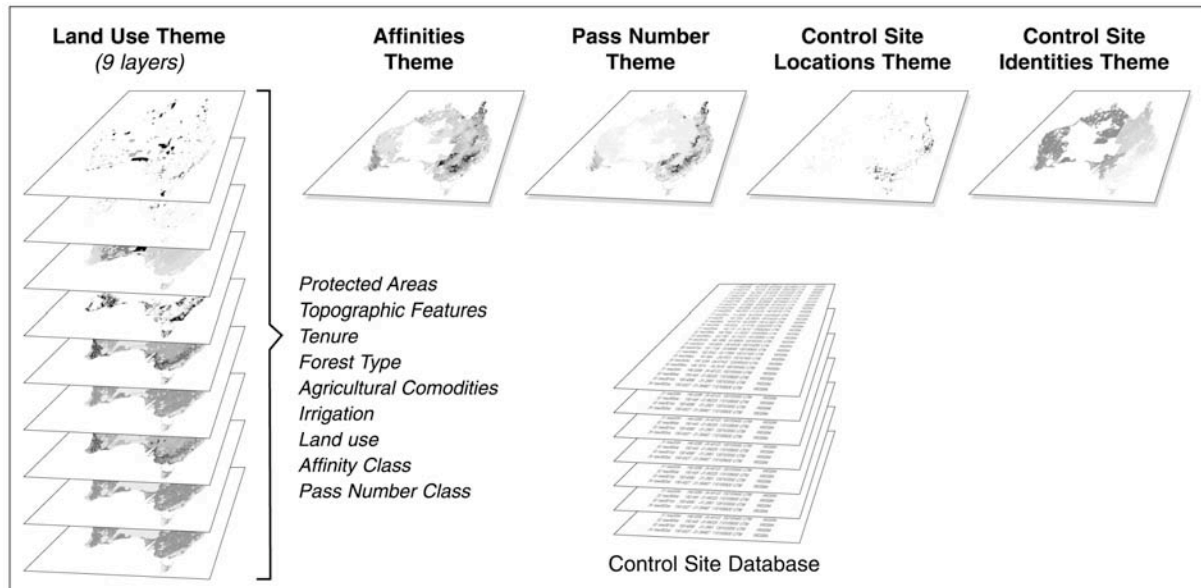
Figure 1. Diagrammatic representation of outputs.

1. _Land use theme_: enables the construction of a land use map. Contains nine independent layers:

   - the protected areas, topographic features, tenure and forest type layers (derived from existing data sources which together allow non-agricultural land uses and the distribution of potentially agricultural land to be inferred);

   - the agricultural commodities and irrigation layers (indicate the specific agricultural land use allocated by SPREAD);

   - the land use layer (constructed by inferring land use from the above six layers and classified according to the Australian Land Use and Management Classification, Version 4); and

   - the affinity class and pass number class layers (constructed as summary versions of the affinities and pass number themes).

2. _Affinities theme_: indicates the difference between the NDVI profile of each target zone and the control site chosen by SPREAD as the best match.

3. _Pass number theme_: shows for each target zone, the number of iterations of the SPREAD algorithm required before a specific agricultural land use allocation was made.

4. _Control site locations theme_: provides control sites locations and basic attributes.

5. _Control site identities theme_: shows for each target zone, a unique identifier for the control site chosen by SPREAD as the best match. It enables the SPREAD allocation for a given pixel to be linked to the control site used.

6. _Control site database_: a relational database containing all the control site data. As well as the location and the 1996 – 97 agricultural land use, additional information on management practices is provided for most control sites. The questions target 1996 – 1997 and the subsequent three years.

General methods

The NDVI images were georeferenced using geographic coordinates (latitude and longitude) and have a 0.01 pixel size (1.1 km by 1.1 km near the equator). The datum used to georeference the images is not known. Comparisons of the images with raster coastline data sets referred to the Australian Geodetic Datum 1966 (AGD66) and the World Geodetic System 1984 (WGS84) showed marginally better agreement with WGS84 and it is assumed the datum used.[1]

The target zones for SPREAD were defined as individual pixels in the NDVI images. To avoid further resampling of the NDVI images all themes and layers were constructed in raster format with geographic coordinates referred to WGS84 and 0.01 pixels exactly aligned with the NDVI pixels.[2]

Resampling of raster data was kept to a minimum. Where possible, resampling of categorical raster data has been by 'principal type' rather than by 'nearest neighbour'. Resampling of categorical raster data by principal type means that each new pixel is given the attribute of the largest proportion of its area. Resampling by nearest neighbour means that each new pixel is given the attribute of the old pixel whose centre is closest to its centre. This is so even if the attribute type of the old pixel with the nearest centre takes up the smallest proportion of the area of the new cell.[3]

---

[1] The raster coastline data sets used in the comparisons were constructed from a 1:100 000 scale vector coastline data set and had 0.01 pixels exactly overlying the NDVI pixels.

[2] All geographic information system (GIS) procedures were performed using ARC/INFO software under Solaris 2.6. ARC/INFO 8.0.1 was used to construct all themes and layers.

[3] In ARC/INFO a categorical raster data set that is not too large or complex can be resampled using the principal type method by first converting it to vector format (specifying a value of 0 for the weed tolerance during the conversion). The vector data set is then converted to a new categorical raster data set with the desired structure. Similarly, the nearest neighbour resampling that occurs in ARC/INFO when a raster data set is converted to a different datum or projection can be avoided by first converting to vector format, then carrying out the change of datum or projection, then converting back to raster format.

Construction of a time sequence of georeferenced, cloud-corrected, national NDVI images

Advanced Very High Resolution Radiometer (AVHRR) data captured by the Australian Centre for Remote Sensing was processed by CSIRO Division of Marine Research. The Environmental Resources Information Network (ERIN), Environment Australia purchased fortnightly maximum NDVI (Normalised Difference Vegetation Index) composite images along with the individual channel and angle data associated with the values in the composite. The maximum NDVI composite images remove the majority of cloud contamination. A number of further processing steps were undertaken by ERIN as detailed in Appendix 1 to arrive at the NDVI images used in the construction of the 1996/97 Land Use of Australia data set. The images were grouped into 50 classes over the positive NDVI range. This was a compromise between removing unnecessary noise in the data while still retaining sensitivity as our interest was in temporal profiles for the allocation of agricultural land use.

Construction of the non-agricultural land use map and the SPREAD input mask

To produce the non-agricultural land use map and the SPREAD input mask the following layers were constructed:

- protected areas;

- topographic features;

- tenure; and

- forest type.

These 4 layers were combined as independent layers into a single data set and through a series of decision rules a land use layer was constructed showing non-agricultural land uses and the distribution of potentially agricultural land (Appendix 4). SLA boundaries were overlain to incorporate SLA identity as an attribute of the potentially agricultural land.

The SPREAD input mask was made by simplifying the non-agricultural land use map.

Protected areas layer

The protected areas layer shows areas that meet the guidelines of the International Union for the Conservation of Nature and Natural Resources (International Union for the Conservation of Nature and Natural Resources, 1994).[4] It was constructed by combining parts of two 1:250 000 scale, national, vector data sets of protected areas. Data for mainland Australian were taken from the Collaborative Australian Protected Areas Database – CAPAD99 (Environment Australia, 2000), while data for Tasmania were taken from the Collaborative Australian Protected Areas Database – CAPAD97 (Environment Australia, 1998). The currency of the mainland Australian data in CAPAD99 ranges from December 1998 to September 1999. The currency of the Tasmanian data in CAPAD97 is as at April 1997.

Though a currency of around 1997 would be most appropriate for the methodology, CAPAD99 was used in preference to CAPAD97, because interpretations by the states and territories of what constitutes a protected area have changed since the publication of CAPAD97. It was necessary to use CAPAD97 for Tasmania because the Tasmanian section of CAPAD99 was incomplete at the time the work was done.

The possibility of excluding protected areas in CAPAD99 with original gazettal dates after 1997 was considered. CAPAD99 includes original gazettal date but it does not retain the 1997 boundaries of protected areas which existed in 1997 but were extended between 1997 and 1999. It would be possible to obtain an approximate 1997 protected areas map from CAPAD99 by excluding protected areas with more recent original gazettal dates but the resulting map would have incorrect boundaries for protected areas that were extended between 1997 and 1999. This procedure was not undertaken. Firstly, the change in land use between 1997 and 1999 for land that was first gazetted as a protected area in that period would generally be negligible. Secondly, correct 1999 boundaries are probably more useful than a hybrid of 1997 and 1999 boundaries.

---

[4] now known as the World Conservation Union

The only attribute retained in the protected areas layer from the original data sets was the International Union for the Conservation of Nature and Natural Resources (IUCN) protected area category, which was encoded with a positive integer. Table A2.2 shows the attributes of the protected areas layer and lists values and meanings.

Land classified as not a protected area was regarded as potentially used for agriculture. All other land, or all protected areas, was regarded as not used for agriculture.

The protected areas layer is shown in Figure 2.

IUCN category

- Ia. Strict nature reserve
- Ib. Wilderness area
- II. National park
- III. National monument
- IV. Habitat/species management area
- V. Protected landscape/seascape
- VI. Managed resource protected area
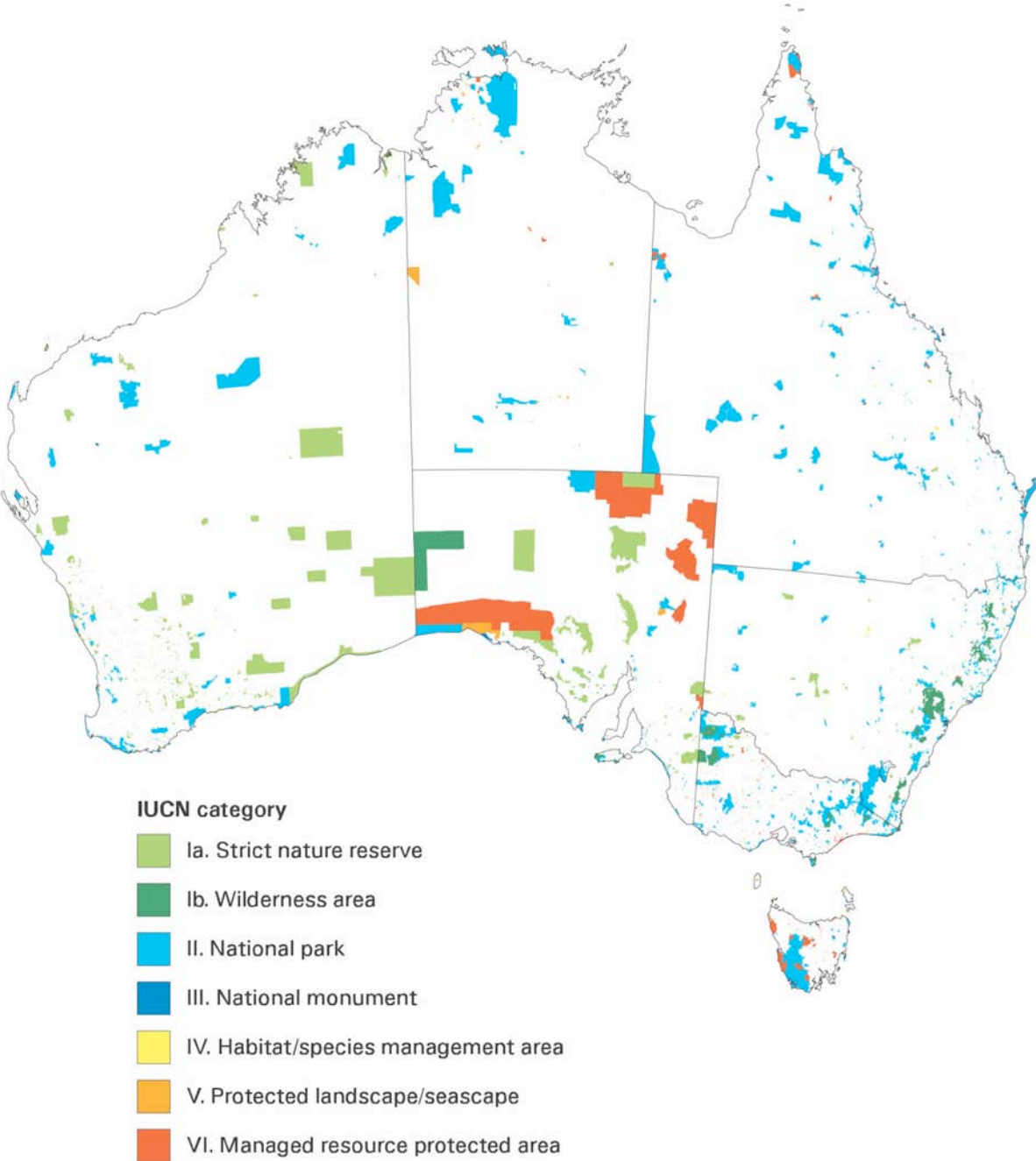
Figure 2. Protected areas layer.

Topographic features layer

The topographic features layer shows topographic features relevant to land use. It was constructed using TOPO-250K Version 1 (February 1999 update, Australian Surveying and Land Information Group, 1999), a 1:250 000 scale, national, vector data set. This data set comprises a number of layers showing different types of topographic features represented by polygons, lines or points. It is broken up into more than 500 tiles that, collectively, cover the whole country. The tiles are updated irregularly. Data currency varies from tile to tile and ranges from pre 1990s to February 1999. This is of little importance for natural topographic features, which generally do not change rapidly, but may mean that man-made topographic features are not shown as they were around 1996 – 1997.

The tiles were assembled into national covers by topographic feature. Only those topographical features likely to impact on the land use assigned to a 0.01 pixel were considered. In the case of line and point features, these were buffered to give an area representation of the features.[5] Table 1 shows the features from TOPO-250K considered for the topographic features layer and the buffer distances used to convert the line and point features to polygons.[6] Table 1 also indicates which features survived the rasterization process and are represented in the topographic features layer.

Table 1.   Features from TOPO-250K used, or considered for use, in the topographic features layer. Buffer distances shown for line and point features.

Feature	Representation in TOPO-250K	Buffer distance	Represented in topographic features layer
Perennial streams	Lines	50 m	No
Water bodies	Polygons	Not buffered	Yes
Built-up areas	Polygons	Not buffered	Yes
Licensed airports	Points	700 m	Yes
Roads, dual carriageway	Lines	50 m	No
Roads, principal	Lines	50 m	No
Roads, secondary	Lines	25 m	No
Railways, multiple track	Lines	25 m	No

Non-perennial streams shown as line features in TOPO-250K were not included as they tend to occur in grazing areas and would mostly be used for grazing. Non-perennial streams shown as polygon features in TOPO-250K were included, however, as they are large watercourses and tend to contain high energy sediments (sands and gravels) rendering them unsuitable even for grazing. All other water bodies shown in TOPO-250K as polygon features were included except those classed as 'land subject to inundation'. Land subject to inundation was excluded as it is suitable for agricultural activities and in particular grazing. Heliports and unlicensed airports shown in TOPO-250K as point features were excluded. Heliports as they are too small to be represented at the scale of mapping and unlicensed airports because they are probably mainly used for grazing. Minor roads and tracks and single track railways shown in TOPO-250K as line features, were excluded as they occupy a very small area. Railways with unknown number of tracks, were excluded as they are most likely to be single track or light rail.

The grids showing the three TOPO-250K feature groups that survived the rasterization process – water bodies, built-up areas and licensed airports – were combined into a single grid – the final topographic features layer. A cell was only given the licensed airport attribute when it did not have a water body or built-up area attribute. The only attributes retained from the original TOPO-250K data

---

[5] TOPO-250K was acquired in ARC/INFO format with double precision geographic coordinates. Tiles were assembled into national covers, polygon covers being processed with a fuzzy tolerance of 0.00001 or smaller. Relevant topographic features represented in TOPO-250K as lines or points were buffered, that is, each point or line feature was converted to a polygon of suitable size surrounding the feature. Prior to buffering, covers were projected to Lambert conformal conic projection, with standard parallels 18 S and 36 S. After buffering, all relevant TOPO-250K layers were converted to geographic coordinates referred to WGS84, then converted to ARC/INFO grid format with 0.01 cells exactly overlying the NDVI pixels.
[6] The buffer distance is the distance from the feature to the boundary of the newly created polygon. In the case of line features, the resulting polygon is irregular in shape but its width is twice the buffer distance and it is centred on the original line. In the case of point features, the resulting polygon is a circle centred on the point with radius equal to the buffer distance.

set were the feature type and perenniality. Table A2.3 shows the attributes of the topographic features layer and lists values and meanings.

Land classified in the topographic features layer as not a topographic feature was regarded as potentially used for agriculture. All other land, or all land classified as a topographic feature, was regarded as not used for agriculture.

The topographic features layer is shown in Figure 3.

Built-up areas and licensed airports

Lakes, watercourses and reservoirs

Swamp

Saline coastal flats and mangroves
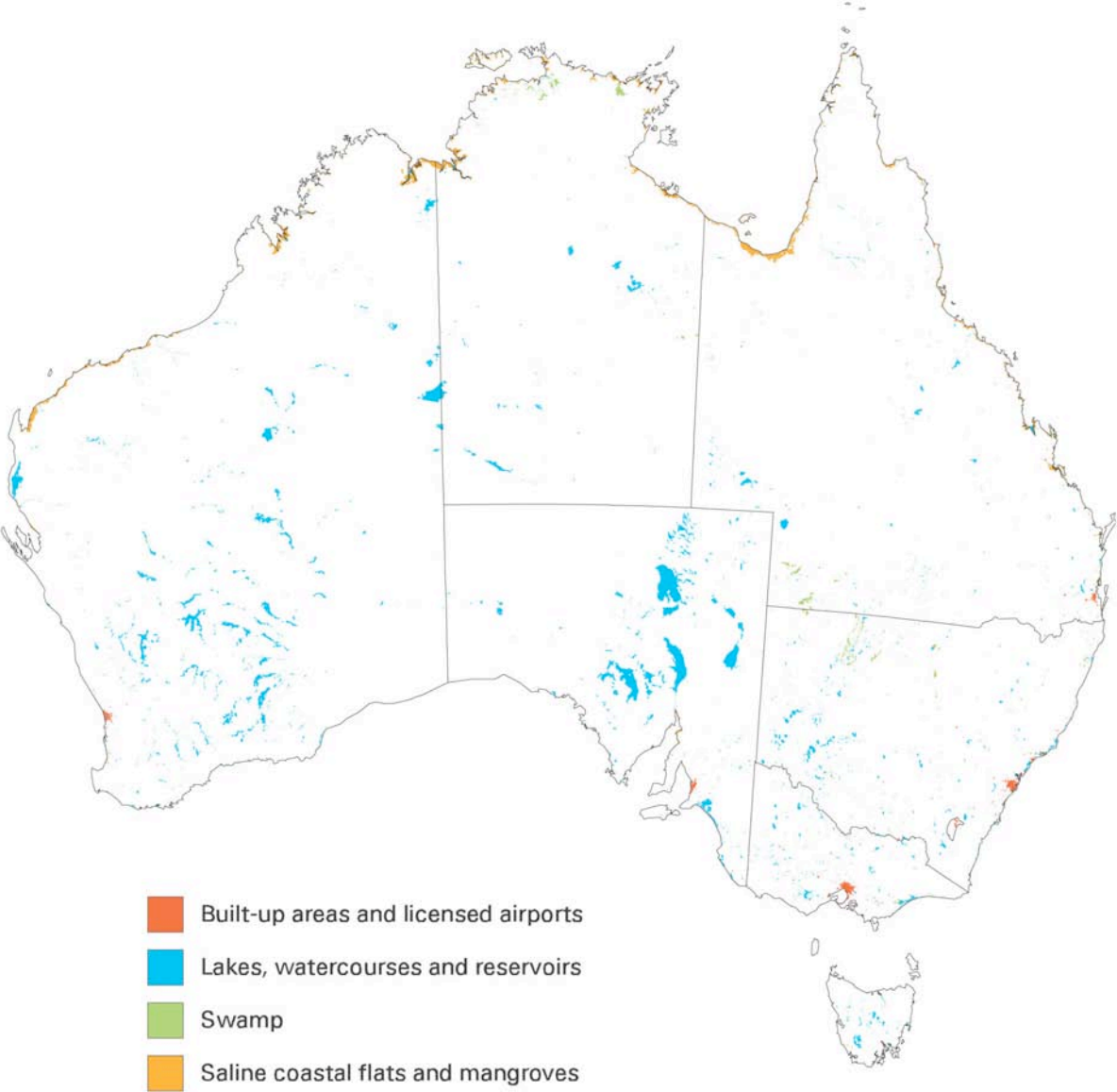
Figure 3.   Topographic features layer.

Tenure layer

The tenure layer shows the distribution of public, private and aboriginal land in Australia. It is based on the 1997 Australian Land Tenure Data Set (Bureau of Rural Sciences, 1997) compiled by the National Forest Inventory (NFI) section of BRS. This national, raster data set has a cell size of 250 m and is a compilation of a range of tenure data published or made available between 1992 and 1995 inclusive.

The tenure layer provides a useful guide to the distribution of agricultural land in Australia. Table 2 summarises Australian land tenure categories and the extent to which each is used for agriculture (including pastoral activities).

Table 2.   Australian land tenure categories and implication for agricultural land use.

Tenure category	Meaning	Extent to which used for agriculture (cropping and grazing)
Private land	Land held under freehold or leasehold title by individuals or non-Aboriginal groups.	Substantial proportion used for agriculture. Other main uses are intensive uses such as residential, manufacturing and industrial, mining.
Aboriginal land	Land held under freehold or leasehold title by Aboriginal groups; land not subject to freehold or leasehold title and reserved for Aborigines.	Used for agriculture and traditional indigenous activities.
Public land	Crown land other than Aboriginal reserves. Includes land used for forestry or nature conservation and managed by public authorities.	Not used for agriculture.

The NFI tenure data set was modified in three ways:

▪   Inclusion of preliminary information about the agricultural or non-agricultural status of aboriginal land.

▪   Removal of slivers with missing or incorrect attributes resulting from state border mismatches along the "straight" sections of state borders.[7]

▪   Correction of tenure covering the Ord River Irrigation Scheme.

Preliminary information on the agricultural status of aboriginal land was provided to BRS in 1997 by agencies in New South Wales, Queensland, South Australia, Western Australia and the Northern Territory. Using this information, an agricultural status qualifier was added to the tenure attributes of cells representing Aboriginal land in the NFI tenure data set. In the Northern Territory, the NFI tenure data set does not show Aboriginal freehold or Aboriginal leasehold land separately from private land. This difficulty was overcome using the Australian Land Tenure (Australian Surveying and Land Information Group, 1993) a 1:4.7 million scale national vector data set.[8]

The NFI tenure data set has slivers with missing or incorrect attributes resulting from state border mismatches. These were removed along the "straight" sections of the borders by assigning the attributes of the adjacent tenure polygon on the same side of the border.[9]

The NFI tenure data set was converted to an ARC/INFO grid with geographic coordinates referred to WGS84 and 0.01 cell size and cells exactly overlying the NDVI pixels. Only the tenure type attribute was retained from the original data set with some of the original tenure categories amalgamated.

The third modification involved correction of the tenure for cells falling within Stage 1 of the Ord River Irrigation Scheme. Digital boundaries supplied by Agriculture WA were used to identify the cells

---

[7] Along state border sections that follow meridians of longitude or parallels of latitude.

[8] Using the state and territory land use information, an agricultural status qualifier was added to the tenure attributes of polygons representing Aboriginal freehold and Aboriginal leasehold land in the Northern Territory in the AUSLIG tenure data set. These polygons were put into a new data set and converted to raster format with the same coordinate system, cell size and cell alignment as the NFI tenure data set. The two raster data sets were overlaid. Wherever non-agricultural Aboriginal freehold coincided with private freehold, the attribute 'non-agricultural Aboriginal freehold land' was transferred from the modified AUSLIG data set to the NFI data set. Likewise for occurrences of non-agricultural Aboriginal leasehold land in the modified AUSLIG data set and private leasehold in the NFI data set. Slivers resulting from mismatches between the two data sets were removed using a semi-automated procedure. Each edit was checked against a 1:2 million scale hard copy of the Northern Territory Pastoral Map (Lands, Planning and Environment, Northern Territory, 1999).

[9] A national vector state boundary data set at 1:100 000 scale was converted to raster format with the same coordinate system, cell size and cell alignment as the NFI tenure data set and used to assign each sliver cell to its correct state, before the edits were undertaken.

concerned, which were previously attributed as crown land. It was necessary to create a new tenure type, 'private freehold or private leasehold', in the absence of more detailed tenure data. Construction of the tenure layer was then complete.

Table A2.4 shows the attributes of the tenure layer and lists values and meanings.

Land classified in the tenure layer as private land or non-agricultural Aboriginal land was regarded as potentially used for agriculture. All other land, including land with no tenure type, was regarded as non-agricultural.

The tenure layer is shown in Figure 4.

Legend:
- Multiple use forests
- Nature conservation and Water production areas
- Private freehold
- Private leasehold
- Reserved crown land and Other crown land
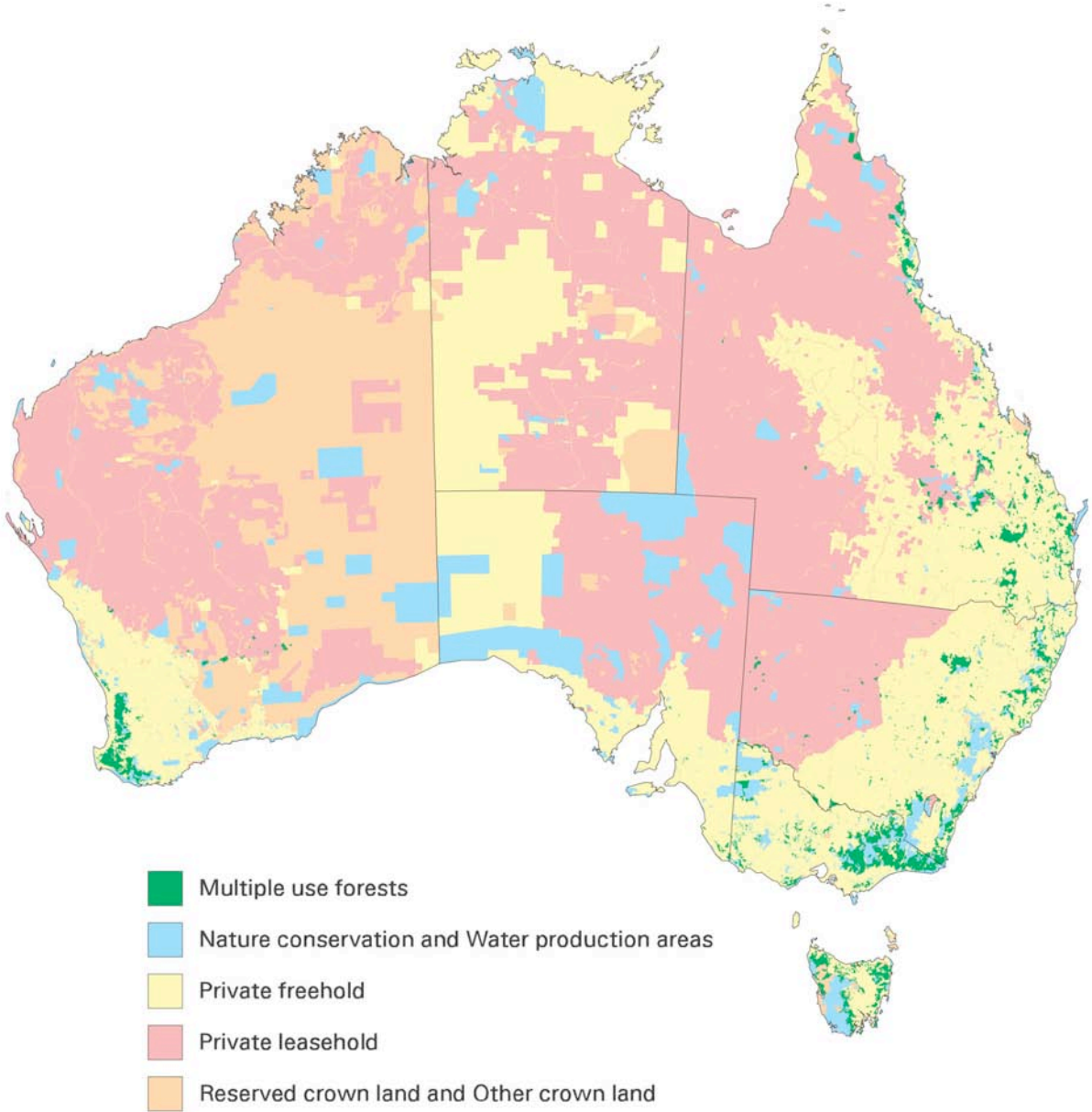
Figure 4.   Tenure layer.

Forest type layer

The forest type layer shows the distribution of forested lands in Australia. Native and plantation forests are distinguished and native forests are classified according to crown cover. It is based on a

250 m cell size, national, raster data set, the 1997 Australian Native and Plantation Forestry Data Set (Bureau of Rural Sciences, 1999) compiled by the NFI section of BRS. This data set is a compilation of a range of forest data. Its currency is 1990 to 1995 inclusive.

The NFI forest data set has the deficiency that it grossly under represents Queensland forest plantations. The data set was modified by inclusion of Queensland plantation data from the 1995 Australian Land Cover Data Set (Bureau of Rural Sciences, 1999). This is a 25 m cell size, raster data set covering most, if not all, of the intensive land use zone. It was prepared from analysis of satellite imagery for the BRS land cover change project (Kitchin and Barson, 1998). It shows seven types of land cover, including plantation forests. The structure of the Queensland part of the data set was modified so that the coordinate system, cell size and cell alignment matched those of the NFI forest data set. Nearest neighbour resampling was used in this case, because of the large size of the data set. Non-forest or unknown forest status cells in the NFI forest data set were reclassified as plantation forest if they coincided with plantation forest cells in the land cover change data set. Figure 5 shows the representation of plantation forests in a region of south-east Queensland before and after modification of the NFI forest data set.
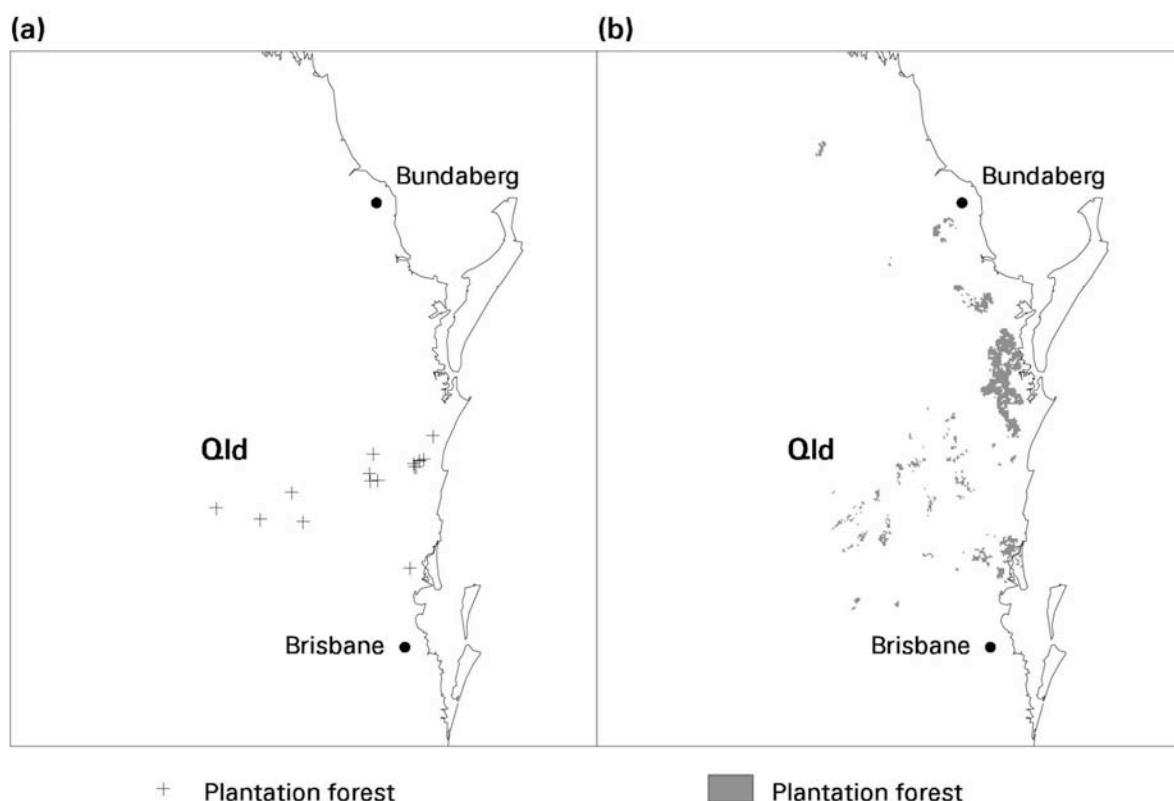
Figure 5. Impact of modifications to NFI plantation forest data using land cover change data for a region of south-east Queensland. (a) shows the raw NFI plantation forest data as crosses whose centres mark discrete 250 m pixels otherwise invisible at this scale; (b) shows the plantation forest data after incoporation of the land cover change data.

Despite modification of the NFI forest data set, areas determined from it may not agree with tabular data supplied by original state sources and must be used as guide only. For the tabular data refer to the relevant NFI publications (NFI 1997, 1998).

Only a summary forest type attribute was retained in the forest type layer from the original data set. Table A2.5 shows the attributes of the forest type layer and lists values and meanings.

Land classified as non-forest, unknown forest status or native woodland was regarded as potentially used for agriculture. Other land, representing native forest with crown cover exceeding 50% or plantation forest, was regarded as not used for agriculture.

The forest type layer is shown in Figure 6.

Native woodland (crown cover 20-50%)

Native open forest (crown cover 50-80%)

Native closed forest (crown cover 80-100%)

Plantation forest (softwood and hardwood)

No data
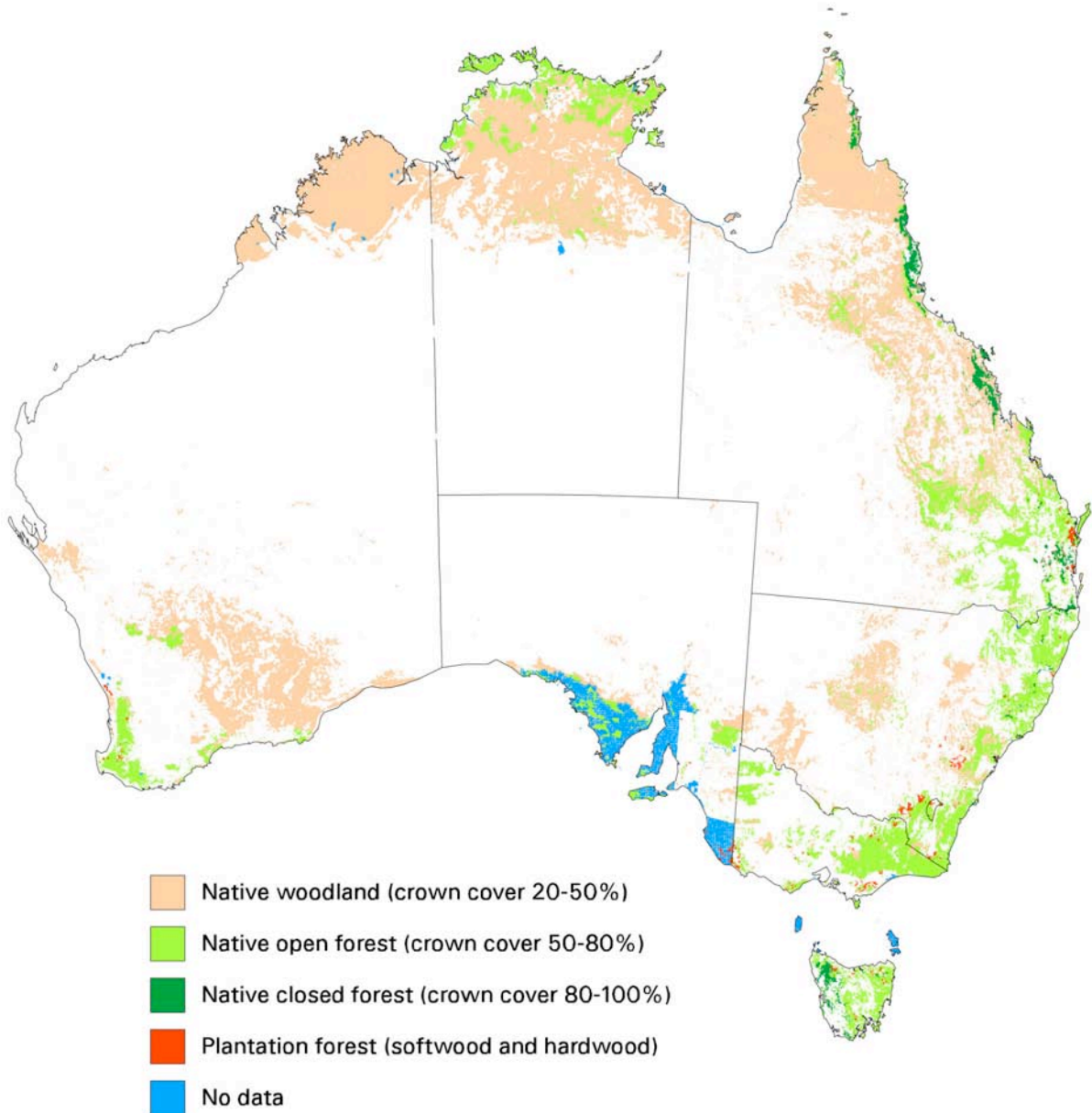
Figure 6.   Forest type layer

The non-agricultural land use map

The non-agricultural land use map shows non-agricultural land uses and the distribution of potentially agricultural land. It was constructed by combining the protected areas, topographic features, tenure and forest type layers into a single ARC/INFO grid.[10] The resulting non-agricultural land use map had the same coordinate system, pixel size and pixel alignment as the NDVI images. The four input layers were preserved independently as attributes of the grid.[11] A land use layer comprising several additional land use classification attributes was added using a series of decision rules[12] documented in Appendix 4. It interprets combinations of input layer values in terms of their land use according to the

---

[10] using the ARC/INFO GRID function 'combine'
[11] in the value attribute table (vat)
[12] written in ARC Macro Language (AML)

Australian Land Use and Management Classification, Version 4 (Bureau of Rural Sciences, 2000). Attributes were retained only for terrestrial pixels.[13]

Two types of agricultural land use were defined using the non-agricultural land use map, potentially agricultural land and potentially agricultural holdings. These were defined as land having any of the combinations of input layer values summarised in Table 3. The land use 'potentially agricultural land' is a subset of the land use 'potentially agricultural holdings'.

Table 3.   Combinations of input layer values taken to represent potentially agricultural land and potentially agricultural holdings. Refer to Tables A2.2, A2.3, A2.4 and A2.5.

Type of agricultural land use	Values of relevant layer attribute			
	Protected areas (*prot_areas*)	Topographic features (*topo_features*)	Tenure (*tenure*)	Forest type (*forest_type*)
Potentially agricultural land	0	0	6, 7, 8, 18 or 22	0, 1 or 2
Potentially agricultural holdings	0	0	6, 7, 8, 18 or 22	0, 1, 2, 3 or 4

We define 'agricultural land' to mean land directly used to produce agricultural commodities, including land used for grazing as well as for crops. 'Agricultural holdings' is defined as land that belongs to agricultural enterprises and includes agricultural land and land not used for agricultural production due to forest cover. 'Potentially' is used because land classified as potentially agricultural land or as potentially agricultural holdings as indicated in Table 3 includes a small amount of non-agricultural land whose spatial distribution cannot be determined using the available data. This non-agricultural land includes rural residential and land used for mining.

The definitions of potentially agricultural land and potentially agricultural holdings, assume that the compatibility of native vegetation with agricultural activities is determined by its crown cover. Specifically, it has been assumed that agricultural activities occur where the native vegetation crown cover is less than 50% and do not occur where the crown cover is greater than 50%. Thus it is assumed that non-forest and woodland are compatible with agricultural activities but that open forest and closed forest are not (*forest_type* = 3 or 4).

The SPREAD method involves processing of each agricultural census reporting area separately. The potentially agricultural land in each census reporting area is divided into target zones. SPREAD allocates agricultural land uses to the target zones in each census reporting area subject to commodity area constraints provided by the census. The agricultural census data used by SPREAD were based on the 1996/97 AgStats database (Australian Bureau of Statistics, 1999). The reporting areas used by the Australian Bureau of Statistics for their agricultural census data are Statistical Local Areas (SLAs). SLAs are similar to Local Government Areas but cover the whole of Australia with no overlap. SLA boundaries change from year to year. The appropriate SLA boundaries for AgStats 96/97 are the Australian Standard Geographical Classification 1996 edition. A digital version of these SLA boundaries (Australian Bureau of Statistics, 1996) is available in vector format with minimum scale around 1:250 000. A SLA attribute was introduced into the non-agricultural land use map by overlaying an equivalently structured, raster version of the 1996 SLA boundaries.[14] This was done for two reasons. Firstly, to prepare a table of area constraints for SPREAD. This involved adjustment and scaling of AgStats for each SLA in accordance with the available area of potentially agricultural land and potentially agricultural holdings. Secondly, a SLA attribute was required in the SPREAD input mask.

---

[13] Pixels representing ocean or estuaries have no attributes and are "NODATA" cells in ARC/INFO terminology. Terrestrial pixels were identified using a grid made from the TOPO-250K coastline.
[14] using the GRID function 'combine'

The SPREAD input mask had two purposes.

1. It defined the target zones within potentially agricultural land to be processed by SPREAD. The target zones were simply defined as single pixels so that each target zone corresponded with an individual pixel in the NDVI images.

2. It classified the target zones according to the SLA to which each belonged.

The SPREAD input mask was constructed in ARC/INFO grid format with the same coordinate system, pixel size and pixel alignment as the NDVI images. It was a simplified version of the non-agricultural land use map in which each cell representing potentially agricultural land to be processed by SPREAD had a value, which uniquely identified its SLA. Cells not to be processed by SPREAD had an alternative value.

The SPREAD input mask is shown in Figure 7.
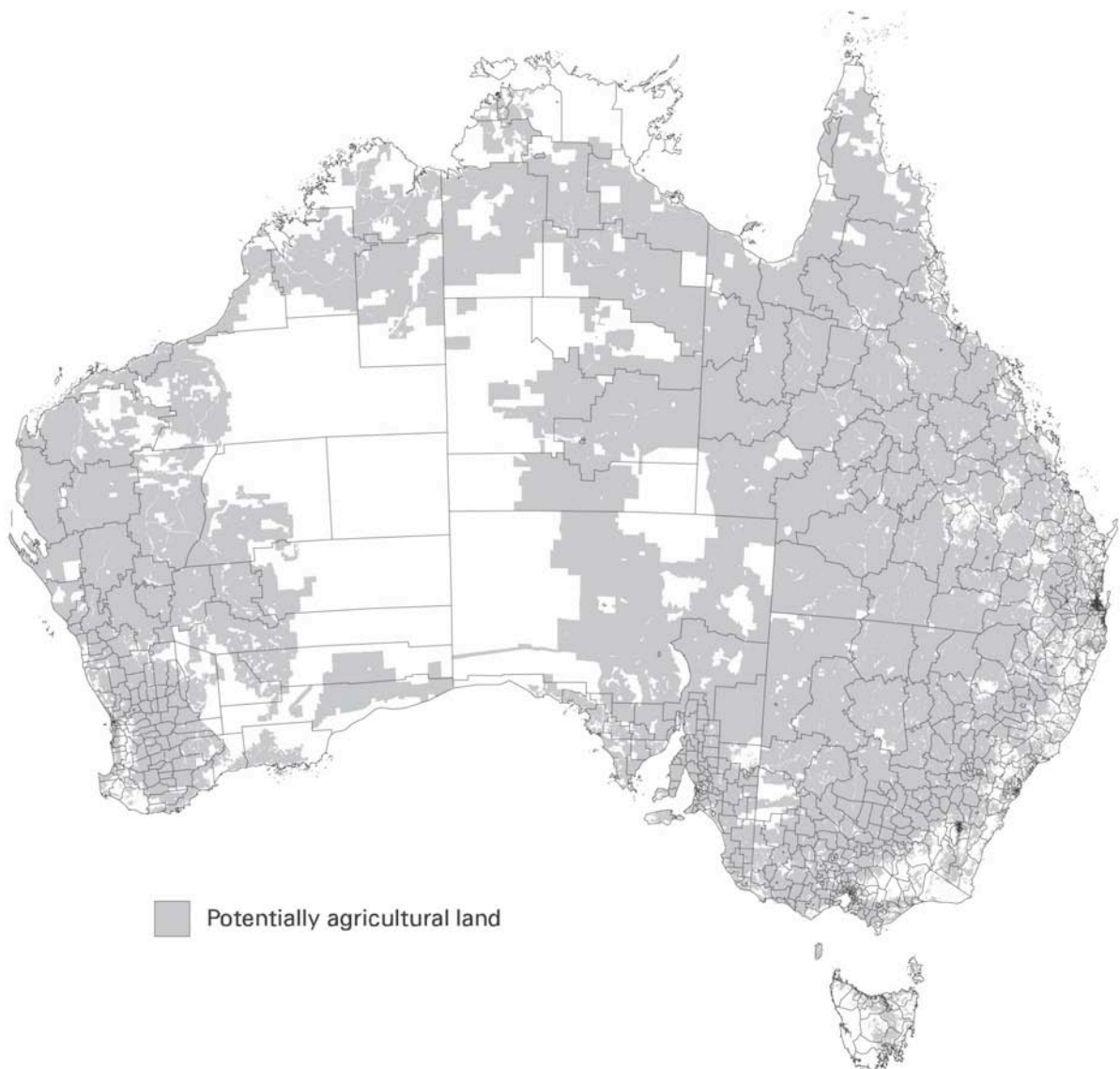
Figure 7.   SPREAD input mask

Construction of a table of commodity area constraints

Overview

The agricultural census data used by SPREAD were taken from the AgStats 96/97 database (Australian Bureau of Statistics, 1999). These data were used to build tables of area constraints for each SLA to be used by SPREAD. To do this it was necessary to modify the AgStats data. The construction of a table of area constraints involved the following:

1. Aggregation of AgStats data.

2. Conversion of AgStats orchard tree data from numbers of trees to areas.

3. Adjustment of AgStats vegetable area data to compensate for multiple cropping.

4. Adjustment of AgStats area data for pastures, cereals, legumes and oilseeds to compensate for double cropping.

5. Further aggregation of AgStats data.

6. Disaggregation of AgStats irrigation data to determine irrigated and dryland components for each commodity group sought by SPREAD.

7. Adjustment of AgStats data to fit the non-agricultural land use map.

8. Construction of area constraint tables.

Aggregation of AgStats data

A hierarchical classification scheme was used to aggregate area data for individual commodities from AgStats 96/97. Table 4 summarises the scheme and the role of each level. Table A2.13 shows the names and code numbers for the commodity groups in each of the three levels of the commodity classification scheme and how the groups at different levels are related.

Table 4.   The three levels in the hierarchical classification scheme for AgStats commodity area data and their roles.

Classification level	Number of categories	Role
ABS Level 3 Classification	117	Most control site land uses known to this level.
Audit Commodity Classification	21	All control site land uses known to this level. SPREAD solutions sought at this level. SPREAD output classified at this level.
ABS Level 1 Classification	9	All control site land uses known to this level. SPREAD solutions could have been sought at this level.

TableA3.1 shows how individual commodity area data from AgStats 96/97 were combined to form area data for the 117 commodity groups in the ABS Level 3 Classification. In most cases the combining process involved simple aggregation of area data. More complicated calculations were needed to convert orchard data from numbers of trees to areas, to adjust for multiple cropping of vegetables and to adjust for double cropping of other commodities.

Conversion of AgStats data - orchard tree areas

AgStats 96/97 reports only the total area of orchards by SLA. Individual orchard types are reported by number of trees rather than area. Orchard tree numbers were converted to orchard areas by:

1. Dividing orchard tree numbers by planting densities to obtain intermediate estimates of areas.

2. Scaling these estimates using SLA-specific scale factors to produce final areas. This scaling used the AgStats item 'Orchard trees (including nuts) – area' (item code 4004101) to constrain the sum of individual orchard types areas to the total orchard area reported by AgStats.

Orchard tree numbers are reported separately in AgStats as orchard trees under six years and trees six years and over. The numbers of trees in the two age categories were added together for each orchard type. The conversion steps were applied to the aggregated data. The final estimates conformed to the ABS Level 3 Classification.

Table 5 shows the planting densities used. Planting densities are highly variable and can be very much larger for trees grown on trellises than for trees grown without support. These estimates were provided to BRS by state agency horticultural experts in 1997.

Table 5.   Planting densities used to convert orchard tree numbers to areas.

Orchard type	Orchard tree densities (no./ha)
Nashi	970
Apples, Loquats	900
Filberts	450
Nectarines, Peaches, Peacharines	440
Oranges, Grapefruit, Lemon/lime, Mardarins, Tangelos, Other citrus, Figs, Guava, Pistachios	420
Other pome	400
Pears, Cherries, Plums, Prunes	390
Other stone fruit	375
Other orchard fruit	350
Persimmons	333
Macadamia	310
Other nuts	300
Olives	290
Almonds	280
Apricots	278
Carambola	220
Lychees, Cashews, Longans	200
Avocados, Walnuts	180
Quinces	156
Dates, Rambutan	150
Custard apples	140
Jackfruit	130
Mangoes	125
Chestnuts, Pecans	100

Adjustment of AgStats data - multiple cropping of vegetables

In most vegetable growing areas, more than one vegetable crop is grown on the same land in a 12 month period. Where this occurs, the sum of the vegetable areas reported in AgStats exceeds the area used for vegetable crops. Allowance was made for this in the area calculations for 'Potatoes' and 'Other vegetables' in the ABS Level 3 Classification from the AgStats vegetable items.

Table 6 shows the total areas reported in AgStats 96/97 for potatoes, other vegetables and irrigated vegetables, by state. Areas for irrigated vegetables are reported in AgStats by the item, 'Irrigation vegetables – area' (item code 5700701).

Table 6.   Total areas reported in AgStats 96/97 for potatoes, other vegetables and irrigated vegetables, by state.

State	Potatoes - area (ha)[a]	Other vegetables - area (ha)[a]	Irrigated vegetables - area (ha)[b]
New South Wales	6603.1	14983.1	14521
Victoria	13386.9	19652.7	19897
Queensland	4925.4	30120.3	23398.3
South Australia	9097.2	5045.2	8040
Western Australia	3370.6	8225.8	7336.4
Tasmania	8062.9	12108.9	15325.5
Northern Territory	0	268.3	262
ACT	0	33.5	2

[a] Could include plots counted more than once.
[b] Includes no plots counted more than once.

The following assumptions were made:

1. Only one crop of potatoes is possible in a 12 month period.

2. No other vegetables are grown on the same land as a potato crop during the AgStats reporting period.

Using these assumptions, two inferences can be made.

1. The area used to grow potatoes is the sum of the AgStats potatoes area items.

2. The area used to grow other vegetables is the sum of the AgStats other vegetables area items multiplied by a multiple cropping adjustment factor.

As most vegetable crops are irrigated, especially in the warmer, drier states of Australia, the data in Table 6 suggest that a reasonable value for the multiple cropping adjustment factor for New South Wales, Queensland, South Australia and Western Australia is 0.5. Discussions with agencies in Victoria and Tasmania indicated that multiple cropping of other vegetables is not as common as in the other states. Reasonable estimates for the multiple cropping adjustment factor would be 0.65 for Victoria and 0.8 for Tasmania. For the Northern Territory and the Australian Capital Territory, where the area of vegetable crops is negligible, it is reasonable to use the value 0.5 for the multiple cropping adjustment factor.

Based on these conclusions, the following steps were used to adjust the AgStats vegetable area data for multiple cropping. The total vegetable growing area was taken to be the area of irrigated vegetables where it exceeded the total vegetable area.

1. For each SLA, the area used to grow potatoes was calculated as the sum of the AgStats potatoes area items.

2. For each SLA, an interim value for the area used to grow other vegetables was calculated as the sum of the AgStats other vegetables area items multiplied by a multiple cropping adjustment factor. The values used for the adjustment factor were:

   - 0.5 for all SLAs in all states except Victoria and Tasmania

   - 0.65 for all SLAs in Victoria

   - 0.8 for all SLAs in Tasmania

3. For each SLA, the total area used to grow potatoes and other vegetables was taken to be the larger of the irrigated vegetables area from AgStats and the sum of the potatoes area from 1 and the other vegetables area from 2.

4. For each SLA, the final value for the area used to grow vegetables other than potatoes was calculated as the total area used to grow potatoes and other vegetables from 3 less the potatoes area from 1.

Adjustment of AgStats data - double cropping of various crops

In some areas, two different commodities other than vegetables, i.e pastures, cereals and non-cereal crops, are grown in a 12 month period. Where this occurs, the sum of the relevant areas reported in AgStats exceeds the area actually used. Adjustments were made to compensate for such double cropping in the calculation of ABS Level 3 Classification areas. This was done using data collected by the Australian Bureau of Agricultural and Resource Economics (ABARE) in the 1996-97 Farm Survey (Australian Bureau of Agricultural and Resource Economics, 1997). The ABARE data are reported on ABARE regions. Like SLAs, ABARE regions cover the whole of Australia without overlap. Table 7 lists the pastures and crops for which the location and extent of double cropping can be determined using ABARE data. Table 7 also indicates the relationship between ABARE commodity groups and ABS Level 3 Classification groups. Where several ABARE commodity groups corresponded to one ABS Level 3 Classification group, the data from ABARE were amalgamated. Where there was no relationship between ABARE commodity groups and ABS Level 3 Classification groups, the ABARE data were not used.

The crops listed in Table 7 were grown as the second crop during the 12 month survey period. For each crop, the ABARE data gives the total area and the area involved in double cropping by ABARE region.

The following steps were taken to adjust for double cropping in the calculation of ABS Level 3 Classification areas.

1. A concordance between ABARE regions and 1996 edition SLAs was established. Vector format digital maps of ABARE regions and 1996 SLAs were overlaid and each SLA was assigned to the ABARE region that contained the largest proportion of its area. Areas were established using an equal-area projection. The majority of SLAs fall entirely in a single ABARE region as ABARE regions are generally much larger than SLAs. (There are 32 ABARE regions compared with approximately 1330 SLAs (1996 edition).)

2. For each ABS Level 3 Classification commodity group, the area double cropped was calculated, using the ABARE data, as a percentage of the total area of that commodity group grown in each ABARE region.

3. Double cropping percentages were attributed to 1996 SLAs using the concordance.

4. For each ABS Level 3 Classification commodity group, the total area grown in each SLA was calculated by adding the relevant AgStats commodity areas using the correspondence shown in Table 7.

5. For each ABS Level 3 Classification commodity group, the adjusted area used in each SLA was calculated by subtracting the area represented by the double cropping percentage.

Table 7.   Pastures and crops (other than vegetables) whose areas were modified for double cropping using ABARE data.

ABARE commodity group identified in double cropping	Corresponding ABS level 3 classification group
Lucerne seed	Pure lucerne
Lucerne hay/silage	Pure lucerne
Pasture seed	Other sown pastures
Pasture hay/silage	Other sown pastures
Oats	Oats
Sorghum	Grain sorghum
Maize	Maize
Barley hay/silage	Cereals for hay/silage
Forage sorghum	Cereals for hay/silage
Maize hay/silage	Cereals for hay/silage
Rice	Rice
Soybean	Soybeans
Peanuts	Peanuts
Mung beans	Mung beans
Field peas	Field peas
Sunflower	Sunflower
Other field crops	No corresponding group
Other field crops hay/silage	No corresponding group
Other fodder crops	No corresponding group

Further aggregation of AgStats data

The ABS Level 3 Classification area data prepared were aggregated to the 21 commodity groups of the Audit Commodity Classification (see Table A2.13).

Disaggregation of AgStats irrigation data

AgStats 96/97 includes 8 irrigation items, which were used to determine irrigated areas for all agricultural commodities except agroforestry. These items are listed in Table 8. Census respondents are asked to report only once any areas irrigated in the reporting year.

Table 8.   Irrigation items in AgStats 96/97.

Descriptor and unit	Code
Cotton - irrigated - area (ha)	1803001
Irrigation pastures - area (ha)	5700501
Irrigation cereals - area (ha)	5700601
Irrigation vegetables - area (ha)	5700701
Irrigation sugar cane - area (ha)	5700801
Irrigation fruit (incl nuts) - area (ha)	5700901
Irrigation grapevines - area (ha)	5701301
Irrigation other crops nec - area (ha)[a]	5701501

[a] Includes the irrigated cotton areas specified by the item 'Cotton - irrigated – area' (1803001).

The area of each Audit Commodity Classification group was split into an irrigated and a dryland component by disaggregating the irrigation data as listed in Table 8. For pastures, cereals excluding rice, rice, legumes and oilseeds, it was necessary to work with the ABS Level 3 subgroups. The assumptions made were:

1. For irrigated pastures: pure lucerne was considered most likely to be irrigated, then other sown pastures with any remaining irrigated pasture area assigned to native pastures. Unassigned irrigated pasture area occurred in 7 SLAs. The unassigned amounts did not exceed 32 ha and so were discarded. It was assumed that the total pasture area was correct rather than the irrigated area.

2. For irrigated cereals: assumed all rice irrigated. Any remaining irrigated cereals area assigned firstly to summer cereals (in the order maize, grain sorghum and millet), then to winter cereals (in the order wheat, barley, cereal rye, buckwheat, oats, triticale and other cereals for grain) and finally to cereals for hay/silage. In 10 SLAs the area of rice was larger than the irrigated cereals area, however, this difference did not exceed 371 ha in a SLA. Unassigned irrigated cereals area occurred in 2 SLAs and as the amounts did not exceed 12 ha they were discarded.

3. For irrigated vegetables: the irrigated area was assigned first to other vegetables, then to potatoes. No SLAs had unassigned irrigated vegetables area. This occurred as the area of irrigated vegetables was used in adjusting vegetable areas for multiple cropping.

4. For irrigated sugar cane: where the area of irrigated sugar cane area was larger than the total sugar cane area the irrigated area was assumed correct. This occurred in two SLAs with the differences no larger than 150 ha.

5. For irrigated fruit: the irrigated area was proportioned between citrus, apples, pears, stone fruit, nuts, berry fruit and plantation fruit. Where the irrigated fruit area exceeded the total of the previously calculated fruit areas, the irrigated fruit area was assumed incorrect. This occurred in 21 SLAs with 51 ha the largest discrepancy.

6. For irrigated grapes: where the irrigated grapes area exceeded the previously calculated grapes area the irrigated grapes area was assumed correct. This occurred in 60 SLAs with discrepancies not exceeding 150 ha.

7. For irrigated cotton: irrigated cotton area did not exceed the cotton area in any SLAs as cotton is collected separately as dryland and irrigated (see Table 8 and Appendix 3).

8. For irrigated other crops: assumed irrigated cotton a component. Where irrigated cotton exceeded the irrigated other crops area, the irrigated cotton area was assumed correct. This occurred in 17 SLAs with discrepancies not exceeding 18501 ha. The area of irrigated other crops excluding cotton was aportioned to the remaining commodity groups in the following order:

   (a) Other non-cereal crops (Audit Commodity Classification) consisting mainly of perennial and summer crops;

   (b) Proportioned between soybeans, peanuts, sunflower and sesame (ABS Level 3 Classification), all summer crops;

   (c) Proportioned between mung beans, other field beans, pigeon peas, oil poppies, safflower (ABS Level 3 Classification) and non-cereal forage crops (Audit Commodity Classification), all summer crops (assumed summer in the case of non-cereal forage crops);

   (d) Proportioned between lupins, field peas, chick peas, vetches, lentils, faba beans, canola and linseed (ABS Level 3 Classification), all winter crops.

Unassigned irrigated other crops excluding cotton area occurred in 66 SLAs. The amounts did not exceed 500 ha or thereabouts and were discarded. The results were aggregated to determine irrigated and dryland legumes and oilseeds at the Audit Commodity Classification level.

Adjustment and scaling of AgStats data to fit the non-agricultural land use map

The final step in the production of area constraints for SPREAD was to adjust and scale the AgStats data to fit the non-agricultural land use map.

The non-agricultural land use map was converted to vector format and projected to an equal area projection using the WGS84 datum. Areas for potentially agricultural land and potentially agricultural holdings were extracted for each SLA.

Ratio of total area of holdings to total commodity areas

0   1.3   2   4   8   16   32   >64
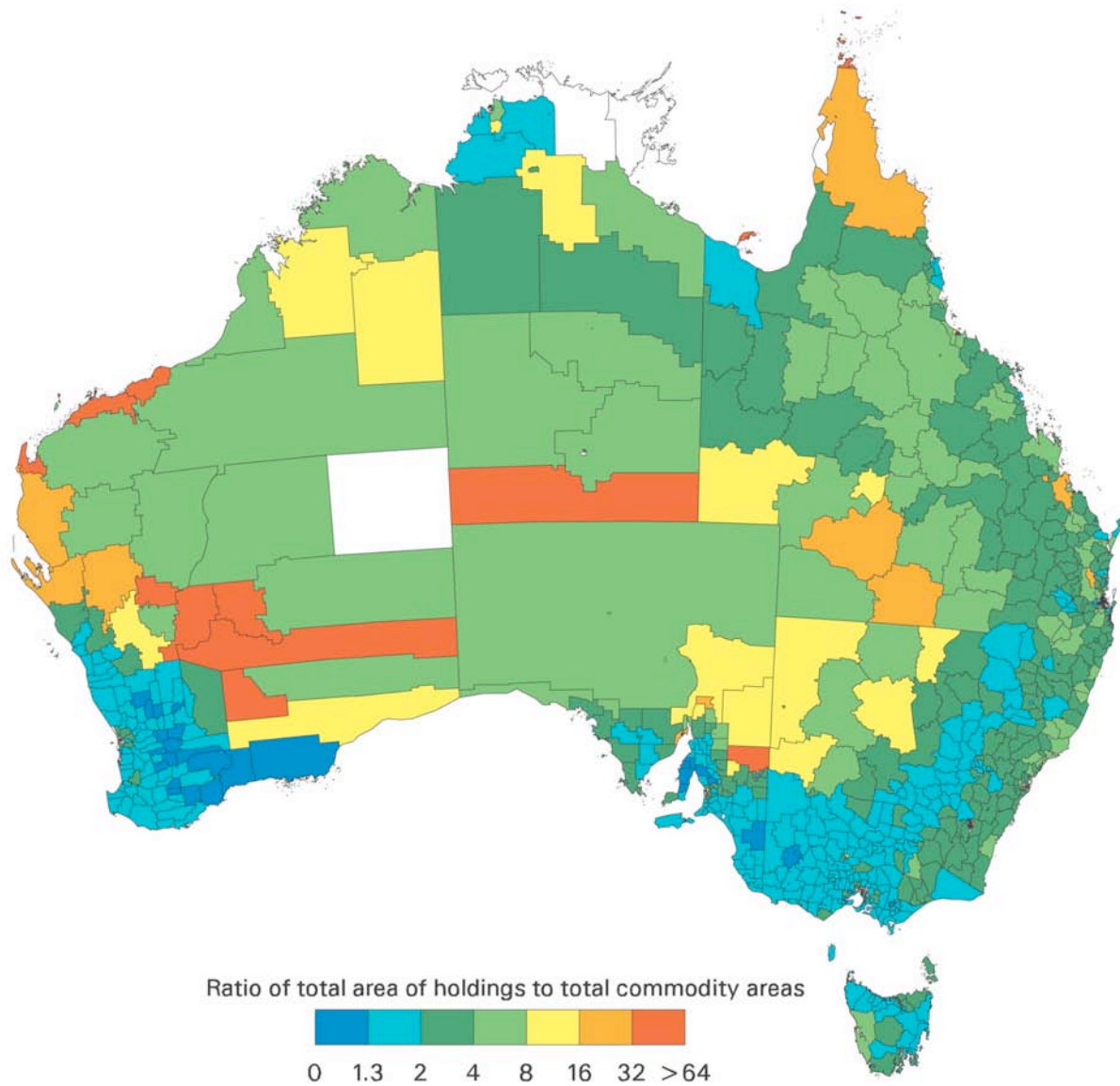
Figure 8. Discrepancy within AgStats between total area of agricultural commodities and total area of holdings.

Table 9 shows a comparison of the modified 1996/97 AgStats area data with the mapped potentially agricultural land areas for all SLAs.

Table 9.   Comparison of AgStats 96/97 area data (after modifications) with the potentially agricultural land areas for all SLAs.

Agricultural area data	Data source	Total area (x 10^6 ha)
Total area of agricultural commodities	Modified 1996/97 AgStats	117
Total area of holdings	AgStats 96/97	466
Mapped area of potentially agricultural land	Non-agricultural land use map	475
Mapped area of potentially agricultural holdings	Non-agricultural land use map	490
Mapped area of potentially agricultural holdings forested[a]	Non-agricultural land use map	15

[a] Potentially forested agricultural holdings = Potentially agricultural holdings – Potentially agricultural land

Ideally the mapped area of potentially agricultural holdings should equal the AgStats total area of holdings. Likewise, the mapped area of potentially agricultural land should equal the modified total area of commodities from AgStats. As Table 9 shows this does not occur and indicates:

1. A major discrepancy within AgStats. The total area of agricultural commodities is much less than the total area of holdings. This discrepancy is too large to be merely a consequence of the inclusion of non-productive forested areas in the total area of holdings. Table 9 shows that forested areas on farming enterprises are around 15 million hectares. Figure 8 shows spatially the variation in magnitude of this discrepancy across Australia.

2. Discrepancies between AgStats and the non-agricultural land use map.

    - The total area of holdings is a little less than the mapped area potentially agricultural holdings. Figure 9 shows spatially the variation in magnitude of this discrepancy.

    - The total area of agricultural commodities is much less than the mapped area of potentially agricultural land.

The conclusions drawn from these findings were:

1. Under reporting of native pasture probably largely accounts for the major discrepancy within AgStats and between AgStats and the non-agricultural land use map. This is supported by:

    - Native pasture being the only agricultural commodity occupying significant area that is easily overlooked by agricultural census respondents as it entails little or no active management.

    - These discrepancies being smallest in the broadacre cropping belt and largest in the rangelands (see Figure 9).

2. Non-distribution to some agricultural enterprises and/or non-return of the agricultural census could account for some of the discrepancy between AgStats and the non-agricultural land use map.

3. The existence of non-agricultural land uses, especially rural residential land use, in the mapped potentially agricultural holdings, probably accounts for some discrepancy between AgStats and the non-agricultural land use map. This is supported by:

    - Through process of elimination, rural residential land use is the only non-agricultural land use likely to occupy relatively large areas of the mapped potentially agricultural holdings.

    - These discrepancies being largest in peri-urban areas and smallest in more remote rural areas (see Figure 8).
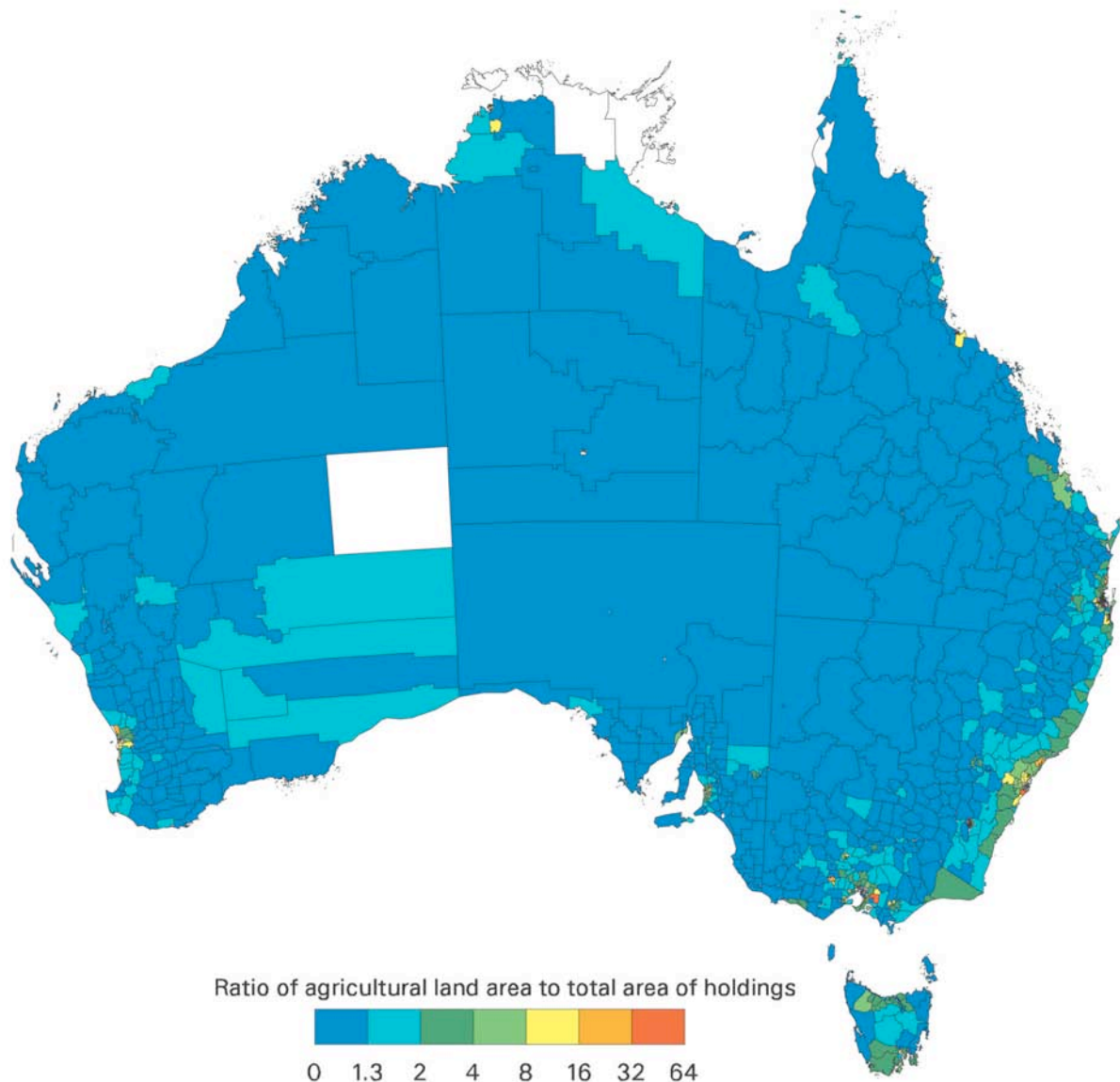
Figure 9.   Discrepancy between AgStats' total area of holdings and the mapped potentially agricultural
holdings area.

To achieve a set of area constraints for SPREAD in agreement with the non-agricultural land use map, it was necessary to further modify the AgStats data. Considering the conclusions above, the following method was employed:

1. For each SLA where the AgStats total area of holdings was greater than zero, the ratio of the mapped area of potentially agricultural holdings to AgStats total area of holdings was calculated. This was called the 'map to AgStats ratio'.

2. The threshold to which the 'map to AgStats ratio' was applied to adjust AgStats to fit the available mapped area was established. Above this threshold, scaling of AgStats was not undertaken.

3. The assumption underlying this approach was that, in SLAs where the available area was much larger than the total of the AgStats commodity areas, this was likely because some of the available area was used for other land uses, most likely intensive land uses such as hobby farms or mining. Therefore, allocating agricultural land uses to all of the available area was inappropriate. The AgStats data was not scaled up and the unallocated potentially agricultural land was assumed used for intensive land uses. The spatial distribution of the potentially agricultural land to which

agricultural land uses were allocated determined the spatial distribution of the unallocated potentially agricultural land by default.

4. Where scaling was undertaken, the after-scaling commodity area total would generally still be less than the available area, so the area of dryland native pasture was increased sufficiently to make the total commodity area equal to the available area.

5. Where scaling was not undertaken, the (non-scaled) commodity area total was generally less than the total area of holdings and the area of dryland native pasture was increased sufficiently to make the total commodity area equal to the total area of holdings.

The number of SLAs falling into the different cases detailed in Table 10 varied depending on the value of the scaling threshold. For the scaling threshold used, most SLAs fell into cases A, B1 and C1.

Table 10. Details of AgStats scaling and adjustment procedures used to achieve compatibility with the non-agricultural land use map. The meanings of the symbols used are as follows for a SLA:

f = AgStats total commodities area

h = AgStats total area of holdings

F = mapped area of potentially agricultural

H = mapped area of potentially agricultural holdings

θ = map to AgStats ratio (θ = H/h)

Θ = map to AgStats ratio threshold

Case	Primary SLA selection criteria	Secondary SLA selection criteria	Adjustment procedures	Sum of adjusted commodity areas
A	$h = 0$	None (all have $f = 0$)	Increase area of dryland native pasture to F for two SLAs on the basis of information from the Indigenous Land Corporation.[a] Otherwise no change.	0 or F
B1	$h > 0$ and $\theta \leq \Theta$ [b]	$\theta f \leq F$ and $f \leq h$ [b]	Scale all commodities by θ; increase scaled area of dryland native pasture by F - θf.	F
B2	$h > 0$ and $\theta \leq \Theta$	$\theta f > F$ and $f \leq h$	Scale all commodities by F/f.	F
B3	$h > 0$ and $\theta \leq \Theta$	$f > h$	Scale all commodities by F/f.	F
C1	$h > 0$ and $\theta > \Theta$ [b]	$f \leq h \leq F$ [b]	No scaling. Increase area of dryland native pasture by h - f.	h
C2	$h > 0$ and $\theta > \Theta$	$h < f \leq F$	Scale all commodities by h/f.	h
C3	$h > 0$ and $\theta > \Theta$	$f \leq F < h$	No scaling. Increase area of dryland native pasture by F - f.	F
C4	$h > 0$ and $\theta > \Theta$	$f > F$ and $h < F$	Scale all commodities by h/f.	h
C5	$h > 0$ and $\theta > \Theta$	$f > F$ and $F \leq h$	Scale all commodities by F/f.	F

[a] The two SLAs were West Arnhem (ASGC code 710154809) and Aurukun (S) (ASGC code 350100250).

[b] Criteria overridden for three SLAs which were placed in case C1. The SLAs were La Trobe (S) - Morwell (ASGC code 255053814), La Trobe (S) - Traralgon (ASGC code 255053815) and Yallourn Works Area (ASGC code 255058509). These SLAs are in the La Trobe Valley and contain large areas used for open cut brown coal mining. Scaling of the AgStats data to fill all the potentially agricultural land was inappropriate for these SLAs. The SLAs would have fallen in either case C1 or B1 depending on the value of Θ.

An appropriate value for the map to AgStats ratio threshold was arrived at through consideration of the data, both visually and analytically. Figure 10 shows how post-scaling total commodity area varies as a function of Θ. Post-scaling total commodity area is a monotonic increasing function of Θ.

For Version 1 of the map, Θ was set to 2. Many areas of potentially agricultural land left unallocated by SPREAD proved, on examination of Landsat TM images, to be agricultural land. The value of the parameter was raised to 4.2 for Version 1a of the map and left at that value for Version 2. Table 11 summarises the results of scaling using Θ = 4.2.

For Θ = 4.2, the total area of agricultural commodities to be allocated was 473 million ha, leaving 1.5 million hectares of the mapped potentially agricultural land not allocated. If Θ had equalled 2, the areas to be allocated would have been 472 million ha with 3.0 million ha left unallocated.
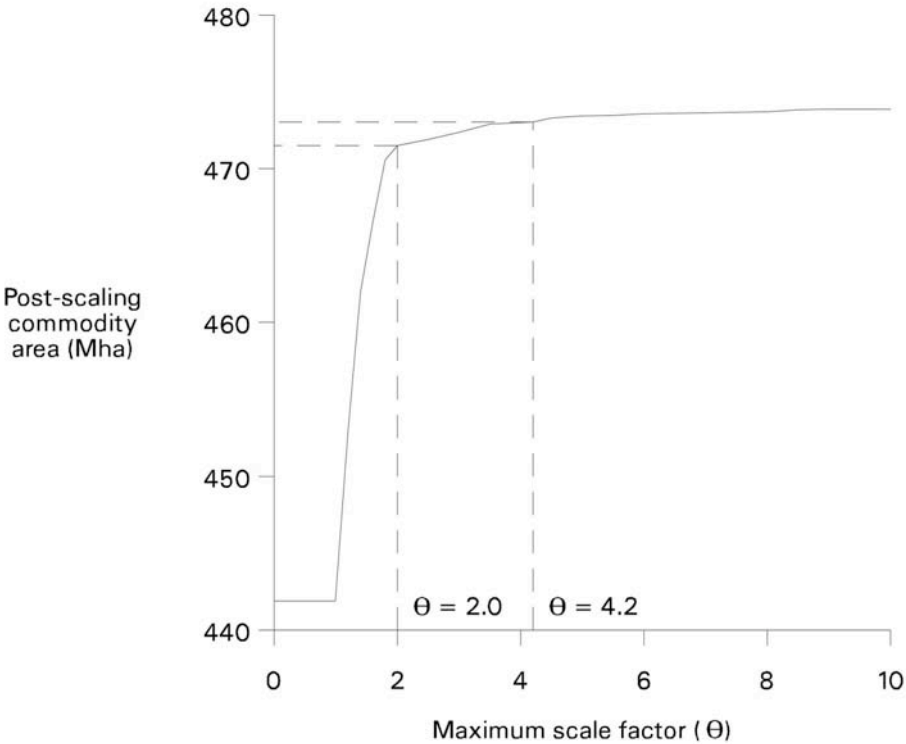
Figure 10.   Graph showing post-scaling total commodity area as a function of Θ.

After running SPREAD, the actual unallocated area of the mapped potentially agricultural land was 1.8 million ha. The actual unallocated area was larger than the calculated 1.5 million ha because SPREAD does not allocate all of the area specified in the table of area constraints. This is because SPREAD can only allocate whole pixels to an agricultural land use.

Figure 11 shows where the unallocated potentially agricultural land occurred. This land is shown as clusters for visibility at the scale mapped. These clusters account for 87% of the unallocated potentially agricultural land with the remaining 13% occurring as scattered areas less than 500 ha. It is assumed that predominantly this unallocated land is rural residential.

Table 11. Summary of results of scaling AgStats data using a scale factor $\Theta = 4.2$ and comparison with other area data. Results shown correspond to the separate scaling cases as given in Table 10. Areas expressed in millions of hectares.

Data type	Data source	Case A	B1	B2	B3	C1	C2	C3	C4 and C5	All SLAs
Number of SLAs	Non-agricultural land use map	352	717	12	2	225	2	1	0	1311
Total area of agricultural commodities	Modified AgStats 96/97	0.0	117	0.4	0.0	0.1	0.0	0.0	0.0	117
Total area of holdings	Modified AgStats 96/97	0.0	465	0.6	0.0	0.3	0.0	0.0	0.0	466
Post-scaling total area of agricultural commodities	Modified and scaled AgStats 96/97	1.2	471	0.5	0.0	0.3	0.0	0.0	0.0	473
Mapped area of potentially agricultural land	Non-agricultural land use map	1.3	471	0.5	0.0	1.7	0.0	0.0	0.0	475
Mapped area of potentially agricultural holdings	Non-agricultural land use map	1.3	485	0.9	0.0	2.1	0.0	0.0	0.0	490
Mapped area of potentially agricultural holdings forested[a]	Non-agricultural land use map	0.0	14.4	0.4	0.0	0.4	0.0	0.0	0.0	15.2

[a] Potentially forested agricultural holdings = Potentially agricultural holdings – Potentially agricultural land

Control sites for agricultural land use

To allocate the dominant land use (commodity based) to each 1.1 km^2 of potentially agricultural land, known locations for each commodity type were required. The 1996/97 AgStats provided the framework in which to select the range of commodities required for a particular region (SLA based). A table, map, instructions and electronic data form were provided to the States indicating the agricultural commodities required in the selected SLAs (see Appendix 7). The electronic data form also collected information on land management practices and the agricultural commodities grown in the years 1997/98, 1998/99 as well as for 1996/97. The returned forms were combined into a database of control sites from which was extracted the location, agricultural land use and irrigation status for construction of input files to SPREAD and the control site locations theme.

Sampling strategy

Sampling for a Network of Rural Commodity Production Sites (1999) provided the sampling strategy implemented by the participating States (Appendix 6). The intention was to not sample agricultural commodities in all SLAs, but to strategically sample the range of major agricultural enterprises occurring within similar biophysical regions. To achieve this, rules were determined for each of the 21 Audit Commodity groups to allow a scattering of sites across the country and optimised within

biophysical regions using the Interim Biogeographic Regionalisation of Australia (IBRA Version 4.1, Australian Nature Conservation Agency 1995/98). These rules are given in Table A6.2.

Clusters of unallocated potentially agricultural land:

● Total area between 500 and 5000 ha

● Total area between 5000 and 50 000 ha

● Total area between 50 000 and 500 000 ha
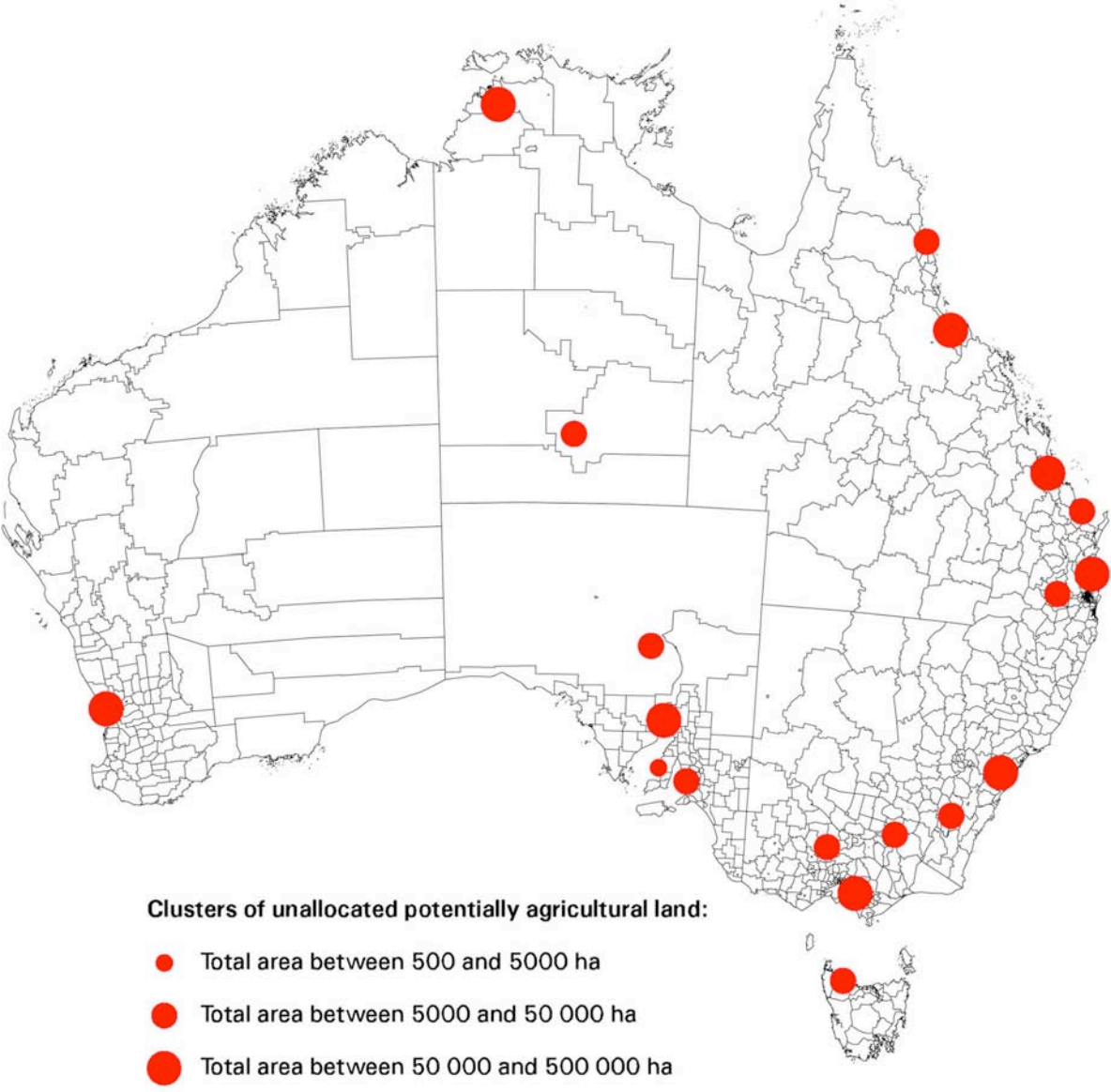
Figure 11. Unallocated potentially agricultural land. The symbol size distorts the real area by 180 times for the smallest symbol down to 4 times for the largest symbol.

Figure 12 shows the SLAs selected for sampling and the number of different agricultural commodities sought in each selected SLA.
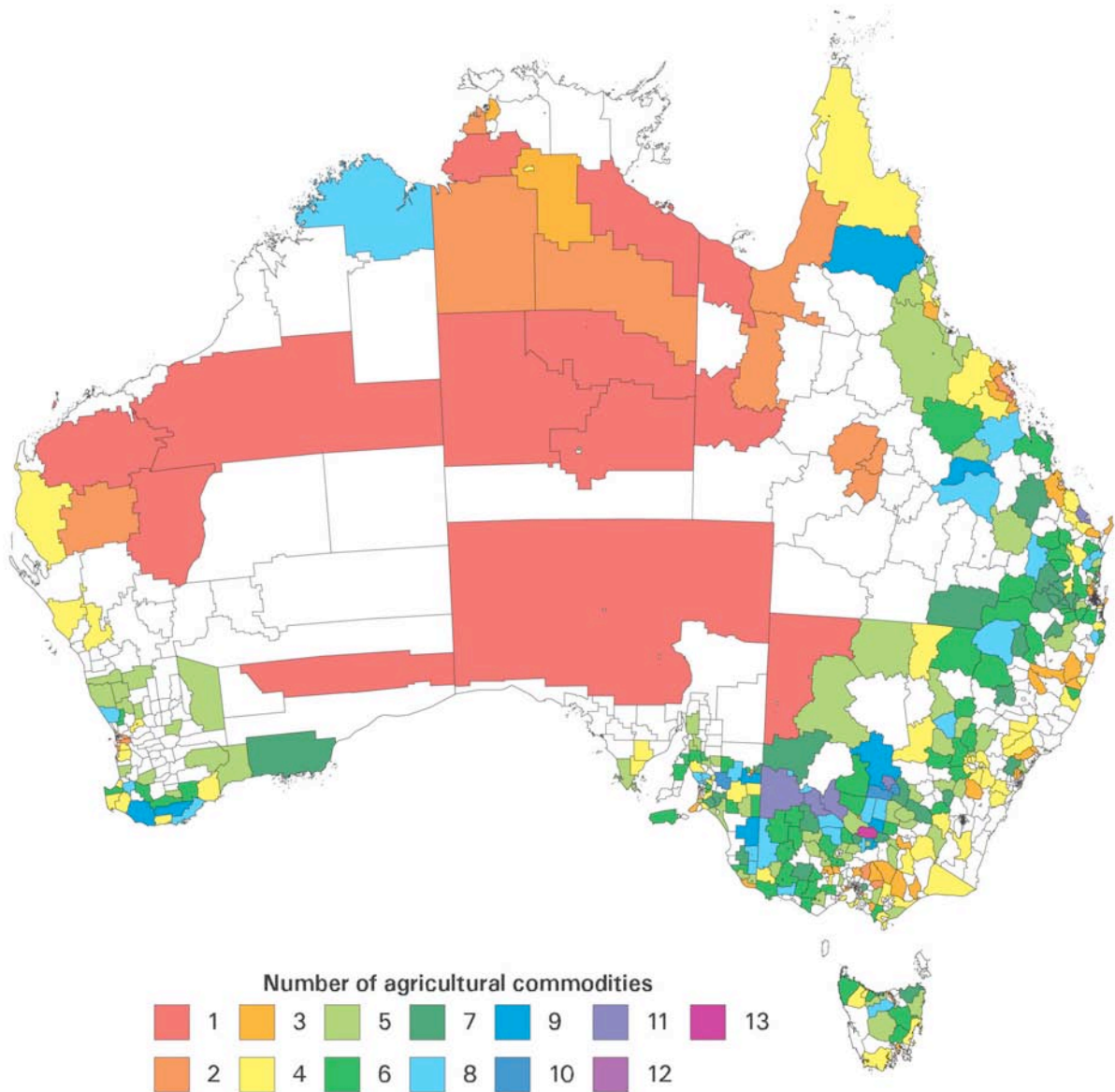
Figure 12. Number of different agricultural commodities sought in selected Statistical Local Areas under sampling strategy.

Control site data form

The electronic form used by the states when collecting control site data is reproduced in Appendix 7. The form was constructed using Microsoft Excel 97 and is called the Control Site Data Form. It provides information on the control site location, the land use in 1996/97 through to 1999, land management practices for the commodities grown and degradation issues affecting the site.

Table 12 shows the number of control sites collected in each state for each commodity group. Irrigated control sites are indicated in italics in brackets. Table 12 also shows those commodity groups for which the states were unable to locate suitable control sites. The control sites for WA were selected from the 1996/97 AgStats presented in 10 km grid cells and supplied by Agriculture WA[15]. Only pasture control sites were provided due to the resolution of the available data.

Table 12. Control sites collected for each commodity by States and used in Version 2 of 1996/97 Land Use of Australia.

| Agricultural commodity | Number of control sites collected by State | | | | | | |
	NSW	VIC	QLD	SA	WA	TAS	NT
Residual/Native pastures	6	29 *(7)*	45	27	10	—	19
Agroforestry	—	9	—	6	—	—	0
Sown pastures	16 *(5)*	42 *(13)*	63 *(12)*	46 *(5)*	10	16 *(3)*	2
Cereals excluding rice	16 *(1)*	32 *(2)*	76 *(5)*	62 *(1)*	—	3	—
Rice	2 *(2)*	3 *(3)*	0	0	0	0	0
Legumes	5	21 *(4)*	21 *(4)*	35	—	1 *(1)*	1 *(1)*
Oilseeds	7 *(2)*	10 *(1)*	7	18	—	3 *(3)*	0
Sugar cane	4	0	73 *(48)*	0	—	0	0
Non-cereal forage crops	—	9 *(4)*	4	—	—	1	—
Cotton	1 *(1)*	0	25 *(24)*	0	0	0	0
Other non-cereal crops	—	1 *(1)*	5 *(5)*	5	—	3 *(1)*	0
Other vegetables	4 *(4)*	6 *(6)*	28 *(28)*	5 *(5)*	—	5 *(5)*	—
Potatoes	3 *(3)*	4 *(4)*	17 *(16)*	6 *(6)*	—	3 *(3)*	0
Citrus	1 *(1)*	1 *(1)*	11 *(9)*	8 *(8)*	—	0	0
Apples	—	4 *(4)*	3 *(3)*	1 *(1)*	—	—	0
Pears	—	3 *(3)*	1	—	—	0	0
Stone fruit	—	7 *(7)*	37 *(9)*	4 *(4)*	—	1 *(1)*	2 *(2)*
Nuts	—	—	18 *(2)*	2 *(2)*	0	0	0
Berry fruit	N/A	N/A	N/A	0	0	0	0
Plantation fruit	2 *(1)*	—	38	0	—	0	1 *(1)*
Grapes	2 *(2)*	7 *(6)*	7 *(2)*	26 *(26)*	—	0	0
State total	69 *(22)*	188 *(66)*	479 *(167)*	251 *(58)*	20 *(0)*	36 *(17)*	25 *(4)*
National total							1068 *(334)*

0 : commodity covered less than 100 ha in a SLA in that State or not reported in 1996/97
— : no control sites collected but commodity covered 100 ha or more in a SLA in that State in 1996/97
( ) : number of irrigated control sites
N/A : not applicable; no control sites requested for berry fruit as maximum area only 301 ha in a SLA.

---

[15] This data is purchased on request by Agriculture WA.

INPUT = **Set of control site data forms**

STEP 1. Extract data from each spreadsheet and combine

STEP 2. Ouput data according to coordinate datum (WGS84, AGD66 or AGD84)

STEP 3. Read data into GIS

STEP 4. Convert coordinates to same datum/projection

STEP 5. Check control sites are correctly located

Remove wrongly located control sites

OUTPUTS = **Control site locations theme (attributes needed to run SPREAD)**

+ ASCII file (all control site attributes)

INPUT 1 = **Control site locations theme**

INPUT 2 = **26 NDVI images**

Extract NDVI profiles for control sites

Figure 13.   Steps in extraction and checking of control sites for use by SPREAD.

Control site data quality control

The control site data forms were individually checked for internal consistency. Inconsistencies were corrected where possible. Forms that could not be corrected were discarded. The statistical package, S-PLUS, was used to extract the raw control site data from each control site data form and combine it into a single flat ASCII file. Further quality control was undertaken using a GIS. Figure 13 summarises the procedure. Control sites were tested against SLA polygons to ensure that the coordinates supplied actually fell within the stated SLA. Control sites that failed this test were discarded. The remaining control sites were used to construct (i) the control site locations theme, containing just those attributes needed to run SPREAD; and (ii) an ASCII file with all attributes.

Extraction of NDVI profiles

The NDVI profiles for the control sites were extracted from the 26 NDVI images by overlaying the images and the control site locations theme in the GIS. These NDVI profiles became SPREAD inputs for the national land use map. The NDVI profiles for a selection of control sites (used in Version 2 of the 1996/97 Land Use of Australia) are given in Appendix 8.

Construction of a database of agricultural land use control sites

The ASCII file containing all control site attributes produced at the end of the quality control procedure was further processed using a UNIX shell script. This script separated the control site attributes into a number of ASCII files structured so that they could be imported directly into the control site database tables. The Version 2 control site database was constructed using Microsoft Access 2000 with tables, forms and some example queries. With all data purged from the tables, the database was completed by: (i) importing the data from the ASCII files (made by the shell script) into the appropriate database tables; and (ii) establishing the appropriate relationships between the tables.

Figure 14 shows a simplified representation of the database's structure (excluding the lookup tables and associated relationship linkages). Figures A7.2 to A7.7 show the presentation of the data within the control site database through a series of forms and subforms.
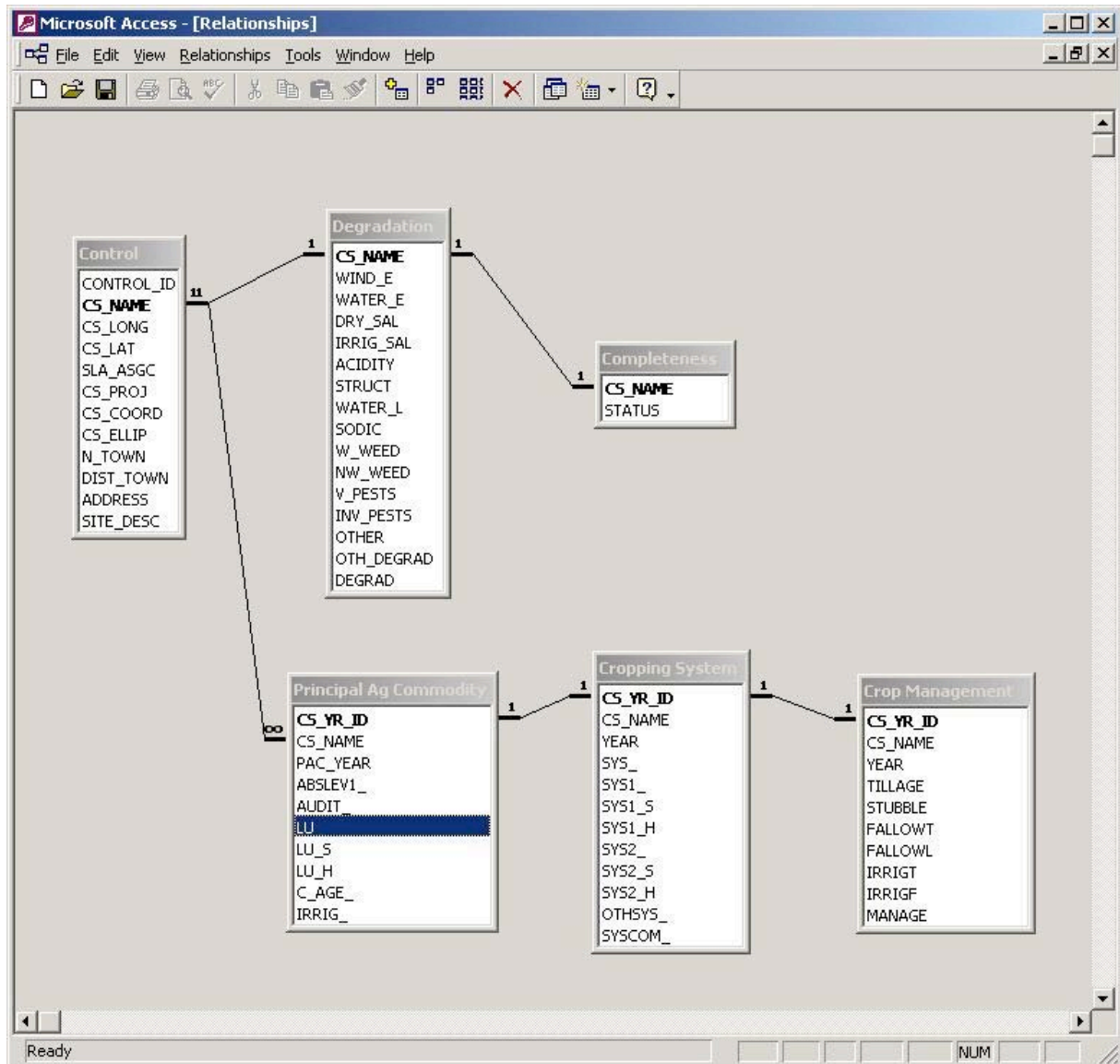
Figure 14. Simplified structure of the Control Site Database for the 1996/97 Land Use of Australia, Version 2. Lookup tables are not shown. The name of the control site (cs_name) is common to all tables however with tables Principal Ag Commodity, Cropping System and Crop Management it is the combination of control site name (cs_name) and year (pac_year or year) that provides the unique identifier represented numerically in cs_year_id.

Version 2 of the Control Site Database contains 1049 control sites. Control sites constructed from data provided by Agriculture WA were not included as they lack all but the attributes needed to run SPREAD. The structure of the control site database allows a multitude of queries to be undertaken. Some examples are given in Appendix 7.

SPREAD: SPatial REallocation of Aggregated Data

Introduction

The SPREAD method involves:

- Dividing the potentially agricultural land in each agricultural census reporting area (SLA) into target zones. Each grid cell or pixel represents a target zone.

- Solving each SLA separately by:

  - Allocating an agricultural land use to each target zone through matching target zones to control sites.

  This is achieved by comparing the NDVI profiles of target zones and control sites. The NDVI profile is a sequence of 26 NDVI values from the NDVI images for an individual grid cell. Using the Gower metric (Gower, 1971), those target zones with the least difference to a particular control site's NDVI profile are assigned its agricultural land use. The Gower metric is a value between 0 and 1 where the smaller the value the more similar the NDVI profiles. Only control sites for the agricultural land uses reported for that SLA are used with preference given to control sites located within or nearby the SLA being solved.

  - Optimising the solution for each SLA subject to the constraint that the total area of target zones allocated an agricultural land use must agree with the modified AgStats data.

  The optimisation involves minimising the sum, over all target zones in the SLA, of the product of the target zone area and the Gower metric difference between target zone and matched control site.

A heuristic equivalent of the linear programming method of SPREAD was used due to the excessive computing resources required by the linear programming method. The heuristic algorithm sorts the land uses and affinities (the Gower metric difference) for all target zones and allocates target zones to the closest land use. The land use allocated is constrained by the threshold set for the affinity (or similarity to control site) and the total area available for that land use to be allocated.

The heuristic algorthim passes through the target records up to the number of land uses available to be allocated. With each pass the algorithm tries to allocate the target zone to the land use with the closest affinity.

To further reduce computing time and problem complexity, pre-allocation rules are also applied to the data. The two pre-allocation rules allocate target zones to a land use based either on a 'closeness' criterion or if only a single land use exists then target zones are allocated to this land use. Any target zones left unallocated after the pre-allocation routines are then allocated using the heuristic algorithm.

The allocation process is continued until the area less than or equal to the required total area is allocated. This is the conservative approach and mimics the linear programming allocation.

The SPREAD methodology is documented in Appendix 5. This section describes the steps taken to apply the SPREAD methodology and code to produce the overall land use map.

Inputs required by SPREAD

For each SLA the SPREAD procedure requires three inputs.

1. The NDVI profiles for the target zones (the zones to be predicted).

2. The NDVI profiles for the control sites (from the sampled sites).

3. The area constraints applied to the various commodities.

A unique identifier is required for each target zone. Unique identifiers were constructed by making an ARC/INFO grid with the same structure and coordinate system as the NDVI images and with a unique integer value for each cell.

The area of each target zone must be supplied. Target zone areas were calculated, in hectares to nine decimal places, for each cell in one column of an ARC/INFO grid with the same structure and coordinate system as the NDVI images. Since the NDVI images use geographic coordinates (longitude and latitude), the areas of all pixels in a single row are the same. A large number of decimal places were used to avoid systematic bias in the area calculations made by SPREAD.

SPREAD determines the area allocated to a land use in a SLA by adding the areas of the individual target zones.

To construct a solution for a given SLA, SPREAD requires a list of appropriate control sites for each land use in the SLA. The control sites chosen for a given land use in a SLA were the four (or fewer) closest to the centroid of the SLA, and within a 500 km radius. If there were no control sites for the land use within the 500 km radius, the nearest one was included in the list.

Two area constraints tables are required, one for allocation of irrigated agriculture and the other for dryland agriculture allocations. To avoid unnecessary processing of SLAs with negligible agriculture, only those SLAs were included where the sum of the areas of all commodities groups to be allocated in each table was greater than 89 ha. The threshold of 89 ha was chosen because it is slightly less than the area of the smallest target zone.

All SPREAD inputs were converted to formatted ASCII text files. Input data in ARC/INFO grid format were unloaded to ASCII text files using the ARC/INFO command 'gridascii'. The NDVI images were converted to ARC/INFO grids and the data unloaded in the same way. A collection of C programs were used to further process all input data to achieve the structure and format required by SPREAD.

Target zone file creation

The target zones are extracted from the ARC/INFO ascii grids for all of Australia. These are produced by the gridascii command using the program *extract.out*. This program accepts a single command line input which is the name of a file with the following structure:

Line 1: Path of output file.

Line 2: Gridascii file containing unique id numbers for each cell in grid. Id numbers run from 1 in the top left and are filled in by row.

Line 3: Path of mask/SLA gridascii file. This grid has either the SLA number for each cell or –9999 if the point is nodata (e.g. sea etc) or –1 for masked data.

Line 4: Path of areas gridascii file. For historical reasons this grid is 2 cells wide and the same height as the other grids. Each cell contains the area of the gridcell for the particular latitude.

Line 5-31: Path(s) to gridascii files giving the imagery for the grid.

Obviously, the grids used for each component must be congruent.

Control site file creation

The control site files are created on win32 systems (due to superior programming facilities). The program used is *controlsites.exe*. The *extract profiles* command under the file menu produces a dialog. The inputs are

Control site file: The path of the master file (described below) giving the control site locations, land uses and imagery. The file has the following tab delimited field: unique id, latitude, longitude, 9 category land use, 21 category land use, NDVI value 1, …,NDVI value 26.

SLA centroid file: The path to the file containing the SLA centroids. The file is tab delimited with fields: SLA number, latitude of centroid, longitude of centroid.

Find nearest: Number of control sites to be located for each SLA.

Output fn: Format of output filenames. The # character is replaced with the filename.

Images: Number of NDVI images.

Area file creation

The structure of this file is described in Appendix 5 and the calculations used in its construction given in Table 10.

The version of SPREAD implemented was influenced by the following 2 characteristics:

1. The total number of land uses that could be allocated in any one solution was 21.

2. Where the total area of target zones in a SLA exceeded the total area of agricultural land uses sought, SPREAD finds the optimum allocation of the land uses and leaves target zones unallocated to account for the area difference.

The first of these characteristics meant that, although the irrigation status of most of the control sites is known, it was not possible to allocate irrigated and dryland versions of the Audit Commodity Classification land uses in a single run of SPREAD. The total number of land uses to be allocated in this case would be approaching 40. The second characteristic meant that it was still possible to achieve this objective by using two successive runs of SPREAD, by masking out those target zones solved in the first run when running the second. The second characteristic also means that for SLAs containing non-agricultural land whose spatial distribution is unknown, the SPREAD solution leaves these target zones as unallocated.

Accordingly, two runs of SPREAD were used, the first to allocate irrigated agricultural land uses, the second to allocate dryland agricultural land uses. Potentially agricultural land that remained unallocated was assumed to be non-agricultural and assigned to 'intensive uses' according to the Australian Land Use and Management Classification (ALUMC), Version 4. A more specific classification at ALUMC's secondary or tertiary level was not possible as the land use could represent a variety of intensive land uses such as rural residential properties and mining.

While it is possible to run the SPREAD software individually for each SLA it is easier to use a batch script to control the program's execution. The script used is called *batchspread.* This script accepts as input a file with four columns and a row for each SLA in the analysis. The four columns are

Column1: 9 digit SLA number.

Column2: SLA name.

Column3: Path to control site input file for SLA.

Column4: Path to file containing answers to questions in the SPREAD script.

Outputs from SPREAD

The outputs of the SPREAD script are detailed in Appendix 5. Several programs process this output to produce the final maps:

> update_gridp3.out: This program makes the gridascii file to be read by ARC/INFO. It takes three arguments. The call is
> *update_gridp3.out command_file template outfn*
> where *command_file* is the path of a command file described below. The *template* is the location of the base gridascii file to be used in producing the final map. *Outfn* is the path of the file used to write the final output.
> The command file has a single column and gives the names (with full paths) of the allocation files)produced by SPREAD.

> Affoutputs: Produces the affinity grid and id grid from the output. The call is
> *affoutputs command_file afftemplate idtemplate affoutfn idoutfn map*
> where *command_file* is the path of a command file described below. The *afftemplate* and *idtemplate* is the location of the base gridascii file to be used in producing the id and affinity map. *affoutfn* and *idoutfn* are the paths of the file used to write the final id and affinity outputs. Map is the land use map produced by update_gridp3.out.
> The command file has a single column and gives the names (with full paths) of the allocation files produced by SPREAD.

Allocation of irrigated and dryland agricultural land uses

Irrigated agricultural land uses were allocated in the first run of SPREAD. Irrigated control sites were available for all agricultural land uses except agroforestry. For this run, the SPREAD input mask was used with all potentially agricultural land unmasked except in the SLA containing the Ord River Irrigation Area. The SLA concerned was Wyndham–East Kimberley (S), Western Australia (ASGC code 545059520). For this SLA, only the potentially agricultural land in the Ord River Irrigation Area was left unmasked. Digital boundary data for Stage 1 of the Ord River Irrigation Area supplied by Agriculture WA were used for this purpose.[16] Without this constraint, SPREAD was found to allocate 4300 ha (of a total of 6100 ha) of irrigated agriculture to target zones outside the Ord River Irrigation Area, which is inconsistent with the known distribution of irrigated agriculture in the SLA.

Dryland agricultural land uses were allocated in the second run of SPREAD. Dryland control sites were available for all agricultural land uses except other vegetables and apples. Irrigated control sites were used for these commodities. For this run, the SPREAD input mask was used with all potentially agricultural land unmasked except the target zones already allocated to irrigated land uses.

Testing the SPREAD allocations against the area constraints tables

For all SLAs, the areas of each commodity group allocated by SPREAD were tested against the areas sought, as specified in the area constraints tables. A discrepancy of up to 366 ha was tolerated without further investigation. The threshold value of 366 ha was chosen because it is approximately the area of three of the largest target zones - the largest target zone is a little smaller than 122 ha. One SLA was found to have an under-allocation of irrigated agriculture. There were no over-allocations of irrigated agriculture. Two SLAs were found to have an under-allocation of dryland agriculture. There were no over-allocations of dryland agriculture.

The SLA with an under-allocation of irrigated agriculture was Yarra Ranges (S) – South-West, Victoria (ASGC code 205607455). The error was non-allocation of any irrigated berry fruit though 368 ha had been sought. The reason for the error is that no berry fruit control sites were obtained due to the small size of the tracts within which berry fruit are grown. No remedial action was taken. This area was allocated to unallocated agricultural land.

The SLAs with an under-allocation of dryland agriculture were Unincorp. Far North, South Australia (ASGC code 435259589) and Victoria, Northern Territory (ASGC code 710304409). For Unincorp. Far North, dryland native pasture was the only commodity to be allocated but the area was too large (31 000 000 ha) for SPREAD to solve. As only one land use was to be allocated, and it was to be allocated to the entire area of potentially agricultural land in the SLA, the allocation was performed manually. For the SLA Victoria, the shortfall was approximately 1000 ha (about nine pixels) in the allocation ~12 000 000 ha, of dryland native pasture. No remedial action was taken in this case.

Strengths and weaknesses of SPREAD approach

The SPREAD approach has a number of strengths and weaknesses. Its strengths are

1. Construction of a map that is subject to sensible constraints in terms of its predictions. In practice this means that aggregations made at a scale larger than the SLA will tend to accurately reflect the (modified) ABS statistics.

2. Providing a technique for integrating AVHRR and Australian Bureau of Statistics agricultural census data.

The weakness of the technique, as applied here, are:

1. The technique cannot deal with mixed land use within a pixel.

2. The technique relies on being able to discriminate between land uses based on the Gower metric (Gower, 1971). This discriminate function is not optimal in this case as it does not weight information effectively.

3. The technique does not allow for uncertainty in our knowledge of the constraints.

---

[16] The boundaries of the Ord River Irrigation Area are contained within the Irrigation Areas of Australia, Version 1a data set.

Appendix 9 provides a more detailed analysis of the SPREAD approach covering the discrimination powers of the NVDI profiles; the effect of the constraint and sample size on the Gower metric and the use of the Gower metric as a discriminator.

Land use classification

Background to national approach to land use/land management classification

The Audit has funded two land use mapping products; a national level land use data set to address broad land use issues, and a finer scale product for the Key Implementation Areas (KIAs) nominated by State agencies. These products have applied an agreed land use classification scheme arising from a joint Commonwealth-State workshop held 17-18 February 1999 (Barson, 1999). The basis for this land use classification is the classification developed by Baxter & Russell (1994) for the Murray-Darling Basin Commission. The Baxter & Russell (1994) approach to land use mapping is based on the concept of 'level of intervention' in the landscape, rather than descriptions of land use based on outputs. The resulting Australian Land Use and Management Classification is a three-tiered hierarchical structure of primary, secondary and tertiary classes. The primary classes are distinguished in order of increasing level of intervention or potential impact on the natural landscape. These primary classes are:

1. Conservation and natural environments

2. Production from relatively natural environments

3. Production from dryland agriculture and plantations

4. Production from irrigated agriculture and plantations

5. Intensive uses

The classification requires the identification of 'prime use' at each level defined in terms of the prime management objective of the land manager. The classification is also designed as a framework within which land management practices can be identified. Land management practices refer to the means by which the land management objective (land use) is achieved. Land management practices are identified in the Baxter & Russell classification as 'management factors'. Characteristic sets of management factors generally apply to each of the 5 primary levels of classification.

A sixth primary class has been added to the Australian Land Use and Management Classification (ALUMC) to classify water features according to use.

The ALUMC has undergone changes following discussions with users of the classification resulting in the current version 4 of the classification (October 2000). The various versions are available at http://www.affa.gov.au by searching for ALUMC. The principles and definitions of the ALUMC as they relate to version 4 are given in Lesslie (2000). Version 4 of ALUMC was applied to Version 2 of the 1996/97 Land Use of Australia according to the rules given in Appendix 4. Appendix 4 also indicates the changes in the land use assigned between Version 1a and Version 2 of the 1996/97 Land Use of Australia.

The ALUMC was used to classify the national land use data set to enable comparison between different land use products applying a classification supported and recognised by the States and Territories. The ALUMC still has issues to resolve in its classification particularly the ability to record multiple uses for a land parcel and clarity on what land uses are assigned to particular classes. Use of the classification and feedback from users should ensure that the classification continues to improve. Of importance is that the framework is correct and that the classification is flexible to allow new classes to be added when needed.

Adapting commodity based classification to land use

SPREAD assigned agricultural land use to one of 19 Audit commodities, as given in Table 13. These Audit commodities are generally combinations of a number of different crop, pasture or horticultural types. The Audit commodities were derived by combining individual AgStats items (Appendix 3). This Audit commodity classification was the basis of the sampling strategy implemented to collect control sites and was developed independently of the ALUMC. With Version 1 of the 1996/97 Land Use of Australia, the Audit requested that an early version of ALUMC be applied to the data set to provide a land use rather than a commodity based product. With subsequent versions of the national land use

Table 13. Land uses in the 1996/97 Land Use of Australia, Version 2 according to the Australian Land Use and Management Classification (ALUMC), Version 4. Indicates the agricultural Audit commodities' (as allocated by SPREAD) ALUMC.

ALUMC primary/secondary class	ALUMC tertiary class	SPREAD Audit commodity
1. Conservation and natural environments		
1.1 Nature conservation		
	1.1.1 Strict nature reserve	
	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 Managed resource protection	1.2.0 Managed resource protection	
	1.2.5 Traditional indigenous uses	
1.3 Other minimal use	1.3.0 Other minimal use	
	1.3.1 Defence	
	1.3.3 Remnant native cover	
2. Production from relatively natural environments		
2.1 Livestock grazing	2.1.0 Livestock grazing	Residual/Native pastures
2.2 Production forestry	2.2.0 Production forestry	
3. Production from dryland agriculture and plantations		
3.1 Plantation forestry	3.1.0 Plantation forestry	
3.2 Farm forestry	3.2.0 Farm forestry	Agroforestry
3.3 Grazing modified pastures	3.3.0 Grazing modified pastures	Sown pastures
3.4 Cropping	3.4.0 Cropping	Other non-cereal crops
	3.4.1 Cereals	Cereals excluding rice
	3.4.3 Hay and silage	Non-cereal forage crops
	3.4.4 Oilseeds and oleaginous fruit	Oilseeds
	3.4.5 Sugar	Sugar cane
	3.4.6 Cotton	Cotton
	3.4.8 Legumes	Legumes
3.5 Perennial horticulture	3.5.0 Perennial horticulture	Plantation fruit
	3.5.1 Tree fruits	Apples
		Citrus
		Pears
		Stone fruit
	3.5.3 Tree nuts	Nuts
	3.5.4 Vine fruits	Grapes
3.6 Seasonal horticulture	3.6.4 Vegetables and herbs	Other vegetables
		Potatoes

ALUMC primary/secondary class	ALUMC tertiary class	SPREAD Audit commodity
4. Production from irrigated agriculture and plantations		
4.3 Irrigated modified pastures	4.3.0 Irrigated modified pastures	Residual/Native pastures
		Sown pastures
4.4 Irrigated cropping	4.4.0 Irrigated cropping	Other non-cereal crops
	4.4.1 Irrigated cereals	Cereals excluding rice
		Rice
	4.4.3 Irrigated hay and silage	Non-cereal forage crops
	4.4.4 Irrigated oilseeds and oleaginous fruit	Oilseeds
	4.4.5 Irrigated sugar	Sugar cane
	4.4.6 Irrigated cotton	Cotton
	4.4.8 Irrigated legumes	Legumes
4.5 Irrigated perennial horticulture	4.5.0 Irrigated perennial horticulture	Plantation fruit
	4.5.1 Irrigated tree fruits	Apples
		Citrus
		Pears
		Stone fruit
	4.5.3 Irrigated tree nuts	Nuts
	4.5.4 Irrigated vine fruits	Grapes
4.6 Irrigated seasonal horticulture	4.6.4 Irrigated vegetables and herbs	Other vegetables
		Potatoes
5. Intensive uses		
	5.0.0 Intensive uses	Unallocated potentially ag. land
5.4 Residential	5.4.1 Urban residential	
5.7 Transport and communication	5.7.1 Airport/aerodomes	
6. Water		
6.1 Lake	6.1.0 Lake	
	6.1.1 Lake - conservation	
6.2 Reservoir	6.2.0 Reservoir	
6.3 River	6.3.0 River	
	6.3.1 River - conservation	
6.5 Marsh/wetlands	6.5.0 Marsh/wetlands	
	6.5.1 Marsh/wetlands - conservation	
6.6 Estuary/coastal waters	6.6.0 Estuary/coastal waters	
	6.6.1 Estuary/coastal waters - conservation	
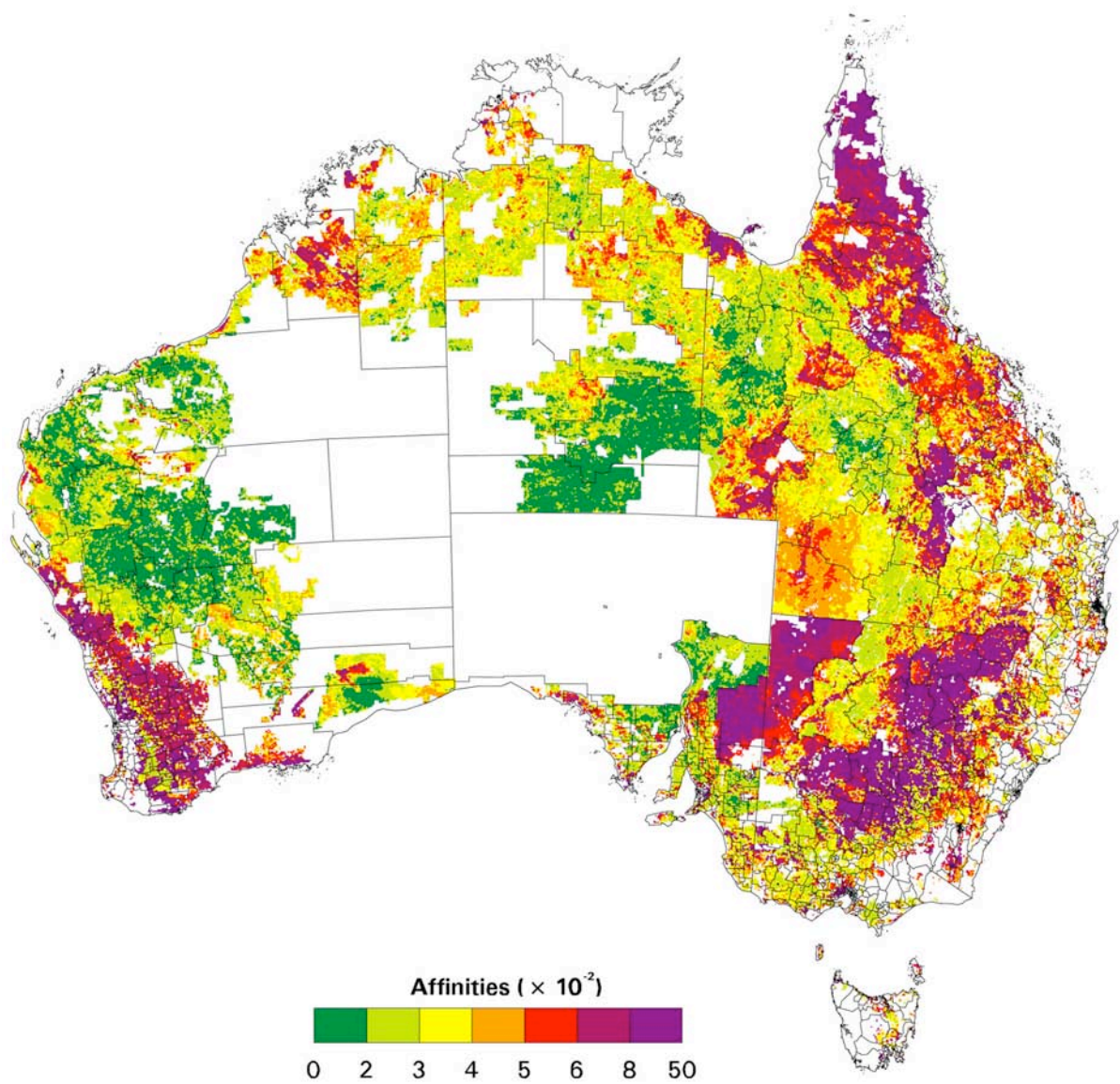
Figure 15.   Affinities theme showing the range of values from 0.000 to 0.483.

data set, the current version of the ALUMC was applied. Table 13 shows the ALUMC classes the Audit commodity categories were assigned according to Version 4 of ALUMC.

Where an Audit commodity was a collection of ALUMC classes the ALUMC class assigned was that which represented the majority of individual crops within the Audit commodity. This particularly applied to the Audit commodities 'other non-cereal crops' and 'plantation fruit'. For example 'other non-cereal crops' includes beverage and spice crops (i.e. hops, tea, coffee), tobacco, flowers and bulbs, herbs (i.e. fennel, coriander) plus others, and falls across the ALUMC classes 3.4 Cropping, 3.5 Perennial horticulture and 3.6 Seasonal horticulture (and the corresponding irrigated classes). Thus 'other non-cereal crops' were assigned to 3.4.0 Cropping or 4.4.0 Irrigated cropping.

Where there was more detail in the Audit commodities (e.g. 3.5.1 Tree fruits or 3.6.4 Vegetables and herbs) these were combined into the relevant tertiary ALUMC class. The information on the individual crop (i.e. apples, stone fruit, potatoes) is retained in the final land use data set in the agricultural commodities layer.

Implementation of land use classification to national level land use mapping

The national land use map is derived from a number of data sets. These data sets when combined are not mutually exclusive (i.e. a protected area might be a forest or a water body). When assigning land use priority is given to

1. Protected areas meeting the International Union for Conservation of Nature and Natural Resources (IUCN) guidelines

2. Topographical features (e.g. water bodies, built-up areas, airports)

3. Tenure (e.g. crown land, leasehold, freehold)

4. Forests (e.g. native forests, plantation forest)

reflecting the reliability of the data sets and the concept of 'level of intervention' in the land use classification.

When applying the ALUMC to the above data sets the following assumptions were made:

- Private land with open or closed native forest with unknown use is assumed to be 1.3.3 Remnant native cover. These areas could potentially be 2.2 Production forestry or 2.1 Livestock grazing.

- Built-up areas assigned to 5.4.1 Urban residential as this constitutes the bulk of the area. Within these built-up areas will occur other intensive uses such as 5.3 Manufacturing and industrial, 5.5 Services, 5.6 Utilities and 5.9 Waste treatment and disposal.

- Institutional crown lands classified as 1.3 Other minimal use rather than 5.5 Services.

- Unallocated potentially agricultural land is assumed to be predominantly intensive uses such as 5.4.2 Rural residential in periurban areas and 5.8 Mining in the La Trobe Valley, Victoria and is assigned to 5.0.0 Intensive uses.

- Irrigated land uses, relate to those areas where SPREAD allocated irrigation to have occurred in 1996/97 and does not indicate all areas where irrigation infrastructure is in place. The Irrigation Areas of Australia, Version 1a indicates designated irrigation boundaries.

- Water bodies within a conservation area have been assigned to 6. Water and the relevant tertiary class (i.e. 6.1.1. Lake – conservation) rather than according to primary class 1. Conservation and Natural Environments.

The application of the ALUMC to prduce the land use layer is given in Appendix 4.
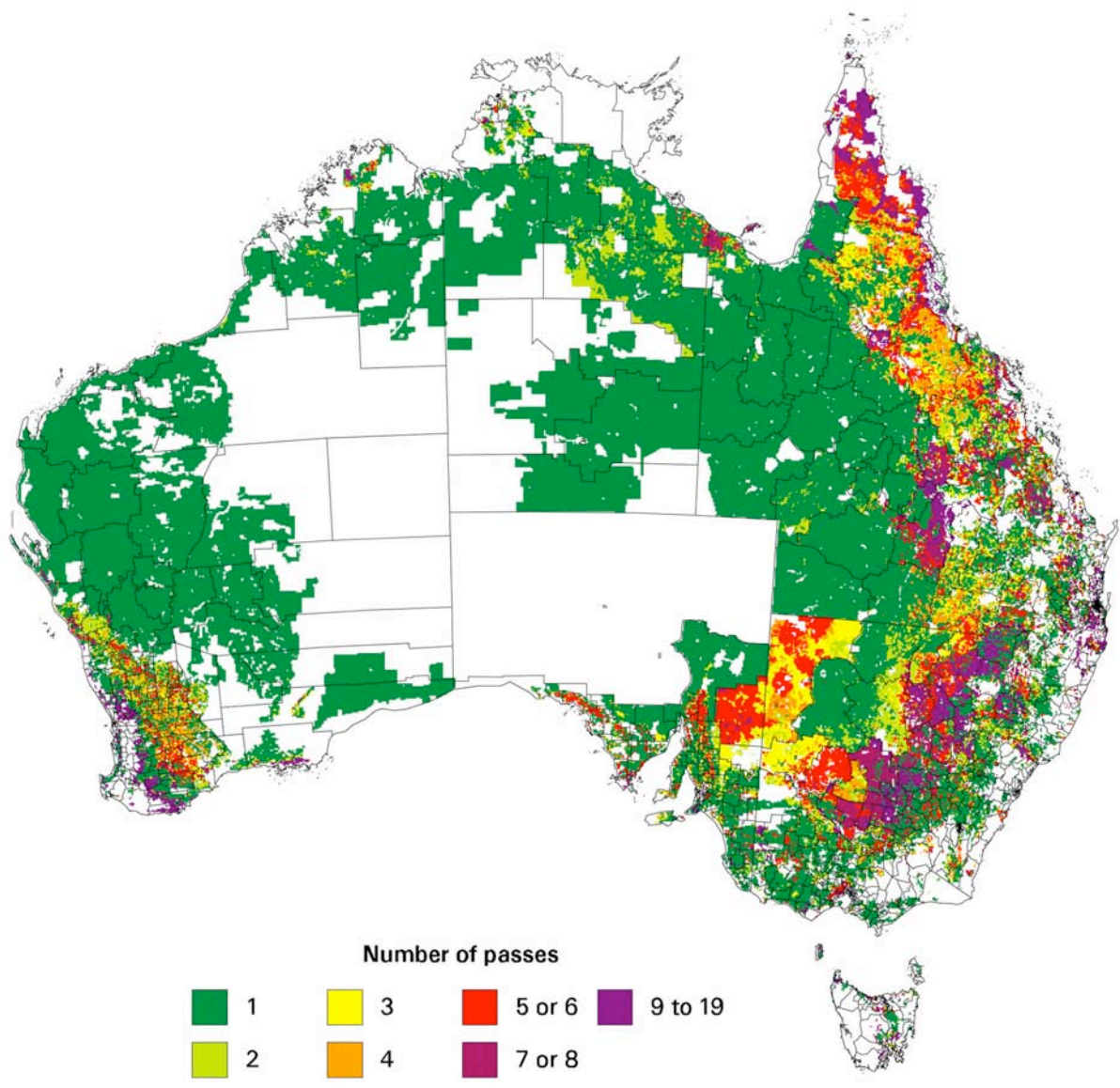
Figure 16. Pass number theme showing the number of passes ranged from 1 to 19.

Assembly of the final land use data set

Overview

SPREAD produces digital map outputs as ASCII text files in ARC/INFO 'gridascii' format. These were converted to ARC/INFO grids. Manual allocation of agricultural land uses was performed for three SLAs. The SPREAD output grids, the non-agricultural land use grid and control site data were then assembled to make the final data set. The structure and components of the final data set have already been described and are shown diagrammatically in Figure 1. The reader is referred to the Metadata and User Guide (Appendix 2) for information about the content of the components of the final data set. The construction of the control site database has already been discussed.

Affinities theme

The two runs of SPREAD each produce a component of the affinities theme: one contains affinity values for irrigated agriculture allocations and the other affinity values for dryland agriculture allocations. These were converted to ARC/INFO grid format to produce the affinities theme. A value of 0 indicates a perfect match and 1 indicates maximum dissimilarity. Figure 15, which shows the affinities theme, suggests that higher affinity values occur where there are more agricultural land uses to allocate within a SLA (refer to Figure 12) or the control site used to solve the land use is not as representative of that land use in the region (affected by distance, geographical region, homogeneity etc) (refer to Figure 20).

Pass number theme

Construction of the pass number theme is the same as for the affinities theme. The two runs of SPREAD each produce a component of the pass number theme: one contains pass number values for irrigated agriculture allocations and the other pass number values for dryland agriculture allocations. These were converted to ARC/INFO grid format to produce the pass number theme. The pass number indicates the number of iterations required to allocate the agricultural land use to a pixel. The smaller the value, the more reliable the land use allocation. Figure 16, which illustrates the pass number theme, shows that the bulk of agricultural land was allocated in 1 pass. Factors affecting the number of passes for an individual pixel are representativeness of the control site used and the number of land uses to allocate within a region as given for the affinities theme.

Land use theme, agricultural commodities layer

The two runs of SPREAD each produce a component of the agricultural commodities layer of the land use theme: one shows irrigated agricultural land use allocations and the other dryland agricultural land use allocations. These were converted to ARC/INFO grid format. From these two grids and the SPREAD input mask, codes were written to a new grid, the agricultural commodities layer, to represent:

- The agricultural commodity allocations – with no distinction made between irrigated and dryland agriculture
- Known non-agricultural land or no data
- Unallocated potentially agricultural land – presumed to be non-agricultural

For the agricultural commodities layer, native pasture, was manually assigned to the unallocated potentially agricultural land in three SLAs. SPREAD failed to solve the SLA Unincorp. Far North (ASGC code 435259589) as the number of pixels to be allocated was too large. AgStats 96/97 indicate that the potentially agricultural land in this SLA should be dryland native pasture. The other manually attributed SLAs were West Arnhem (ASGC code 710154809) and Aurukun (S) (ASGC code 350100250). These SLAs have no agricultural holdings according to AgStats 96/97. On information from the Indigenous Land Corporation, the potentially agricultural land was classified as dryland native pasture.
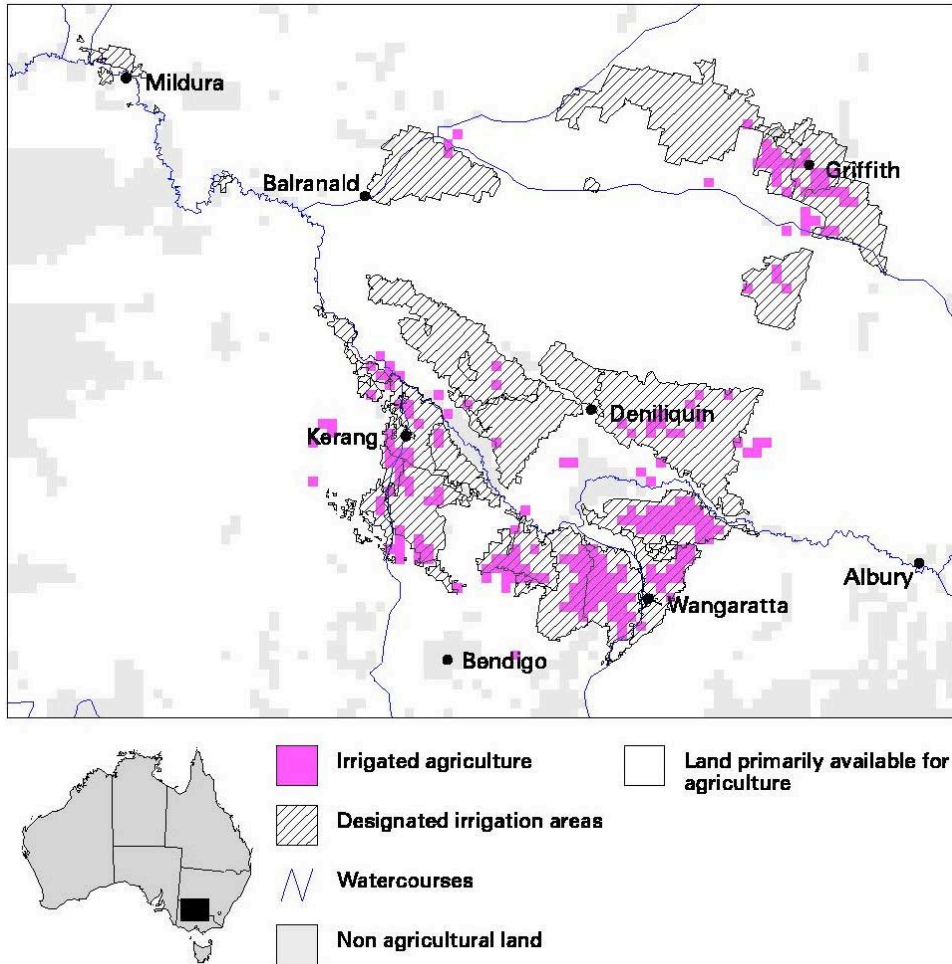
Figure 17. Selected region of Australia showing the irrigation layer in relation to designated irrigation areas and major watercourses. The designated irrigation areas are from the Australian Irrigation Areas, Version 1a.

Land use theme, irrigation layer

The irrigation layer of the land use theme was constructed from the two SPREAD outputs (in ARC/INFO grid format) that form the basis of the agricultural commodities layer. From these grids and the SPREAD input mask, codes were written to a new grid, the irrigation layer, to represent:

▪ Irrigated agricultural land use

▪ Dryland agricultural land use

▪ Non-agricultural land, no data or unallocated potentially agricultural land – this last presumed to be non-agricultural land

The 3 SLAs whose pixels were manually allocated to native pasture in the agricultural commodities layer are shown as dryland agricultural land use.

Figure 17 illustrates the irrigation layer.

Land use theme, affinity class layer

The affinity class layer of the land use theme was constructed from the affinities theme by classifying the affinity values into three classes with, as nearly as possible, equal numbers of pixels in each class. Codes were written to a new grid, the affinity class layer, to represent:

▪ The three affinity classes

▪ Pixels without affinity values which had received manual agricultural land use allocations

▪ Other pixels without affinity values

Land use theme, pass number class layer

The pass number class layer of the land use theme was constructed from the pass number theme by classifying the pass number values into three classes with, as nearly as possible, equal numbers of pixels in each class. Codes were written to a new grid, the pass number class layer, to represent:

▪ The three pass number classes

▪ Pixels without pass number values which had received manual agricultural land use allocations

▪ Other pixels without pass number values

Land use theme, final assembly

In the land use theme, attributes are shown for all terrestrial pixels. Pixels representing ocean or estuaries have no attributes and are 'NODATA' cells in ARC/INFO terminology. Terrestrial pixels were identified using a grid made from the TOPO-250K coastline.

The first step in the final assembly of the land use theme was to write the information in the non-agricultural land use map and the agricultural commodities, irrigation, affinity class and pass number class layers to a new ARC/INFO grid. This was done using the ARC/INFO GRID function 'combine' so that the information in each of the input grids was preserved in the value attribute table (vat) of the output grid.

The second step was to transfer additional attributes to the vat of the output grid from the first step, using relational database joins. Attributes were transferred from the vat of the non-agricultural land use map; those defining land uses were discarded but those defining the protected areas, topographic features, tenure and forest type layers were retained. Descriptive attributes were then added to the exclusively numerical attributes already assembled.

The final step was to add attributes defining land use and constituting the land use layer. This was done using the macro used to add land use attributes to the non-agricultural land use map. The macro (written in ARC Macro Language) is reproduced in Appendix 4. It interprets combinations of input layer values in land use terms, using the Australian Land Use and Management Classification, Version 4 (Bureau of Rural Sciences, 2000). The land use attributes were produced as a lookup table and also joined permanently to the vat of the land use theme grid.

Figure 18 illustrates the land use theme.
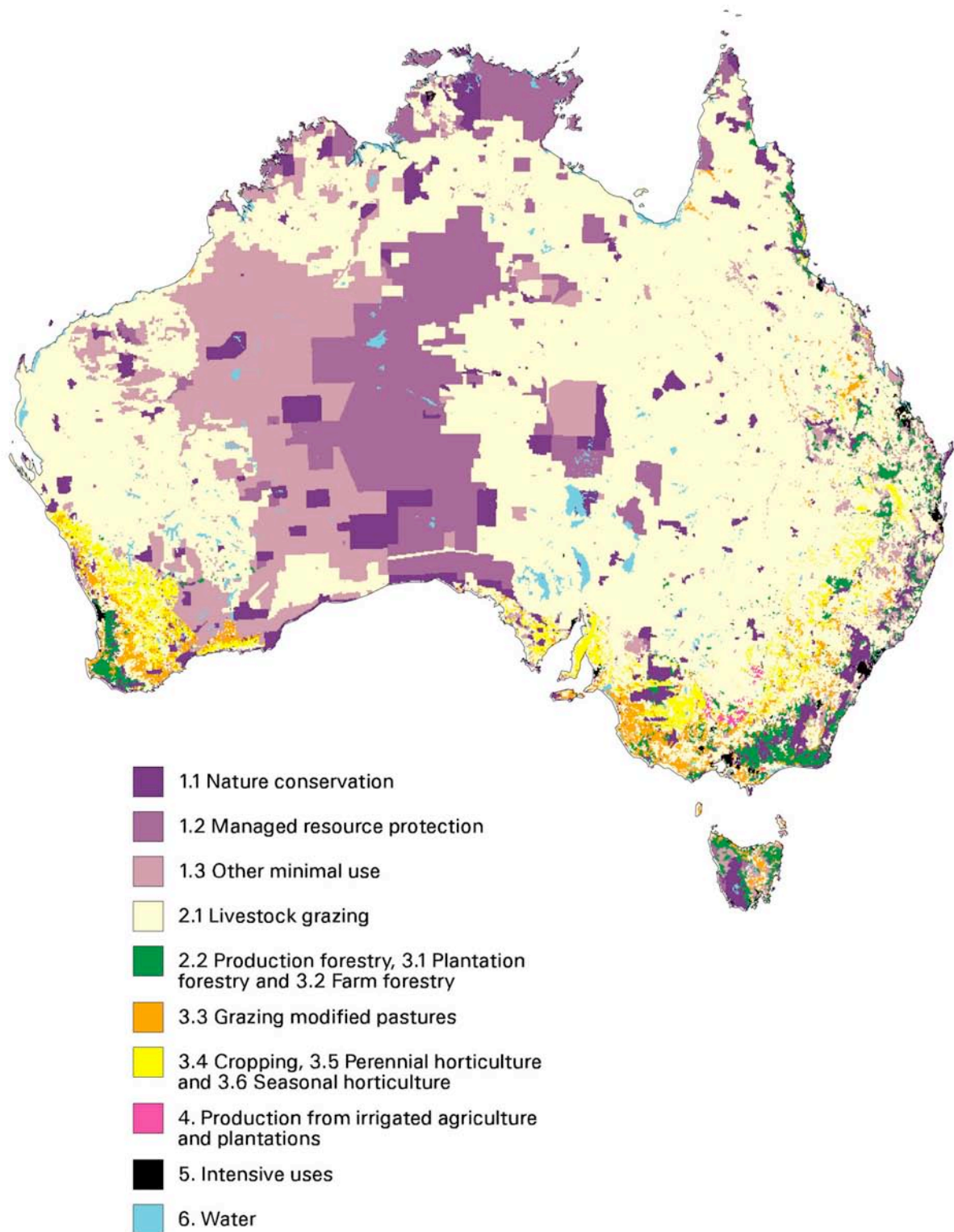
Figure 18. Land use theme summarised into 10 categories following the Australian Land Use and Management Classification, Version 4.
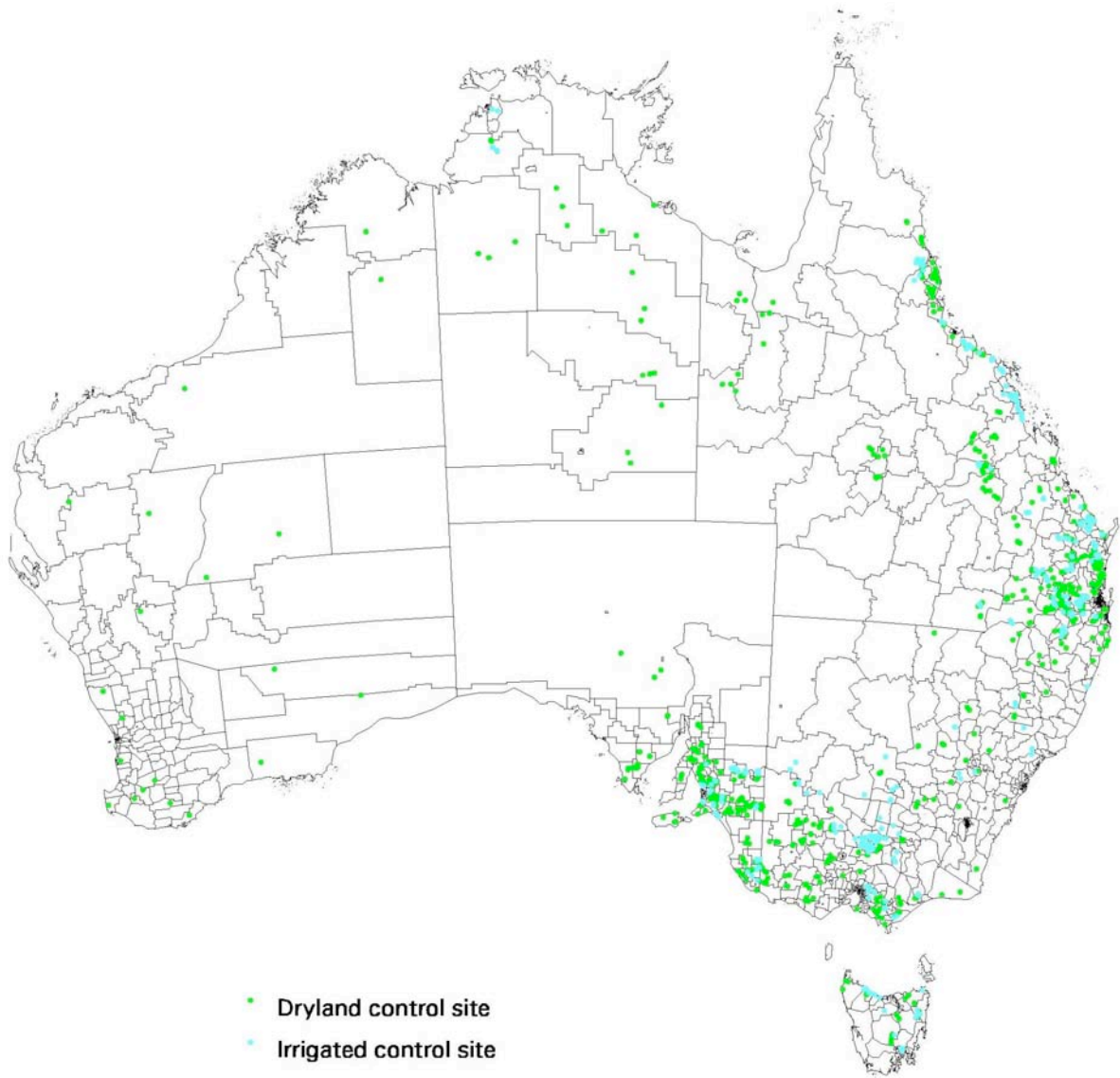
Figure 19. Control site locations theme showing irrigated and dryland control sites used by SPREAD to assign agricultural land use.

Control site locations theme

The control site locations theme was constructed as an ARC/INFO point cover by an automated routine that extracted control site data from completed electronic questionnaire forms, then processed the data and checked for errors. Only the attributes potentially required by SPREAD were included. Figure 19 illustrates the control site locations theme.

Control site identities theme

SPREAD produces an output that enables identification of the control site matched to each target zone. This can be converted to ARC/INFO grid format and is then called the control site number grid. The control site number grid has integer values, which, within each SLA, are unique identifiers of the control site matched to the cell. (The same control site number grid cell value may represent different control sites in different SLAs.) The two runs of SPREAD each produced a control site number grid: one contains control site identifiers for irrigated agriculture allocations and the other control site identifiers for dryland agriculture allocations. A macro was used to read both grids in conjunction with additional data sources. For each pixel with a value in one of the control site number grids, the macro identified the control site used for the agricultural land use allocation and wrote a nationally unique identifier for the control site to a new grid, the control site identities theme. The additional data sources required by the macro were a grid storing the SLA code for each cell and the SPREAD input files containing control site lists for each SLA.

Figure 20 illustrates the control site identities theme.
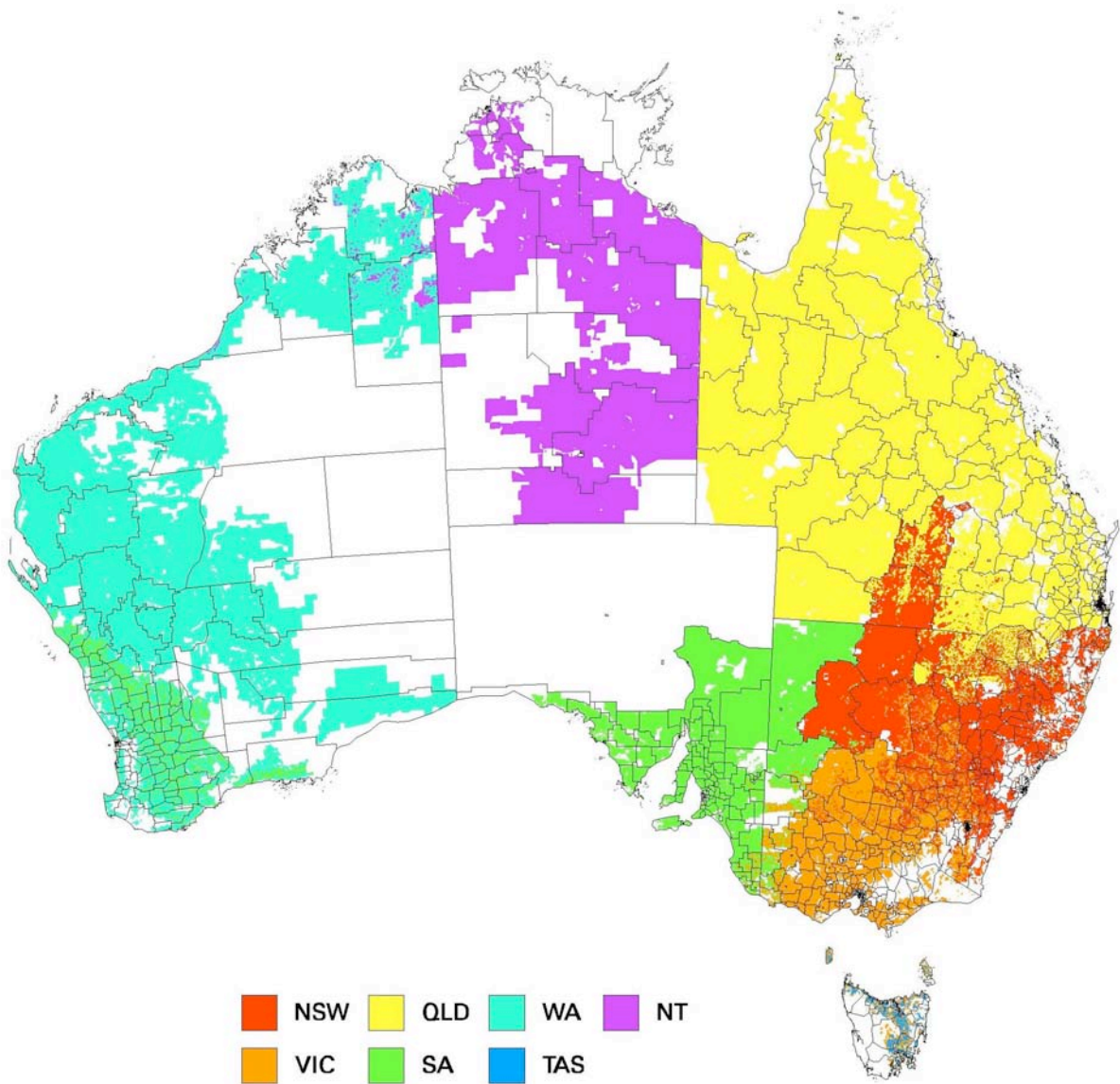
Figure 20. Control site identities theme indicating which State the control site used to assign the agricultural land use was obtained.

Key findings

The data set

The 1996/97 Land Use of Australia, Version 2 is an area representation of dominant land use by level of intervention or intensity of land use. Land use has been classified using the Australian Land Use and Management Classification (ALUMC), Version 4 (Lesslie, 2000). Agricultural land use has been predicted using the SPREAD method (Walker & Mallawaarachchi, 1998) from satellite imagery and agricultural census data for the 1996 – 97 year (ABS's 1996/97 AgStats data). The actual agricultural land use may differ from year-to-year reflecting crop and pasture rotations and the intermittent use of irrigation. Control sites, provided by various state and territory agencies, were used to assign the agricultural land uses on a region (Statistical Local Area) by region basis. Over a thousand control sites were used, with 734 dryland and 334 irrigated control sites covering 20 agricultural commodity groups. Non-agricultural land use was obtained from a number of available digital data sets relevant to the benchmark year of 1996/97. The data set is available for download from the Australian Natural Resources Data Library (http://adl.brs.gov.au/ADLsearch/).

The 1996/97 Land Use of Australia, Version 2 is the first national land use map to be released in digital form. It was compiled using a nationally consistent methodology and should serve as a spatial benchmark for land use in Australia circa 1996. It has a flexible data structure so that users can modify the land use classification to suit their requirements. It includes reliability indicators for the agricultural land uses. It embodies a spatially corrected version of the commodity area data from the 1996/97 AgStats database.

Most feedback on hardcopy maps of the 1996/97 Land Use of Australia was on Version 1 of the data set. Generally the feedback related to over-reporting of livestock grazing and under-reporting of horticulture. The need to distinguish between irrigated and dryland agriculture was also raised as being important for the usefulness of the product. The amount of unallocated land was also queried. Subsequent versions (1a and 2) of the data set attempted to address these issues. Raising the threshold for scaling of AgStats data led to less unallocated land. In Version 2, irrigated and dryland agricultural land uses were distinguished. The coarse pixel size of the data set (about 1 km) limits the ability to allocate land use precisely and, to some extent, leads to under-reporting of some land uses and over-reporting of others.

Users of the national land use map familiar with Carpenteria Shire bordering the south-east corner of the Gulf of Carpentaria have indicated that the distribution shown for the modified pasture in that shire is incorrect. This is a failure of SPREAD that is thought to illustrate the need for control sites that adequately represent each SLA. Control sites that are located too far away from a given SLA may represent quite different biophysical conditions and may have the wrong phenological characteristics as a consequence.

Feedback on non-agricultural land use reflects the states' access to better data sets than available nationally and is an issue that requires coordination. The Commonwealth has been establishing standards in the collation of data from the states for producing national data sets such as protected areas and forests. These initiatives are undergoing updates on a regular basis (every 3-4 years) and should lead to improvement in the quality and accuracy of the data provided.

Comparison of the national land use product with regional land use maps covering three of the Key Implementation Areas (namely the Fitzroy catchment in Queensland, the Gippsland region of Victoria and the Mt Lofty Ranges region of South Australia) indicates that the national product addresses well the major land uses (see Appendix 10). The extent of agreement between the national land use map and these KIA land use maps was about 81%[17]. The major differences relate to difficulties classifying pasture types in the regional mapping, intepretation of the ALUMC and conversion of the classification

---

[17] Based on comparison at the secondary level of the ALUMC, Version 4, with allowances made for anomalies in the original regional mapping and introduced during conversion of the land use classification to ALUMC Version 4.

schemes used in the regional mapping to ALUMC Version 4 for comparison with the national product. This suggests the importance of clear definitions for the classification of land use. This is being addressed in consultation with the states and territories and is documented in Lesslie (2001) for Version 5 of the ALUMC. It also highlights the differences between states in the products produced and the difficulty in compiling a national product from regional data sets, even though they have considerably more detail than the 1996/97 Land Use of Australia data set. This could be addressed through access to the rules or assumptions used in assigning land uses. This would enable greater consistency and facility to update data sets with newer versions of the ALUMC. This is possible with the national product in which land uses are assigned based on underlying data sets using an automated set of rules (see Appendix 4).

Content of the data set

The 1996/97 Land Use of Australia provides quantative information on the extent and location of major land uses within Australia. The most extensive land use is 'livestock grazing' covering 430 Mha or 56% of Australia. Collectively, agricultural land represents 473 Mha or nearly 62% of the continent. Just under 2.2 Mha of land was irrigated for agriculture, representing about 0.5% of all agricultural land or 5% of the area under crops, horticulture and modified pastures. Cropping (dryland and irrigated) covered 22 Mha (or nearly 3%) of Australia with cereals representing 18 Mha. Of the 323000 ha under horticulture (perennial and seasonal) 73% was irrigated.

Nearly 47 Mha (or 6 %) of Australia has the land use of 'nature conservation'. This does not include protected waterbodies such as the salt lakes in South Australia like Lake Eyre. These are classified as 6.1.1 Lake – conservation. 'Water' occupies 13 Mha (or nearly 2%) of Australia, with 60% of this being water features with conservation classification (primary class 1). Eighty-five percent of Australia's 'nature conservation' area is gazetted IUCN categories strict nature reserve and national park.

Thirteen percent (or 100 Mha) of Australia is 'managed resource protection'. Most of this area (89%) is for traditional indigenous uses. 'Other minimal use' occupies 15% of the continent. Covering 118 Mha, 77% of this area is reserved, vacant or institutional crown land. Remnant native cover on private land covers nearly 28 Mha within the minimal use category.

Forestry (production and plantation) tends to be confined to regions of Australia with higher rainfall and covers nearly 2% of the continent.

'Intensive uses' occupy about 2.4 Mha, or 0.3% of Australia. 'Intensive uses' encompasses both urban and peri-urban areas and open-cut mines. Open-cut mines represent a very small proportion of the built environment and would include mines such as the brown coal mines in the La Trobe Valley, Victoria.

An alternative version of the 1996/97 Land Use of Australia, Version 2 was produced for the Australian Natural Resources Atlas where water features are classified according to their conservation category (primary class 1). This reallocates 60% of water features to primary class 1 rather than primary class 6. The atlas web site (http://audit.ea.gov.au/ANRA/atlas_home.cfm) gives further information on land use as derived from this alternative version of the data set.

Limitations of the data set and future improvements

A number of minor intensive land uses, most notably rural residential land and mining, proved difficult to distinguish from agricultural land. The combination of these land uses was mapped using an indirect approach resting on some simple assumptions. This approach has led to errors in some SLAs. A better approach to mapping rural residential land would greatly assist in more accurately determining the spatial extent of agricultural land. The result needs to be consistent with the way AgStats discriminates between farms and hobby farms. One approach might be to assume for rural residential land that parcel size does not exceed a particular threshold. Digital cadastral maps could then be used to determine the extent of rural residential land. Mining generally covers too small an area to be represented using 0.01 degree pixels. The important exceptions are the large open cut brown coal mines in the La Trobe valley of Victoria and the large open cut iron ore mines in Western Australia. The spatial extent of these mines could, no doubt, be determined using existing digital or hard copy maps.

Fine scale heterogeneity, both spatial and temporal, of agricultural land use is not well handled by SPREAD. Where a target zone (pixel) contains more than one agricultural land use or contaminated by non-agricultural land uses such as roads, buildings or water bodies, appropriate matching of the pixel to a control site is difficult. Some agricultural land uses, such as the various types of horticulture, tend to occupy such small areas that it is difficult to find control sites with a large enough area of the land use to cover a whole pixel. This also makes the appropriate matching of target zone pixels to control sites difficult. These are problems arising from fine-scale spatial heterogeneity of agricultural land use. A possible solution may be to use finer resolution imagery with smaller pixels or, at least, to do this in selected regions such as SLAs with smaller land parcel size or SLAs with horticulture. In the current use of the SPREAD methodology it has been assumed that all the agricultural land uses have a characteristic phenology that extends over a twelve month period. Reality is more complicated as some crops are grown either in summer or winter and double cropping or even multiple cropping, in the case of vegetables, occurs. Again, the appropriate matching of target zones to control sites is made difficult. This arises from fine-scale temporal heterogeneity of agricultural land use. A possible solution may be, in the implementation of SPREAD, to seek to characterise phenology over two consecutive six monthly periods independently. An additional approach to fine-scale spatial and temporal heterogeneity of agricultural land use might be to create artificial control sites by mixing the NDVI profiles from existing control sites. Control site profiles for different commodities could be mixed and the summer and winter portions of the profiles constructed independently.

The SPREAD methodology illustrates the usefulness of AgStats in producing a spatially explicit product and emphases the importance of regularly collecting AgStats data. However, the matching of AgStats area data to mapped areas of agricultural land requires assumptions and adjustments based on the assumptions. In most SLAs, the total reported commodity areas is significantly less than the area of agricultural land – the shortfall is assumed to be due to under-reporting of native pasture. There is probably little that can be done about this. There are, undoubtedly, indeterminate errors in AgStats such as: under-reporting due to omission of farms from the census; over-reporting in some SLAs and under-reporting in others due to the farm business address not being in the SLA where the property is located; cases where a farm falls in more than one SLA. Proabably little can be done about these cases, too, though geocoding would help to define the extent of the problem. The number of assumptions required to use the area data from the 1996/97 AgStats database would have been reduced if it had contained: more detailed irrigation data; area data for specific types of orchard crops; data documenting instances of double cropping or multiple cropping and the crops involved. The applicability of the data would have been increased if the database had contained area data for existing agroforestry as well as new plantings. Some of these shortcomings could probably be avoided in future by requesting and funding specific additions to the AgStats questionnaire. If AgStats data were geocoded to properties as trialled in Gippsland, Victoria, for the 1996/97 agricultural census (Randall and Barson, 2001) this would improve the accuracy of the data and facilitate its spatial correction; it would also facilitate the identification of ground control sites for the SPREAD method. The data would need to be released at a resolution appropriate for the commodity (e.g. more detail would be needed for small scale enterprises such as horticulture and less for broadacre cropping).

The ability of SPREAD to discriminate between the NDVI profiles of target zones (pixels to which agricultural land use allocations are to be made) limits the accuracy of the agricultural land use allocations. This discriminating power could be improved in several ways. Alternatives to the Gower metric could lead to better discrimination. The variability observed among NDVI profiles for control sites for the same land use indicates that a large number of control sites are required. It is likely that more control sites would have improved the accuracy of the agricultural land use allocations. On the other hand, substitution of a more flexible method of discrimination for the Gower metric should reduce the optimum number of control sites. Discrimination could probably be improved by redefining the agricultural commodity groups to be mapped. For instance it might be optimistic to expect SPREAD to be able to discriminate between apples and pears. On the other hand, the sown pasture category may be too heterogeneous to be represented by a small number of control sites.

The performance of the heuristic implementation of SPREAD is poorly understood. Investigation of the empirical performance of the heuristic implementation in a large range of situations could lead to a better understanding of it and possibly to improvements.

Applications

In policy

A major benefit of the national land use map and its database is that it provides an updated representation of land use that is based on a consistent method for the whole country. As such it provides decision-makers with a national overview of where and what we are doing around our country and it establishes this in a context that is independent of jurisdictional boundaries.

The map gives key signals about the distribution of land uses, their coherence or patchiness, the limits of their extent, and proximity to major centres and transport infrastructure. It is now possible to compare land use with climatic factors such as rainfall reliability, soil type, land-slope and water availability. It is also possible to anticipate vulnerability due to over-reliance of a region on an industry and where opportunities exist for diversification or changes to land use or management practices. Decision-makers now have the opportunity to compare land use with hazards such as salt, flooding, drought, or fire, and always with the benefit that the considerations are couched in their broader and national contexts. With nationally consistent land use information, an understanding based, not only on the 'what', but also on the 'why' and 'how' is made possible.

The national land use map is in fact a land use database supported by a GIS. Apart from hardcopy or static images its GIS-based database provides information concerning overlapping or multiple land uses as well as data reliability measures. Overlapping land use interests may be indicated by the occurrence of, for example, a built-up area within a conservation area.

In regulation

Movement to deregulate industries heightens the need to appreciate the broader implications of decisions, considering both the threats and also the growth and development opportunities. Industry-based administration and management is supported by full information about the distribution and management issues of its members. The national land use map contributes information important for industry-based strategic planning, for example, to take advantage of increasingly deregulated domestic and global trading or to decide where to locate a new factory or office.

In management

An historical impediment to good resource management has been the problem of single-issue assessments and an inability to consider adjacent area effects. The relationship between cause and effect is typically complex with many components and issues contributing to management problems. The national land use map makes it possible to avoid making assumptions about the uniqueness or otherwise of a problem, because now, all potentially similar situations can be identified throughout the whole country. Land managers can now quickly review other situations to see if the same issues exist and by doing so can respond in more appropriate ways.

In research and education

The national land use map may be of use to researchers investigating or modelling land use-related phenomena in diverse fields such as economics, soil science or biodiversity. It may also be of use to teachers at all levels of the education system and to students in the higher levels.

Potential applications using the national land use map

As a fundamental data set, the 1996/97 Land Use of Australia can be integrated with additional information from Audit and other sources to deliver products that meet special requirements. Much of the use made to date has been focussed on combinations with other data sets to improve information for natural resource management. Other potential applications are given below.

Where the focus is on catchment rather than national scale issues, more detailed land use mapping should be used in preference to the national product. When available, this detailed land use mapping should be used in consultation with the relevant state(s) to ensure that the land use interpretation is appropriate for the issue under consideration. Care with use of detailed land use mapping is required when comparing regions or catchments, if the mapping has been undertaken at different times, using different classifications and by different agencies using different methods.

Primary attribute maps

The national land use map can be used to provide a series of background information products to inform decision-making and assist in the presentation of policy proposals. In general, this type of product would be developed to show individual or specific combinations of land use classes on a relevant base, often with additional information relevant to particular issues. Primary examples would include:

- products showing features, boundaries and areas such as rivers and water storages, drainage basins and groundwater provinces on map(s) showing areas used for irrigated crops, pastures and horticulture;

- maps showing pair-wise comparisons such as land use by soil type, groundwater characteristics, erosion potential, surface and groundwater availability, climate zone, and tenure;

- maps combining appropriate tenure classes, protected areas, forests etc;

- a mask showing non-agicultural land as a basis for improving the accuracy of analyses requiring this as a fundamental data layer;

- products combining relevant and up-to-date information on non-agricultural land uses at scales appropriate to the consideration of national issues.

Products addressing profitability and sustainability of land use

The 1996/97 Land Use of Australia can be used to provide a series of products in which the map supports information on diversity of environment and related patterns in economic use of land. The products should be designed to be used with other information (e.g. climate and soils) to arrive at a general picture of the diversity of land use at a broad regional scale including, if possible, examples of options for land use change in some areas. Each map product should be supplemented with explanatory notes. The suggested approaches require statistically and spatially relating the land use data to other data sets and/or the integration of Audit themes, for example:

- Integration with ASRIS (Australian Soil Resources Information System) soils and landscape to show which soils are the most important for what uses and enable comparisons between types. Key products would show statistical relationships between land uses and the soils data to indicate fertility status and likelihood of land degradation.

- Relating current land use to climate reliability projections to illustrate risk. The key product would show the relationships between national scale land use and rainfall reliability.

- Relating land use to social factors using data sets representing social themes.

- Integrating Audit Theme 5.1 data with the the 1996/97 Land Use of Australia data set.

- Amalgamating Audit Theme 6.2 data relating economic values to land use type and highlighting competitive land uses, including urban encroachment, irrigation, and tourism.

- Integrating with AgStats livestock numbers data to produce maps showing stocking densities.

- Integrating with AgStats tonnes of production data or value of production data to produce maps showing tonnes per pixel or dollars per pixel.

Products related to natural resource management priorities - salinity

The national land use map could be used in products targeting salinity problems. These products will be important for Commonwealth programs, especially the Salinity and Water Quality Action Plan. The maps should assist the Commonwealth to build a general picture of the problem of land use induced salinity from continental scale to regional scale. To the extent possible, this should be complemented with examples of possible mitigation measures for selected areas. As there is no single solution to all

occurrences of salinisation, a solution may have to be developed for different landscape types. Each map should be supplemented with explanatory notes. Priority consideration should be given to:

- a map of Australia showing cropping land use and areas affected by or at risk from salinity

- a map of Australia showing irrigated areas of pasture and cropping land use and areas affected by or at risk from salinity;

- other (regional scale) maps to show land use in the priority catchments for the Salinity and Water Quality Action Plan and relationships between land use and mitigation options.

Applications to support decision-making on land use change

Multi-objective assessment and decision support using appropriate frameworks for integration of data on land use and land use change and information from other relevant sources to:

- Use land use mapping in multi-criterion analyses as a theme for preference scenarios such as deciding what areas to revegetate. Specific lands could be targeted such as the riparian environment, road corridors, low production agricultural lands and degraded lands. The impact of a given scenario on aesthetics, productivity and water balance could be reported.

- Use the integrated information for ecological services design (eg. shape, size and layout of designs to enhance remnant vegetation).

- Develop, test and demonstrate trade-off and sensitivity analysis (integrating different stakeholder and decision criteria preferences).

- Explore land use competition futures (water and land availability).

Recommendations

Implications for management of Australia's natural resources

Australia's lands are used and valued in many ways. The national land use map and its supporting database give a snapshot of Australia's land use at the end of the 20th Century. It provides a basis for reviewing land use and, with information from other sources, for investigating how well land use is matched to land qualities and to the needs and aspirations of Australians, now and into the future. Plans for improved land use can be based on the national land use map, meeting objectives such as profitable production, maintenance of biodiversity and ecological health, social amenity, utility and aesthetic values.

The database demonstrates the complexity of land use issues. Throughout Australia, for any single mapped presentation of prevalent land use, there are typically several other associated uses. Ultimately, the way we use an area of land in the future depends on the values we place upon its different aspects and whether the different and multiple uses can coexist, either by being complementary or by being able to endure competition. With the national land use database there is now a frame of reference from which to make future land use decisions.

In the management of Australia's natural resources:

- The national land use map provides a spatial benchmark for land use in Australia *circa* 1996.

- Users should modify the land use classification to suit their purposes allowed by the inbuilt flexibility of the data set.

- Users should consider the agricultural land use reliability indicators provided.

- The data set should be recognised as a source of spatially corrected agricultural commodity area data derived from the 1996/97 AgStats database and used as such when the opportunity arises.

- Use of the national land use map for appropriate purposes in government, industry, research and education should be encouraged.

- Possibilities for integration of the national land use map with other thematic data relevant to natural resource management should be explored.

A current natural resource management task is the mapping of both land use and land management practices at regional scales in areas nominated by the states. It is expected that use of geocoded ABS AgStats data will facilitate the mapping and allow matching of land management practices to land uses. The intention is to extend the work of these pilot programs and to use purpose-designed supplementary agricultural census questions to address land management practices nationally. For future extensions of the work:

- Consideration should be given to the SPREAD method, using AVHRR imagery, for areas where typical paddock size is sufficiently large (> 1 km^2). The method is quick and control sites could be devised using the geocoded agricultural census data in conjunction with property boundary data

- Consideration should be given to the SPREAD method, using Landsat TM or MSS imagery, for areas where the typical paddock size is small (< 1 km^2).

- Geocoding of agricultural census data by ABS should receive continued support and encouragement.

- Continued development of the national land use classification scheme should be encouraged.

- Use of a standardised approach to land use mapping at regional scales should be promoted.

Improvements to the national land use map

To ensure the success of future implementations of the methodology used to compile the national land use map and to improve shortcomings of the current implementation:

- Better approaches to mapping the non-agricultural rural land uses, particularly rural residential land and mining, should be explored.

- A solution to dealing with fine-scale spatial heterogeneity of agricultural land use – where the land use parcel sizes are significantly smaller than the pixel size – should be sought. One possible solution may be to use finer resolution imagery with smaller pixels or, at least, to do this in selected regions. Another solution may be to use artificial control site profiles constructed by mathematically mixing real control site profiles.

- A solution to dealing with fine-scale temporal heterogeneity of agricultural land use – where the characteristic phenology time course lasts only six months rather than a year – should be sought. One possible solution may be, in the implementation of SPREAD, to characterise phenology over two consecutive six monthly periods, independently. Another solution may be, again, to use artificial control site profiles constructed by mathematically mixing real control site profiles.

- Because of the importance of agricultural census data to land use mapping, the continued, regular collection of agricultural census data must be encouraged. The potential release of fully-geocoded agricultural census data should also be encouraged. This would provide a way to identify and quantify under-reporting and over-reporting errors and to facilitate the spatial correction of the data and to facilitate the identification of ground control sites for the SPREAD method.

- If an implementation of the SPREAD method werre planned before finalisation of questions for the next agricultural census, it would be wise to review the census questions and request supplementary questions as appropriate.

- The possibility to improve SPREAD's capacity to discriminate between the NDVI profiles of target zones should be investigated. Options include increasing the number of control sites, using a better discriminating metric and grouping different commodities into more easily discriminated groups.

- Better understanding of the heuristic implementation of SPREAD and its limitations.

Suggested approaches to these issues have been discussed in more detail in the Key Findings section.

Choice of land use methods and suggestions for the future

For a country as large and diverse as Australia the task of maintaining accurate land use mapping is substantial. Strategies to accomplish this range from comprehensive assessment based on a single method, to small area assessments tailored to specific issues. The choice of a method will depend on practical considerations such as cost and availability of data but also the purpose for which the land use data is needed. The uptake and adoption of new technologies such as GPS location referencing and internet surveys widens the options for future land use assessment.

Future cost estimate based on current AVHRR-based continental-scale land use mapping

The investment of the NLWRA in the Land Use Mapping of the Continent Using AVHRR Data project amounted to a cost of approximately 12.5 cents km^{-2}. This provided a nationally consistent map and database showing land use at a scale nominally between 1:1 000 000 and 1:2 500 000. (At this scale 1mm on a map represents 1–2.5 km.) The mapping method relied on:

1. AVHRR imagery, which was freely available but required computer processing to remove cloud effects;

2. Existing publicly available data such as roads, water features, conservation areas, forests, and census statistics, some of which had a licence fee;

3. Ground control data sampling and an adequate number and distribution of sample points;

4. Skilled staff for software development and application;

5. Computing facilities with sufficient size and processing speeds; and included costs for:

6. Database management, documentation, reporting, map production, management and product distribution.

The ability to make future revisions of the continental land use map and database depends on the availability of updated imagery, agricultural statistics and control data, topographical and infrastructure data, and skilled personnel with access to adequate computing facilities.

For a revision based on the proposed 2000–2001 agricultural census, collection of appropriate ground control data could cost $500 000, data licensing could be $10 000, and staff time and computing time could be an extra $200 000.

An upper estimate to re-run the AVHRR-based method is $1 000 000 (about 13 cents km^{-2}) whereas a lower estimate is $250 000 (about 3.3 cents km^{-2}).

Future cost estimate based on current land use mapping by other methods

Detailed land use mapping has been done for the NLWRA covering approximately 35 percent of Australia's land area. The mapped areas, the Key Implementation Areas (KIAs) used by other NLWRA projects, were mapped at scales between 1:25 000 and 1:250 000, the latter resolution applying to the extensive land use areas of WA. The mapping methods ranged from conventional on-ground mapping, to ground-based mapping augmented by ABS statistics and unit record matching to a property cadastre. If a total cost of $1 400 000 is used then this represents a cost of about 50 cents km^{-2}.

The finer detail and potentially greater accuracy of ground-based and related methods has the benefit of being more reliable for decision making in small regions and catchments. The sacrifice is the higher cost, the need for skilled mapping personnel, and a lack of a broader overview to place all in context. The time needed and the recurrent expenses make progressive updates costly.

Future options

The task of future land use mapping and revision of the national land use database will be facilitated by the increasing use of digital technologies for mapping and data collection. Changes to the design and collection methods of the ABS agricultural census will also help such as a proposal being considered by ABS to spatially reference (or geocode) subsequent agricultural censuses. This has been trialled in Gippsland, Victoria using the 1996/97 agricultural census (Randall & Barson, 2001). With improved ground-based information from a spatially explicit land use census as control data, the AVHRR method could be re-run with high levels of confidence, particularly over areas of more extensive use such as broadacre cropping. In smaller, more intensively used areas it would be preferable to use imagery with a smaller pixel size such as Landsat TM. A practical combination of land use mapping and survey techniques is the most likely to yield efficient and valuable land use information into the future.

References

Australian Bureau of Agricultural and Resource Economics 1997, *1996 – 97 Farm Survey*.

Australian Bureau of Statistics, 1996, *Statistical Local Areas, Australian Standard Geographical Classification (ASGC) 1996* (digital map, ArcView shapefile format).

Australian Bureau of Statistics, 1999, *AgStats: Small Area of Agricultural Commodity Data 1996-97*.

Australian Nature Conservation Agency, 1995/98, *Interim Biogeographic Regionalisation of Australia – IBRA, Version 4.1* (digital map, ARC/INFO cover format).

Australian Surveying and Land Information Group (now Geoscience Australia – Division of National Mapping), 1993, *Australian Land Tenure Data* (digital map, ARC/INFO cover format).

Australian Surveying and Land Information Group (now Geoscience Australia – Division of National Mapping), 1999, *GEODATA TOPO-250K (Series 1) Topographic Data* (digital map, ARC/INFO cover format, February 1999 update).

Barson, M.M. 1999, *Workshop on Land Use Management Mapping*, Report to the National Land and Water Resources Audit, Bureau of Rural Sciences, Canberra.

Baxter, J.T. and Russell, L.D. 1994, *Land use mapping requirements for natural resource management in the Murray-Darling Basin*, Project M305: Task 6, Department of Conservation and Natural Resources, Victoria.

Bureau of Rural Resources (now Bureau of Rural Sciences) 1992, Sheep and Cattle Distribution and Density (hard copy maps at 1:10 million scale).

Bureau of Rural Sciences, 1999, *Native Forest and Plantations of Australia, 250m* (digital map, ARC/INFO grid format, 250 m cell size, contains data compiled in 1997).

Bureau of Rural Sciences after Commonwealth Scientific and Industrial Research Organisation, 1991, *Digital Atlas of Australian Soils* (digital map, ARC/INFO cover format). http://www.affa.gov.au/content/data.cfm

Bureau of Resource Sciences (now Bureau of Rural Sciences), 1997, *Australian Tenure* (digital map, ARC/INFO grid format, 250 m cell size).

Bureau of Rural Sciences, 2000, *1995 Land Cover Theme: Queensland* (digital map, ARC/INFO grid format, 25 m cell size).

Bureau of Rural Sciences 2000, *Report of proceedings of a Commonwealth-State Land Use Mapping Workshop*, 3-5 October 2000, unpubl.

Commonwealth of Australia, 1991, *Decade of Landcare Plan: Commonwealth Component*, AGPS, Canberra.

Division of National Mapping (now Geoscience Australia – Division of National Mapping), 1980, *Atlas of Australian Resources*, 3rd Series, Volume 1, Soils and Land Use, Commonwealth Government Printer, Canberra.

Division of National Mapping (now Geoscience Australia – Division of National Mapping), 1982, *Atlas of Australian Resources*, 3rd Series, Volume 3, Agriculture, Commonwealth Government Printer, Canberra.

Environment Australia, 1998, *Collaborative Australian Protected Areas Database – CAPAD97* (digital map, ARC/INFO cover format).

Environment Australia, 2000, *Collaborative Australian Protected Areas Database – CAPAD99* (digital map, ARC/INFO cover format).

Gower, J.C. 1971, 'A general coefficient of similarity and some of its properties', *Biometrics,* vol. 27, pp. 857-871.

International Union for the Conservation of Nature and Natural Resources 1994, *Guidelines for Protected Area Management Categories,* CNPPA with the assistance of WCMC, IUCN, Gland, Switzerland and Cambridge, UK.

Kitchin, M.B. and Barson, M.M. 1998, *Monitoring Land Cover Change – specifications for the remote sensing of agricultural land cover change project 1990-1995*, Bureau of Rural Sciences, Canberra.

Lands, Planning and Environment, Northern Territory, 1999, *Northern Territory Pastoral Map* (hard copy map at 1:2 million scale).

Lesslie, R. 2000. Land Use Mapping Workshop, Bureau of Rural Sciences, Canberra, 3-5 October, 2000.

Lesslie, R. 2001, *Land Use Mapping at Catchment Scale: Principles, Procedures and Definitions*, Bureau of Rural Sciences, Canberra.

National Forest Inventory 1997, *National Plantation Inventory of Australia*, Bureau of Resource Sciences, Canberra.

National Forest Inventory 1998, *Australia's State of the Forests Report 1998*, Bureau of Rural Sciences, Canberra.

National Land and Water Resources Audit, 2001, *Australian Water Resources Assessment 2000. Surface water and groundwater – availability and quality*, Commonwealth of Australia.

Randall, L. and Barson, M. 2001, *Mapping agricultural commodities and land management practices from geocoded agricultural census data*, BRR6 Report to the National Land and Water Resources Audit.

Walker, P.A. and Mallawaarachchi, T. 1998, 'Disaggregating agricultural statistics using NOAA-AVHRR NDVI', *Remote Sens. Environ.,* vol. 63, pp. 112-125.

Appendix 1. NDVI processing

Shane Cridland, Environment Australia (October, 1999)

The original data used in this project was recorded by the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA 14 satellite. This instrument collects data for the entire earth in 5 channels at .01 degree pixel size daily. The ACRES receiving station at Alice Springs captured the Australian data broadcast by the satellite. This data was then transferred to CSIRO Marine Laboratories Division of Marine Research, Hobart for processing. The daily overpasses were registered and rectified to geographic coordinates. The digital counts from the red and infrared channels were calibrated to radiance using the corrected pre-launch calibration coefficients and an NDVI {NDVI = (infrared-red)/(infrared+red)} image calculated.

Significant areas in the images from daily overpasses are affected by cloud contamination. Cloud contamination lowers the NDVI values. Therefore, the maximum NDVI value occurring at each pixel over a compositing period (14 days) was selected and placed in a composite image. The maximum NDVI value is the value that should be least contaminated by cloud, smoke, dust, pollution and other atmospheric aerosols. However not all contamination is removed. Compositing over longer periods removes more contamination but allows more real change in vegetative cover to occur within the compositing period with a resultant loss of temporal sensitivity.

The Environmental Resources Information Network purchased the 14 day maximum NDVI composite images along with the individual channel and angle data associated with the values in the composite. The AVHRR instruments are known to lose sensitivity with time. Therefore the red and infrared data were converted back to raw counts and re-calibrated using calibration coefficients calculated from equations estimating the loss of sensitivity in the AVHRR channels. The loss of sensor sensitivity was estimated from an "invariant" target site in the Lybian desert over a three year period (equations 8 and 9 in "Revised post-launch calibration of channels 1 and 2 of the Advanced Very High Resolution Radiometer on board the NOAA-14 spacecraft" by Rao and Chen published on the NOAA website at http://psbsgi1.nesdis.noaa.gov:8080/EBB/ml/niccal1.html). These equations were accepted because they give NDVI data that show no long term trend in the Australian deserts.

A new NDVI was then calculated and rescaled into the byte data range (Rescaled NDVI = (NDVI *200)+50). The land values 0 to 1 were rescaled to 50 to 250 because although theoretically, all land NDVI values are positive, some bare soil values lie marginally below the theoretical soil line (NDVI=0). Scaling the data into this range does not result in loss of information (Roderick et al., 1996).

The rescaled data were then screened for any residual contamination as follows. Processing the rescaled data allows for larger percentage variation around the smaller NDVI values.

Step 1 – mask out all data that showed a large decrease followed by an immediate large increase (i.e. a "dip"). A transient drop is typical of cloud or other aerosol contamination. However the screening method will also discriminate against flood, snow and in some instances, fire.

Pixels that failed the following tests were masked out

>0.96x(Time –1) and (> 0.96x(Time +1) or > 0.90x(Time +2))

   [(Time – 1) is the preceding image and (Time + 1) is the following image]

> 0.90x(Time –2) and (> 0.96x(Time +1) or > 0.90x(Time +2))

- if (Time – 1) and (Time – 2) were masked out then the following test was applied

> 0.85x(Time+1) or > 0.65x(Time+2)

As the screening was done from earliest image to latest image (Time+1) and (Time+2) were still unprocessed and so values could not be masked out.

Step 2 – mask out all data that showed a very large increase followed by an immediate very large decrease (i.e. a "spike"). In some images there were single scan lines of unrealistic high values, in others there were some scatted transient very high values.

Pixels that **failed** the following tests were masked out

<1.3x(Time-1) and (<1.3x(Time+1) or <1.5x(Time+2))

< 1.5x(Time-2) and (< 1.3(Time+1) or <1.5x(Time+2))

- if (Time–1) and (Time–2) were masked out then the following test was applied

       <1.75x(Time+1) or < 2.00x(Time+2)

- if (Time+1) and (Time+2) were masked out then the following test was applied

       < 1.75x(Time-1) or < 2.00x(Time-2)

Step 3 – fit a temporal spline to each pixel and calculate values for the masked out points.

Step 4 – compare the calculated value to the masked out original value and 'unmask' those where the original value is between 96 percent and 130 percent of the calculated value. If the spline predicted a value near the original masked out value, the original value was preferred.

Step 5 – repeat steps 3 and 4 twice more. Unmasking a data point affects the spline and thus the estimates of other masked out values near it. Thus the splining and checking procedure were repeated twice to get the best estimates of masked out values.

To create a data set with estimated values substituted for the masked out values, the splined values were left in the images.

Step 6 – spatially average values that could not be splined. In some images there were a few values (up to 0.003 percent of values) that could not be properly splined. Most of these values occurred in salt lakes where different amounts of water versus salt gave wildly fluctuating values. Some were also due to several images in a row being cloud affected and thus having no data to guide the spline through this area.

The data were then grouped into 50 classes over the positive NDVI range (i.e. 4 rescaled units or 0.02 NDVI units per class). This project is looking at temporal profiles. Therefore the 50 classes form a compromise between removing unnecessary noise in the data while still retaining sensitivity.

Reference

Roderick, M., Smith, R.C.G. and Cridland, S.W. 1996, 'The precision of the NDVI from AVHRR observations', *Remote Sensing of Environment* 56: 57-65.

Appendix 2. 1996/97 Land Use of Australia, Version 2 metadata and user guide

Page 0 metadata

Data set

Title

1996/97 Land Use of Australia, Version 2, National Land and Water Resources Audit

Custodian

Bureau of Rural Sciences

Jurisdiction

Australia

Description

Abstract

A land use map of Australia showing agricultural and non-agricultural land uses for 1.4.1996 to 31.3.1997 with a 0.01 degree cell size. A product of the National Land Use Mapping Project of the National Land and Water Resources Audit with five digital maps referred to as themes:

1. Land use - the principal theme, all others contribute to it. It has 9 layers preserved independently in its value attribute table (vat):

- Protected areas

- Topographic features

- Tenure

- Forest type

- Agricultural commodities

- Irrigation

- Land use

- Affinity class

- Pass number class

Protected areas, topographic features, tenure and forest type layers are existing digital maps used to determine non-agricultural land uses and distribution of agricultural land use. The agricultural commodities and irrigation layers show specific agricultural land uses which are interpretive/modelled. They were constructed by automated analysis of a one year sequence of normalised difference vegetation index (NDVI) images using control sites to provide agricultural land uses at known locations and agricultural census data to provide area constraints. The land use layer shows the land use derived from the 6 previous layers

2. Affinities and pass number - a guide to reliability of agricultural land uses in the land use theme providing data only for cells that received specific agricultural land use allocations based on automated comparison with control sites

3. Control site locations - locations of all useable control sites collected by States and Territories

4. Control site identities - identity of control site used to allocate its agricultural land use for each agricultural cell in the land use theme.

Australian Land Use Management Classification (ALUMC) V4 is used in the land use layer (www.affa.gov.au). It is defined in the vat of the land use theme and in a separate lookup table. The vat of the land use theme retains the attributes of the underlying data, therefore, the user can adopt an alternative land use classification.

Search words

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

Geographic extent

112.5050 -44.0050, 154.0050 -44.0050, 154.0050 -9.9950, 112.5050 -9.9950

Data currency

Beginning date

Not Known

Ending date

30SEP1999

Data set status

Status

Complete

Maintenance and update frequency

Not planned

Access

Stored data set format

DIGITAL ARC/INFO 8.0.1 under SunOS

Available format types

DIGITAL – ARC/INFO raster

DIGITAL – ARC/INFO vector (one theme)

Access constraint

Data are available subject to a Commonwealth licence agreement. The National Land and Water Resources Audit (the Commonwealth) has copyright.

Use of the data is to be acknowledged in any visual or published materials with a statement including the name and source of the data as: "1996/97 Land Use of Australia, Version 2, National Land and Water Resources Audit".

Specific acknowledgments are listed in the completeness section.

Data quality

Lineage

1. Construction of the land use theme - non-agricultural land uses and distribution of agricultural land was determined by overlaying raster versions of 4 existing data sets. Final raster versions of these data are preserved as independent layers in the land use theme:

    a) Protected areas layer - constructed using 1:250 000 scale vector data sets. 1999 Collaborative Australian Protected Areas Database (CAPAD99) and CAPAD97 for Tasmania. CAPAD97 was used for Tasmania as CAPAD99 had incomplete data for Tasmania and CAPAD2000 was not available.

    b) Topographic features layer - constructed using February 1999 update of the Australian Surveying and Land Information Group (AUSLIG) 1:250 000 scale topographic vector data, TOPO-250K (Version 1). Line and point features were buffered prior to conversion to raster format.

    c) Tenure layer - constructed using 1997 National Forest Inventory (NFI) tenure 250 m raster data. Information from state and territory departments in 1997 was used to classify aboriginal freehold and aboriginal leasehold areas as agricultural or non-agricultural. Boundaries by Agriculture WA were used to incorporate private tenure for the Ord River Irrigation Area.

d) Forest type layer - constructed using 1997 NFI combined native and plantation forestry 250 m raster data. The Australian Land Cover Change 1995 Land Cover data was overlain to supplement Queensland plantation forest data as they were underrepresented.

Specific agricultural land uses were allocated using SPREAD: SPatial REallocation of Aggregated Data (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 data (reported on small regions and giving the area devoted to each agricultural land use). A computer program embodying an adaptation of SPREAD (compleXia Pty Ltd) was implemented. NDVI images were obtained from Advanced Very High Resolution Radiometer (AVHRR) data from the Australian Centre for Remote Sensing, processed by CSIRO Division of Marine Research, Hobart and ERIN, Environment Australia. 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 of commodities and irrigation. Agricultural census data were from the Australian Bureau of Statistics' AgStats. The smallest areas used for reporting of AgStats data are Statistical Local Areas (SLAs) (Standard Geographic Classification 1996 boundaries). Modifications made to the AgStats data are documented in the Final Project Report.

The land use classification used is the Australian Land Use Management Classification V4 (www.affa.gov.au). A macro was used to construct a land use lookup table, which was then permanently joined to the vat.

2. Affinities theme and pass number theme were produced by the SPREAD program. Reclassed versions serve as the affinity class and pass number class layers of the land use theme.

3. Control site locations theme is an output of a macro that processes and checks control site data. It is in vector format and has point features representing control sites collected for specific agricultural land use allocations in the land use theme. Each point has attributes specifying its agricultural land use for the year 1.4.1996 to 31.3.1997.

4. The control site identities theme was produced by further automated processing of SPREAD output.

Positional accuracy

1. Land use theme. 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 are as follows:

     CAPAD99 and CAPAD97 – vector data, positional accuracy 1 m to 500 m

     TOPO-250K (Version 1) – vector data, error less than 160 m for at least 90% of well-defined points

     NFI tenure data set – 250 m raster data, positional accuracy largely within 125 m

     NFI combined native and plantation forestry data set – 250 m raster data, positional accuracy 100 m to 1 km.

To construct the land use theme, these data sets were converted to 0.01 degree raster format which would increase errors by up to approximately 700 m.

Subdivision of potentially agricultural land into specific agricultural land uses was based on automated analysis of composited, geo-referenced and rectified AVHRR satellite imagery with geographic coordinates and 0.01 degree cells.

The final land use theme was produced in raster format with geographical coordinates and 0.01 degree (approximately 1 km) cell size. Therefore, the positional accuracy of this theme is approximately 1 – 2 km.

2. Affinities theme, number of passes theme and control site identities themes. Positional accuracy is as for the land use theme. (These themes provide data only for cells that underwent analysis for specific agricultural land use allocations.)

3. Control site locations theme. The horizontal positional accuracy of the control site locations theme is approximately 100 m.

Attribute accuracy

1. Land use theme. 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 (AUSLIG TOPO-250K, Version 1) 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 are expected to be high, with consequent high accuracy in initial land use assignments. The accuracy of the specific agricultural land use allocations based on automated interpretation of NDVI images is variable, ranging from low to high. The affinities theme and the number of passes theme give an indirect indication of the accuracy of the allocation for each cell: the smaller the affinity and the smaller the number of iterations of the SPREAD routine, the higher the accuracy of the allocation is likely to be.

2. Affinities theme, number of passes theme and control site identities themes. These themes contain data derived directly from the SPREAD program and have data only for cells that underwent analysis for specific agricultural land use allocations. Their attribute accuracy should be 100%.

    In the affinities theme each data cell has a value between 0 and 1, a measure of difference between the NDVI data for the cell and NDVI data for the particular control site representing the land use allocated. A value of 0 indicates a perfect match and 1 indicates maximum dissimilarity. In the pass number theme each data cell has a value between 1 and 19 inclusive, indicating the number of iterations used to allocate specific agricultural land use to the cell. The smaller the cell value, the more reliable the specific agricultural land use allocation.

3. Control site locations theme. Control site data were collected using an electronic questionnaire provided to State and Territory agencies to complete in the field. The information provided in each returned questionnaire was inspected for completeness and logical consistency. Automated procedures were then used to further check the logical consistency of the information provided, in particular, that the coordinates given fell within the stated Statistical Local Area. (See report for more information.) Control sites that failed any of the tests were rejected. The attribute accuracy for the control site locations theme should be high but has not been tested directly.

Attributes of the land use theme are:

prot_areas – protected areas layer code
prot_areas_desc – protected area description

topo_features – topographic features layer code
topo_feat_desc – topographic features description

tenure – tenure layer code
tenure_desc – tenure description

forest_type – forest type layer code
forest_type_desc – forest type description

spread – agricultural commodities layer code (SPREAD output)
spread_desc – agricultural commodity description (SPREAD output)

irrigation – irrigation layer code (SPREAD output)
irrigation_desc – irrigation status description (SPREAD output)

lu_code – land use layer code (ALUMC Version 4)
lu_desc – land use description (ALUMC Version 4, primary land use)
lu_desc2 – land use description (ALUMC Version 4, secondary land use)

lu_desc3 – land use description (ALUMC Version 4, tertiary land use)
t-code – land use alphanumeric code (ALUMC Version 4, tertiary code)

affinities – affinity class layer code (SPREAD output)
affinities_desc – affinity class description (SPREAD output)

pass_no – pass number class layer code (SPREAD output)
pass_no_desc – pass number class description (SPREAD output)

Logical consistency

Assignment of land uses based on the four existing data layers and the two SPREAD output layers was done with the aid of a macro. The attribute combination corresponding to each land use assignment was tested by inspection to verify that land use assignments were as intended and were logically consistent. For the control site locations theme, all points are labelled.

Completeness

Coverage and classification are complete. Verification of spatial and attribute data is discussed in the report.

Specific Acknowledgments:

The data set was derived and compiled by the Bureau of Rural Sciences. Land uses were derived using data from the 1997 and 1999 Collaborative Australian Protected Areas Database (Environment Australia), TOPO-250K Version 1 (AUSLIG), the National Forest Inventory 1997 tenure and forest data (Bureau of Rural Sciences), Normalised Difference Vegetation Index images (Environment Australia) and AgStats 1996/97 (Australian Bureau of Statistics). Control sites provided by state and territory agencies: 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, Northern Territory Dept of Lands, Planning and Environment.

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).

Contact information

Contact organisation
Bureau of Rural Sciences

Contact position
Data Manager

Mail address 1
PO Box E11

Mail address 2
-

Suburb or place or locality
KINGSTON

State or locality 2
ACT

Country

Australia

Postcode

2604

Telephone

612 6272 4232

Facsimile

612 6272 4687

Electronic mail address

dataman@brs.gov.au

Metadata date

18JAN2001

Additional metadata

The 1996/97 Land Use of Australia, Version 2, User Guide.

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 Audit, Canberra.

Walker, P.A. & Mallawaarachchi, T. 1998, 'Disaggregating agricultural statistics using NOAA-AVHRR NDVI', *Remote Sens. Environ.,* vol. 63, pp. 112-125.

Barson, M and Randall, L. 2001, *Coordination of land use mapping of key implementation areas. Final Report for Project BRR6*, National Land and Water Resources Audit, Canberra.

The land use theme

Structure of the land use theme

The land use theme is in ARC/INFO grid format. It is an integer grid and has a vat (value attribute table). The grid comprises nine layers, each defined by a group of attributes in the vat. Table A2.1 lists the vat attributes and shows how they define the layers.

Table A2.1. Attributes of the land use theme showing their meanings and how they define the six layers.

Attribute	Meaning	Layer
value	Cell value	Not applicable
count	Number of cells with given value	"
prot_areas	Protected area code	Protected areas layer
prot_areas_desc	Protected area description	"
topo_features	Topographic features code	Topographic features layer
topo_feat_desc	Topographic features description	"
tenure	Tenure code	Tenure layer
tenure_desc	Tenure description	"
forest_type	Forest type	Forest type layer
forest_type_desc	Forest type description	"
spread	Agricultural commodity code: SPREAD output	Agricultural commodities layer
spread_desc	Agricultural commodity description: SPREAD output	"
irrigation	Irrigation status code: SPREAD output	Irrigation layer
irrigation_desc	Irrigation status description: SPREAD output	"
lu_code	Land use code: ALUMC Version 4	Land use layer
lu_desc	Land use description: ALUMC Version 4, primary land use	"
lu_desc2	Land use description: ALUMC Version 4, secondary land use	"
lu_desc3	Land use description: ALUMC Version 4, tertiary land use	"
t-code	Land use code: ALUMC Version 4, tertiary code	"
affinities	Affinity class code for affinity to allocated control site: SPREAD output	Affinity class layer
affinities_desc	Affinity class description for affinity to allocated control site: SPREAD output	"
pass_no	Pass number class code for number of passes through the SPREAD routine needed to allocate a control site: SPREAD output	Pass number class layer
pass_no_desc	Pass number class description for number of passes through the SPREAD routine needed to allocate a control site: SPREAD output	"

The land use attributes, *lu_code*, *lu_desc*, *lu_desc2*, *lu_desc3* and *t-code* are also supplied in a separate lookup table, <grid_name>.lut, which includes the grid cell value as the relate column.

Data dictionary for the land use theme

<u>The protected areas layer</u>

The protected areas layer shows protected areas that meet the guidelines of the World Conservation Union (IUCN, 1994). The layer is defined by the attributes *prot_areas* (a numerical code) and *prot_areas_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.2.

Table A2.2. Attributes of the protected areas layer of the land use theme showing values and meanings.

prot_areas	prot_areas_desc	Meaning
0	Not a protected area	Not a protected area
11	Ia. Strict nature reserve	IUCN category Ia protected area: strict nature reserve; a protected area managed mainly for science.
12	Ib. Wilderness area	IUCN category Ib protected area: wilderness area; a protected area managed mainly for wilderness protection.
20	II. National park	IUCN category II protected area: national park; a protected area managed mainly for ecosystem conservation and recreation.
30	III. Natural monument	IUCN category III protected area: natural monument; a protected area managed for conservation of specific natural features.
40	IV. Habitat/species management area	IUCN category IV protected area: habitat/species management area; a protected area managed mainly for conservation through management intervention.
50	V. Protected landscape/seascape	IUCN category V protected area: protected landscape/seascape; a protected area managed mainly for landscape/seascape conservation and recreation.
60	VI. Managed resource protected areas	IUCN category VI protected area: managed resource protected area; a protected area managed mainly for the sustainable use of natural ecosystems.

The topographic features layer is defined by the attributes *topo_features* (a numerical code) and *topo_feat_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.3.

Table A2.3. Attributes of the topographic features layer of the land use theme showing values and meanings.

topo_features	topo_feat_desc	Meaning
0	Not classified as a topographic feature	Not classified as a topographic feature.
1	Lake, perennial	Lake that normally contains water except in unusually dry periods – the term 'lake' meaning a naturally occurring body of water surrounded by land.
2	Lake, non-perennial	Lake that contains water for several months of each year and is dry for the rest of the year.
3	Watercourse, perennial	Watercourse that normally contains water except in unusually dry periods – the term 'watercourse' meaning a natural channel along which water may flow from time to time.
4	Watercourse, non-perennial	Watercourse that contains water for several months of each year and is dry for the rest of the year. Minor streams not shown.
5	Swamp	Land which is so saturated with water that it is not suitable for agricultural (including pastoral) use and presents a barrier to free passage; the degree of wetness may vary with the season.
6	Mangrove	A dense growth of trees of certain species found on muddy foreshore flats and along tidal watercourses especially in tropical and subtropical waters.
7	Saline coastal flat	A nearly level tract of land between mean high water and the extent of the highest astronomical tide.
8	Reservoir	A body of water collected and stored behind a man-made barrier for some specific use.
9	Licensed airport	An airport licensed by the Civil Aviation Authority for the movement of aircraft and the receipt and discharge of cargo; excludes heliports.
10	Built-up area	A populated zone where buildings are so close together that intervening space can not be represented as polygons at 1:250 000 scale.

The tenure layer

The tenure layer is defined by the attributes *tenure* (a numerical code) and *tenure_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.4.

Table A2.4. Attributes of the tenure layer of the land use theme showing values and meanings.

tenure	tenure_desc	Meaning
0	Ocean, estuary with no tenure; no data	Ocean or estuary; also areas where the tenure is not known.
1	Multiple use forests	Forestry areas on public land managed and controlled by state and territory forestry services in accordance with forestry acts and regulations. Includes state forests and timber reserves.
4	Nature conservation areas	National parks, nature reserves, state and territory recreation areas, conservation parks, environmental parks etc. Crown land reserved for environmental conservation and recreational purposes. Includes aboriginal freehold land leased back to conservation authorities as national park and jointly controlled. The term 'crown land' means land not subject to freehold or leasehold title of any individual or incorporated group.
6	Private freehold	Land held under freehold title: mainly privately owned land. Freehold title held, with special conditions attached, by designated Aboriginal communities, in all states except the Northern Territory, is classified separately as 'Private freehold – Aboriginal' (*tenure* = 8). For the Northern Territory, 'Private freehold' (*tenure* = 6) includes 'Private freehold – Aboriginal' (*tenure* = 8).
7	Private leasehold	Land held under leasehold title: leased from the crown, regarded as 'privately owned' land. Leasehold title held, with special conditions attached, by designated Aboriginal communities, in all states except the Northern Territory, is classified separately as 'Private leasehold – Aboriginal' (*tenure* = 18). For the Northern Territory, 'Private leasehold' (*tenure* = 7) includes 'Private leasehold – Aboriginal' (*tenure* = 18).
8	Private freehold – Aboriginal	Land held under freehold title, with special conditions attached, by designated Aboriginal communities.
9	Reserved crown land – Aboriginal reserve	Crown land reserved for Aborigines; under the control of state and territory government Aboriginal affairs authorities.
10	Reserved crown land – not elsewh. class.	Reserved crown land not elsewhere classified; includes stock routes.
11	Water production	Crown land reserved to protect a water supply catchment or accommodate works associated with water supplies. Includes privately or publicly owned land used for other purposes but subject to land use or access restrictions.

12	Reserved crown land – defence reserve	Crown land reserved for use by the armed forces.
13	Reserved crown land – mine reserve	Crown land held in reserve for mining.
14	Other crown land – vacant	Crown land not reserved for any purpose.
15	Other crown land – institutional	Institutional crown land – utilities, scientific, research, educational, other.
18	Private leasehold – Aboriginal	Land held under leasehold title, with special conditions attached, by designated Aboriginal communities.
20	Private freehold – Aboriginal, non-ag.	Aboriginal freehold land with negligible agriculture.
21	Private leasehold - Aboriginal, non-ag.	Aboriginal leasehold land with negligible agriculture.
22	Private freehold or private leasehold	Land that falls into either the 'Private freehold' or the 'Private leasehold' categories (*tenure* = 6 or 7). This category only applies to the Ord River irrigation area of Western Australia.

<u>The forest type layer</u>

The forest type layer is defined by the attributes *forest_type* (a numerical code) and *forest_type_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.5.

Table A2.5. Attributes of the forest type layer of the land use theme showing values and meanings.

forest_type	forest_type_desc	Meaning
0	Non-forest	Non-forest: crown cover between 0% and 20%.
1	No data	No forest data.
2	Native woodland	Native forest with crown cover between 20% and 50%.
3	Native open forest	Native forest with crown cover between 50% and 80%.
4	Native closed forest	Native forest with crown cover between 80% and 100%.
5	Plantation forest	Softwood or hardwood plantation forest.

The agricultural commodities layer is defined by the attributes *spread* (a numerical code) and *spread_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.6.

Table A2.6. Attributes of the agricultural commodities layer of the land use theme showing values and meanings.

spread	spread_desc	Meaning
-1	Non-agricultural land or no data	Non-agricultural land or no data.
0	Unallocated potentially ag. land	Potentially agricultural land for which no agricultural land use was allocated by SPREAD. The total area submitted to SPREAD exceeds the total commodity area available, for the SLA concerned. The land is non-forested and non-public. It is probably mainly non-agricultural. Intensive uses may be prominent, especially rural residential ('hobby farms') in periurban areas and mining in the La Trobe valley.
1	Residual/Native pastures	Native pasture of variable quality.
2	Agroforestry	Agroforestry
3	Sown pastures	Sown pastures
4	Cereals excluding rice	Cereals excluding rice (eg wheat, oats, barley, grain sorghum, maize, millet)
5	Rice	Rice
6	Legumes	Legumes (eg soybeans, peanuts, lupins)
7	Oilseeds	Oilseeds (eg canola, sunflower)
8	Sugar cane	Sugar cane
9	Non-cereal forage crops	Non-cereal forage crops
10	Cotton	Cotton
11	Other non-cereal crops	Other non-cereal crops (eg tea, coffee, turf, herbs)
12	Other vegetables	Other vegetables
13	Potatoes	Potatoes
14	Citrus fruit	Citrus fruit (eg oranges, lemons)
15	Apples	Apples
16	Pears	Pears (includes quinces and nashi)
17	Stone fruit	Stone fruit (eg apricots, figs, olives, peaches, avocados)
18	Nuts	Nuts (eg macadamia, almonds)
20	Plantation fruit	Plantation fruit (eg bananas, kiwifruit, pineapples)
21	Grapes	Grapes

The irrigation layer is defined by the attributes *irrigation* (a numerical code) and *irrigation_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.7.

Table A2.7. Attributes of the irrigation layer of the land use theme showing values and meanings.

irrigation	irrigation_desc	Meaning
-999	Non-ag or unalloc pot ag land or no data	Non-agricultural land or no data; unallocated potentially agricultural land.
0	Dryland agriculture	Dryland agriculture
1	Irrigated agriculture	Irrigated agriculture

The land use layer

The land use layer is defined by the attributes *lu_code* (a numerical code), *lu_desc* (the primary classification), *lu_desc2* (the secondary classification), *lu_desc3* (the tertiary classification) and *t-code* (the tertiary code). The tertiary code is a string of three numbers separated by periods indicating, respectively, the primary, secondary and tertiary classifications. These attributes, and their values, use the ALUMC, Version 4, October 2000 described at http://www.affa.gov.au (search the site for ALUMC).

The values of *lu_code* are three digit integers. The three digits indicate the primary, secondary and tertiary classes in the ALUMC. The three digits are the same as the three numbers forming the t-code, and are in the same order. For example, *lu_code* = 500 indicates primary class 5 Intensive uses (t-code 5.0.0), *lu_code* = 540 indicates secondary class 5.4 Residential (t-code 5.4.0) and *lu_code* = 542 indicates tertiary class 5.4.2 Rural residential (t-code 5.4.2). Refer to the macro used to construct the land use classification lookup table for more details.

The values of *lu_desc* (the primary classification in words) and their meanings and corresponding ranges of values for *lu_code* are listed in Table A2.8.

Table A2.8. Values and meanings for the attributes, lu_code and lu_desc, of the land use classification layer of the land use theme.

lu_code	lu_desc	Meaning
0	NO DATA	No data.
100 to less than 200	CONSERVATION AND NATURAL ENVIRONMENTS	Land used primarily for conservation purposes, based on the maintenance of the essentially natural ecosystems present.
200 to less than 300	PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS	Land used primarily for primary production based on limited change to the native vegetation.
300 to less than 400	PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS	Land used mainly for primary production, based on dryland farming systems.
400 to less than 500	PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS	Land used mostly for primary production, based on irrigated farming.
500 to less than 600	INTENSIVE USES	Land subject to extensive modification, generally in association with closer residential settlement, commercial or industrial uses.
600 to less than 700	WATER	Water features. Water is regarded as an essential aspect of the classification, but it is primarily a cover type.

The values of *lu_desc2, lu_desc3* and *t-code* follow the ALUMC Version 4. See http://www.affa.gov.au (search the site for ALUMC) for more information.

The affinity class layer

The affinity class layer is defined by the attributes *affinities* (a numerical code) and *affinities_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.9.

Table A2.9. Attributes of the affinity class layer of the land use theme showing values and meanings.

affinities	affinities_desc	Meaning
-999	Non-ag or unalloc pot ag land or no data	Non-agricultural land or no data; unallocated potentially agricultural land.
-998	Manual alloc - commonwealth agency input	Potentially agricultural land in two SLAs to which dryland native pasture (*spread* = 1 and *irrigation* = 0) was allocated manually.[a] These two SLAs have no agricultural holdings according to the 1996 - 97 AgStats database. The potentially agricultural land they contain is thought to be best classified as dryland native pasture, on the basis of information from the Indigenous Land Corporation.
-997	Manual alloc - area too large for SPREAD	Potentially agricultural land in an SLA to which dryland native pasture (*spread* = 1 and *irrigation* = 0) was allocated manually.[b] The SPREAD program fails to give a solution because the number of pixels to be allocated is too large. The adjusted and scaled 1996 - 97 AgStats data indicate that all of the potentially agricultural land in the SLA should be dryland native pasture.
1	0.000 to 0.030	Affinity of the cell to the allocated control site is in the range 0.000 to 0.030. These are the most reliable matches.
2	0.030 to 0.047	Affinity of the cell to the allocated control site is in the range 0.030 to 0.047. These matches are of intermediate reliability.
3	0.047 to 0.483	Affinity of the cell to the allocated control site is in the range 0.047 to 0.483. These are the least reliable matches.

[a] The SLAs are West Arnhem (ASGC code 710154809) and Aurukun (S) (ASGC code 350100250).
[b] The SLA is Unincorp. Far North (ASGC code 435259589).

The pass number class layer is defined by the attributes *pass_no* (a numerical code) and *pass_no_desc* (a brief description). The values of these attributes and their meanings are listed in Table A2.10.

Table A2.10. Attributes of the pass number class layer of the land use theme showing values and meanings.

pass_no	pass_no_desc	Meaning
-999	Non-ag or unalloc pot ag land or no data	Non-agricultural land or no data; unallocated potentially agricultural land.
-998	Manual alloc - commonwealth agency input	Potentially agricultural land in two SLAs to which dryland native pasture (*spread* = 1 and *irrigation* = 0) was allocated manually.[a] These two SLAs have no agricultural holdings according to the 1996 - 97 AgStats database. The potentially agricultural land they contain is thought to be best classified as dryland native pasture, on the basis of information from the Indigenous Land Corporation.
-997	Manual alloc - area too large for SPREAD	Potentially agricultural land in an SLA to which dryland native pasture (*spread* = 1 and *irrigation* = 0) was allocated manually.[b] The SPREAD program fails to give a solution because the number of pixels to be allocated is too large. The adjusted and scaled 1996 - 97 AgStats data indicate that all of the potentially agricultural land in the SLA should be dryland native pasture.
1	1 pass	Allocation of a control site to the cell required only 1 pass or iteration of the SPREAD procedure. These are the most reliable matches.
2	2 or 3 passes	Allocation of a control site to the cell required 2 or 3 passes or iterations of the SPREAD procedure. These matches are of intermediate reliability.
3	4 to 19 passes inclusive	Allocation of a control site to the cell required only 4 to 19 passes or iterations of the SPREAD procedure. These are the least reliable matches.

[a] The SLAs are West Arnhem (ASGC code 710154809) and Aurukun (S) (ASGC code 350100250).
[b] The SLA is Unincorp. Far North (ASGC code 435259589).

The affinities theme

Structure of the affinities theme

The affinities theme is in ARC/INFO grid format. It is a floating point grid and has no value attribute table (vat).

Data dictionary for the affinities theme

The affinities theme provides data only for pixels to which specific agricultural land uses were allocated by SPREAD. The theme does not include data for those pixels to which specific agricultural land uses were allocated manually. In the theme, each data pixel has a value between 0 and 1. The value is a measure of the similarity between the NDVI data for the pixel and the NDVI data for the particular control site representing the land use allocated. The measure of difference used is the

Gower metric (Walker and Mallawaarachchi, 1998; Gower, 1971). A value of 0 indicates a perfect match and 1 indicates maximum dissimilarity.

The pass number theme

Structure of the pass number theme

The pass number theme is in ARC/INFO grid format. It is an integer grid and has a vat with the attributes *value* (cell value) and *count* (number of cells with given value).

Data dictionary for the pass number theme

The pass number theme, like the affinities theme, provides data only for pixels to which specific agricultural land uses were allocated by SPREAD. The theme does not include data for those pixels to which specific agricultural land uses were allocated manually. In the theme, each data pixel has a value ranging from 1 to 19 inclusive. The value indicates the number of iterations of the SPREAD routine used to allocate the specific agricultural land use to the pixel. The smaller the cell value, the more reliable the specific agricultural land use allocation.

The control site locations theme

Structure of the control site locations theme

The control site locations layer is an ARC/INFO point cover. It has a point attribute table (pat) with the attributes listed in Table A2.11.

Table A2.11. Attributes of the control site locations theme and their meanings.

Attribute	Meaning
area	Mandatory ARC/INFO attribute (not relevant to point features)
perimeter	Mandatory ARC/INFO attribute (not relevant to point features)
<cover_name>#	Unique point feature identification number (mandatory ARC/INFO attribute assigned automatically)
<cover_name>-id	Point feature identification number (mandatory ARC/INFO attribute definable by user)
cs_id	Unique control site numerical identifier
file_name	Unique control site alphanumeric identifier
ste_code	State code
ste_name	State name
sla_code	Nine digit Statistical Local Area code
sla_name	Statistical Local Area name
abslev1	Agricultural land use code – 9 commodity groups
abslev1_desc	Agricultural land use description – 9 commodity groups
audit_com	Agricultural land use code – 21 commodity groups
audit_com_desc	Agricultural land use description – 21 commodity groups
abslev3_desc	Agricultural land use description – 117 commodity groups
irrigated	Irrigation status ('yes' or 'no')

Data dictionary for the control site locations theme

The four mandatory ARC/INFO attributes have no specific meaning for the data.

The attributes *cs_id* and *file_name* are unique identifiers for the control sites. The values of *cs_id* are positive integers. The values of *file_name* are alphanumeric strings. The values of *cs_id* change from

one version of the land use map to the next. The values of *file_name* do not change from one version of the land use map to the next - they stay the same indefinitely.

The attributes *ste_code* and *ste_name* indicate the state in which the control site is situated. The values of the attribute *ste_code* are the integers 1 to 7 inclusive and are seven of the Australian Standard Geographic Classification (ASGC) codes for Australian states and territories. The values of the attribute *ste_name* give the state names in words.

The attributes sla_code and sla_name indicate the Statistical Local Area (SLA) in which the control site is situated. SLAs are used by the Australian Bureau of Statistics for reporting the 1996 – 97 agricultural and population census data. SLAs are similar to Local Government Areas but the complete set of SLAs covers the whole of Australia without overlap. SLA boundaries change from year to year. The boundaries referred to in the control site locations theme are the ASGC 1996 Edition. The values of the attribute *sla_code* are nine digit integers and are the ASGC codes for the SLAs. They are unique identifiers of the SLAs. The values of the attribute *sla_name* give the SLA names in words. They are not unique identifiers of the SLAs.

The attributes *abslev1*, *abslev1_desc*, *audit_com*, *audit_com_desc* and *abslev3_desc* indicate the specific agricultural land use for the control site in the year 1.4.96 to 31.3.97. The values of the attributes *abslev1, abslev1_desc, audit_com, audit_com_desc* and *abslev3_desc* are drawn from a hierarchical classification of agricultural land uses. The classification is designed so that it can be used with the agricultural commodity area data from the 1996 – 97 agricultural census of the Australian Bureau of Statistics. It was used to aggregate the agricultural census data before constructing area constraints for SPREAD. The correspondence between attributes of the control site locations theme and elements of the classification scheme is summarised in Table A2.12. The relevant levels of the classification scheme are set out in full in Table A2.13. Note that there is no attribute storing the ABS Level 3 codes. This is because some Queensland control sites have more than one ABS Level 3 classification, the precise classification being uncertain. In all of these cases, the multiple ABS Level 3 classifications fall into a single Audit Commodity classification.

Table A2.12. Correspondence between attributes of the control site locations theme and elements of the hierarchical classification scheme for agricultural land uses.

Attribute	Classification scheme element
abslev1	ABS Level 1 Classification - land use code
abslev1_desc	ABS Level 1 Classification - land use description
audit_com	Audit Commodity Classification - land use code
audit_com_desc	Audit Commodity Classification - land use description
abslev3_desc	ABS Level 3 Classification - land use description

Table A2.13. The hierarchical classification of agricultural land uses used to classify SPREAD inputs, showing the three levels recorded in the control site locations theme.

ABS level 1 code	ABS level 1 classification	Audit commodity code	Audit commodity classification	ABS level 3 code	ABS level 3 classification
1	Residual/Native pastures	1	Residual/Native pastures	1	Residual/Native pastures
2	Agroforestry	2	Agroforestry	2	Agroforestry
3	Sown pastures	3	Sown pastures	3	Pure lucerne
				4	Other sown pastures
				5	Now superfluous
4	Cereals	4	Cereals excluding rice	6	Wheat
				7	Oats
				8	Barley
				9	Cereal rye
				10	Buckwheat
				11	Grain sorghum
				12	Maize
				13	Millet
				14	Triticale
				15	Other cereals for grain
				16	Cereals for hay/silage
		5	Rice	17	Rice
5	Non-cereal crops	6	Legumes	18	Soybeans
				19	Peanuts
				20	Mung beans
				21	Other field beans
				22	Lupins
				23	Field peas
				24	Pigeon peas
				25	Chick peas
				26	Vetches
				27	Lentils
				28	Faba beans
		7	Oilseeds	29	Canola
				30	Sunflower
				31	Linseed
				32	Oil poppies
				33	Safflower
				34	Sesame
		8	Sugar cane	35	Sugar cane
		9	Non-cereal forage	36	Non-cereal crops

			crops		for silage/green feed
				37	Non-cereal crops for hay
		10	Cotton	38	Cotton
		11	Other non-cereal crops	39	Hops
				40	Coffee
				41	Tea
				42	Nurseries/ Flowers
				43	Aloe vera
				44	Broom millet
				45	Lab lab purpureus
				46	Fennel
				47	Lavender
				48	Popcorn
				49	Tobacco
				50	Coriander
				51	Ginger
				52	Mustard
				53	Turf
				54	Pyrethrum
				55	Peppermint
				56	Other non-cereal crops
6	Vegetables	12	Other vegetables	57	Other vegetables
		13	Potatoes	58	Potatoes
7	Orchards	14	Citrus fruit	59	Oranges
				60	Grapefruit
				61	Lemon/lime
				62	Mandarins
				63	Tangelos
				64	Other citrus
		15	Apples	65	Apples
		16	Pears	66	Pears
				67	Quinces
				68	Nashi
				69	Other pome
		17	Stone fruit	70	Apricots
				71	Cherries
				72	Figs
				73	Nectarines
				74	Olives
				75	Peaches
				76	Peacharines
				77	Persimmons

				78	Plums
				79	Prunes
				80	Other stone fruit
				81	Other orchard fruit
				82	Avocados
				83	Carambola
				84	Custard apples
				85	Dates
				86	Jackfruit
				87	Guava
				88	Loquats
				89	Lychees
				90	Mangoes
				91	Rambutan
				92	Longans
		18	Nuts	93	Macadamia
				94	Almonds
				95	Cashews
				96	Chestnuts
				97	Filberts
				98	Pecans
				99	Pistachios
				100	Walnuts
				101	Other nuts
8	Berry/ Plantation fruit	19	Berry fruit	102	Blackcurrants
				103	Blueberries
				104	Gooseberries
				105	Loganberries
				106	Raspberries
				107	Strawberries
				108	Other berry fruit
		20	Plantation fruit	109	Bananas
				110	Babacos
				111	Kiwifruit
				112	Papaws
				113	Passionfruit
				114	Pepinos
				115	Pineapples
				116	Rosella
				117	Other tropical fruit
9	Grapes	21	Grapes	118	Grapes

!

The attribute *irrigation* indicates the irrigation status of the control site for the year 1.4.96 to 31.3.97. Values are 'yes' meaning irrigated or 'no' meaning not irrigated.

The control site identities theme

Structure of the control site identities theme

The control site identities theme is in ARC/INFO grid format. It is an integer grid and has a vat with the attributes *value* (cell value), *count* (number of cells with given value) and *file_name* (unique alphanumeric identifier for the control site matched to the pixel by SPREAD).

Data dictionary for the control site identities theme

The control site identities theme provides data only for pixels to which specific agricultural land uses were allocated by SPREAD. The theme does not include data for those pixels to which specific agricultural land uses were allocated manually. In the theme, the value of each data pixel is a positive integer, which is a unique identifier for the control site matched to the pixel by SPREAD. The value is the same as the value of the attribute *cs_id* for the matched control site in the control site locations theme. Each data pixel also has an alphanumeric attribute, the *file_name* attribute, which is also a unique identifier for the matched control site. The value is the same as the value of the attribute *file_name* for the allocated control site in the control site locations theme. As explained previously, the alphanumeric identifier of a control site, the value of *file_name* in the control site identities and locations themes, does not change from one version of the land use map to the next but, rather, stays the same indefinitely. The numerical identifier of a control site, the value of *cs_id* in the control site identities and locations themes, does change from one version of the land use map to the next.

References

Gower, J C, 1971. A general coefficient of similarity and some of its properties. *Biometrics* 27: 857 - 871.

IUCN, 1994. *Guidelines for Protected Area Management Categories.* CNPPA with the assistance of WCMC. IUCN, Gland, Switzerland and Cambridge, UK.

Walker, P, and Mallawaarachchi, T, 1998. Disaggregating agricultural statistics using NOAA-AVHRR NDVI. *Remote Sens Environ*, 63: 112 - 125.

Further Reading

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 Audit, Canberra.

Barson, M. and Randall, L. 2001. *Coordination of land use mapping of key implementation areas. Final Report for Project BRR6*. National Land and Water Resources Audit, Canberra.

Appendix 3. AgStats items extracted to construct commodity groups

Table A3.1 shows the individual AgStats items extracted from the 1996/97 AgStats database and the ABS Level 3 Classification assigned. For the relationship between the ABS Level 3 Classification and the Audit Commodity Classification, which was the level at which the SPREAD method solved for agricultural land use, refer to Table A2.13. For conversion of orchard tree numbers to areas refer to Table 5.

Table A3.1. AgStats items extracted to construct commodity groups.

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Trees and shrubs planted			
Seedlings - area sown	704011	Agroforestry	2
Seed sown - area	704311	Agroforestry	2
Pastures			
Lucerne and other species - area at 31 March 1997	1000401	Other sown pastures	4
Lucerne (pure) - area at 31 March 1997	1000501	Pure lucerne	3
Pasture legumes (excl lucerne) - area at 31 March 1997	1001201	Other sown pastures	4
Sown grasses - area at 31 March 1997	1001301	Other sown pastures	4
Native or naturalised pasture at 31 March 1997	1001701	Native pasture	1
Mix of perennial grasses & legumes - area at 31 March 1997	1002101	Other sown pastures	4
Mix of annual grasses & legumes - area at 31 March 1997	1002201	Other sown pastures	4
Cereals			
Wheat for grain - area	1500101	Wheat	6
Oats for grain - area	1500801	Oats	7
Barley for grain - area	1501701	Barley	8
Cereal Rye for grain - area	1502301	Cereal rye	9
Buckwheat for grain - area	1503001	Buckwheat	10
Grain sorghum (for grain) - area	1504101	Grain sorghum	11
Maize for grain - area	1505301	Maize	12
Millet & panicum (inc. canary seed) - area	1507601	Millet	13
Rice for grain - area	1508501	Rice	17
Triticale for grain - area	1508801	Triticale	14
Other cereals for grain (NEC) - area	1510601	Other cereals for grain	15
Cereals (incl. forage sorghum) cut for hay - area	1510801	Cereals for hay/silage	16
Cereals fed off or for silage - area	1511001	Cereals for hay/silage	16

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Non-cereal crops			
Aloe vera - area	1800301	Aloe vera	43
Mung beans - area	1800601	Mung beans	20
Other field beans - area	1800901	Other field beans	21
Soybeans - area	1801701	Soybeans	18
Broom millet (fibre) - area	1802201	Broom millet	44
Cotton - irrigated - area	1803001	Cotton	38
Cotton - non irrigated - area	1803101	Cotton	38
Hops - total area	1805101	Hops	39
Lab Lab Purpureus (seed) - area	1806001	Lab lab purpureus	45
Fennel (bitter) - (Foeniculum Vulgae) - area	1806401	Fennel	46
Lavender - area	1806501	Lavender	47
Linseed / Linola (clean seed) - area	1806701	Linseed	31
Lupins for grain - area	1807001	Lupins	22
Oil poppies - area	1807701	Oil poppies	32
Peanuts - area	1808101	Peanuts	19
Field peas for grain - area	1809101	Field peas	23
Pigeon peas - area	1900201	Pigeon peas	24
Chick peas - area	1900301	Chick peas	25
Coffee - area	1900401	Coffee	40
Popcorn - area	1900501	Popcorn	48
Canola - area	1900901	Canola	29
Safflower - area	1901401	Safflower	33
Sesame - area	1901501	Sesame	34
Crops fed off or cut for green feed or silage	1901911	Non-cereal crops for silage/green feed	36
Sugar cane cut for crushing - area	1902101	Sugar cane	35
Sugar cane cut for plants - area	1902301	Sugar cane	35
Sugar cane (standover) - area	1902501	Sugar cane	35
Sugar cane (newly planted) - area	1902601	Sugar cane	35
Sunflower - area	1903901	Sunflower	30
Tea - area	1904101	Tea	41
Tobacco - area	1904401	Tobacco	49
Vetches for seed - area	1904801	Vetches	26
Lentils - area	1905201	Lentils	27
Coriander - area	1907201	Coriander	50
Ginger - area	1907401	Ginger	51
Faba beans (incl tick and horse) - area	1907601	Faba beans	28
Mustard seed - area	1908101	Mustard	52
Cultivated turf - area	1908601	Turf	53
Pyrethrum - area	1908801	Pyrethrum	54
Peppermint - area	1908901	Peppermint	55
Crops (excl cereals) cut for hay - area	1909301	Non-cereal crops for hay	37
Non cereal crops (Not Elsewhere Classified)	1910301	Other non-cereal crops	56

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Non-cereal crops (cont'd)			
Nurseries - area	1918201	Nurseries/flowers	42
Cut flowers - area	1918401	Nurseries/flowers	42
Vegetables			
Beans french & runner - for seed - area	3400501	Other vegetables	57
Carrot seed - area	3401001	Other vegetables	57
Cabbage (chinese) for seed - area	3401501	Other vegetables	57
Cauliflower seed - area	3401801	Other vegetables	57
Onion seed - area	3402001	Other vegetables	57
Peas green - for seed - area	3402501	Other vegetables	57
Potatoes - for seed - area	3403101	Potatoes	58
Pumpkins - for seed - area	3403501	Other vegetables	57
Radish seed - area	3404001	Other vegetables	57
Vegetable seed - other (not elsewhere classified) - area	3409901	Other vegetables	57
Potatoes - early/spring - harvest before 31 March - area	3503101	Potatoes	58
Potatoes (main/autumn) harvested after 31 March - area	3503601	Potatoes	58
Artichokes - area	3600201	Other vegetables	57
Asparagus - total area	3600601	Other vegetables	57
Broad beans - area	3601001	Other vegetables	57
French and runner beans (processing) - area	3601101	Other vegetables	57
French and runner beans (fresh market) - area	3601201	Other vegetables	57
Beetroot - area	3601501	Other vegetables	57
Broccoli - area	3601701	Other vegetables	57
Brussel sprouts - area	3601801	Other vegetables	57
Cabbages - area	3601901	Other vegetables	57
Chinese cabbage (Buckchoi and Wombak) - area	3602001	Other vegetables	57
Capsicum chillies and peppers - area	3602101	Other vegetables	57
Carrots - area	3602401	Other vegetables	57
Cauliflower - area	3602701	Other vegetables	57
Celery - area	3602901	Other vegetables	57
Chokos - area	3603001	Other vegetables	57
Cucumbers - area	3603201	Other vegetables	57
Eggplant - area	3603401	Other vegetables	57
Witloof chicory (french endive) - area	3603601	Other vegetables	57
Fennel (sweet) - area	3603701	Other vegetables	57
Garlic - area	3603901	Other vegetables	57
Gherkins - area	3604101	Other vegetables	57
Herbs - lemon grass etc - area	3604201	Other vegetables	57
Horse radish - area	3604301	Other vegetables	57
Leeks - area	3604401	Other vegetables	57
Lettuce - area	3604501	Other vegetables	57

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Vegetables (cont'd)			
Marrows and squashes - area	3604701	Other vegetables	57
Zucchini - area	3604801	Other vegetables	57
Melons rock (incl cantaloupe) - area	3605101	Other vegetables	57
Melons water - area	3605201	Other vegetables	57
Melons (not elsewhere classified) - area	3605301	Other vegetables	57
Melons bitter (gourd) - area	3605401	Other vegetables	57
Mushrooms - area	3605801	Other vegetables	57
Okra - area	3605901	Other vegetables	57
Onions spring (incl shallots) - area	3606001	Other vegetables	57
Onions white and brown - area	3606101	Other vegetables	57
Parsley - area	3606301	Other vegetables	57
Parsnips - area	3606401	Other vegetables	57
Peas green (for processing) - area	3606601	Other vegetables	57
Peas green (for fresh market) - area	3606701	Other vegetables	57
Peas snow - area	3606901	Other vegetables	57
Pumpkins triambles trombones etc. - area	3607101	Other vegetables	57
Radish - area	3607201	Other vegetables	57
Rhubarb - area	3607401	Other vegetables	57
Silver beet and spinach - area	3607801	Other vegetables	57
Sprouts (alfalfa mung bean etc.) - area	3607901	Other vegetables	57
Sweet corn - area	3608001	Other vegetables	57
Sweet potatoes - area	3608101	Other vegetables	57
Tomatoes (processing) - area	3608401	Other vegetables	57
Tomatoes (fresh market) - area	3608501	Other vegetables	57
Swedes - area	3608901	Other vegetables	57
Turnips (white) - area	3609101	Other vegetables	57
Vegetables other (not elsewhere classified) - area	3609701	Other vegetables	57
Orchards			
Oranges trees under 6 years	4200711	Oranges	59
Oranges trees 6 years and over	4200712	Oranges	59
Grapefruit trees under 6 years	4201001	Grapefruit	60
Grapefruit trees 6 years and over	4201002	Grapefruit	60
Lemon and lime trees under 6 years	4201201	Lemon/lime	61
Lemons and limes trees 6 years and over	4201202	Lemon/lime	61
Mandarins trees under 6 years	4201401	Mandarins	62
Mandarins trees 6 years and over	4201402	Mandarins	62
Tangelos trees under 6 years	4201501	Tangelos	63
Tangelos trees 6 years and over	4201502	Tangelos	63
Citrus fruit other (NEC) - trees under 6 years	4201701	Other citrus	64
Citrus fruit other (NEC) -trees 6 years and over	4201702	Other citrus	64
Apples trees under 6 years	4202211	Apples	65
Apples trees 6 years and over	4202212	Apples	65

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Orchards (cont'd)			
Pears (excluding Nashi) trees under 6 years	4202811	Pears	66
Pears (excluding Nashi) trees 6 years and over	4202812	Pears	66
Quinces - trees under 6 years	4203001	Quinces	67
Quinces - trees 6 years and over	4203002	Quinces	67
Nashi trees under 6 years	4203111	Nashi	68
Nashi trees 6 years and over	4203112	Nashi	68
Pome fruit NEC) trees under 6 years	4203201	Other pome	69
Pome fruit (NEC) trees 6 years and over	4203202	Other pome	69
Apricots trees under 6 years	4203901	Apricots	70
Apricots trees 6 years and over	4203902	Apricots	70
Avocados trees under 6 years	4204101	Avocados	82
Avocados trees 6 years and over	4204102	Avocados	82
Carambola trees under 6 years	4204201	Carambola	83
Carambola trees 6 years and over	4204202	Carambola	83
Cherries trees under 6 years	4204301	Cherries	71
Cherries trees 6 years and over	4204302	Cherries	71
Custard apples trees under 6 years	4204501	Custard apples	84
Custard apples trees 6 years and over	4204502	Custard apples	84
Dates trees under 6 years	4204601	Dates	85
Dates trees 6 years and over	4204602	Dates	85
Jackfruit trees under 6 years	4204701	Jackfruit	86
Jackfruit trees 6 years and over	4204702	Jackfruit	86
Figs trees under 6 years	4204801	Figs	72
Figs trees 6 years and over	4204802	Figs	72
Guava trees under 6 years	4204901	Guava	87
Guava trees 6 years and over	4204902	Guava	87
Loquats - trees under 6 years	4205101	Loquats	88
Loquats - trees 6 years and over	4205102	Loquats	88
Lychees - trees under 6 years	4205201	Lychees	89
Lychees - trees 6 years and over	4205202	Lychees	89
Mangoes trees under 6 years	4205301	Mangoes	90
Mangoes trees 6 years and over	4205302	Mangoes	90
Nectarines trees under 6 years	4205501	Nectarines	73
Nectarines trees 6 years and over	4205502	Nectarines	73
Olives - trees under 6 years	4205701	Olives	74
Olives - trees 6 years and over	4205702	Olives	74
Longans - trees under 6 years	4205801	Longans	92
Longans - trees 6 years and over	4205802	Longans	92
Peaches - trees under 6 years	4206211	Peaches	75
Peaches - 6 years and over	4206212	Peaches	75
Peacharines - trees under 6 years	4206301	Peacharines	76
Peacharines - trees 6 years and over	4206302	Peacharines	76

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Orchards (cont'd)			
Persimmons - trees under 6 years	4206401	Persimmons	77
Persimmons - trees 6 years and over	4206402	Persimmons	77
Plums - trees under 6 years	4206601	Plums	78
Plums - trees 6 years and over	4206602	Plums	78
Prunes - trees under 6 years	4206701	Prunes	79
Prunes - trees 6 years and over	4206702	Prunes	79
Rambutan trees under 6 years	4206901	Rambutan	91
Rambutan trees 6 years and over	4206902	Rambutan	91
Stone fruit (NEC) trees under 6 years	4207701	Other stone fruit	80
Stone fruit (NEC) trees 6 years and over	4207702	Other stone fruit	80
Orchard fruit NEC - trees under 6 years	4207801	Other orchard fruit	81
Orchard fruit NEC - trees 6 years and over	4207802	Other orchard fruit	81
Almonds trees under 6 years	4208101	Almonds	94
Almonds trees 6 years and over	4208102	Almonds	94
Cashews trees under 6 years	4208301	Cashews	95
Cashews trees 6 years and over	4208302	Cashews	95
Chestnuts trees under 6 years	4208501	Chestnuts	96
Chestnuts trees 6 years and over	4208502	Chestnuts	96
Filberts hazelnuts & cobnuts trees under 6 years	4208701	Filberts	97
Filberts hazelnuts & cobnuts trees 6 years and over	4208702	Filberts	97
Macadamia trees under 6 years	4209001	Macadamia	93
Macadamia trees 6 years and over	4209002	Macadamia	93
Pecans trees under 6 years	4209201	Pecans	98
Pecans trees 6 years and over	4209202	Pecans	98
Pistachios trees under 6 years	4209301	Pistachios	99
Pistachios trees 6 years and over	4209302	Pistachios	99
Walnuts trees under 6 years	4209501	Walnuts	100
Walnuts trees 6 years and over	4209502	Walnuts	100
Nuts (NEC) trees under 6 years	4209701	Other nuts	101
Nuts (NEC) trees 6 years and over	4209702	Other nuts	101
Berry/Tropical fruit			
Black currants - area not yet bearing	4300401	Blackcurrants	102
Black currants - bearing area	4300402	Blackcurrants	102
Blueberries not yet bearing area	4300901	Blueberries	103
Blueberries bearing area	4300902	Blueberries	103
Gooseberries area not yet bearing	4301101	Gooseberries	104
Gooseberries bearing area	4301102	Gooseberries	104
Loganberries not yet bearing area	4301401	Loganberries	105
Loganberries bearing area	4301402	Loganberries	105
Raspberries - not yet bearing area	4301901	Raspberries	106
Raspberries - bearing area	4301902	Raspberries	106

AgStats 96/97		ABS level 3 classification	
Commodity item	**Code**	**Commodity group**	**Code**
Berry/Tropical fruit (cont'd)			
Strawberries - not yet bearing area	4302201	Strawberries	107
Strawberries - Bearing area	4302202	Strawberries	107
Berry and other small fruit (NEC) not yet bearing area	4302901	Other berry fruit	108
Berry and other small fruit (NEC) - bearing area	4302902	Other berry fruit	108
Babacos not yet bearing area	4304001	Babacos	110
Babacos bearing area	4304002	Babacos	110
Bananas - not yet bearing area	4304601	Bananas	109
Bananas - bearing area	4304602	Bananas	109
Kiwi fruit /zespri - not yet bearing area	4305001	Kiwifruit	111
Kiwi fruit / zespri - bearing area	4305002	Kiwifruit	111
Papaws / Papaya - not yet bearing area	4305401	Papaws	112
Papaws / Papaya - bearing area	4305402	Papaws	112
Passionfruit not yet bearing area	4305701	Passionfruit	113
Passionfruit bearing area	4305702	Passionfruit	113
Pepinos not yet bearing area	4305801	Pepinos	114
Pepinos bearing area	4305802	Pepinos	114
Pineapples - not yet bearing area	4306001	Pineapples	115
Pineapples - bearing area	4306002	Pineapples	115
Rosella not yet bearing area	4306301	Rosella	116
Rosella bearing area	4306302	Rosella	116
Tropical fruit (NEC) -not yet bearing area	4306601	Other tropical fruit	117
Tropical fruit (NEC) - bearing area	4306602	Other tropical fruit	117
Grapes			
Grapes - total area	4803011	Grapes	118

Appendix 4. Construction of land use lookup table

```
/**************************************************************************
/* brclasv2.aml
/*
/* AML used to produce the land use lookup table for the 1996/97 Land Use /* of
Australia, Version 2 (January, 2001). This lookup table is joined
/* permanently to the value attribute table of the land use grid. The
/* lookup table provides an interpretation of the basic layers in the land
/* use grid classified according to the Australian Land Use and Management
/* Classification (ALUMC), Version 4, October 2000.  This classification is
/* based on the 'level of intervention' in the landscape as proposed by
/* Baxter & Russell (1994).  The resulting lookup table differs from
/* previous versions in that irrigated and non-irrigated agricultural land
/* uses are distinguished.
/*
/* The AML can be used to produce a lookup table for the land use grid
/* where
/*      1. Specific agricultural land uses have been assigned using the
/*      SPREAD program (Walker et al, 1998)
/*      2. Specific agricultural land uses have not been assigned
/* The user is asked to indicate whether or not the grid to be processed
/* contains agricultural land uses assigned by SPREAD.
/*
/* The AML is written such that the ordering of the commands is very
/* important to the classification given.  Please keep this in mind if you
/* wish to change the classification.
/*
/* The lookup table produced by brclasv2.aml has six columns, as follows :
/* value        This column can be used to relate the lookup table to the
/*              cell values in the land use grid.
/* lu_code      Three digit number indicating ALUMC primary, secondary
/*              and tertiary classes. For example, 500 indicates
/*              primary class 5 Intensive uses, 540 indicates secondary class
/*              5.4 Residential and 541 indicates tertiary class 5.4.1 Urban
/*              residential.
/* lu_desc      ALUMC primary class in words.
/* lu_desc2     ALUMC secondary class in words.
/* lu_desc3     ALUMC tertiary class in words.
/* t-code       ALUMC tertiary code. Text string indicating
/*              primary.secondary.tertiary class.  The t-code is
/*              complimentary to lu_code.  The t-code should remain constant
/*              if further categories are added to the ALUMC classes.
/*
/* References :
/* Baxter, J.T. and Russell, L.D. (1994). Land use mapping requirements
/* for natural resource management in the Murray-Darling Basin.  Report to
/* the Murray-Darling Basin Commission.  Project M305: Task 6.  Department
/* of Conservation and Natural Resources, Victoria.
/* Lesslie, R. (2000).  Land Use Mapping Workshop, Bureau of Rural
/* Sciences, Canberra, 3-5 October, 2000.
/* http://www.affa.gov.au (search the site for ALUMC)
/* 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 Audit, Canberra.
/* Walker, P.A. and Mallawaarachchi, T. 1998. Disaggregating agricultural
/* statistics using NOAA-AVHRR NDVI. Remote Sens. Environ. 63:112-125.
/*
/* Land use descriptions in 1996/97 Land of Australia, Version 2 as
/* classified according to ALUMC Version 4 to secondary level.
/*
/* ----------------------------------------------------------------------
/* LU_CODE      LU_DESC                            LU_DESC2
/* ----------------------------------------------------------------------
```

```
/* 100 < 200    1. CONSERVATION AND NATURAL ENVIRONMENTS
/* 110 - 117                              Nature conservation
/* 120 - 125                              Managed resource protection
/* 130 - 133                              Other minimal use
/* 200 < 300    2. PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS
/* 210                                    Livestock grazing
/* 220                                    Production forestry
/* 300 < 400    3. PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS
/* 310                                    Plantation forestry*
/* 320                                    Farm forestry*
/* 330                                    Grazing modified pastures
/* 340 - 348                              Cropping (new tertiary
/*                                        class added)
/* 350 - 357                              Perennial horticulture
/* 360 - 364                              Seasonal horticulture
/* 400 < 500    4. PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS
/* 430                                    Irrigated modified pastures
/* 440 - 448                              Irrigated cropping (new
/*                                        tertiary class added)
/* 450 - 457                              Irrigated perennial
/*                                        horticulture
/* 460 - 464                              Irrigated seasonal horticulture
/* 500 < 600    5. INTENSIVE USES
/* 541                                    Residential **
/* 571                                    Transport and communication
/* 600 < 700    6. WATER
/* 610 - 611                              Lake
/* 620                                    Reservoir
/* 630 - 631                              River
/* 650 - 651                              Marsh/wetland
/* 660 - 661                              Estuary/coastal waters
/* -------------------------------------------------------------
/* * All Plantation forestry (3.1) and Farm Forestry (3.2) is assumed
/* dryland as do not have access to data to indicate whether irrigated or
/* not.
/*
/* ** Residential (5.4) includes Manufacturing and industrial (5.3) and
/* Services (5.5).
/*
/*
/* Please note that the Australian Land Use and Management Classification
/* (ALUMC), Version 4, is the preferred land use scheme of the National
/* Land and Water Resources Audit and is to be registered through the
/* Australian Spatial Data Infrastructure.  The classification is now
/* relatively stable with definitions of classes being finalised.  Attempts
/* have been made to assign land use to the most suitable class based on
/* available information.
/*
/* The way in which the various layers of the land use grid are categorised
/* leads to some categories not aligning with an ALUM tertiary or secondary
/* class. Where this occurs, the dominant land use by area is the land use
/* assigned.  This particularly applies to built-up areas in the
/* topo_features layer and other non-cereal crops and plantation fruit in
/* the spread layer.
/*
/* Where an area has multiple land uses the 'prime use' is the land use
/* assigned.  For example a built-up area in a national park is assigned
/* the ALUMC of 5.4.1 Urban residential.  The principle of 'prime use' is
/* implemented for those data layers of equivalent reliability.
/*
/*
/* LAYERS IN THE LAND USE GRID IN ORDER OF PREFERENCE/ASSIGNMENT
/* (See metadata and user guide for 1996/97 Land Use of Australia,
/* Version 2 or final report (Stewart et al, 2001))
/*
/* 1. prot_areas = Australian protected areas that meet the World
/*             Conservation Union guidelines (formerly the International
/*             Union for the Conservation of Nature and Natural Resources)
```

```
/*
/* -----------------------------------------------------------------------
/* PROT_AREAS          PROT_AREAS_DESC
/* -----------------------------------------------------------------------
/* 0                   Not a protected area
/* 11                  Ia. Strict nature reserve
/* 12                  Ib. Wilderness area
/* 20                  II. National park
/* 30                  III. Natural monument
/* 40                  IV. Habitat/species management area
/* 50                  V. Protected landscape/seascape
/* 60                  VI. Managed resource protected areas
/* -----------------------------------------------------------------------
/*
/* 2. tenure = Australian tenure
/*
/* -----------------------------------------------------------------------
/* TENURE              TENURE_DESC
/* -----------------------------------------------------------------------
/* 0                   Ocean, estuary with no tenure; no data
/* 1                   Multiple use forests
/* 4                   Nature conservation areas
/* 6                   Private freehold
/* 7                   Private leasehold
/* 8                   Private freehold - Aboriginal
/* 9                   Reserved crown land - Aboriginal reserve
/* 10                  Reserved crown land - not elsewhere classified
/* 11                  Water production
/* 12                  Reserved crown land - defence reserve
/* 13                  Reserved crown land - mine reserve
/* 14                  Other crown land - vacant
/* 15                  Other crown land - institutional
/* 18                  Private leasehold - Aboriginal
/* 20                  Private freehold - Aboriginal, non-agricultural
/* 21                  Private leasehold - Aboriginal, non-agricultural
/* 22                  Private freehold or private leasehold
/* -----------------------------------------------------------------------
/*
/* 3. topo_features = Topographical features
/*
/* -----------------------------------------------------------------------
/* TOPO_FEATURES       TOPO_FEAT_DESC
/* -----------------------------------------------------------------------
/* 0                   Not classified as a topographic feature
/* 1                   Lake, perennial
/* 2                   Lake, non-perennial
/* 3                   Watercourse, perennial
/* 4                   Watercourse, non-perennial (minor streams not shown)
/* 5                   Swamp
/* 6                   Mangrove
/* 7                   Saline coastal flat
/* 8                   Reservoir
/* 9                   Licensed airport
/* 10                  Built-up area
/* -----------------------------------------------------------------------
/*
/* 4. forest_type = Australian native and plantation forests
/*
/* -----------------------------------------------------------------------
/* FOREST_TYPE         FOREST TYPE
/* -----------------------------------------------------------------------
/* 0                   Non-forest
/* 1                   No data
/* 2                   Native forest, woodland (crown cover 20 - 50 %)
/* 3                   Native forest, open forest (crown cover 51 - 80 %)
/* 4                   Native forest, closed forest (crown cover 81 - 100 %)
/* 5                   Plantation forest
/* -----------------------------------------------------------------------
```

```
/*
/* 5. spread = spatial reallocation of aggregated data - agricultural
/*              commodities allocated using NDVI profiles and ABS AgStats
/*              for 1996/97.  Agricultural land use allocated according to
/*              the Audit commodity classification as given below.
/*
/* -------------------------------------------------------------------
/* SPREAD             SPREAD_DESC
/* -------------------------------------------------------------------
/* -1                 Non-agricultural land or no data
/* 0                  Unallocated potentially agricultural land
/* 1                  Residual/Native pastures
/* 2                  Agroforestry
/* 3                  Sown pastures
/* 4                  Cereals excluding rice
/* 5                  Rice
/* 6                  Legumes
/* 7                  Oilseeds
/* 8                  Sugar cane
/* 9                  Cotton
/* 11                 Other non-cereal crops
/* 12                 Other vegetables
/* 13                 Potatoes
/* 14                 Citrus
/* 15                 Apples
/* 16                 Pears
/* 17                 Stone fruit
/* 18                 Nuts
/* 19                 Berry fruit
/* 20                 Plantation fruit
/* 21                 Grapes
/* -------------------------------------------------------------------
/*
```

```
/* 6. irrigation = irrigated or dryland agriculture according to SPREAD
/*          allocation
/*
/* ----------------------------------------------------------------------
/* IRRIGATION           IRRIGATION_DESC
/* ----------------------------------------------------------------------
/* -999                 Non-agricultural land or no data; unallocated
/*                      potentially agricultural land
/* 0                    Dryland agriculture
/* 1                    Irrigated agriculture
/* ----------------------------------------------------------------------
/*
/*************************************************************************
/* Changes in brclasv2.aml compared with brclass.aml.
/* brclass.aml used to produce lookup table for the 1996/97 Land Use of
/* Australia, Version 1a (July, 2000).
/*
/*----------------------------------------------------------------------
/* BRCLASS (July/August, 2000)  BRCLASV2 (December, 2000)
/*----------------------------------------------------------------------
/* 114  Natural monuments              114     Natural feature protection
/* 130  Other non-production use       130     Other minimal use
/* 124  Indigenous uses                125     Traditional indigenous uses
/* 911  Wetlands - inland              650     Marsh/wetland
/* 912  Wetlands - coastal             660     Estuary/coastal waters
/* 921  Inland water courses -  630        River
/*          Permanent/semi-permanent
/* 922  Inland water courses           630     River
/*          Ephemeral
/* 931  Inland water bodies            610     Lake
/*          Permanent/semi-permanent
/* 932  Inland water bodies            610     Lake
/*          Ephemeral
/* 561  Utilities - water storage      620     Reservoir
/*1411  Cropping - Cereals -           341/441  Cropping/Irrigated cropping
/*      Cereals excluding rice         - Cereals
/*1412  Cropping - Cereals - Rice      341/441
/*1430  Cropping - Hay and silage      343/443 Cropping/Irrigated cropping
/*                                     - Hay and silage
/*1440  Cropping - Oilseeds            344/444 Cropping/Irrigated cropping
/*                                     - Oilseeds and oleaginous fruit
/*1450  Cropping - Sugar cane          345/445 Cropping/Irrigated cropping
/*                                     - Sugar
/*1460  Cropping - Cotton              346/446 Cropping/Irrigated cropping
/*                                     - Cotton
/*1480  Cropping - Legumes             348/448 Cropping/Irrigated cropping
/*                                     - Legumes (EXTRA CLASS ADDED TO
/*                                     ALUMC)
/*1490  Cropping/Horticulture - 340/440  Cropping/Irrigated cropping
/*                                     (Other non-cereal crops)
/*1511  Horticulture - Fruit           351/451  Perennial horticulture/
/*      - Citrus                       Irrigated perennial horticulture
/*                                     - Tree fruits
/*1512  Horticulture - Fruit           351/451
/*      - Apples
/*1513  Horticulture - Fruit           351/451
/*      - Pears
/*1514  Horticulture - Fruit           351/451
/*      - Stone fruit
/*1516  Horticulture - Fruit           350/450 Perennial horticulture/
/*      - Plantation fruit             Irrigated perennial horticulture
/*1517  Horticulture - Fruit           354/454  Perennial horticulture/
/*      - Grapes                       Irrigated perennial horticulture
/*                                     - Vine fruits
/*1541  Horticulture - Vegetables      364/464 Seasonal horticulture/
/*      - Other vegetables             Irrigated seasonal horticulture
/*                                     - Vegetables and herbs
/*1542  Horticulture - Vegetables      364/464
```

```
/*      - Potatoes
/*1000  Unallocated agricultural    300      PRODUCTION FROM DRYLAND
/*      land                                 AGRICULTURE AND PLANTATIONS
/*                                           (Potentially agricultural land,
/*                                           excludes forest on non-public
/*                                           land. Temporary class used for
/*                                           mask prior to incorporation of
/*                                           SPREAD output.)
/*                                  500      INTENSIVE USES
/*                                           (Unallocated potentially ag.
/*                                           land, ie potentially ag. land
/*                                           to which SPREAD did not
/*                                           allocate any agricultural land
/*                                           use.)
/* ------------------------------------------------------------------
/*
/************************************************************************


/* 1. Copy vat file of grid; establish whether lookup table is to cover
/* agricultural land uses assigned by SPREAD
&term 9999
&sv gridm = [entryname [getgrid * 'Select the grid for which the lookup ~
table is to be made' -none]]
&if [null %gridm%] &then &return No grid selected... stopping AML
&ty Grid %gridm% selected...
&sv lut = %gridm%.lut
&if [exists %lut% -info] &then &return INFO table %lut% ~
already exists... stopping AML
&sv ag_values = [query '~
Does the grid contain agricultural land uses assigned by SPREAD ~
(type y or n)' .FALSE.]

copyinfo %gridm%.vat %lut%

/* 2. Add items; drop unwanted items if present

/* Australian Land Use and Management Classification (V4) code
additem %lut% %lut% lu_code 4 5 b

/* ALUM Classification (V4) Primary class description
additem %lut% %lut% lu_desc 70 70 c

/* ALUM Classification (V4) Secondary class description
additem %lut% %lut% lu_desc2 70 70 c

/* ALUM Classification (V4) Tertiary class description
additem %lut% %lut% lu_desc3 70 70 c

/* Audit commodity classification description
/* ITEM ONLY REQUIRED FOR SPREAD OUTPUT
additem %lut% %lut% t-code 10 10 c
```

```
/* TAG to keep track of values assigned
additem %lut% %lut% tag 2 1 b

/* Drop unwanted items which may be present
&if [iteminfo %lut% -info prot_areas_desc -exists] &then
dropitem %lut% %lut% prot_areas_desc

&if [iteminfo %lut% -info topo_feat_desc -exists] &then
dropitem %lut% %lut% topo_feat_desc

&if [iteminfo %lut% -info tenure_desc -exists] &then
dropitem %lut% %lut% tenure_desc

&if [iteminfo %lut% -info forest_type_desc -exists] &then
dropitem %lut% %lut% forest_type_desc

&if [iteminfo %lut% -info spread_desc -exists] &then
dropitem %lut% %lut% spread_desc

&if [iteminfo %lut% -info irrigation_desc -exists] &then
dropitem %lut% %lut% irrigation_desc

&if [iteminfo %lut% -info affinities -exists] &then
dropitem %lut% %lut% affinities

&if [iteminfo %lut% -info affinities_desc -exists] &then
dropitem %lut% %lut% affinities_desc

&if [iteminfo %lut% -info pass_no -exists] &then
dropitem %lut% %lut% pass_no

&if [iteminfo %lut% -info pass_no_desc -exists] &then
dropitem %lut% %lut% pass_no_desc

/* 3. Start defining/assigning ALUM Classification (V4)


/* 1. CONSERVATION AND NATURAL ENVIRONMENTS

tables
sel %lut%

/* 1.1 NATURE CONSERVATION
/* 1.1.1 Strict nature reserve
resel prot_areas eq 11
calc lu_code = 111
calc lu_desc3 = 'Strict nature reserve'
calc t-code = '1.1.1'
calc tag = 1
commit

/* 1.1.2 Wilderness area
resel prot_areas eq 12 and tag ne 1
calc lu_code = 112
calc lu_desc3 = 'Wilderness area'
calc t-code = '1.1.2'
calc tag = 1
commit
```

```
/* 1.1.3 National park
resel prot_areas eq 20 and tag ne 1
calc lu_code = 113
calc lu_desc3 = 'National park'
calc t-code = '1.1.3'
calc tag = 1
commit

/* 1.1.4 Natural feature protection
resel prot_areas eq 30 and tag ne 1
calc lu_code = 114
calc lu_desc3 = 'Natural feature protection'
calc t-code = '1.1.4'
calc tag = 1
commit

/* 1.1.5 Habitat/species management area
resel prot_areas eq 40 and tag ne 1
calc lu_code = 115
calc lu_desc3 = 'Habitat/species management area'
calc t-code = '1.1.5'
calc tag = 1
commit

/* 1.1.6 Protected landscape
resel prot_areas eq 50 and tag ne 1
calc lu_code = 116
calc lu_desc3 = 'Protected landscape'
calc t-code = '1.1.6'
calc tag = 1
commit

resel tag eq 1
calc lu_desc2 = 'Nature conservation'
commit

/* 1.2 Managed resource protection
resel prot_areas eq 60 and tag ne 1
calc lu_code = 120
calc lu_desc2 = 'Managed resource protection'
calc t-code = '1.2.0'
calc tag = 1
commit

/* 1.2.5 Traditional indigenous uses
/* includes Aboriginal land with negligible agriculture but no IUCN status
resel tenure in {9,20,21} and lu_code eq 120
calc lu_code = 125
calc lu_desc3 = 'Traditional indigenous uses'
calc t-code = '1.2.5'
commit
resel tenure in {9,20,21} and tag ne 1
calc lu_code = 125
calc lu_desc2 = 'Managed resource protection'
calc lu_desc3 = 'Traditional indigenous uses'
calc t-code = '1.2.5'
calc tag = 1
commit
```

```
/* 1.2.2 Surface water supply
/* Managed resource protection areas according to prot_areas data set,
/* which overlie water supply reserve according to tenure are classed as
/* surface water supply
resel tenure eq 11 and lu_code eq 120
calc lu_code = 122
calc lu_desc3 = 'Surface water supply'
calc t-code = '1.2.2'
commit

/* 1.1.7 Other conserved area
resel tenure eq 4 and tag ne 1
calc lu_code = 117
calc lu_desc2 = 'Nature conservation'
calc lu_desc3 = 'Other conserved area'
calc t-code = '1.1.7'
calc tag = 1
commit

/* 1.3 Other minimal use
/* tenure 10 includes stock routes (1.3.2)
/* tenure 15 (institutional crown lands) classified as Other minimal use
/* rather than Services (5.5)
resel tenure in {10,11,12,13,14,15} and tag ne 1
calc lu_code = 130
calc lu_desc2 = 'Other minimal use'
calc t-code = '1.3.0'
calc tag = 1
commit

/* 1.3.1 Defence
resel tenure eq 12 and lu_code eq 130
calc lu_code = 131
calc lu_desc3 = 'Defence'
calc t-code = '1.3.1'
commit

/* 1.3.3 Remnant native cover
resel lu_code = 130 and forest_type in {2,3,4}
calc lu_code = 133
calc lu_desc3 = 'Remnant native cover'
calc t-code = '1.3.3'
commit

/* Select all attributed and assign to CONSERVATION AND NATURAL
/* ENVIRONMENTS
resel tag eq 1
calc lu_desc = 'CONSERVATION AND NATURAL ENVIRONMENTS'
commit
```

```
/* 6. WATER

/* 6.1 Lake
resel topo_features eq 1 or topo_features eq 2
calc lu_code = 610
calc lu_desc = 'WATER'
calc lu_desc2 = 'Lake'
calc lu_desc3 = ''
calc t-code = '6.1.0'
resel tag eq 1
calc lu_code = 611
calc lu_desc3 = 'Lake - conservation'
calc t-code = '6.1.1'
commit

/* 6.2 Reservoir
resel topo_features eq 8
calc lu_code = 620
calc lu_desc = 'WATER'
calc lu_desc2 = 'Reservoir'
calc lu_desc3 = ''
calc t-code = '6.2.0'
commit

/* 6.3 River
resel topo_features eq 3 or topo_features eq 4
calc lu_code = 630
calc lu_desc = 'WATER'
calc lu_desc2 = 'River'
calc lu_desc3 = ''
calc t-code = '6.3.0'
resel tag eq 1
calc lu_code = 631
calc lu_desc3 = 'River - conservation'
calc t-code = '6.3.1'
commit

/* 6.5 Marsh/wetland
resel topo_features eq 5
calc lu_code = 650
calc lu_desc = 'WATER'
calc lu_desc2 = 'Marsh/wetland'
calc lu_desc3 = ''
calc t-code = '6.5.0'
resel tag eq 1
calc lu_code = 651
calc lu_desc3 = 'Marsh/wetland - conservation'
calc t-code = '6.5.1'
commit

/* 6.6 Estuary/coastal waters
resel topo_features eq 6 or topo_features eq 7
calc lu_code = 660
calc lu_desc = 'WATER'
calc lu_desc2 = 'Estuary/coastal waters'
calc lu_desc3 = ''
calc t-code = '6.6.0'
resel tag eq 1
calc lu_code = 661
calc lu_desc3 = 'Estuary/coastal waters - conservation'
calc t-code = '6.6.1'
commit

resel lu_code ge 600 and lu_code lt 700
calc tag = 1
commit
```

```
/* 5. INTENSIVE USES

/* 5.4.1 Urban residential
/* Areas classified as built up areas in the NLUM include
/* 5.3 Manufacturing and industrial, 5.4.1 Urban residential,
/* and 5.5 Services. 5.4.1 Urban residential constitutes the bulk of
/* the area.
resel topo_features eq 10
calc lu_code = 541
calc lu_desc = 'INTENSIVE USES'
calc lu_desc2 = 'Residential'
calc lu_desc3 = 'Urban residential'
calc t-code = '5.4.1'
calc tag = 1
commit

/* 5.7 Transport and communication
resel topo_features eq 9
calc lu_code = 571
calc lu_desc = 'INTENSIVE USES'
calc lu_desc2 = 'Transport and communication'
calc lu_desc3 = 'Airports/aerodromes'
calc t-code = '5.7.1'
calc tag = 1
commit


/* 2. PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS

/* 2.2 Production forestry
/* Note that the land uses assigned are based on the underlying data
/* sets used. The currencies of these data sets are variable but tend
/* to approximate the period April 1996 to March 1997. The forests of
/* south-west Western Australia are classified as 2.2, Production
/* forestry, reflecting data sets used. The primary use of these forests
/* is now however conservation rather than production forestry.
/* Production forestry takes precedence over Managed Resource protected
/* areas.

resel tenure eq 1 and forest_type ne 5 and prot_areas in {0,60} and ~
topo_features = 0
calc lu_code = 220
calc lu_desc = 'PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS'
calc lu_desc2 = 'Production forestry'
calc lu_desc3 = ''
calc t-code = '2.2.0'
calc tag = 1
commit
```

```
/* 3. PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS

/* 3.1 Plantation forestry
resel forest_type eq 5 and topo_features = 0 and prot_areas = 0
calc lu_code = 310
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Plantation forestry'
calc lu_desc3 = ''
calc t-code = '3.1.0'
calc tag = 1
commit

/* Select tenure classes potentially available for agriculture.
/* TEMPORARY CLASS before SPREAD output assigned an ALUMC.
/* Excludes land already assigned a land use.
resel tenure in {6,7,8,18,22} and tag ne 1
calc lu_code = 300
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc t-code = '3.0.0'
calc tag = 1
commit


/* 1.3.3. Remnant native cover
/* Private land with open or closed native forest with unknown use.
/* Assume remnant native cover (1.3.3) as don't know if used for
/* production forestry (2.2).
resel lu_code = 300 and forest_type in {3,4}
calc lu_code = 133
calc lu_desc = 'CONSERVATION AND NATURAL ENVIRONMENTS'
calc lu_desc2 = 'Other minimal use'
calc lu_desc3 = 'Remnant native cover'
calc t-code = '1.3.3'
commit

/* Only native forest data available.
/* Assume remnant native cover (1.3.3) as don't know if used for
/* production forestry (2.2).
resel forest_type in {2,3,4} and tag ne 1
calc lu_code = 133
calc lu_desc = 'CONSERVATION AND NATURAL ENVIRONMENTS'
calc lu_desc2 = 'Other minimal use'
calc lu_desc3 = 'Remnant native cover'
calc t-code = '1.3.3'
calc tag = 1
commit

/* Remaining data assigned to no data
resel tag ne 1
calc lu_code = 0
calc lu_desc = 'NO DATA'
calc tag = 1
commit
```

```
/* REMOVE ITEMS NOT NEEDED IN THE LOOKUP TABLE AND STOP AML IF THE LOOKUP
/* TABLE IS TO BE FOR THE MASK ONLY; OTHERWISE CONTINUE
&if not %ag_values% &then
  &do
    q
    dropitem %lut% %lut% count prot_areas tenure forest_type ~
    topo_features t-code tag
    &return Lookup table completed... excludes land uses assigned by SPREAD
  &end


/* ADD TO LOOKUP TABLE AGRICULTURAL LAND USES ALLOCATED BY SPREAD

/* 2.1 Livestock grazing
/* No class for irrigated native pastures - assign to 4.3 Irrigated
/* modified pastures
/* spread_desc = 'Residual/Native pastures'
resel spread eq 1 and irrigation eq 0
calc lu_code = 210
calc lu_desc = 'PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS'
calc lu_desc2 = 'Livestock grazing'
calc lu_desc3 = ''
calc t-code = '2.1.0'
commit

resel spread eq 1 and irrigation eq 1
calc lu_code = 430
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated modified pastures'
calc lu_desc3 = ''
calc t-code = '4.3.0'
commit

/* 3.2/4.2 Farm forestry
/* spread_desc = 'Agroforestry'
resel spread eq 2 and irrigation eq 0
calc lu_code = 320
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Farm forestry'
calc lu_desc3 = ''
calc t-code = '3.2.0'
commit

resel spread eq 2 and irrigation eq 1
calc lu_code = 420
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated farm forestry'
calc lu_desc3 = ''
calc t-code = '4.2.0'
commit

/* 3.3/4.3 Modified pastures
/* spread_desc = 'Sown pastures'
resel spread eq 3 and irrigation eq 0
calc lu_code = 330
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Grazing modified pastures'
calc lu_desc3 = ''
calc t-code = '3.3.0'
commit

resel spread eq 3 and irrigation eq 1
calc lu_code = 430
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated modified pastures'
calc lu_desc3 = ''
calc t-code = '4.3.0'
commit
```

```
/* 3.5/4.5 Perennial horticulture
/* spread_desc = 'Citrus fruit'
resel spread eq 14 and irrigation eq 0
calc lu_code = 351
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = 'Tree fruits'
calc t-code = '3.5.1'
commit

resel spread eq 14 and irrigation eq 1
calc lu_code = 451
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = 'Irrigated tree fruits'
calc t-code = '4.5.1'
commit

/* spread_desc = 'Apples'
resel spread eq 15 and irrigation eq 0
calc lu_code = 351
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = 'Tree fruits'
calc t-code = '3.5.1'
commit

resel spread eq 15 and irrigation eq 1
calc lu_code = 451
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = 'Irrigated tree fruits'
calc t-code = '4.5.1'
commit

/* spread_desc = 'Pears'
resel spread eq 16 and irrigation eq 0
calc lu_code = 351
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = 'Tree fruits'
calc t-code = '3.5.1'
commit

resel spread eq 16 and irrigation eq 1
calc lu_code = 451
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = 'Irrigated tree fruits'
calc t-code = '4.5.1'
commit
```

```
/* spread_desc = 'Stone fruit'
resel spread eq 17 and irrigation eq 0
calc lu_code = 351
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = 'Tree fruits'
calc t-code = '3.5.1'
commit

resel spread eq 17 and irrigation eq 1
calc lu_code = 451
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = 'Irrigated tree fruits'
calc t-code = '4.5.1'
commit

/* spread_desc = 'Nuts'
resel spread eq 18 and irrigation eq 0
calc lu_code = 353
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = 'Tree nuts'
calc t-code = '3.5.3'
commit

resel spread eq 18 and irrigation eq 1
calc lu_code = 453
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = 'Irrigated tree nuts'
calc t-code = '4.5.3'
commit

/* spread_desc = 'Plantation fruit'
resel spread eq 20 and irrigation eq 0
calc lu_code = 350
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = ''
calc t-code = '3.5.0'
commit

resel spread eq 20 and irrigation eq 1
calc lu_code = 450
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = ''
calc t-code = '4.5.0'
commit

/* spread_desc = 'Grapes'
resel spread eq 21 and irrigation eq 0
calc lu_code = 354
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Perennial horticulture'
calc lu_desc3 = 'Vine fruits'
calc t-code = '3.5.4'
commit
```

```
resel spread eq 21 and irrigation eq 1
calc lu_code = 454
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated perennial horticulture'
calc lu_desc3 = 'Irrigated vine fruits'
calc t-code = '4.5.4'
commit

/* 3.6/4.6 Seasonal horticulture
/* spread_desc = 'Other vegetables'
resel spread eq 12 and irrigation eq 0
calc lu_code = 364
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Seasonal horticulture'
calc lu_desc3 = 'Vegetables and herbs'
calc t-code = '3.6.4'
commit

resel spread eq 12 and irrigation eq 1
calc lu_code = 464
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated seasonal horticulture'
calc lu_desc3 = 'Irrigated vegetables and herbs'
calc t-code = '4.6.4'
commit

/* spread_desc = 'Potatoes'
resel spread eq 13 and irrigation eq 0
calc lu_code = 364
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Seasonal horticulture'
calc lu_desc3 = 'Vegetables and herbs'
calc t-code = '3.6.4'
commit

resel spread eq 13 and irrigation eq 1
calc lu_code = 464
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated seasonal horticulture'
calc lu_desc3 = 'Irrigated vegetables and herbs'
calc t-code = '4.6.4'
commit

/* 3.4.1/4.4.1 Cereals
/* spread_desc = 'Cereals excluding rice' (includes cereals for hay/silage)
resel spread = 4 and irrigation eq 0
calc lu_code = 341
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Cereals'
calc t-code = '3.4.1'
commit

resel spread = 4 and irrigation eq 1
calc lu_code = 441
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated cereals'
calc t-code = '4.4.1'
commit

/* spread_desc = 'Rice'
resel spread = 5 and irrigation eq 0
calc lu_code = 341
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Cereals'
calc t-code = '3.4.1'
```

```
commit

resel spread = 5 and irrigation eq 1
calc lu_code = 441
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated cereals'
calc t-code = '4.4.1'
commit

/* 3.4.3/4.4.3 Hay & Silage
/* spread_desc = 'Non-cereal forage crops'
resel spread eq 9 and irrigation eq 0
calc lu_code = 343
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Hay and silage'
calc t-code = '3.4.3'
commit

resel spread eq 9 and irrigation eq 1
calc lu_code = 443
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated hay and silage'
calc t-code = '4.4.3'
commit

/* 3.4.4/4.4.4 Oilseeds and oleaginous fruit
/* spread_desc = 'Oilseeds'
resel spread eq 7 and irrigation eq 0
calc lu_code = 344
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Oilseeds and oleaginous fruit'
calc t-code = '3.4.4'
commit

resel spread eq 7 and irrigation eq 1
calc lu_code = 444
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated oilseeds and oleaginous fruit'
calc t-code = '4.4.4'
commit
```

```
/* 3.4.5/4.4.5 Sugar cane
/* spread_desc = 'Sugar cane'
resel spread eq 8 and irrigation eq 0
calc lu_code = 345
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Sugar'
calc t-code = '3.4.5'
commit

resel spread eq 8 and irrigation eq 1
calc lu_code = 445
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated sugar'
calc t-code = '4.4.5'
commit

/* 3.4.6/4.4.6 Cotton
/* spread_desc = 'Cotton'
resel spread eq 10 and irrigation eq 0
calc lu_code = 346
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Cotton'
calc t-code = '3.4.6'
commit

resel spread eq 10 and irrigation eq 1
calc lu_code = 446
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated cotton'
calc t-code = '4.4.6'
commit

/* 3.4.8/4.4.8 Legumes (extra class added)
/* spread_desc = 'Legumes'
resel spread eq 6 and irrigation eq 0
calc lu_code = 348
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = 'Legumes'
calc t-code = '3.4.8'
commit

resel spread eq 6 and irrigation eq 1
calc lu_code = 448
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = 'Irrigated legumes'
calc t-code = '4.4.8'
commit
```

```
/* Other non-cereal crops (includes flowers and bulbs,
/* beverage and spice crops, tobacco, woody fodder plants)
/* spread_desc = 'Other non-cereal crops'
resel spread eq 11 and irrigation eq 0
calc lu_code = 340
calc lu_desc = 'PRODUCTION FROM DRYLAND AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Cropping'
calc lu_desc3 = ''
calc t-code = '3.4.0'
commit

resel spread eq 11 and irrigation eq 1
calc lu_code = 440
calc lu_desc = 'PRODUCTION FROM IRRIGATED AGRICULTURE AND PLANTATIONS'
calc lu_desc2 = 'Irrigated cropping'
calc lu_desc3 = ''
calc t-code = '4.4.0'
commit

/* Unallocated potentially agricultural land.
/* Assume mainly non-agricultural; intensive uses prominent, especially
/* rural residential ('hobby farms') in periurban areas and mining in the
/* La Trobe valley.
/* spread_desc = 'Unallocated potentially ag. land'
resel spread eq 0
calc lu_code = 500
calc lu_desc = 'INTENSIVE USES'
calc lu_desc2 = ''
calc lu_desc3 = ''
calc t-code = '5.0.0'
commit

/* REMOVE ITEMS NOT NEEDED IN THE LOOKUP TABLE AND STOP AML
q
dropitem %lut% %lut% count prot_areas tenure forest_type topo_features spread ~
irrigation tag

&return Lookup table completed... includes land uses assigned by SPREAD
```

Appendix 5. SPREAD documentation

Kim Malafant and Dawn Fordham, compleXia Pty Ltd (May 1999, updated December 1999)

SPREAD methodology Phase 2

Introduction

This document outlines the basic operation of the affinity calculations (Phase 2) for the SPREAD methodology as outlined by Walker and Mallawaarachchi (1998). The affinity calculations are based on the Gower metric (Gower, 1971) and use information calculated from Phase 1 of the method. The data required for the analysis includes:

> A fortnightly NDVI file for target records (pixels) within the SLA to be analysed.

> A set of control files for each SLA containing pixels of defined land uses and their NDVI signatures.

> A file specifying the land use coding scheme(s) to be used and information on the cut-off values for similar control sites for each land use.

The program uses the above files to perform the analyses outlined below. Output from the analysis includes:

> An output file summarising the analysis.

> Two files titled aff#sla-id# and aff2#sla-id#. The files only differ in that aff#sla-id# has additional header records. The file (aff#sla-id#) summarises for each target record the affinities to each of the land uses. The fields are pairs of values for the land uses. The pairs are ordered such that the highest affinity land use (smallest similarity) and the land use number appear first followed by the second highest affinity, then the third etc. This file may be used to produce a "first-cut" land use map for the SLA being analysed and is used in the allocation phase of SPREAD (Phase 3), which refines the initial allocation.

Current limitations to the implementation include:

> The number of control sites (records) per analysis is restricted to 200. Although this can easily be increased, the interpretation of the control site analysis on 200 sites is not a simple task. As the number of control sites increases in comparison to the number of land uses, the allocation becomes more complex and the probability of control sites with different land uses being similar increases.

> The number of land uses is currently limited to 30 (21 for the Audit Commodity classes and 9 for the ABS Level 1 land use classes). This can easily be changed.

> The number of variables used in the calculation is limited to 50 and should not need to be increased. This includes the 26 NDVI readings plus additional calculated values.

> All file formats are currently FIXED. This includes the number and order of fields as well as the FORTRAN formats for reading the data. This could be modified at a later stage but ensures consistency with the previous CSIRO datasets and consistency for generating the new BRS datasets.

This document outlines detail on the data files required, the outputs and examples of the files and analysis.

Basic static input files

There are two (really three) basic input files (agname.lst, fields.lst, fields.lst2) required to run the affinities component of the SPREAD algorithm. These files describe the "names" of each of the agricultural classes for the different (two) land use schemes and the list of fields to be used in the analysis. Examples of the files and their layout are shown below.

Agricultural names

The file (agname.lst) describes the land use coding schemes being used. Currently the code assumes only TWO schemes: a so-called higher order land use, which corresponds to the ABS level 1 classification with 9 classes; and the Audit Commodity ID with 21 classes. The file (shown below) has the higher order land use first followed by the Audit Commodity ID. The first number (9) is the number of classes (n), in fixed format (field of five, right justified - FORTRAN i5), followed by the n lines containing three fields:

The ID of the class.

The cut-off value for the land use. This is used for the allocation phase of SPREAD but is not used in the affinity calculation. However, the code expects this field to be present in the file.

The name of the class

The format for the fields is fixed. The current format is: a field of width 5 right justified for the class ID; a field of 8 right justified with decimals; one space and a field of up to 30 characters. In FORTRAN the format is (i5,f8.0,1x,a30). The Audit Commodity ID classes follow the same format. The code EXPECTS this format for the file.

```
    9
    1   0.999 Residual
    2   0.999 Agroforestry
    3   0.999 Pastures
    4   0.999 Cereals
    5   0.999 Non-cereal crops
    6   0.999 Vegetables
    7   0.999 Orchards
    8   0.999 Berry and Plantation Fruits
    9   0.999 Grapes
   21
    1   0.999 Residual
    2   0.999 Agroforestry
    3   0.999 Pastures
    4   0.999 Cereals
    5   0.999 Rice
    6   0.999 Legumes
    7   0.999 Oilseeds
    8   0.999 Sugar Cane
    9   0.999 Forage Crops
   10   0.999 Cotton
   11   0.999 Other Non-cereal Crops
   12   0.999 Other Vegetables
   13   0.999 Potatoes
   14   0.999 Citrus
   15   0.999 Apples
   16   0.999 Pears
   17   0.999 Stone Fruit
   18   0.999 Nuts
   19   0.999 Berry Fruit
   20   0.999 Plantation Fruit
   21   0.999 Grapes
```

The file (fields.lst) contains a description of the fields, which may be used in computing the affinities from the input data. Each line consists of three fixed format fields: the field ID in a field of 9 right justified; the range of the values for the field in a fixed field of 8; one space and a character string describing the field of up to 30 characters. The FORTRAN format for this is (i9,f8.0,1x,a30).

```
        5    20.00 Seasonality
        6    20.00 Length of Growing Season
        7    20.00 Minimum NDVI for Year
        8    20.00 Maximum NDVI for Year
        9    20.00 Total Biomass
       10    20.00 Biomass in Growing Season
       11    20.00 Average Biomass in Season
       12    20.00 1st NDVI Reading
       13    20.00 2nd NDVI Reading
       14    20.00 3rd NDVI Reading
       15    20.00 4th NDVI Reading
       16    20.00 5th NDVI Reading
       17    20.00 6th NDVI Reading
       18    20.00 7th NDVI Reading
       19    20.00 8th NDVI Reading
       20    20.00 9th NDVI Reading
       21    20.00 10th NDVI Reading
       22    20.00 11th NDVI Reading
       23    20.00 12th NDVI Reading
       24    20.00 13th NDVI Reading
       25    20.00 14th NDVI Reading
       26    20.00 15th NDVI Reading
       27    20.00 16th NDVI Reading
       28    20.00 17th NDVI Reading
       29    20.00 18th NDVI Reading
       30    20.00 19th NDVI Reading
       31    20.00 20th NDVI Reading
       32    20.00 21st NDVI Reading
       33    20.00 22nd NDVI Reading
       34    20.00 23rd NDVI Reading
       35    20.00 24th NDVI Reading
       36    20.00 25th NDVI Reading
       37    20.00 26th NDVI Reading
```

A second fields file (fields.lst2) reorganises the field file above into two columns and is used in the main "SPREAD" script. Only the field ID and description from this file are used as a means of identifying to the user the possible inputs. The field ID is used as a comma separated list to identify the fields for comparison in the affinity calculations.

Dynamic input data

The main inputs to the process are two files describing the control sites and the target sites. The current formats for these two files reflect the original CSIRO layout, which was generated from the SPANS system. Some of the fields in these files will not be generated by the BRS system but have been "kept" so that the original files can be used as tests.

Control sites

The control file (shown below) is generated for each SLA in the analysis. The name of the control file can be any legal UNIX filename as this is one of the inputs to the program or script. The current system ignores all entries down to and including the "DATA" line in the file. The script EXPECTS a line with the word "DATA" in capitals to appear immediately before the data for the control sites. The basic format of the file following the "DATA" line is:

Field 1 is the control label or id (eg. 25bfdd3). This is a character string up to 16 characters in length placed anywhere in a field of 16.

The next four fields are not required for the new method but are kept for compatibility with the CSIRO files. These fields MUST be present in the data - they may contain zero values but the code expects to be able to skip these four fields.

The next seven fields contain measures of seasonality, length of growing season, minimum NDVI for the year, maximum NDVI for the year, total biomass, biomass in the growing season and the average biomass in the growing season. They may or may not be used in the analysis and may be set to zero but MUST be present.

The next 26 fields are the fortnightly NDVI readings.

The last two fields are the Audit commodity ID and the ABS Level 1 classification code.

The format of the file is FIXED. The control site id occurs in the first 16 locations, with the rest of the fields occupying fields of 10 characters wide. The FORTRAN format is (a16,50f10.0).

```
ID pt
TITLE pt
MAPID ??
WINDOW 00 0 0 20480 15360
TABTYPE 2
FTYPE fixed
KEYFIELD 0
KEYBASE 0
NRECORD 531
 1   5 15.000000 0         0 0 Morton number
 2   4 11.000000 0      key1 key1
 3   1 10.200000 0      min1 min1
 4   1 10.200000 0      min2 min2
 5   1 10.200000 0      min3 min3
 6   1 10.200000 0    field6 field6
 7   1 10.200000 0    field7 field7
 8   1 10.200000 0    field8 field8
 9   1 10.200000 0    field9 field9
10   1 10.200000 0   field10 field10
11   1 10.200000 0   field11 field11
12   1 10.200000 0   field12 field12
13   1 10.200000 0   field13 field13
14   1 10.200000 0   field14 field14
15   1 10.200000 0   field15 field15
16   1 10.200000 0   field16 field16
17   1 10.200000 0   field17 field17
18   1 10.200000 0   field18 field18
19   1 10.200000 0   field19 field19
20   1 10.200000 0   field20 field20
21   1 10.200000 0   field21 field21
22   1 10.200000 0   field22 field22
23   1 10.200000 0   field23 field23
24   1 10.200000 0   field24 field24
25   1 10.200000 0   field25 field25
26   1 10.200000 0   field26 field26
DATA
        25bfdd3     2878.      14.     3581.     5097.           2.
8.        8.      19.     145.     111.      14.      4.        5.
7.        5.       5.       6.       5.       4.      4.        3.
3.        4.       4.       5.       7.       5.      5.        6.
5.        4.       4.       3.       3.       4.      4.        5.
12.        1.
        25e9a9c     3561.      13.     3654.     5050.           1.
8.        8.      19.     141.     107.      13.      4.        5.
```

124

```
5.        5.        6.        7.        5.        4.        4.        4.
3.        3.        4.        5.        5.        5.        6.        7.
5.        4.        4.        4.        3.        3.        4.        5.
20.        1.
        25e9bfc       3540.        13.      3678.     5054.        1.
6.        6.       19.      135.       87.       14.        3.        5.
7.        5.        5.        6.        5.        3.        4.        3.
3.        4.        3.        5.        7.        5.        5.        6.
5.        3.        4.        3.        3.        4.        3.        5.
8.        2.
        25e9eac      12712.        13.      3682.     5054.        1.
6.        6.       19.      135.       87.       14.        3.        5.
7.        5.        5.        6.        5.        3.        4.        3.
3.        4.        3.        5.        7.        5.        5.        6.
5.        3.        4.        3.        3.        4.        3.        5.
21.        1.
```

Resource or locations file (targets)

The target file (shown below) is used for each SLA in the analysis. The script expects the target file to be named p"SLA ID".tba so that for an SLA ID of 16150 the filename expected is "p16150.tba". The current system ignores all entries down to and including the "DATA" line in the file. The script EXPECTS a line with the word "DATA" in capitals to appear immediately before the data for the control sites. The basic format of the file following the "DATA" line is:

Field 1 is the control label or id. This is a character string up to 16 characters in length placed anywhere in a field of 16.

The next three fields are not required for the new method but are kept for compatibility with the CSIRO files. These fields MUST be present in the data - they may contain zero values but the code expects to be able to skip these three fields.

The next field is the area in hectares for the target zone. This field MUST be present and is used in the allocation algorithms of Phase 3.

The next seven fields contain measures of seasonality, length of growing season, minimum NDVI for the year, maximum NDVI for the year, total biomass, biomass in the growing season and the average biomass in the growing season. They may or may not be used in the analysis and may be set to zero but MUST be present.

The next 26 fields are the fortnightly NDVI readings

The format of the file is FIXED. The control site id occurs in the first 16 locations, with the rest of the fields occupying fields of 10 characters wide. The FORTRAN format is (a16,50f10.0) as for the control file. Two less values than for the control file are input here.

```
ID pt
TITLE pt
MAPID ??
WINDOW 00 0 0 20480 15360
TABTYPE 2
FTYPE fixed
KEYFIELD 0
KEYBASE 0
NRECORD 531
  1   5 15.000000 0          0 0 Morton number
  2   4 11.000000 0      key1 key1
  3   1 10.200000 0      min1 min1
  4   1 10.200000 0      min2 min2
  5   1 10.200000 0      min3 min3
  6   1 10.200000 0    field6 field6
  7   1 10.200000 0    field7 field7
  8   1 10.200000 0    field8 field8
```

```
 9  1 10.200000 0   field9 field9
10  1 10.200000 0  field10 field10
11  1 10.200000 0  field11 field11
12  1 10.200000 0  field12 field12
13  1 10.200000 0  field13 field13
14  1 10.200000 0  field14 field14
15  1 10.200000 0  field15 field15
16  1 10.200000 0  field16 field16
17  1 10.200000 0  field17 field17
18  1 10.200000 0  field18 field18
19  1 10.200000 0  field19 field19
20  1 10.200000 0  field20 field20
21  1 10.200000 0  field21 field21
22  1 10.200000 0  field22 field22
23  1 10.200000 0  field23 field23
24  1 10.200000 0  field24 field24
DATA
        6f46ffc      351.       13.    11966.     103.8        1.
12.       16.      26.     248.      248.       21.        8.         9.
9.        7.       7.       8.        7.        9.        7.         6.
8.        7.       8.       9.        9.        7.        7.         8.
7.        9.       7.       6.        8.        7.        8.         9.
        6f479ec      390.       13.    11994.     103.8        1.
12.       10.      28.     249.      249.       21.        9.         9.
9.        7.       7.       9.        9.       10.        7.         4.
6.        7.       9.       9.        9.        7.        7.         9.
9.       10.       7.       4.        6.        7.        9.         9.
        6f479fc      459.       13.    11998.     121.2        1.
12.       10.      28.     249.      249.       21.        9.         9.
9.        7.       7.       9.        9.       10.        7.         4.
6.        7.       9.       9.        9.        7.        7.         9.
9.       10.       7.       4.        6.        7.        9.         9.
        6f47a6c      357.       13.    11978.     121.2        1.
12.       12.      27.     250.      250.       21.        8.        10.
9.        7.       7.       8.        8.       10.        7.         5.
7.        7.       8.      10.        9.        7.        7.         8.
8.       10.       7.       5.        7.        7.        8.        10.
        6f47a8c      277.       13.    11970.     131.8        1.
12.       16.      26.     248.      248.       21.        8.         9.
9.        7.       7.       8.        7.        9.        7.         6.
8.        7.       8.       9.        9.        7.        7.         8.
7.        9.       7.       6.        8.        7.        8.         9.
        6f47b0b      441.       14.    11985.     121.2        1.
12.       12.      27.     250.      250.       21.        8.        10.
9.        7.       7.       8.        8.       10.        7.         5.
7.        7.       8.      10.        9.        7.        7.         8.
8.       10.       7.       5.        7.        7.        8.        10.
        6f47b4c      465.       13.    11994.     131.8        1.
12.       11.      28.     252.      252.       21.        9.        10.
8.        7.       7.       8.        8.       10.        7.         4.
6.        6.       9.      10.        8.        7.        7.         8.
8.       10.       7.       4.        6.        6.        9.        10.
        6f47b5c      469.       13.    11998.     104.5        1.
12.       11.      28.     252.      252.       21.        9.        10.
8.        7.       7.       8.        8.       10.        7.         4.
6.        6.       9.      10.        8.        7.        7.         8.
8.       10.       7.       4.        6.        6.        9.        10.
        6f47b6c      376.       13.    11994.     155.5        1.
12.       11.      28.     252.      252.       21.        9.        10.
8.        7.       7.       8.        8.       10.        7.         4.
```

```
6.        6.        9.       10.        8.        7.        7.        8.
8.       10.        7.        4.        6.        6.        9.       10.
         6f47b7c       377.       13.     11998.      160.1       1.
12.       11.       28.      252.      252.       21.        9.       10.
8.        7.        7.        8.        8.       10.        7.        4.
6.        6.        9.       10.        8.        7.        7.        8.
8.       10.        7.        4.        6.        6.        9.       10.
```

Output files

Three main files are produced as output from the affinity calculation phase of the SPREAD process. The user controls the amount of output generated.

Analysis output file

The analysis output file (gower#sla-id#.ana, eg. gower16150.ana) provides the major output file of the analysis for the affinity calculations. Depending on the options chosen this file will contain information on:

A general header indicating the SLA being analysed.

The description of the copyright and implementation details as requested by CSIRO. This also includes the full reference to the published paper outlining the method.

Information on the control file and SLA or target file being used.

The variables used in the affinity calculations including their code, description and range.

The individual control site affinity analyses. This uses the minimum affinity cut-off value as specified by the user (see example run - Section 5) to identify which control sites are similar.

The control site affinity sensitivity analysis if requested by the user. This uses a user chosen percentage change value, which is applied to the highest NDVI value and the values either side. This analysis is output for each of the control sites.

An individual report on the analysis for each of the target or location records if requested by the user. For a large number of targets this would generate an EXTENSIVE amount of output. It is provided for testing and intensive analysis of target sites, which are not easily allocated.

Two (crude) histograms showing the allocation of the target records to each of the ABS level 1 and Audit Commodity ID classes. This is also provided as a quick summary of the allocations.

An annotated example of a complete output for the test data sets is shown in Appendix 1. It must be stressed that this is ALL the output; individual target reports would not normally be generated

Affinity output files

Two files titled aff#sla-id# and aff2#sla-id#. These files provide the required input to the Phase 3 analysis. The files only differ in that aff#sla-id# has additional header records. The record structure is as follows:

Field 1 is the record code or ID. In the BRS case this corresponds to the cell number.

Field 2 is the area (in hectares) of the cell.

The next 42 fields are pairs of values for the 21 low order land uses. The pairs are ordered such that the highest affinity land use (smallest similarity) and the land use number appear first followed by the second highest affinity, then the third etc. Land uses that have no affinity, for example, because no control sites exist for them, have a similarity of "2.0" and a zero land use code.

The next 18 fields are pairs of values for the high order land uses with the same format as for the low order land uses.

The two aff files are used within Phase 3. The FORTRAN format for the output is (a16,f10.2,100(f6.3,i4)).

The first affinity output file is used in the subsequent allocation phases of the SPREAD algorithm. This file is called aff#sla-id# and summarises the affinities between target records and both the Audit

Commodity land use classes and the ABS Level 1 land use classes. An annotated (bold) example of the file is shown below.

```
NUMBER OF RECORDS        10
NUMBER OF SITES           4
NUMBER OF LUs            21
NUMBER OF HIGH LU         9
DATA
```

The first five records summarise the numbers of target records analysed, the number of control sites and the number of land uses in the two classifications. The line with "DATA" is required by the script to separate "header" information and the data values.

The second affinity output file is also used in the subsequent allocation phases of the SPREAD algorithm. This file is called aff2#sla-id# and summarises the affinities between target records and both the Audit Commodity land use classes and the ABS Level 1 land use classes. An annotated (bold) example of the file is shown below.

```
            1     15.50 0.057   6 0.060  14 0.066  21 0.073  13 0.075
12 0.078  17 0.091   3 0.102   4 0.104  10 0.104   5 0.109   7 0.111   9
2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000
0 2.000   0 0.057   5 0.060   7 0.066   9 0.073   6 0.091   3 0.102   4
2.000   0 2.000   0 2.000   0
            2      4.40 0.058  14 0.063   6 0.066  21 0.074  17 0.075
12 0.081  13 0.100   3 0.104  10 0.104   5 0.105   4 0.106   7 0.108   9
2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000
0 2.000   0 0.058   7 0.063   5 0.066   9 0.075   6 0.100   3 0.104   4
2.000   0 2.000   0 2.000   0
            3    102.20 0.052  14 0.067  21 0.068  17 0.070   6 0.074
12 0.080  13 0.099   3 0.104   9 0.104   4 0.107   7 0.109  10 0.109   5
2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000
0 2.000   0 0.052   7 0.067   9 0.070   5 0.074   6 0.099   3 0.104   4
2.000   0 2.000   0 2.000   0
            4    103.80 0.052  14 0.063  21 0.066  17 0.069   6 0.073
12 0.081  13 0.100   3 0.103   7 0.105   4 0.107  10 0.107   5 0.114   9
2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000
0 2.000   0 0.052   7 0.063   9 0.069   5 0.073   6 0.100   3 0.105   4
2.000   0 2.000   0 2.000   0
            5     94.80 0.053  14 0.062  21 0.067  17 0.067   6 0.077
12 0.086  13 0.102   7 0.105  10 0.105   5 0.105   3 0.108   9 0.108   4
2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000   0 2.000
0 2.000   0 0.053   7 0.062   9 0.067   5 0.077   6 0.105   4 0.105   3
2.000   0 2.000   0 2.000   0
```

Values of "2.000" for a land use affinity indicate that no affinity to that land use was or could be calculated. These values are eliminated from further consideration in the allocation phase of the SPREAD implementation.

Example run script

The following output is an example run of the SPREAD process for the test dataset. Inputs to the script are shown in **bold**. Comments on the script and the example are shown in ***bold italics***.

Script started on Thu May 13 11:33:55 1999

```
ComplexServer:kim 41 % spread 16150[1] Orange[2] orange.ctl[3]
```

The three arguments to the SPREAD program are in the order of: the SLA-id number of the SLA being analysed (1); the name of the SLA being analysed (2); and the name of the control file to use in the analysis (3).

```
--------------------------------------------------------------------------

                                SPREAD
                 A procedure for re-allocating aggregated
               Agricultural statistics using NOAA-AVHRR NDVI

           Developed by Paul Walker(1) and Thilak Mallawaarachchi(2)
                    (1) CSIRO Wildlife and Ecology, Canberra
                    (2) CSIRO Tropical Agriculture, Townsville

             Software implementation by Kim Malafant and Dawn Fordham
                      compleXia Pty Ltd, Canberra, 1999

                 Copyright CSIRO Wildlife and Ecology, 1999

The methodology is documented in: Walker, P.A. and Mallawaarachchi,T
(1998). Disaggregating agricultural statistics using NOAA-AVHRR NDVI.
Remote sensing of the Environment, 63:112-125.

--------------------------------------------------------------------------
```

The following information summarises the SLA being analysed and the control file to use in the analysis.

```
Get location NDVI profiles for SLA ->  Orange
Get Control site NDVI Profiles from file ->  orange.ctl
Processing Location Profiles
Calculating Gower Metric
```

The list of fields below identify to the user the fields and their ID. The user may choose any of these fields for inclusion in the analysis.

```
List of fields available for Gower Metric Analysis

        5 Seasonality                       6 Length of Growing Season
        7 Minimum NDVI for Year     8 Maximum NDVI for Year
      9 Total Biomass                      10 Biomass in Growing Season
     11 Average Biomass in Season

     12 1st NDVI Reading          13 2nd NDVI Reading
     14 3rd NDVI Reading          15 4th NDVI Reading
     16 5th NDVI Reading          17 6th NDVI Reading
     18 7th NDVI Reading          19 8th NDVI Reading
     20 9th NDVI Reading          21 10th NDVI Reading
     22 11th NDVI Reading         23 12th NDVI Reading
```

```
        24 13th NDVI Reading          25 14th NDVI Reading
        26 15th NDVI Reading          27 16th NDVI Reading
        28 17th NDVI Reading          29 18th NDVI Reading
        30 19th NDVI Reading          31 20th NDVI Reading
        32 21st NDVI Reading          33 22nd NDVI Reading
        34 23rd NDVI Reading          35 24th NDVI Reading
        36 25th NDVI Reading          37 26th NDVI Reading

Enter required fields (5-37) comma separated (return for all NDVIs only)
Fields -> <CR>
Using default fields[4]
```

To specify a particular set of fields the user would enter a comma separated list at the Fields prompt. For example: 5,6,7,11,23,34. Return <CR> indicates to the program to use the default list of fields - currently only the 26 NDVI values (4).

```
Perform Control Site & Location Comparisons (y or n) -> y
Enter Minimum Affinity Cut-off (Default 0.05) -> <CR>[5]
```

The user can choose to compare the control sites or not as well as comparing the location or target records to the control sites. If this is selected then the user has the option to specify a cut-off value for deciding if control sites are similar or not. By entering <CR> the default value of 0.05 is selected for the cut-off (5).

```
Output Individual Pixel Analyses (y or n) -> y
```

The user can choose to output the results of the individual target pixel analyses or not. This option can generate an enormous amount of information and should only (generally) be used for checking small sets of difficult target pixels. That is, target pixels, which have difficulty in being allocated to particular land uses.

```
Perform Control Site Sensitivity Analyses (y or n) -> y
Enter Percentage NDVI Change (Default 20) - > <CR>[6]
```

The user can choose to perform a sensitivity analysis on the control sites. This analysis allows the user to choose a percentage change value, which is applied to the highest NDVI value and the values either side. This analysis is output for each of the control sites. By entering <CR> the default value of 20.0 (percentage change) is selected for application to the highest NDVI value (6).

```
Script done on Thu May 13 11:34:17 1999
```

References

Gower, J.C. (1971). A general coefficient of similarity and some of its properties. *Biometrics* **27**: 857-871.

Walker, P.A. and Mallawaarachchi, T. (1998). SPREAD: A method for disaggregating agicultural production statistics using NOAA-AVHRR NDVI. *Remote Sensing of the Environment*. **63**: 112-115.

Appendix A5.1. SPREAD affinity analysis output example

The following is an example output from the affinity analysis phases of SPREAD. It should be noted that this is a COMPLETE output and that the individual target record analyses would not generally be required. Comments on the output are provided in bold.

General header indicating SLA being analysed.

```
SPREAD Analysis for - Orange
```

Copyright and implementation details plus reference.

```
===============================================================================
                              SPREAD
                A procedure for re-allocating aggregated
             Agricultural statistics using NOAA-AVHRR NDVI

         Developed by Paul Walker(1) and Thilak Mallawaarachchi(2)
                 (1) CSIRO Wildlife and Ecology, Canberra
                 (2) CSIRO Tropical Agriculture, Townsville

         Software implementation by Kim Malafant and Dawn Fordham
                    compleXia Pty Ltd, Canberra, 1999

              Copyright CSIRO Wildlife and Ecology, 1999

The methodology is documented in: Walker, P.A. and Mallawaarachchi,T
(1998). Disaggregating agricultural statistics using NOAA-AVHRR NDVI.
Remote sensing of the Environment, 63:112-125.


===============================================================================
```

Control and Target files being used. These are internal script filenames provided for checking if the program fails.

```
        Using Control Site File - pc16150.tmp
        Using SLA Data File     - pd16150.tmp
```

Description of variables and their ranges used in the analysis.

```
        Variables used in Affinity Calculations

   Code   Variable Description          Range

    12   1st NDVI Reading              20.00
    13   2nd NDVI Reading              20.00
    14   3rd NDVI Reading              20.00
    15   4th NDVI Reading              20.00
    16   5th NDVI Reading              20.00
    17   6th NDVI Reading              20.00
    18   7th NDVI Reading              20.00
    19   8th NDVI Reading              20.00
    20   9th NDVI Reading              20.00
    21   10th NDVI Reading             20.00
    22   11th NDVI Reading             20.00
    23   12th NDVI Reading             20.00
    24   13th NDVI Reading             20.00
```

```
                25  14th NDVI Reading                    20.00
                26  15th NDVI Reading                    20.00
                27  16th NDVI Reading                    20.00
                28  17th NDVI Reading                    20.00
                29  18th NDVI Reading                    20.00
                30  19th NDVI Reading                    20.00
                31  20th NDVI Reading                    20.00
                32  21st NDVI Reading                    20.00
                33  22nd NDVI Reading                    20.00
                34  23rd NDVI Reading                    20.00
                35  24th NDVI Reading                    20.00
                36  25th NDVI Reading                    20.00
                37  26th NDVI Reading                    20.00
```

Control site affinity analysis. In this case there are only four control sites and the "default" minimum affinity value of 0.05 has been used. ANY control sites that have an affinity less than or equal to the minimum value are deemed to be similar and need close inspection.

```
            Individual Control Sites Affinity Analysis
            Number of Control Sites =      4
            Minimum Affinity Value =     0.0500

Control    1 [ 12 - Other Vegetables              ] :
             has    3 possible similar control sites:
                    2 [ 20]  Plantation Fruit            0.023
                    3 [  8]  Sugar Cane                  0.010
                    4 [ 21]  Grapes                      0.010
```

The analysis above shows that control site 1, which has land use 12 (other vegetables) is similar to 3 other control sites. These are: control site 2 with land use 20 (Plantation Fruit) with an affinity of 0.023; control site 3 with land use 8 (Sugar Cane) with an affinity of 0.10; and with control site 4 with land use 21 (Grapes) and an affinity of 0.10.

Control sites that are similar should be investigated if their land uses are not the same. The use of similar control sites with different land uses will cause confusion in the allocation phase of the SPREAD algorithm.

```
Control    2 [ 20 - Plantation Fruit              ] :
             has    2 possible similar control sites:
                    3 [  8]  Sugar Cane                  0.033
                    4 [ 21]  Grapes                      0.033
Control    3 [  8 - Sugar Cane                     ] :
             has    1 possible similar control sites:
                    4 [ 21]  Grapes                      0.000
```

The output from the control site sensitivity analysis follows. The user has chosen the "default" of a 20 percent change to test for sensitivity.

```
            Individual Control Sites Affinity Sensitivity Analysis
            Percentage NDVI Change =    20

Control    1: (Original) :    4.00  5.00  7.00  5.00  5.00  6.00
                              5.00  4.00  4.00  3.00  3.00  4.00
                              4.00  5.00  7.00  5.00  5.00  6.00
                              5.00  4.00  4.00  3.00  3.00  4.00
                              4.00  5.00
              (Modified) :    4.00  6.00  8.40  6.00  5.00  6.00
                              5.00  4.00  4.00  3.00  3.00  4.00
                              4.00  5.00  7.00  5.00  5.00  6.00
                              5.00  4.00  4.00  3.00  3.00  4.00
```

```
                                      4.00   5.00
                    Maximum NDVI is at Time =     3 Affinity   =  0.007
```

For control site 1, the first maximum NDVI occurs for reading 3. Therefore readings 2, 3 and 4 are increased by 20 percent (e.g. reading 3 increases from 7.00 to 8.40) and the affinity between the original and modified readings calculated. If the affinity increase is large it indicates that the control site may be sensitive to changes in NDVI value and should be investigated further. In this case, the affinity increase is only 0.007, which indicates almost no change.

This analysis may be completed for every control site as determined by the user (see the example run - Section 5).

```
Control    2: (Original) :   4.00   5.00   5.00   5.00   6.00   7.00
                             5.00   4.00   4.00   4.00   3.00   3.00
                             4.00   5.00   5.00   5.00   6.00   7.00
                             5.00   4.00   4.00   4.00   3.00   3.00
                             4.00   5.00
               (Modified) :   4.00   5.00   5.00   5.00   7.20   8.40
                             6.00   4.00   4.00   4.00   3.00   3.00
                             4.00   5.00   5.00   5.00   6.00   7.00
                             5.00   4.00   4.00   4.00   3.00   3.00
                             4.00   5.00
                    Maximum NDVI is at Time =     6 Affinity   =  0.007

Control    3: (Original) :   3.00   5.00   7.00   5.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00   7.00   5.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00
               (Modified) :   3.00   6.00   8.40   6.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00   7.00   5.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00
                    Maximum NDVI is at Time =     3 Affinity   =  0.007

Control    4: (Original) :   3.00   5.00   7.00   5.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00   7.00   5.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00
               (Modified) :   3.00   6.00   8.40   6.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00   7.00   5.00   5.00   6.00
                             5.00   3.00   4.00   3.00   3.00   4.00
                             3.00   5.00
                    Maximum NDVI is at Time =     3 Affinity   =  0.007
```

The following analysis provides an individual report on the affinity between each of the target sites and the control sites. This analysis report is controllable by the user and is generally not requested.

```
              Locations and Control Sites Affinity Analysis

       Landuse Affinity Analysis for:          6f46ffc
    Control Site Affinities (1st 10):  0.158 0.158 0.167 0.167
  Minimum Affinity with Control Site:    1 Affinity =  0.158
                 Landuse [ 12] = Other Vegetables
        Higher Order Landuse [  1] = Residual
```

The summary above indicates the affinities up to the first ten control sites in order of lowest affinity. That is, these are the "closest" control sites to the target. The Audit Commodity ID (Landuse) for this example is 12 (Other Vegetables) and the ABS Level 1 land use (Higher Order Landuse) is 1 (Residual). This is only an example dataset and this result would not be normal for legitimate control and target information. The smallest affinity is 0.158. In this example more than one control site has the same affinity.

```
            4 Minimum Control Site Affinities (Number Controls =    4)

   The Closest Affinity is to Control Site      1 [ Affinity =  0.158 ]
                                                  [ Landuse  =     12 ]
                                                  [ High LU  =      1 ]
   2nd Closest Affinity is to Control Site      2 [ Affinity =  0.158 ]
                                                  [ Landuse  =     20 ]
                                                  [ High LU  =      1 ]
   3rd Closest Affinity is to Control Site      3 [ Affinity =  0.167 ]
                                                  [ Landuse  =      8 ]
                                                  [ High LU  =      2 ]
   4th Closest Affinity is to Control Site      4 [ Affinity =  0.167 ]
                                                  [ Landuse  =     21 ]
                                                  [ High LU  =      1 ]
```

The summary above provides more information for up to the closest ten control sites to the target record. The output includes the control site ids in order with their affinities, Audit Commodity Id (landuse) and ABS Level 1 ID (High LU).

```
    Landuse Affinity Analysis for:           6f479ec
  Control Site Affinities (1st 10):  0.163 0.163 0.173 0.173
 Minimum Affinity with Control Site:    1 Affinity =  0.163
                 Landuse [ 12] = Other Vegetables
       Higher Order Landuse [  1] = Residual

            4 Minimum Control Site Affinities (Number Controls =    4)

   The Closest Affinity is to Control Site      1 [ Affinity =  0.163 ]
                                                  [ Landuse  =     12 ]
                                                  [ High LU  =      1 ]
   2nd Closest Affinity is to Control Site      2 [ Affinity =  0.163 ]
                                                  [ Landuse  =     20 ]
                                                  [ High LU  =      1 ]
   3rd Closest Affinity is to Control Site      3 [ Affinity =  0.173 ]
                                                  [ Landuse  =      8 ]
                                                  [ High LU  =      2 ]
   4th Closest Affinity is to Control Site      4 [ Affinity =  0.173 ]
                                                  [ Landuse  =     21 ]
                                                  [ High LU  =      1 ]
```

```
Number of Location Records Processed =       10
```

The individual report finishes with an indication of the number of target records that have been processed. The report for the rest of the target records in the test set has been eliminated for compactness.

The next two outputs of the analysis provide (crude) histograms of the allocation of the target records to the Audit Commodity Classes (21) and to the ABS Level 1 classes (9). They are always provided in the report as a quick summary of the distribution of the allocations of the target records.

```
        Frequency Distribution for Landuse Classes (  21 )
        Based on Closest Control Site Affinities

Code:    1 [Residual                      ] ->
Code:    2 [Agroforestry                  ] ->
Code:    3 [Pastures                      ] ->
Code:    4 [Cereals                       ] ->
Code:    5 [Rice                          ] ->
Code:    6 [Legumes                       ] ->
Code:    7 [Oilseeds                      ] ->
Code:    8 [Sugar Cane                    ] ->
Code:    9 [Forage Crops                  ] ->
Code:   10 [Cotton                        ] ->
Code:   11 [Other Non-cereal Crops        ] ->
Code:   12 [Other Vegetables              ] -> +++++++++++++++++++++++
Code:   13 [Potatoes                      ] ->
Code:   14 [Citrus                        ] ->
Code:   15 [Apples                        ] ->
Code:   16 [Pears                         ] ->
Code:   17 [Stone Fruit                   ] ->
Code:   18 [Nuts                          ] ->
Code:   19 [Berry Fruit                   ] ->
Code:   20 [Plantation Fruit              ] ->
Code:   21 [Grapes                        ] ->

        Frequency Distribution for HIGH ORDER Landuse Classes (    9 )
        Based on Closest Control Site Affinities

Code:    1 [Residual                      ] -> +++++++++++++++++++++++
Code:    2 [Agroforestry                  ] ->
Code:    3 [Pastures                      ] ->
Code:    4 [Cereals                       ] ->
Code:    5 [Non-cereal crops              ] ->
Code:    6 [Vegetables                    ] ->
Code:    7 [Orchards                      ] ->
Code:    8 [Berry and Plantation Fruits   ] ->
Code:    9 [Grapes                        ] ->
```

SPREAD methodology Phase 3

Introduction

This document outlines the basic operation of the allocation calculations (Phase 3) for the SPREAD methodology as outlined by Walker and Mallawaarachchi (1998). The allocation calculations are based on either a heuristic sorting method or a Simplex Linear Programming formulation (see Press et. al., 1992) and use information calculated from Phases 1 and 2 of the method. The data required for the analysis includes:

Two files titled aff#sla-id# and aff2#sla-id#. The files only differ in that aff#sla-id# has additional header records. The file (aff#sla-id#) summarises for each target record the affinities to each of the land uses. The fields are pairs of values for the land uses and are ordered such that the highest affinity land use (smallest similarity) and the land use number appear first followed by the second highest affinity, then the third etc.

A file specifying the land use areas for the 21 low order land uses and 9 high order land uses for each SLA.

The program uses the above files to perform the analyses outlined below. Output from the analysis includes:

An output file summarising the analysis.

Output files, which provide information on: the (possible) pre-allocation of target zones; a list of the target zones and their allocated land uses; data files that are dependent on the algorithm used for allocation.

Current limitations to the implementation (see also Limitations) include:

The number of control sites (records) per analysis is restricted to 200. Although this can easily be increased, the interpretation of the control site analysis on 200 sites is not a simple task. As the number of control sites increases in comparison to the number of land uses, the allocation becomes more complex and the probability of control sites with different land uses being similar increases.

The number of land uses is currently limited to 30 (21 for the Audit Commodity classes and 9 for the ABS Level 1 land use classes). This can easily be changed.

The number of variables used in the calculation is limited to 50 and should not need to be increased. This includes the 26 NDVI readings plus additional calculated values.

The allocation algorithms assume a maximum of 20000 target records although this can be modified. Increasing this value has direct effects on the size of the tableau required for the LP solution. If the number of target records is NUMREC and the number of land uses is NLU then the dimensions of the LP tableau are: [MAXREC + (2 * NLU) + 5] rows and [MAXREC * NLU + 1] columns. These are maximum requirements but may exceed the available space on some machines.

This document outlines detail on the data files required, the outputs and examples of the files and analysis.

Basic static input files

There is only one basic input file (areas.lst) required to run the allocation component of the SPREAD algorithm. This file provides information on land use areas for each SLA.

Agricultural areas

The name of the file containing the areas for each of the land uses (both high and low) is provided as input to the SPREAD procedure. This file can exist anywhere as a full path can be specified. The file can contain records for many different SLAs as the code searches the file trying to match the SLA number (#sla-id#).

Records in the file have a simple structure:

Field 1 is the SLA id (#sla-id#).

The next 21 fields are the areas for the 21 low order land uses.

The final 9 fields are the areas for the 9 high order land uses.

The format for the fields is free format.

Dynamic input data

The main inputs to the allocation process are the two files titled aff#name# and aff2#name#. These files are also described in the Phase 2 documentation. The files only differ in that aff#name# has additional header records (as described in the Phase 2 documentation). The record structure is as follows:

Field 1 is the record code or ID. In the BRS case this corresponds to the cell number

Field 2 is the area (in hectares) of the cell

The next 42 fields are pairs of values for the 21 low order land uses. The pairs are ordered such that the highest affinity land use (smallest similarity) and the land use number appear first followed by the second highest affinity, then the third etc. Land uses that have no affinity, for example, because no control sites exist for them, have a similarity of "2.0" and a zero land use code.

The next 18 fields are pairs of values for the high order land uses with the same format as for the low order land uses.

Output files

After the allocation is completed three output files are produced.

Analysis output file

Gam#name#.ana is an output file of the allocation run including a pass by pass summary, allocation summary etc. This file is only produced for the heuristic allocation algorithm. An example appears below.

```
Heuristic Allocation Summary

        0 Records were pre-allocated

    Pass   1 Land Use Allocation Summary

     6983 Records Allocated from  17640 Records
     6983 Additional Records Allocated on Pass    1

      0.0 Hectares allocated  984457.1 Hectares available - [ 1] Residual
      0.0 Hectares allocated       0.0 Hectares available - [ 2] Agroforestry
 569998.4 Hectares allocated  569998.5 Hectares available - [ 3] Pastures
 128694.3 Hectares allocated  202468.9 Hectares available - [ 4] Cereals
  10986.5 Hectares allocated   10986.6 Hectares available - [ 5] Non-cereal crops
    835.7 Hectares allocated      835.8 Hectares available - [ 6] Vegetables
    633.0 Hectares allocated      633.1 Hectares available - [ 7] Orchards
      0.0 Hectares allocated        0.0 Hectares available - [ 8] Berry and
                                                                  Plantation Fruits
    286.0 Hectares allocated      286.0 Hectares available - [ 9] Grapes

    Pass   2 Land Use Allocation Summary

     7734 Records Allocated from  17640 Records
      751 Additional Records Allocated on Pass    2

      0.0 Hectares allocated  984457.1 Hectares available - [ 1] Residual
      0.0 Hectares allocated        0.0 Hectares available - [ 2] Agroforestry
 569998.4 Hectares allocated  569998.5 Hectares available - [ 3] Pastures
```

```
202432.0 Hectares allocated  202468.9 Hectares available - [ 4] Cereals
 10986.5 Hectares allocated   10986.6 Hectares available - [ 5] Non-cereal
                                                                 crops
   835.7 Hectares allocated      835.8 Hectares available - [ 6] Vegetables
   633.0 Hectares allocated      633.1 Hectares available - [ 7] Orchards
     0.0 Hectares allocated        0.0 Hectares available - [ 8] Berry and
                                                                 Plantation
                                                                 Fruits
   286.0 Hectares allocated      286.0 Hectares available - [ 9] Grapes

     Pass   3 Land Use Allocation Summary

      7750 Records Allocated from  17640 Records
        16 Additional Records Allocated on Pass    3

     0.0 Hectares allocated  984457.1 Hectares available - [ 1] Residual
     0.0 Hectares allocated        0.0 Hectares available - [ 2] Agroforestry
569998.4 Hectares allocated  569998.5 Hectares available - [ 3] Pastures
202468.8 Hectares allocated  202468.9 Hectares available - [ 4] Cereals
 10986.5 Hectares allocated   10986.6 Hectares available - [ 5] Non-cereal
                                                                 crops
   835.7 Hectares allocated      835.8 Hectares available - [ 6] Vegetables
   633.0 Hectares allocated      633.1 Hectares available - [ 7] Orchards
     0.0 Hectares allocated        0.0 Hectares available - [ 8] Berry and
                                                                 Plantation
                                                                 Fruits
   286.0 Hectares allocated      286.0 Hectares available - [ 9] Grapes


     Pass   4 Land Use Allocation Summary

      7750 Records Allocated from  17640 Records
         0 Additional Records Allocated on Pass    4

     0.0 Hectares allocated  984457.1 Hectares available - [ 1] Residual
     0.0 Hectares allocated        0.0 Hectares available - [ 2] Agroforestry
569998.4 Hectares allocated  569998.5 Hectares available - [ 3] Pastures
202468.8 Hectares allocated  202468.9 Hectares available - [ 4] Cereals
 10986.5 Hectares allocated   10986.6 Hectares available - [ 5] Non-cereal crops
   835.7 Hectares allocated      835.8 Hectares available - [ 6] Vegetables
   633.0 Hectares allocated      633.1 Hectares available - [ 7] Orchards
     0.0 Hectares allocated        0.0 Hectares available - [ 8] Berry and
                                                                 Plantation Fruits
   286.0 Hectares allocated      286.0 Hectares available - [ 9] Grapes

     Pass   5 Land Use Allocation Summary

      7750 Records Allocated from  17640 Records
         0 Additional Records Allocated on Pass    5

     0.0 Hectares allocated  984457.1 Hectares available - [ 1] Residual
     0.0 Hectares allocated        0.0 Hectares available - [ 2] Agroforestry
569998.4 Hectares allocated  569998.5 Hectares available - [ 3] Pastures
202468.8 Hectares allocated  202468.9 Hectares available - [ 4] Cereals
 10986.5 Hectares allocated   10986.6 Hectares available - [ 5] Non-cereal crops
   835.7 Hectares allocated      835.8 Hectares available - [ 6] Vegetables
   633.0 Hectares allocated      633.1 Hectares available - [ 7] Orchards
     0.0 Hectares allocated        0.0 Hectares available - [ 8] Berry and
                                                                 Plantation Fruits
   286.0 Hectares allocated      286.0 Hectares available - [ 9] Grapes

     Pass   6 Land Use Allocation Summary

      7750 Records Allocated from  17640 Records
         0 Additional Records Allocated on Pass    6

     0.0 Hectares allocated  984457.1 Hectares available - [ 1] Residual
     0.0 Hectares allocated        0.0 Hectares available - [ 2] Agroforestry
```

138

```
   569998.4 Hectares allocated   569998.5 Hectares available - [ 3] Pastures
   202468.8 Hectares allocated   202468.9 Hectares available - [ 4] Cereals
    10986.5 Hectares allocated    10986.6 Hectares available - [ 5] Non-cereal crops
      835.7 Hectares allocated      835.8 Hectares available - [ 6] Vegetables
      633.0 Hectares allocated      633.1 Hectares available - [ 7] Orchards
        0.0 Hectares allocated        0.0 Hectares available - [ 8] Berry and
                                                                   Plantation Fruits
      286.0 Hectares allocated      286.0 Hectares available - [ 9] Grapes

        9890 Records left unallocated after   6 passes

       Summary of Unallocated Records

Record                 2 of       4.4 Hectares unallocated
                                Closest landuse is [ 7] Orchards
Record                 3 of     102.2 Hectares unallocated
                                Closest landuse is [ 7] Orchards
Record                 4 of     103.8 Hectares unallocated
                                Closest landuse is [ 7] Orchards
Record                 5 of      94.8 Hectares unallocated
                                Closest landuse is [ 7] Orchards
Record                 6 of     149.3 Hectares unallocated
                                Closest landuse is [ 7] Orchards
```

Pre-allocation output file

Gam#name#.pre is a summary of the target records pre-allocated. This file will be present for both allocation algorithms but may contain no pre-allocated records. An example is shown below.

```
      Pre-allocation Analysis Summary


      Applying pre-allocation rule 1 (closeness)

Location              157 DIRECTLY Allocated to High Order Landuse    6

      Applying pre-allocation rule 2 (single landuse)


      Number of landuses more than one [  6]


       1 Records out of     200 pre-allocated
```

Allocation output file

Gam#name#.alc is a file containing the allocation summary for each target record. This file has four fields:

1. Field 1 is the record ID.

2. Field 2 is a composite field indicating the landuse that the record has been allocated to followed by a code indicating the landuse class ("l" for low and "h" for high).

3. Field 3 indicates the pass on which the record was allocated. A number of codes are used: "p" indicates that the record was pre-allocated (this can be checked in the ".pre" file); "u" indicates that the record remains unallocated, the pass number (field 2) will be zero; "r" indicates that the record was allocated to the residual class after the allocation algorithms were run; "l" indicates that the record was allocated by the LP algorithm; a number indicates the pass on which the record was allocated.

4. Field 4 is the area (hectares) of the allocated cell.

An example is shown below.

```
3126   0h   u    103.3
3127   3h   1    206.8
3128   0h   u     61.9
3129   0h   u    103.4
3130   3h   1    103.4
3131   3h   1     15.3
3132   4h   2    103.4
3133   3h   1     87.8
3134   3h   1    206.7
3135   0h   u    103.4
3136   0h   u    103.4
3137   3h   1     48.6
3138   3h   1    206.6
```

Implementation details

Two versions of the source code have been implemented at BRS:

1. A single processor version of the code compiled using the "standard" FORTRAN 77 compiler(s), which should run on any SUN SPARC system with sufficient swap space. Approximate timings for 200 target records with 9 land uses yielded a real time of 3.5 minutes for solving the LP. The Makefile and SPREAD shell script for this version are shown in Appendix 2.

2. A multi-processor version of the code compiled using the Fujitsu (frt) FORTRAN compiler. This version has been compiled for 4 processors and will only execute on the SUN E6000 systems. Users need an additional line in their ".cshrc" file of the form "setenv PARALLEL 4" to execute this version. Any attempt to run the code without this option set will result in an aborted run. Approximate timings for 200 target records with 9 land uses yielded a real time of 1.08 minutes, approximately 4 times faster than the single processor version. The Makefile and SPREAD shell script for this version are shown in Appendix 3.

Limitations

Currently two limitations apply to Phase 3 of the SPREAD algorithm. Both limitations apply to the size of the problem, which may be undertaken by the procedure. These limitations are:

1. A limit of 20,000 target records applies for the heuristic algorithm and as a general limit on other structures. This may be easily changed by modifying the parameter MAXREC in the FORTRAN source code and recompiling the code using the supplied Makefile.

2. The second limitation applies to the size of the tableau that the LP algorithm can process. Currently this is limited to 5000 target records for 21 landuses and 7700 target records for 9 landuses. The restriction is placed on the algorithm by the current version of the FORTRAN compiler(s) at BRS. The restriction by the compiler is on the maximum size of a single structure (~ 2 Gbytes) although the operating system will quite happily accommodate much larger structures. Newer versions of the compiler may not have this restriction. The restriction applies to both the SUN and Fujitsu compilers. Possible methods to overcome this current restriction include:

   Manipulate the cutoff values for the closeness pre-allocation rule so that target zones with a clearly defined landuse (high single affinities) are pre-allocated leaving only the less clearly defined target zones to be allocated using the LP algorithm.

   Group or cluster the target zones as suggested by Paul Walker into similar zones based on affinity, which will reduce the total number of target zones.

   Note: Subsequent discussions with SUN Canberra (Paul Hutton) indicate that this restriction has been removed in the V5 64-bit compilers. The current BRS compilers are for the 32-bit systems and are 3 to 4 years out of date. Updated versions will allow all possible tableaus (~20000 plus target records) to be run.

Example run script

The following output is an example run of the SPREAD process for a test dataset. Inputs to the script are shown in **bold**. Comments on the script and the example are shown in ***bold italics***.

```
ComplexServer:kim 41 % spread 16150[1] Orange[2] orange.ctl[3]
```

The three arguments to the SPREAD program are in the order of: the SLA-id number of the SLA being analysed (1); the name of the SLA being analysed (2); and the name of the control file to use in the analysis (3). The SPREAD code expects, in general, to find the files in the current directory. In this example the control file could be anywhere as long as the full path is specified.

Note that the two arguments for the "batch" file option are no longer included.

```
-----------------------------------------------------------------------

                              SPREAD
                 A procedure for re-allocating aggregated
               Agricultural statistics using NOAA-AVHRR NDVI

         Developed by Paul Walker(1) and Thilak Mallawaarachchi(2)
                  (1) CSIRO Wildlife and Ecology, Canberra
                  (2) CSIRO Tropical Agriculture, Townsville

            Software implementation by Kim Malafant and Dawn Fordham
                     compleXia Pty Ltd, Canberra, 1999

                 Copyright CSIRO Wildlife and Ecology, 1999

The methodology is documented in: Walker, P.A. and Mallawaarachchi,T
(1998). Disaggregating agricultural statistics using NOAA-AVHRR NDVI.
Remote sensing of the Environment, 63:112-125.

-----------------------------------------------------------------------
```

The following information summarises the SLA being analysed and the control file to use in the analysis.

```
Get location NDVI profiles for SLA ->  Orange
Get Control site NDVI Profiles from file ->  orange.ctl
Processing Location Profiles
Calculating Gower Metric
```

The list of fields below identify to the user the fields and their ID. The user may choose any of these fields for inclusion in the analysis.

```
List of fields available for Gower Metric Analysis

      5 Seasonality                    6 Length of Growing Season
      7 Minimum NDVI for Year    8 Maximum NDVI for Year
     9 Total Biomass                  10 Biomass in Growing Season
    11 Average Biomass in Season

    12 1st NDVI Reading          13 2nd NDVI Reading
    14 3rd NDVI Reading          15 4th NDVI Reading
    16 5th NDVI Reading          17 6th NDVI Reading
    18 7th NDVI Reading          19 8th NDVI Reading
    20 9th NDVI Reading          21 10th NDVI Reading
    22 11th NDVI Reading         23 12th NDVI Reading
    24 13th NDVI Reading         25 14th NDVI Reading
```

```
   26 15th NDVI Reading           27 16th NDVI Reading
   28 17th NDVI Reading           29 18th NDVI Reading
   30 19th NDVI Reading           31 20th NDVI Reading
   32 21st NDVI Reading           33 22nd NDVI Reading
   34 23rd NDVI Reading           35 24th NDVI Reading
   36 25th NDVI Reading           37 26th NDVI Reading

Enter required fields (5-37) comma separated (return for all NDVIs only)
Fields -> **<CR>**
Using default fields[4]
```

To specify a particular set of fields the user would enter a comma separated list at the Fields prompt. For example: 5,6,7,11,23,34. Return <CR> indicates to the program to use the default list of fields - currently only the 26 NDVI values (4).

```
Perform Control Site & Location Comparisons (y or n) -> **y**
Enter Minimum Affinity Cut-off (Default 0.05) -> **<CR>**[5]
```

In Phase 2, the user can choose to compare the control sites or not as well as comparing the location or target records to the control sites. If this is selected then the user has the option to specify a cut-off value for deciding if control sites are similar or not. By entering <CR> the default value of 0.05 is selected for the cut-off (5).

```
Output Individual Pixel Analyses (y or n) -> **y**
```

The user can choose to output the results of the individual target pixel analyses or not. This option can generate an enormous amount of information and should only (generally) be used for checking small sets of difficult target pixels. That is, target pixels, which have difficulty in being allocated to particular land uses.

```
Perform Control Site Sensitivity Analyses (y or n) -> **y**
Enter Percentage NDVI Change (Default 20) - > **<CR>**[6]
```

The user can choose to perform a sensitivity analysis on the control sites. This analysis allows the user to choose a percentage change value, which is applied to the highest NDVI value and the values either side. This analysis is output for each of the control sites. By entering <CR> the default value of 20.0 (percentage change) is selected for application to the highest NDVI value (6).

If the answer to the question on performing the Site and location comparisons is "n" then all the Phase 2 (Gower) calculations are skipped. This allows the allocation routine to be run on already existing Phase 2 files, if required.

After Phase 2 has been run three files are produced:

An output file of the analysis named gower#sla-id#.ana. This is a simple name change from the original documentation. The layout and structure is as described in the Phase 2 documentation.

Two files titled aff#sla-id# and aff2#sla-id#. These files are also described in the Phase 2 documentation and they provide the required input to the Phase 3 analysis. The files only differ in that aff#sla-id# has additional header records (as described in the Phase 2 documentation). The record structure is as follows:

1. Field 1 is the record code or ID. In the BRS case this corresponds to the cell number.

2. Field 2 is the area (in hectares) of the cell.

3. The next 42 fields are pairs of values for the 21 low order land uses. The pairs are ordered such that the highest affinity land use (smallest similarity) and the land use number appear first followed by the second highest affinity, then the third etc. Land uses

that have no affinity, for example, because no control sites exist for them, have a similarity of "2.0" and a zero land use code.

4. *The next 18 fields are pairs of values for the high order land uses with the same format as for the low order land uses.*

The two aff files are used within Phase 3. The ".ana" file summarises the analysis for Phase 2.

The next set of questions provides the input to the Phase 3 analysis.

```
Perform Site Allocation Analyses (y or n) -> y
Continuing with Allocation Analysis
```

A "y" answer continues the analysis for Phase 3, while an "n" exits from the script and the analysis terminates.

```
Enter Allocation Method (h|euristic or l|p) -> h
```

Determine the type of allocation algorithm to use. The "heuristic" algorithm sorts the land uses and affinities and allocates the target cells to the land use that is closest. A number of passes through the algorithm are possible, depending on the number of land uses available. The LP algorithm runs the linear programming allocation routine.

Two pre-allocation rules will also be run before either of the two allocation routines. The two rules allocate target records to a land use based either on a "closeness" criterion or if only a single land use exists then target records are allocated to this land use in a similar manner to the heuristic algorithm. Any records left unallocated after the pre-allocation routines are then allocated using the chosen routine.

```
Enter Allocation LandUse Choice (h|igh or l|ow) -> l
```

Allocation can be either to the 9 classes (high order) or the 21 ABS (low order) land use classes. The high order classes are completely contained within the low order classes at the moment. However, this is not a restriction that the code and/or algorithms place on the input data. The two classifications could be completely separate. Also the number of classes (9,21) can be specified in the input (see Phase 2 documentation).

```
Ensure Entry for Each Target Zone (y or n) -> y
```

A "y" answer to this ensures that each target zone record will have at least one affinity recorded for the allocation algorithm(s) even if none of the affinities pass the minimum affinity acceptance value. The value chosen will be the affinity for the closest land use.

```
Enter Minimum Affinity Acceptance (Default Use All) -> 0.5
```

The minimum affinity acceptance criteria. Any values greater than this value will NOT be recorded against the target zone and land use. A <cr> will accept all affinity entries for the target zone.

The following questions only appear if the heuristic allocation algorithm is chosen.

```
Provide allocation summary (y or n) -> y
```

A "y" answer to this will print a list of target records that remain unallocated after both the pre-allocation and allocation algorithms have been run.

```
Pool unallocated records to Residual (y or n) -> n
```

A "y" answer will automatically allocate as many remaining unallocated target records to the residual class as is possible (only restricted by total area of the residual class). A response of "n" will leave the records unallocated.

Note that a "y" answer to the allocation summary question AND to this question will result in a truncated list (possibly and generally zero records) in the allocation summary.

```
Use conservative allocation (y or n) -> y
```

Allocation to land use classes is done until the total area of the class is allocated. This option allows the allocation to only allocate area less than or equal to the total ("y") or to allocate a target record even though it may exceed the total area when the last allocated record was below the total ("n").

For example consider that the total area was 200 Ha, currently there is 190 Ha allocated and the next record to be allocated is 12 Ha. If we use the conservative allocation ("y") rule then this record WILL NOT be allocated to the land use since the total allocated area would now be 202 Ha. If the non-conservative allocation ("n") rule were used then the record WOULD BE allocated to the land use with a total allocated area of 202 Ha.

In general, the conservative rule should probably be used.

```
Enter number of search passes (1 to 21) -> 6
```

Number of passes to use in the allocation. The number of passes identifies the number of "closest" affinities on which to allocate. For example, if 5 passes are specified then the algorithm will continue to try and allocate a target record down to its fifth closest land use affinity. That is, if the record cannot be allocated on its closest land use affinity, then the algorithm will try and allocate it on the basis of its second closest land use, then the third, etc down to the number of passes.

The number of land uses limits the total number of possible passes.

```
Enter Filename for LandUse Areas -> areas.lst
```

The name of the file containing the areas for each of the land uses (both high and low). This file can exist anywhere as a full path can be specified. The file can contain records for many different SLAs as the code searches the file trying to match the SLA number (#sla-id#).

Records in the file have a simple structure:

> *Field 1 is the SLA id (#sla-id#).*

> *The next 21 fields are the areas for the 21 low order land uses.*

> *The final 9 fields are the areas for the 9 high order land uses.*

```
Running Allocation Analysis for SLA 12600 (Carrathool)
Feasible Solution found
```

The following additional output appears if the LP algorithm is used as the allocation algorithm.

```
Running LP Algorithm on saved Tableau
Tableau read
Parameter List ->   200    9 1800  219 1801  222  219    0    0
Tableau and RHS read
Estimated time (minutes) to solve =       5.50
Feasible Solution found
```

After the allocation is completed three output files are produced:

1. *gam#sla-id#.ana is a summary output file of the allocation run including a pass by pass summary, allocation summary etc.*

2. *gam#sla-id#.pre is a summary of the target records pre-allocated*

3. *gam#sla-id#.alc is a file containing the allocation summary for each target record. This file has four fields:*

    Field 1 is the record ID

    Field 2 is a composite field indicating the landuse that the record has been allocated to followed by a code indicating the landuse class ("l" for low and "h" for high).

    Field 3 indicates the pass on which the record was allocated. A number of codes are used: "p" indicates that the record was pre-allocated (this can be checked in the ".pre" file); "u" indicates that the record remains unallocated, the pass number (field 2) will be zero; "r" indicates that the record was allocated to the residual class after the allocation algorithms were run; "l" indicates that the record was allocated using the LP algorithm; a number indicates the pass on which the record was allocated.

    Field 4 is the area (hectares) of the allocated cell.

References

Press, W.H., Teukolsky, S.A., Vetterling, W.T. and Flannery, B.P. (1992). Numerical Recipes in C, The Art of Scientific Computing, Second Edition. Cambridge University Press, USA.

Walker, P.A. and Mallawaarachchi, T. (1998). SPREAD: A method for disaggregating agicultural production statistics using NOAA-AVHRR NDVI. *Remote Sensing of the Environment*. **63**: 112-115.

Appendix A5.2. Makefile and SPREAD script for single processor version

```sh
#!/bin/sh
#Routine outputs:
#
#         Spread script for SINGLE PROCESSOR version of the code
#
help()
{
/usr/ucb/echo "The SPREAD script requires three arguments:"
/usr/ucb/echo " "
/usr/ucb/echo "The first argument is the SLA code (eg. 16150)"
/usr/ucb/echo "The second argument is the SLA name (eg. Orange)"
/usr/ucb/echo "The third argument is the name of the control point file (eg.
Orange.ctl)"
}

header()
{
/usr/ucb/echo " "
/usr/ucb/echo "----------------------------------------------------------------
--"
/usr/ucb/echo " "
/usr/ucb/echo "                            SPREAD"
/usr/ucb/echo "             A procedure for re-allocating aggregated"
/usr/ucb/echo "         Agricultural statistics using NOAA-AVHRR NDVI"
/usr/ucb/echo " "
/usr/ucb/echo " Developed by Paul Walker(1) and Thilak Mallawaarachchi(2)"
/usr/ucb/echo "            (1) CSIRO Wildlife and Ecology, Canberra"
/usr/ucb/echo "            (2) CSIRO Tropical Agriculture, Townsville"
/usr/ucb/echo " "
/usr/ucb/echo " Software implementation by Kim Malafant and Dawn Fordham"
/usr/ucb/echo "          compleXia Pty Ltd, Canberra, 1999"
/usr/ucb/echo " "
/usr/ucb/echo "                 Copyright CSIRO Wildlife and Ecology, 1999"
/usr/ucb/echo " "
/usr/ucb/echo "     The methodology is documented in: Walker, P.A. and
                  Mallawaarachchi,T (1998)."
/usr/ucb/echo "     Disaggregating agricultural statistics using NOAA-AVHRR NDVI.
                  Remote sensing"
/usr/ucb/echo " of the Environment, 63:112-125."
/usr/ucb/echo " "
/usr/ucb/echo "----------------------------------------------------------------
--"
}
#       Input command is spread $1 $2 $3
#               where  $1 is sla code
#                      $2 is sla name
#                      $3 is the name of the control point file
#
#       Check for the required number of arguments
#
header
if [ $# -lt 3 -o $# -gt 3 ]; then
        help
        exit 1
fi
#
#       Check that the resource file actually exists
#
if [ ! -f p$1.tba ]; then
        /usr/ucb/echo "Resource file p$1.tba does not exist in this directory"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
#
```

```
#       Check that the control point file actually exists
#
if [ ! -f $3 ]; then
        /usr/ucb/echo "Control Point file $3 does not exist"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
#
#       Check that the Agricultural landuse name file actually exists
#
if [ ! -f agname.lst ]; then
        /usr/ucb/echo "Landuse Name file does not exist in this directory"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
#
/usr/ucb/echo "Get location NDVI profiles for SLA -> " $2
/usr/ucb/echo "Get Control site NDVI Profiles from file -> " $3
unalias mv
unalias cp
#
# Split out the data from the SLA file - expects DATA as separator
#
/usr/ucb/echo "Processing Location Profiles"
csplit -s p$1.tba %DATA%+1
mv xx00 pd$1.tmp
csplit -s $3 %DATA%+1
mv xx00 pc$1.tmp
#
#       Now pass the resource file and control points to the Gower
#       Metric calculations and other options
#
/usr/ucb/echo "Calculating Gower Metric"
/usr/ucb/echo " "
/usr/ucb/echo "List of fields available for Gower Metric Analysis"
/usr/ucb/echo " "
cat fields.lst2
#
correct="n"
while [ "$correct" != "y" ]
do
        /usr/ucb/echo " "
        /usr/ucb/echo "Enter required fields (6-38) comma separated (return for all
NDVI's only)"
        /usr/ucb/echo -n "Fields -> "
        read flist
        if [ "$flist" = "" ]; then
                /usr/ucb/echo "Using default fields"

        flist="13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,
36,37,38"
                numlist=26
#               flist="12,13,14,15,16,17,18,19,20,21,22,23"
#               numlist=12
                correct="y"
        else
                numlist=`/usr/ucb/echo "$flist" | sed "s/,/ /g" | wc --words`

                newlist=`/usr/ucb/echo "$flist" | sed "s/,/ /g"`
                for i in $newlist
                {
                        if [ $i -lt 6 -o $i -gt 38 ]; then
                                /usr/ucb/echo " "
                                /usr/ucb/echo "You have entered an incorrect field
value"
                                correct="n"
                                break
                        fi
```

```
                        correct="y"
                }
        fi
done
#
# Set the indicator for the area field - currently field 5 so is
# the fourth data field. The first field is the ID.
#
acode=4
#
/usr/ucb/echo $2 > param$1.$$
/usr/ucb/echo "pc$1.tmp" >> param$1.$$
/usr/ucb/echo "37,$numlist" >> param$1.$$
/usr/ucb/echo $flist >> param$1.$$
/usr/ucb/echo "pd$1.tmp" >> param$1.$$
/usr/ucb/echo "37,$numlist,$acode" >> param$1.$$
#
answer1="m"
/usr/ucb/echo " "
while [ "$answer1" != "y" -a "$answer1" != "n" ]
do
        /usr/ucb/echo -n "Perform Control Site & Location Comparisons (y or n) -> "
        read answer1
done
#
minaff="0.05"
if [ "$answer1" = "y" ]; then
        /usr/ucb/echo -n "Enter Minimum Affinity Cutoff (Default 0.05) -> "
        read minaff
        if [ "$minaff" = "" ]; then
                minaff="0.05"
        fi
#
        answer2="m"
        while [ "$answer2" != "y" -a "$answer2" != "n" ]
        do
                /usr/ucb/echo -n "Output Individual Pixel Analyses (y or n) -> "
                read answer2
        done
fi
/usr/ucb/echo "$answer1 $answer2 $minaff" >> param$1.$$
#
answer3="m"
/usr/ucb/echo " "
while [ "$answer3" != "y" -a "$answer3" != "n" ]
do
        /usr/ucb/echo -n "Perform Control Site Sensitivity Analyses (y or n) -> "
        read answer3
done
#
minper="20.0"
if [ "$answer3" = "y" ]; then
        /usr/ucb/echo -n "Enter Percentage NDVI Change (Default 20) - > "
        read minper
        if [ "$minper" = "" ]; then
                minper="20.0"
        fi
fi
/usr/ucb/echo "$answer3 $minper" >> param$1.$$
#
if [ "$answer1" = "y" -o "$answer3" = "y" ]; then
        ./gower < param$1.$$ > gower$1.ana
        if [ "$answer1" = "y" ]; then
                cat fort.10 fort.8 > aff$1
                mv fort.8 aff2$1
        fi
#
        rm -f param$1.$$ pc$1.tmp pd$1.tmp fort* > /dev/null
```

```
                /usr/ucb/echo "Gower Affinity Calculations Completed"
fi
#
answer4="m"
/usr/ucb/echo " "
while [ "$answer4" != "y" -a "$answer4" != "n" ]
do
                /usr/ucb/echo -n "Perform Site Allocation Analyses (y or n) -> "
                read answer4
done
#
if [ "$answer4" = "n" ]; then
                /usr/ucb/echo "Exiting from Current Analysis"
                exit
fi
#
/usr/ucb/echo "Continuing with Allocation Analysis"
#
method="m"
while [ "$method" != "h" -a "$method" != "l" ]
do
                /usr/ucb/echo -n "Enter Allocation Method (h|euristic or l|p) -> "
                read method
done
#
landlp="m"
while [ "$landlp" != "h" -a "$landlp" != "l" ]
do
                /usr/ucb/echo -n "Enter Allocation LandUse Choice (h|igh or l|ow) -> "
                read landlp
done
#
ensure="m"
while [ "$ensure" != "y" -a "$ensure" != "n" ]
do
                /usr/ucb/echo -n "Ensure Entry for Each Target Zone (y or n) -> "
                read ensure
done
#
/usr/ucb/echo -n "Enter Minimum Affinity Acceptance (Default Use All) -> "
read minact
if [ "$minact" = "" ]; then
                minact="1.05"
fi
#
/usr/ucb/echo $1 > gam$1.$$
/usr/ucb/echo "aff$1" >> gam$1.$$
/usr/ucb/echo "aff2$1" >> gam$1.$$
/usr/ucb/echo "$method,$landlp,$ensure" >> gam$1.$$
/usr/ucb/echo "$minact" >> gam$1.$$
#
if [ "$method" = "h" ]; then
                unalloc="m"
                while [ "$unalloc" != "y" -a "$unalloc" != "n" ]
                do
                                /usr/ucb/echo -n "Provide allocation summary (y or n) -> "
                                read unalloc
                done
                pool="m"
                while [ "$pool" != "y" -a "$pool" != "n" ]
                do
                                /usr/ucb/echo -n "Pool unallocated records to Residual (y or n) -> "
                                read pool
                done
                conserve="m"
                while [ "$conserve" != "y" -a "$conserve" != "n" ]
                do
                                /usr/ucb/echo -n "Use conservative allocation (y or n) -> "
```

```
                        read conserve
            done
#
            if [ "$landlp" = "h" ]; then
                    maxpass="9"
            else
                    maxpass="21"
            fi
#
            /usr/ucb/echo -n "Enter number of search passes (1 to $maxpass) -> "
            read numpass
            if [ "$numpass" = "" ]; then
                    numpass="1"
            fi
            /usr/ucb/echo "$unalloc,$pool,$conserve" >> gam$1.$$
            /usr/ucb/echo "$numpass" >> gam$1.$$
fi
#
/usr/ucb/echo -n "Enter Filename for LandUse Areas -> "
read areafile
if [ ! -f "$areafile" ]; then
            /usr/ucb/echo "LandUse Areas file $areafile does not exist"
            /usr/ucb/echo "Please check the file location"
            exit 1
fi
#
/usr/ucb/echo "$areafile" >> gam$1.$$
#
/usr/ucb/echo "Running Allocation Analyis for SLA" $1 "($2)"
#
./gamclean < gam$1.$$ > gam$1.ana
#
if [ "$method" = "l" ]; then
            /usr/ucb/echo "Running LP Algorithm on saved Tableau"
            /usr/ucb/echo "$landlp" >> lp$1.$$
            cat lp$1.$$ fort.26 > lpin$1.$$
            /bin/time ./lprun < lpin$1.$$
fi
rm -f gam$1.$$
if [ -f fort.2 ]; then
        mv fort.2 gam$1.tab
fi
if [ -f fort.3 ]; then
        if [ -f fort.12 ]; then
                    cat fort.12 fort.3 > temp
        else
                    mv fort.3 temp
        fi
        rm -f fort.12
        sort -k 1 temp > fort.12
        rm -f temp fort.3
        rm -f lp$1.$$ lpin$1.$$
fi
if [ -f fort.7 ]; then
        mv fort.7 gam$1.ana
fi
if [ -f fort.8 ]; then
        mv fort.8 gam$1.pre
fi
if [ -f fort.12 ]; then
        mv fort.12 gam$1.alc
fi
retcode=`head -1 fort.23`
rm -f fort.23 fort.26 fort.66
#
```

```
# Check the return code
#
if [ $retcode -eq -1 ]; then
        /usr/ucb/echo "No feasible LP Solution was found"
        exit -1
fi
#
if [ $retcode -eq 1 ]; then
        /usr/ucb/echo "Objective function is unbounded"
        exit 1
fi
#
# If we get here then must have a feasible solution
#
/usr/ucb/echo "Feasible Solution found"


#
# Makefile for the SINGLE PROCESSOR version of the SPREAD analysis program(s)
#

CC              =       /opt/SUNWspro/SC4.0/bin/cc
F77             =       /opt/SUNWspro/SC4.0/bin/f77
FFLAGS  =       -e

OBJS1   = gower.o heap.o
OBJS2   = gamclean.o hew.o prealloc.o heap.o
OBJS3   = lprun.o

all:    gower gamclean lprun

gower:  $(OBJS1)
        $(F77) $(FFLAGS) -o gower $(OBJS1)
gamclean:       $(OBJS2)
        $(F77) $(FFLAGS) -o gamclean $(OBJS2)
lprun:  $(OBJS3)
        $(F77) $(FFLAGS) -o lprun $(OBJS3)
gower.o: gower.f
        $(F77) $(FFLAGS) -c $<
gamclean.o: gamclean.f
        $(F77) $(FFLAGS) -c $<
lprun.o: lprun.f
        $(F77) $(FFLAGS) -c $<
hew.o: hew.f
        $(F77) $(FFLAGS) -c $<
prealloc.o: prealloc.f
        $(F77) $(FFLAGS) -c $<
simplex.o: simplex.f
        $(F77) $(FFLAGS) -c $<
heap.o: heap.c
        $(CC) $(CFLAGS) -c $<

clean:
        rm -f *.o gower gamclean lprun
```

Appendix A5.3. Makefile and SPREAD script for multi processor version

```sh
#!/bin/sh
#Routine outputs:
#
#       This version of the script is for the MP compiled versions
#       of the source code ONLY
#
help()
{
/usr/ucb/echo "The SPREAD script requires three arguments:"
/usr/ucb/echo " "
/usr/ucb/echo "The first argument is the SLA code (eg. 16150)"
/usr/ucb/echo "The second argument is the SLA name (eg. Orange)"
/usr/ucb/echo "The third argument is the name of the control point file (eg.
Orange.ctl)"
}

header()
{
/usr/ucb/echo " "
/usr/ucb/echo "-------------------------------------------------------------------
--"
/usr/ucb/echo " "
/usr/ucb/echo "                          SPREAD"
/usr/ucb/echo "          A procedure for re-allocating aggregated"
/usr/ucb/echo "       Agricultural statistics using NOAA-AVHRR NDVI"
/usr/ucb/echo " "
/usr/ucb/echo " Developed by Paul Walker(1) and Thilak Mallawaarachchi(2)"
/usr/ucb/echo "          (1) CSIRO Wildlife and Ecology, Canberra"
/usr/ucb/echo "          (2) CSIRO Tropical Agriculture, Townsville"
/usr/ucb/echo " "
/usr/ucb/echo " Software implementation by Kim Malafant and Dawn Fordham"
/usr/ucb/echo "          compleXia Pty Ltd, Canberra, 1999"
/usr/ucb/echo " "
/usr/ucb/echo "                    Copyright CSIRO Wildlife and Ecology, 1999"
/usr/ucb/echo " "
/usr/ucb/echo " The methodology is documented in: Walker, P.A. and Mallawaarachchi,T
(1998)."
/usr/ucb/echo " Disaggregating agricultural statistics using NOAA-AVHRR NDVI. Remote
sensing"
/usr/ucb/echo " of the Environment, 63:112-125."
/usr/ucb/echo " "
/usr/ucb/echo "-------------------------------------------------------------------
--"
}
#       Input command is spread $1 $2 $3
#               where  $1 is sla code
#                      $2 is sla name
#                      $3 is the name of the control point file
#
#       Check for the required number of arguments
#
header
if [ $# -lt 3 -o $# -gt 3 ]; then
        help
        exit 1
fi
#
#       Check that the resource file actually exists
#
if [ ! -f p$1.tba ]; then
        /usr/ucb/echo "Resource file p$1.tba does not exist in this directory"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
```

```
#
#       Check that the control point file actually exists
#
if [ ! -f $3 ]; then
        /usr/ucb/echo "Control Point file $3 does not exist"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
#
#       Check that the Agricultural landuse name file actually exists
#
if [ ! -f agname.lst ]; then
        /usr/ucb/echo "Landuse Name file does not exist in this directory"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
#
/usr/ucb/echo "Get location NDVI profiles for SLA -> " $2
/usr/ucb/echo "Get Control site NDVI Profiles from file -> " $3
unalias mv
unalias cp
#
# Split out the data from the SLA file - expects DATA as separator
#
/usr/ucb/echo "Processing Location Profiles"
csplit -s p$1.tba %DATA%+1
mv xx00 pd$1.tmp
csplit -s $3 %DATA%+1
mv xx00 pc$1.tmp
#
#       Now pass the resource file and control points to the Gower
#       Metric calculations and other options
#
/usr/ucb/echo "Calculating Gower Metric"
/usr/ucb/echo " "
/usr/ucb/echo "List of fields available for Gower Metric Analysis"
/usr/ucb/echo " "
cat fields.lst2
#
correct="n"
while [ "$correct" != "y" ]
do
        /usr/ucb/echo " "
        /usr/ucb/echo "Enter required fields (6-38) comma separated (return for all
NDVI's only)"
        /usr/ucb/echo -n "Fields -> "
        read flist
        if [ "$flist" = "" ]; then
                /usr/ucb/echo "Using default fields"
                flist="13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
33 34 35 36 37 38"
                numlist=26
                correct="y"
        else
                numlist=`/usr/ucb/echo "$flist" | sed "s/,/ /g" | wc --words`

                newlist=`/usr/ucb/echo "$flist" | sed "s/,/ /g"`
                for i in $newlist
                {
                        if [ $i -lt 6 -o $i -gt 38 ]; then
                                /usr/ucb/echo " "
                                /usr/ucb/echo "You have entered an incorrect field
value"
                                correct="n"
                                break
                        fi
                        correct="y"
                }
```

```
        fi
done
#
# Set the indicator for the area field - currently field 5 so is
# the fourth data field. The first field is the ID.
#
acode=4
#
/usr/ucb/echo $2 > param$1.$$
/usr/ucb/echo "pc$1.tmp" >> param$1.$$
/usr/ucb/echo "37 $numlist" >> param$1.$$
/usr/ucb/echo $flist >> param$1.$$
/usr/ucb/echo "pd$1.tmp" >> param$1.$$
/usr/ucb/echo "37 $numlist $acode" >> param$1.$$
#
answer1="m"
/usr/ucb/echo " "
while [ "$answer1" != "y" -a "$answer1" != "n" ]
do
        /usr/ucb/echo -n "Perform Control Site & Location Comparisons (y or n) -> "
        read answer1
done
#
minaff="0.05"
if [ "$answer1" = "y" ]; then
        /usr/ucb/echo -n "Enter Minimum Affinity Cutoff (Default 0.05) -> "
        read minaff
        if [ "$minaff" = "" ]; then
                minaff="0.05"
        fi
#
        answer2="m"
        while [ "$answer2" != "y" -a "$answer2" != "n" ]
        do
                /usr/ucb/echo -n "Output Individual Pixel Analyses (y or n) -> "
                read answer2
        done
fi
/usr/ucb/echo "$answer1 $answer2 $minaff" >> param$1.$$
#
answer3="m"
/usr/ucb/echo " "
while [ "$answer3" != "y" -a "$answer3" != "n" ]
do
        /usr/ucb/echo -n "Perform Control Site Sensitivity Analyses (y or n) -> "
        read answer3
done
#
minper="20.0"
if [ "$answer3" = "y" ]; then
        /usr/ucb/echo -n "Enter Percentage NDVI Change (Default 20) - > "
        read minper
        if [ "$minper" = "" ]; then
                minper="20.0"
        fi
fi
/usr/ucb/echo "$answer3 $minper" >> param$1.$$
#
if [ "$answer1" = "y" -o "$answer3" = "y" ]; then
        ./gower < param$1.$$ > gower$1.ana
        if [ "$answer1" = "y" ]; then
                cat fort.10 fort.8 > aff$1
                mv fort.8 aff2$1
        fi
#
        rm -f param$1.$$ pc$1.tmp pd$1.tmp fort* > /dev/null
        /usr/ucb/echo "Gower Affinity Calculations Completed"
fi
```

```
#
answer4="m"
/usr/ucb/echo " "
while [ "$answer4" != "y" -a "$answer4" != "n" ]
do
        /usr/ucb/echo -n "Perform Site Allocation Analyses (y or n) -> "
        read answer4
done
#
if [ "$answer4" = "n" ]; then
        /usr/ucb/echo "Exiting from Current Analysis"
        exit
fi
#
/usr/ucb/echo "Continuing with Allocation Analysis"
#
method="m"
while [ "$method" != "h" -a "$method" != "l" ]
do
        /usr/ucb/echo -n "Enter Allocation Method (h|euristic or l|p) -> "
        read method
done
#
landlp="m"
while [ "$landlp" != "h" -a "$landlp" != "l" ]
do
        /usr/ucb/echo -n "Enter Allocation LandUse Choice (h|igh or l|ow) -> "
        read landlp
done
#
ensure="m"
while [ "$ensure" != "y" -a "$ensure" != "n" ]
do
        /usr/ucb/echo -n "Ensure Entry for Each Target Zone (y or n) -> "
        read ensure
done
#
/usr/ucb/echo -n "Enter Minimum Affinity Acceptance (Default Use All) -> "
read minact
if [ "$minact" = "" ]; then
        minact="1.05"
fi
#
/usr/ucb/echo $1 > gam$1.$$
/usr/ucb/echo "aff$1" >> gam$1.$$
/usr/ucb/echo "aff2$1" >> gam$1.$$
/usr/ucb/echo "$method,$landlp,$ensure" >> gam$1.$$
/usr/ucb/echo "$minact" >> gam$1.$$
#
if [ "$method" = "h" ]; then
        unalloc="m"
        while [ "$unalloc" != "y" -a "$unalloc" != "n" ]
        do
                /usr/ucb/echo -n "Provide allocation summary (y or n) -> "
                read unalloc
        done
        pool="m"
        while [ "$pool" != "y" -a "$pool" != "n" ]
        do
                /usr/ucb/echo -n "Pool unallocated records to Residual (y or n) -> "
                read pool
        done
        conserve="m"
        while [ "$conserve" != "y" -a "$conserve" != "n" ]
        do
                /usr/ucb/echo -n "Use conservative allocation (y or n) -> "
                read conserve
        done
```

```
#
        if [ "$landlp" = "h" ]; then
                maxpass="9"
        else
                maxpass="21"
        fi
#
        /usr/ucb/echo -n "Enter number of search passes (1 to $maxpass) -> "
        read numpass
        if [ "$numpass" = "" ]; then
                numpass="1"
        fi
        /usr/ucb/echo "$unalloc,$pool,$conserve" >> gam$1.$$
        /usr/ucb/echo "$numpass" >> gam$1.$$
fi
#
/usr/ucb/echo -n "Enter Filename for LandUse Areas -> "
read areafile
if [ ! -f "$areafile" ]; then
        /usr/ucb/echo "LandUse Areas file $areafile does not exist"
        /usr/ucb/echo "Please check the file location"
        exit 1
fi
#
/usr/ucb/echo "$areafile" >> gam$1.$$
#
/usr/ucb/echo "Running Allocation Analyis for SLA" $1 "($2)"
#
./gamclean < gam$1.$$ > gam$1.ana
#
if [ "$method" = "l" ]; then
        /usr/ucb/echo "Running LP Algorithm on saved Tableau"
        /usr/ucb/echo "$landlp" >> lp$1.$$
        cat lp$1.$$ fort.26 > lpin$1.$$
        ./lprun < lpin$1.$$
fi
rm -f gam$1.$$
if [ -f fort.2 ]; then
        mv fort.2 gam$1.tab
fi
if [ -f fort.3 ]; then
        if [ -f fort.12 ]; then
                cat fort.12 fort.3 > temp
        else
                mv fort.3 temp
        fi
        rm -f fort.12
        sort -k 1 temp > fort.12
        rm -f temp fort.3
        rm -f lp$1.$$ lpin$1.$$
fi
if [ -f fort.7 ]; then
        mv fort.7 gam$1.ana
fi
if [ -f fort.8 ]; then
        mv fort.8 gam$1.pre
fi
if [ -f fort.12 ]; then
        mv fort.12 gam$1.alc
fi
retcode=`head -1 fort.23`
rm -f fort.23 fort.26 fort.66
#
```

```
# Check the return code
#
if [ $retcode -eq -1 ]; then
        /usr/ucb/echo "No feasible LP Solution was found"
        exit -1
fi
#
if [ $retcode -eq 1 ]; then
        /usr/ucb/echo "Objective function is unbounded"
        exit 1
fi
#
# If we get here then must have a feasible solution
#
/usr/ucb/echo "Feasible Solution found"


#
# Makefile for the MP Versions of the SPREAD analysis program(s)
#

CC              =       /opt/SUNWspro/SC4.0/bin/cc
F77             =       /opt/FSUNf90/bin/frt
FFLAGS  =       -Fixed -A 2 -w -f i -E cfistu
                        -Kparallel,reduction,eval,preex,instance=4

OBJS1    = gower.o heap.o
OBJS2    = gamclean.o hew.o prealloc.o heap.o
OBJS3    = lprun.o

all:    gower gamclean lprun

gower:  $(OBJS1)
        $(F77) $(FFLAGS) -o gower $(OBJS1)
gamclean:       $(OBJS2)
        $(F77) $(FFLAGS) -o gamclean $(OBJS2)
lprun:  $(OBJS3)
        $(F77) $(FFLAGS) -o lprun $(OBJS3)
gower.o: gower.f
        $(F77) $(FFLAGS) -c $<
gamclean.o: gamclean.f
        $(F77) $(FFLAGS) -c $<
lprun.o: lprun.f
        $(F77) $(FFLAGS) -c $<
hew.o: hew.f
        $(F77) $(FFLAGS) -c $<
prealloc.o: prealloc.f
        $(F77) $(FFLAGS) -c $<
simplex.o: simplex.f
        $(F77) $(FFLAGS) -c $<
heap.o: heap.c
        $(CC) $(CFLAGS) -c $<

clean:
        rm -f *.o gower gamclean lprun
```

Appendix 6. Sampling for a network of rural commodity production sites

Warren Müller, CSIRO Mathematical and Information Sciences, and Paul Walker, CSIRO Wildlife and Ecology (November, 1999)

Extract from: Müller, W.J. and Walker, P.A. 1999, Sampling for a Network of Rural Commodity Production Sites, Report Number CMIS 99/188, CSIRO Mathematical and Information Sciences. See full report for Appendices 1 – 10 mentioned in following extract.

Introduction

This report presents the design of a sampling frame and the selection of a sample of land use control sites. The growth profiles of these sites based on NDVI images will be used to enable identification of land use in their regions, resulting in the production of a national land use map using the SPREAD procedure (Walker and Mallawaarachchi, 1998). The goal is to select the control sites needed for the SPREAD procedure such that every commodity type is sampled, and that each Statistical Local Area (SLA) must have sufficient control sites for mapping commodity types, within the constraints of available funds.

Data supplied

There were three sources of data which have been used in the determination of the frame and selection of the sample:

1. Areas of land use for 117 commodities (level 3 data) in 1336 SLAs, obtained from the Australian Bureau of Statistics. The revised version supplied in May 1999 has been used. A sample of these data is given in Appendix 1.

2. Areas of all SLAs contained in each of 80 regions defined by the Interim Biogeographic Regionalisation of Australia (IBRA). A sample of these data is given in Appendix 2.

3. A confusion matrix prepared by Paul Walker and Mike Young (CSIRO Wildlife and Ecology) and updated by Phil Tickle (BRS). In this matrix the likelihoods of confusing the signals from 20 aggregated commodity groups (the Audit Commodity Classification – see below) were rated for each pair as high (2), moderate (1) or low (0). The matrix is given in Appendix 3.

The areas of geographic overlap between eleven agro-ecological regions in Australia and SLAs were also supplied. They were not used, as they do not provide a sufficiently fine classification.

Audit commodity classification

Based on previous experience (Paul Walker, pers. comm.), the ABS level 3 data were reduced to areas for 20 commodity groups in each of the 1336 SLAs by summing over all level 3 commodities in each group. These 20 groups together with 'Residual' were termed the Audit Commodity Classification. The data were checked for internal consistency. The relationship between the Audit Commodity Classification, the ABS level 1 and level 3 classifications of commodities and the classifications used in the questionnaire is given in Appendix 4.

Spatial resolution

We are assuming that the GIS to support the creation of the land use map will have a grid resolution of no less than 100m, and more likely 250m. Thus it was assumed that any commodity group with **less than 100ha** in a SLA could not be detected by AVHRR nor mapped using the GIS. In such cases, the sampling procedure will not select these SLAs.

Small area problems go beyond these simple exclusions. In many cases where more than a total area of 100ha of a commodity group was present, it could be sufficiently scattered so that no single area was sufficiently large to be detected. Further, a commodity group may consist of a number of different level 3 commodities. If a SLA is selected for such a commodity group, a decision needs to be made as to which particular level 3 commodity to sample and there needs to be a sufficiently large contiguous area of this commodity.

Sampling frame

The sampling frame is based on unique combinations of SLAs and commodity groups. Given the commodity groups and the number of SLAs there are potentially more than 25000 combinations. However given that the SPREAD procedure uses AVHRR imagery and given the spatial resolution assumption above the numbers of combinations reduces substantially.

The sample frame was then defined as all SLAs in which at least one of the 20 commodity groups had 100ha or more production in the SLA. There were 737 SLAs in the sample frame and 599 SLAs with no commodity groups with production of 100ha or more. Of the 737, 139 only had 100ha or more production for a single commodity group, and that was mostly pasture (all but 15). A full listing of the 1336 SLAs is given in Appendix 5, broken into three categories

(a) More than one commodity group with production of 100ha or more (598);

(b) 100ha or more production for a single commodity group (139);

(c) No commodity groups with production of 100ha or more (599).

The commodity groups present and their total areas are also identified in these lists. The numbers of SLAs where each of the 20 commodity groups has 100ha or more are given in Table A6.1.

Table A6.1. Number of SLAs with a 100ha or more of the commodity group.

Commodity group	No. of SLAs with 100ha or more	Commodity group	No. of SLAs with 100ha or more
Agroforestry	60	Other vegetables	108
Pastures	719 (124)[a]	Potatoes	97
Cereals excluding rice	536 (6)	Citrus	39
Rice	18	Apples	28
Legumes	299	Pears	9
Oilseeds	258	Stone fruit	86
Sugar cane	49 (6)	Nuts	32 (2)
Non-cereal forage crops	119	Berry fruit	3
Cotton	38	Plantation fruit	26
Other non-cereal crops	192	Grapes	84 (1)

[a] Numbers in brackets are the number of SLAs where this is the only commodity group over 100ha

Selection of sample

We understand that there are insufficient resources to sample with replication each of these SLA x Commodity Group combinations. The central task therefore was which of these combinations do we need to sample to ensure:

All commodity groups are sampled;

SLAs that are key areas for production of a commodity group are sampled;

SLAs that are not directly sampled have sufficient sample points for relevant commodity groups in close proximity. We assumed close proximity meant within the same IBRA region;

The variability in the growth patterns of a commodity group, due for instance to soil and rainfall factors, is reflected in the sample. We addressed this variability by ensuring that sample points from different IBRA regions were collected for each commodity group;

SLAs with a diversity of commodity groups are more likely to be sampled;

SLAs with commodity groups that could be confused because of their growth pattern are more likely to be sampled. We addressed this by developing a confusion index.

Initial sample selection

For each of the 20 commodity groups, detailed tables were produced giving distribution of areas in each SLA for the commodity group over the whole of Australia and ranking the SLAs by decreasing area of the commodity group. These data are given in Appendix 6.

Tabulations and rankings in decreasing area were then performed for each of the 20 commodity groups for each state separately. For these purposes, ACT was combined with NSW. These data are given in Appendix 7.

From an examination of the information in appendices 6 and 7, initial criteria were adopted for selection of an initial sample of SLAs for each commodity group as given in Table A6.2.

Table A6.2. Criteria adopted for each commodity group to select initial sample of SLAs.

Commodity	Initial sample
Agroforestry	All SLAs down to 70% of total production in Australia
Pastures	All SLAs containing 5% or more of production within their state
Cereals excluding rice	All SLAs containing 5% or more of production within their state
Rice	All SLAs containing 1% or more of production in Australia
Legumes	All SLAs containing 5% or more of production for within their state
Oilseeds	All SLAs containing 5% or more of production for within their state
Sugar cane	All SLAs containing 1% or more of production in Australia
Non-cereal forage crops	All SLAs containing 1% or more of production for within their state
Cotton	All SLAs containing 1% or more of production in Australia
Other non-cereal crops	All SLAs containing 5% or more of production for within their state
Other vegetables	All SLAs containing 1% or more of production for within their state
Potatoes	All SLAs containing 1% or more of production for within their state
Citrus	All SLAs containing 1% or more of production in Australia
Apples	All SLAs containing 1% or more of production in Australia
Pears	All SLAs containing 1% or more of production in Australia
Stone fruit	All SLAs containing 1% or more of production for within their state
Nuts	All SLAs containing 1% or more of production in Australia
Berry fruit	Not included, as insufficient SLAs with 100ha or more
Plantation fruit	All SLAs containing 1% or more of production in Australia
Grapes	All SLAs containing 1% or more of production in Australia

Based on these criteria, a sample of 367 SLAs throughout Australia was obtained. A full listing of the sample and the numbers of commodity groups with 100ha or more in each SLA is given in Appendix 8. This sample contained 729 occasions where a commodity group was selected due to satisfying one of the criteria above, and 1144 occasions where 100ha or more of a commodity group was present in an SLA which had been included in the sample because of other commodity groups.

There were only three SLAs in which there were more than 100ha of berry fruit (Appendix 6), and even these areas were relatively small; 301, 211 and 181ha. It is unlikely that even in these a satisfactory sampling site with 100ha of berry fruit in close proximity would be found. Consequently it

was decided that this methodology would be unable to detect berry fruit and another strategy would need to be adopted. The methodology to sample berry fruit is not covered in this report.

Coverage of IBRAs

For each of the 80 IBRAs, the commodity groups with 100ha or more in a SLA which was wholly or partly (100ha or more) within the IBRA were identified. Because many SLAs cross IBRA boundaries and it is unknown where within a SLA a commodity group is found, it has to be assumed that the commodity group could be present in an IBRA with 100ha or more of that SLA contained in it. Full details of IBRAs in which each commodity group could be present are given in Appendix 9. This possible presence is indicated by a 'YES' in the column headed 'present'.

For each commodity group, the IBRAs for which one or more SLAs in the IBRA (i.e. 100ha or more) were selected in the sample are identified in Appendix 9 by a 'YES' in the column headed 'sampled'.

The IBRAs where commodity groups could be present were compared with the selected sample. From Table A6.3 it can be seen that in the vast majority of cases each commodity group present somewhere in an IBRA would be sampled in a SLA wholly or partly in that IBRA. For the 20 commodity groups there was only 21 occasions when an IBRA was not included in the sample when it could potentially be included. A detailed examination of Appendix 9 shows that in most of these cases the areas involved were relatively small. Their exclusion means that the nearest production site for that commodity in those cases would not be within the IBRA, i.e. there would be potentially a greater distance to the nearest control site. Noting the small areas, this would be unlikely to distort overall production figures.

Consequently it was considered that the cases where an IBRA was not represented in the sample were not important, and the sample was regarded as satisfactory for this criterion.

Table A6.3. Coverage of selected sample by commodity group with IBRAs.

Commodity group	Numbers of IBRAs (out of 80) where commodity group is :	
	Present in the IBRA	**Selected in the sample**
Agroforestry	34	34
Pastures	80	79
Cereals excluding rice	69	63
Rice	4	4
Legumes	44	42
Oilseeds	50	45
Sugar cane	12	12
Non-cereal forage crops	48	48
Cotton	17	17
Other non-cereal crops	46	44
Other vegetables	44	44
Potatoes	34	33
Citrus	17	17
Apples	17	17
Pears	8	8
Stone fruit	39	39
Nuts	19	17
Berry fruit	7	6
Plantation fruit	16	16
Grapes	28	27

Spatial relationship between SLAs, IBRAs and the selected sample

The map at the back of the report shows all SLAs, with those selected coloured according to the numbers of commodity groups to be sampled in them. The 80 IBRAs are overlayed in heavy black. Some IBRAs contain many SLAs, whereas others are mainly just a single SLA. The areas of IBRAs and SLAs also vary dramatically, however the larger areas tend to be in semi-arid and arid regions where production other than pasture will be small.

It would be possible to identify the IBRAs where the commodity groups were not represented in the sample, consider the spatial implications and manually change the sample slightly, however this is unlikely to have any real effect on the production information for the reasons already given.

Confusion among commodity groups

For the 367 SLAs in the selected sample and for the remaining 370 SLAs in the sampling frame, a confusion index was obtained from the confusion matrix (Appendix 3) by summing the confusion scores for each pair of commodity groups with 100ha or more in the SLA.

Total confusions are presented in the column 'tconfuse' in Appendix 10. The total confusions ranged from 58 to 0 in the selected sample, and from 20 to 0 in the other SLAs. Thus generally all the SLAs with high likelihood of confusion have been included in the sample, and control sites will be obtained for the commodity groups within them. Five SLAs not in the sample had confusion totals of 20 (2) and 19 (3), with the remainder 14 or less. These five could be examined to see if they should be added to the sample.

Conclusion

The selected sample of 367 provides a good basis for calibrating the signals for the commodity groups.

Some fine tuning of the sample could be done manually based on the information provided in this report. The sample could be augmented by

Adding SLAs to the sample to cover all IBRAs for all commodity groups

Adding SLAs where the confusion index was relatively high

Adding SLAs not well covered from spatial considerations with reference to the map.

Conversely, the sample could be trimmed by

Deleting SLAs where other SLAs within the IBRA provided sufficient control sites

Deleting SLAs with low confusion, where satisfactory control sites were in nearby SLAs

Whilst such changes to the sample would violate the conditions for inclusion set out in the second table in this report, the resulting sample may be superior overall.

Reference

Walker, P.A. and Mallawaarachchi,T. 1998, 'Disaggregating Agricultural Statistics Using NOAA-AVHRR NDVI', *Remote Sens. Environ.* 63: 112-125.

Listing of Appendices

Appendix 1: ABS Level 3 Data

Appendix 2: IBRA Areas for each SLA

Appendix 3: Confusion Matrix

Appendix 4: Audit Commodity Classification

Appendix 5: Occurrence of Commodity Groups in SLAs

Appendix 6: Distribution of Commodity Group Areas – Overall

Appendix 7: Distribution of Commodity Group Areas – by State

Appendix 7. Control site database documentation

Each State and Territory agency participating in the collection of agricultural control sites was provided with instructions, a table and map indicating the Statistical Local Areas and agricultural commodities to sample and an electronic control site data form. The information provided on the control site data form was then used to construct the control site database and the control site locations theme. Appendix 7 provides

1. Instructions for completing the control site data form

2. Example of the sampling table (Table A7.1) and map (Figure A7.2)

3. Control site data form

4. Example of layout of control site database

5. Examples of querying the control site database

6. Maps showing location and agricultural commodity of control sites by State (for 1996/97 land use)

Instructions for completing the control site data form

Selection of control sites

Please refer to Table 1 [the Queensland version reproduced here as Table A7.1] for the list of agricultural commodities to be sampled in each Statistical Local Area (SLA) for your State. SLAs are virtually the same as Local Government Areas.

For each commodity listed against a SLA the objective is to obtain information from **3 different sites**. This may not be possible in all cases (see criteria below).

Please select a site located in the paddock or orchard in which the particular commodity grew in **1996-97**. Try to avoid sites close to roads or other features such as remnant stands of vegetation or large dams.

The site selected should be located in the centre of **4 km^2** dominated (>50%) by the commodity (i.e. > 200 ha within a 400 ha area) (see Figure 1 [reproduced here as Figure A7.1]).   It should be possible in most cases for Pastures and Cereals excluding rice. For other commodities where an attempt has been made to locate a control site within a 4km^2 area has failed, a smaller representative area is allowed. For Rice, Legumes, Sugar Cane, and Cotton an area **2 km^2** dominated by the commodity is allowed (i.e. > 100 ha within 200 ha area). For Agroforestry, Oilseeds, Non-cereal forage crops, Other non-cereal crops, Other Vegetables, Potatoes, Citrus, Apples, Pears, Stonefruit, Nuts, Plantation fruit, and Grapes an area **1 km^2** dominated by the commodity is allowed (i.e. > 50 ha within 100 ha area). Within a SLA control sites for a commodity do not need to be at the same size, remembering a 4km^2 area is best and preferred for our end use.

Where a selected commodity is grown in the same SLA under different conditions (e.g. irrigated and non-irrigated), or a range of crops are grown under the commodity classification (e.g. wheat, oats and barley are classified as cereals excluding rice), attempt to obtain control sites that reflect the importance of that practice in the SLA (if required, this data can be derived from AgStats 96/97).

For pastures, where indicated in Table 1 [see Table A7.1] (i.e. for NSW, VIC, QLD, SA, WA) please attempt to locate one control site in pure lucerne. These are located in SLAs already selected for sampling and where there is at least 1000 ha of lucerne. This data has been requested so the potential of lucerne to lower water tables can be assessed.

Control sites should be located at least 2 km apart, regardless of whether the sites are for the same or different commodities. This will ensure that the information for different control sites won't overlap when used to interpret the remote sensing imagery (which has a grid cell size of 1.1 km).

Keep in mind that the final map will be produced at 1:1 000 000 so areas will be mapped as homogeneous which we know are not.
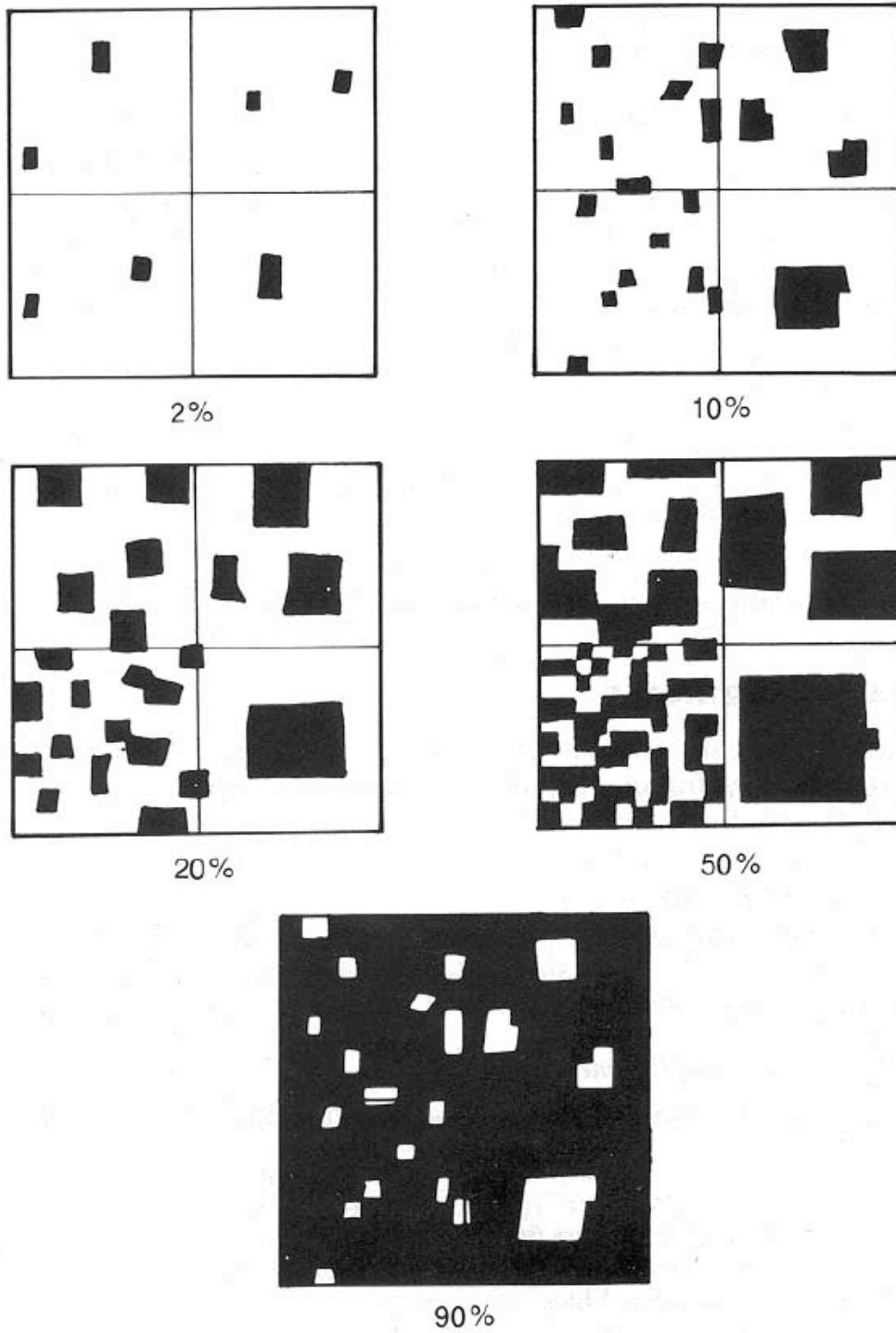

Figure A7.1. [Figure 1 in the original control site data form instructions document.] Chart for estimating abundance of an agricultural commodity. Each quarter of any one square has the same area of black (from the *Australian Soil and Land Survey Field Handbook* (Second edition)).

Points of clarification

These points have been derived from ABS' Agricultural Census for each State for the Season 1996-97 (from which AgStats 96/97 is produced).

Agricultural commodities (substitute in relevant year for subsequent years after 1996)

- **Pastures**:
Includes pastures grazed and pastures cut for hay (lucerne, other sown or native pastures). Other sown pastures includes : lucerne and other species (not pure lucerne); pasture legumes (excluding lucerne); mix of perennial grasses and legumes; and mix of annual grasses and legumes.
Native pasture includes native or naturalised pasture.

- **Cereals excluding rice**:
Cereals for hay/silage includes forage sorghum and cereals fed off
Grain sorghum is 1997 harvest (NSW, VIC, QLD).
Maize is 1997 harvest (NSW, VIC, QLD).

- **Rice**:
Rice is 1997 harvest (NSW).

- **Sugar cane**:
Sugar cane is 1996 season (NSW, QLD).

- **Other vegetables**:
Other vegetables relates to vegetables (excluding potatoes) planted during year ended 31 December 1996

- **Potatoes**:
Potatoes relate to two (2) crops – early crop (planted after 31 March 1996 and harvested before 31 March 1997) and main crop (planted before 31 March 1997 but not yet harvested).

- **Nuts**:
Macadamia nuts are 1996 harvest (NSW, QLD).

Irrigated refers to any area of pasture or crop irrigated one or more times.

Double cropping means where two (2) separate crops have been grown on the area at different times of the year.

Definitions of tillage practices:
- **Conventional tillage**: more than two (2) passes using discs, tines, ploughs etc
- **Minimum tillage**: one or two passes only prior to sowing
- **Direct drill**: no cultivation (apart from the actual sowing operation)
The cultivations were made for fallow weed control or seedbed preparation prior to sowing of broadacre crops.

Stubble management relates to disposal of crop and pasture stubble (trash) prior to sowing:
- **Incorporated**: stubble was ploughed into the soil
- **Retained**: stubble was left intact (no cultivation, crop/pasture direct drilled)
- **Other**: includes when stubble was mulched and most stubble removed by baling or heavy grazing
Where stubble was lightly grazed, report how the remaining stubble was handled.

Fallow type and fallow length relates to preparation for the 1996/97 crop.
- **Cultivated**: cultivation with or without herbicide
- **Uncultivated / herbicide**: complete chemical fallow using knockdown herbicide only
- **Pasture topping**: preventing seed development by spraying herbicide at milky dough stage

Determining the location of a control site

Please provide the location of the control site as latitude and longitude (given as longitude first, then latitude in decimal degrees). Australia has positive longitudes (E) and negative latitudes (S)).

Please indicate the projection (Universal Transverse Mercator Projection preferred), the coordinate system (e.g. AGD66, Australian Map Grid, WGS84) and the ellipsoid (e.g. Australian National Spheriod, CLARKE 1866) used.

Attachments C and D with the Control Site Data Form are provided to allow conversion from grid coordinate systems (Eastings and Northings) to latitude and longitude using Redfearn's formulae (Empire Survey Review No. 69, 1948).[18]

Where access to a Global Positioning System (GPS) is available please adopt the following settings:

Positioning Technique: Point positioning and navigation (This technique requires only one GPS receiver which can be hand-held, and gives an accuracy 95% of the time within 100 m of the "true" position.) See http://www.auslig.gov.au/geodesy/gpsovrvw.htm for further details.
Datum: World Geodetic System 1984 (WGS84)
Height: Ellipsoidal
Coordinates: Geographic coordinates latitude and longitude (decimal degrees)

Please note if comparing with a hardcopy map using Australian Geodetic Datum 1966 (AGD66) the coordinates (latitude and longitude) and height will differ to those using the above preferred settings for a GPS.

Photography

A photograph of one control site per commodity in a SLA is required. The intention is to use the photos to produce a visual library of land uses and attempt to show the differences in the same commodity between locations (e.g. irrigated versus non-irrigated; crop types within the same commodity group; management practices). Thus the photograph can be a general shot of the surrounding area, or more focused on the control site itself.

Preference is that a colour slide is taken.

Please return processed slides labelled with control site filename (see below) and description if needed.

Return of the control site data form

Complete this form with as many details as possible. The minimum is the "Site location details" and "Agricultural commodity harvested at site in 1996/97".

The form should be returned as a Microsoft Excel Workbook (preferably 97 or 5.0/95) saved with name conforming to the following convention:

1. Abbreviation of State: 2 or 3 letters e.g. nt, nsw

2. SLA #: 2 digits e.g. 01, 02, 03,…10,11,…70,…etc

3. Abbreviation of agricultural commodity: 2 letters as given in table following

---

[18] These attachments were adapted from the Geocentric Datum of Australia Technical Manual (1998) produced by the Intergovernmental Committee on Surveying and Mapping (ICSM) (http://www.anzlic.org.au/icsm/gdatm/chapter5.htm).

Abbreviation	Agricultural commodity
af	Agroforestry
pa	Pastures
ce	Cereals excluding rice
ri	Rice
le	Legumes
os	Oilseeds
sc	Sugar cane
fc	Non-cereal forage crops
co	Cotton
nc	Other non-cereal crops
ov	Other vegetables
po	Potatoes
ci	Citrus
ap	Apples
pe	Pears
sf	Stone fruit
nu	Nuts
bf	Berry fruit
pf	Plantation fruit
gr	Grapes

4. Control site #: i.e. 1, 2 or 3

Example

The Victorian SLA called 'Wyndham (C) - Werribee' (SLA code 205207265) has the SLA # of 1 and has been selected for control sites for the following agricultural commodities – pastures, cereals excluding rice and other vegetables. Thus the Excel worksheets to be returned would be named:

vic01pa1.xls
vic01pa2.xls
vic01pa3.xls

vic01ce1.xls
vic01ce2.xls
vic01ce3.xls

vic01ov1.xls
vic01ov2.xls
vic01ov3.xls

Return the completed "Control Site Data Form" either via email as an attachment or placed on BRS's ftp site.   Email attachments should be sent to **landuse@brs.gov.au** and contain only the Excel workbook (i.e. no accompanying text). Please email the Control Site Data Forms individually.

To access BRS' ftp site choose one of the following options:

1. Via DOS or Unix prompt
> ftp 152.91.71.102
Name: anonymous
Password: email name
> cd /nric/landuse96/controls
> bi *(to put in binary mode)*
> put control_site_file.xls *(to transfer file)*
> ls -l *(to check file size)*
> bye

2. Via Netscape
ftp://152.71.91.102
File -> Upload file *(control_site_file.xls)*

3. Via ftp client (e.g. WS_FTP pro)
ftp address: 152.71.91.102
Drag and drop control_site_file.xls

Please contact your Project Leader or
Jane Stewart
Coordinator for Control Site Collection
National Land Use Mapping Project
Tel : (02) 6272-3541   Postal Address :   Bureau of Rural Sciences
Fax : (02) 6272-4687   GPO Box E11
E-mail : Jane.Stewart@brs.gov.au   Kingston ACT 2604
if you have any questions relating to completing the Control Site Data Form.

Table A7.1.   Example of the sampling table. This is a reproduction of the Queensland version of Table 1 in the original control site data form instructions document.

Table 1. Statistical Local Areas in which control sites are to be located and the crop types to be sampled - QUEENSLAND

SLA #	SLA CODE	SLA NAME	Agroforestry	Pastures	Cereals Excluding Rice	Rice	Legumes	Oilseeds	Sugar Cane	Non-Cereal Forage Crops	Cotton	Other Non-Cereal Crops	Other Vegetables	Potatoes	Citrus	Apples	Pears	Stone Fruit	Nuts	Berry Fruit	Plantation Fruit	Grapes	INCLUDE	EXTRAS	TOTAL
1	305103496	Gold Coast (C) Bal in BSD		xx					SS	SS		xx											2	2	4
2	305202023	Caboolture (S) Bal in BSD		xx	xx																SS		1	2	3
3	305405983	Pine Rivers (S) Bal		xx	xx																SS		1	2	3
4	305506283	Redland (S) Bal		xx						SS		xx											1	2	3
5	310154917	Maroochy (S) Bal in S Cst SSD																	SS				1	0	1
6	310155752	Noosa (S) - Noosa-Noosaville																	SS				1	0	1
7	310200557	Beaudesert (S) - Pt B		xx	xx		xx			SS		xx						SS					2	4	6
8	310200800	Boonah (S)		xx	xx		xx					xx	SS					SS					2	4	6
9	310202031	Caboolture (S) - Pt B		xx	xx							xx		SS							SS		2	3	5
10	310202138	Caloundra (C) - Rail Corridor		xx					xx			xx			xx			SS	SS		SS		3	4	7
11	310203050	Esk (S)		xx	xx		xx					xx	SS	SS									2	4	6
12	310203250	Gatton (S)		xx	xx		xx					xx	SS	SS				SS					3	4	7
13	310203973	Ipswich (C) - South-West		xx	xx					SS	xx	xx											1	4	5
14	310204450	Laidley (S)		xx	xx		xx	xx				xx	SS	SS									2	5	7
15	310204918	Maroochy (S) Bal		xx	xx				SS					SS	xx			SS					3	3	6
16	310205758	Noosa (S) Bal		xx	xx				xx					SS				SS					2	3	5
17	315101984	Burnett (S) - Pt B		xx	xx		xx		xx	SS		xx	SS	SS	xx			SS	SS		SS		5	6	11
18	315102532	Cooloola (S) (excl. Gympie)		xx	xx		xx					xx	SS	SS				SS	SS				4	4	8
19	315103300	Gayndah (S)		xx	xx		xx	xx	xx						SS								1	5	6
20	315103750	Hervey Bay (C)		xx					xx									SS					1	2	3
21	315104000	Isis (S)		xx					SS	SS				SS									3	1	4
22	315104300	Kilkivan (S)		xx	xx		xx			SS													1	3	4
23	315104350	Kingaroy (S)		xx	xx		SS			SS		xx						xx					2	4	6
24	315104400	Kolan (S)		xx	xx				SS									SS					2	2	4
25	315105100	Miriam Vale (S)		xx	xx				xx	SS													1	3	4
26	315105450	Mundubbera (S)		xx	xx		xx								SS			SS				xx	2	4	6
27	315105500	Murgon (S)		xx	xx		xx			SS		xx											1	4	5
28	315106850	Tiaro (S)		xx	xx		xx	xx		SS								xx					1	5	6
29	315107450	Wondai (S)		xx	xx		xx	xx		SS		xx											1	5	6
30	320052150	Cambooya (S)		xx	xx		xx	xx		SS		xx	SS										2	5	7

Data from AgStats 96/97 (ABS, 1999). Analysis performed by CSIRO Mathematical and Information Sciences.

SS - include (satisfies criteria); xx - extras (present in SLA)

Table 1. Statistical Local Areas in which control sites are to be located and the crop types to be sampled - QUEENSLAND

SLA #	SLA CODE	SLA NAME	Agroforestry	Pastures	Cereals Excluding Rice	Rice	Legumes	Oilseeds	Sugar Cane	Non-Cereal Forage Crops	Cotton	Other Non-Cereal Crops	Other Vegetables	Potatoes	Citrus	Apples	Pears	Stone Fruit	Nuts	Berry Fruit	Plantation Fruit	Grapes	INCLUDE	EXTRAS	TOTAL
31	320052350	Chinchilla (S)		xx	xx		xx	xx		SS	xx	xx	SS										2	6	8
32	320052400	Clifton (S)		xx	xx		xx	xx		SS	xx	xx											1	6	7
33	320052550	Crows Nest (S)		xx	xx							xx						SS					1	3	4
34	320054200	Jondaryan (S)		xx	xx		xx	xx		SS	SS	xx											2	5	7
35	320055000	Millmerran (S)		xx	xx		xx	xx		SS	SS	xx											2	5	7
36	320056050	Pittsworth (S)		xx	xx		xx	xx		SS	SS	xx											2	5	7
37	320056450	Rosalie (S)		xx	xx		xx	xx		SS	xx	xx											1	6	7
38	320056600	Stanthorpe (S)		xx	xx								SS			SS	SS	SS				xx	4	3	7
39	320056700	Tara (S)		xx	SS		xx	xx			xx	xx											1	5	6
40	320056750	Taroom (S)		xx	xx		xx				xx	SS											1	4	5
41	320057100	Waggamba (S)		xx	SS		xx	xx			SS	xx											2	4	6
42	320057150	Wambo (S)		xx	SS		SS	xx		SS	SS	SS											5	2	7
43	320057263	Warwick (S) - East		xx	xx		xx	xx				xx		SS									1	5	6
44	320057265	Warwick (S) - North		xx	xx		xx	xx				xx		SS									1	5	6
45	325050300	Balonne (S)		xx	SS		xx	xx			SS	xx										xx	2	5	7
46	330102101	Calliope (S) - Pt A		xx	xx													SS					1	2	3
47	330150350	Banana (S)		xx	SS		SS	xx		SS	xx	SS											4	3	7
48	330150500	Bauhinia (S)	SS	xx	SS		xx	SS		SS	xx	xx											4	4	8
49	330152104	Calliope (S) - Pt B		xx	xx													SS					1	2	3
50	330153000	Emerald (S)		xx	xx		SS	SS		SS	SS	xx			SS							xx	5	4	9
51	330154550	Livingstone (S)		xx	xx		xx											SS		xx	SS		2	4	6
52	330155850	Peak Downs (S)		xx	xx		xx	SS				xx											1	4	5
53	335050900	Boulia (S)		SS																			1	0	1
54	335053850	Ilfracombe (S)	SS	xx																			1	1	2
55	335054050	Isisford (S)		xx						SS													1	1	2
56	335054700	Longreach (S)		xx						SS													1	1	2
57	340054762	Mackay (C) - Pt A							SS														1	0	1
58	340100600	Belyando (S)	SS	xx	xx		xx	SS				xx											2	4	6
59	340101700	Broadsound (S)	SS	xx	xx		xx	xx	SS	SS		xx											3	5	8
60	340104765	Mackay (C) - Pt B		xx					SS														1	1	2

Data from AgStats 96/97 (ABS, 1999). Analysis performed by CSIRO Mathematical and Information Sciences.

SS - include (satisfies criteria); xx - extras (present in SLA)

Table 1. Statistical Local Areas in which control sites are to be located and the crop types to be sampled - QUEENSLAND

SLA #	SLA CODE	SLA NAME	Agroforestry	Pastures	Cereals Excluding Rice	Rice	Legumes	Oilseeds	Sugar Cane	Non-Cereal Forage Crops	Cotton	Other Non-Cereal Crops	Other Vegetables	Potatoes	Citrus	Apples	Pears	Stone Fruit	Nuts	Berry Fruit	Plantation Fruit	Grapes	INCLUDE	EXTRAS	TOTAL
61	340105050	Mirani (S)		xx	xx				SS														1	2	3
62	340105700	Nebo (S)		xx	xx					SS		xx											1	3	4
63	340106550	Sarina (S)		xx			xx		SS														1	2	3
64	340107330	Whitsunday (S)		xx	xx				SS														1	2	3
65	345150950	Bowen (S)		xx			xx						SS					SS					2	2	4
66	345151900	Burdekin (S)		xx	xx				SS				SS					SS					3	2	5
67	345152700	Dalrymple (S)		xx	xx			xx			xx			SS									1	4	5
68	345153800	Hinchinbrook (S)		xx					SS									xx					1	2	3
69	345156831	Thuringowa (C) - Pt B		xx					xx					SS				SS			xx		2	3	5
70	350100200	Atherton (S)		xx	xx		xx		xx			xx		SS				SS	SS				3	5	8
71	350102078	Cairns (C) - Pt B		xx					SS			xx						xx			SS		2	3	5
72	350102200	Cardwell (S)		xx					SS									SS			SS		3	1	4
73	350102501	Cook (S) (excl. Weipa)		xx	xx		xx			SS													1	3	4
74	350102800	Douglas (S)		xx	xx				SS														1	1	2
75	350103700	Herberton (S)		xx	xx		xx		xx					SS									1	4	5
76	350104150	Johnstone (S)		xx					SS			xx			xx			xx			SS		2	3	5
77	350104850	Mareeba (S)		SS	xx		xx		xx			SS	SS		xx			SS	xx				4	5	9
78	355051950	Burke (S)		SS																			1	0	1
79	355052250	Carpentaria (S)		SS						SS													2	0	2
80	355052450	Cloncurry (S)		SS	xx																		1	1	2

Data from AgStats 96/97 (ABS, 1999). Analysis performed by CSIRO Mathematical and Information Sciences.

SS - include (satisfies criteria); xx - extras (present in SLA)

Table 1. Statistical Local Areas in which control sites are to be located and the crop types to be sampled - QUEENSLAND

KEY :
SLA #	Number of Statistical Local Area as on map
SLA CODE	SLA Australian Standard Geographical Classification (9 digit code)
SLA NAME	Name of Statistical Local Area

Agricultural Commodities according to Audit Commodity Classification - Criteria for inclusion

Agroforestry	All SLAs down to 70 % of total production in Australia
Pastures	All SLAs which contain 5 % or more of state's production
Cereals excluding rice	All SLAs which contain 5 % or more of state's production
Rice	All SLAs which contain 1 % or more of Australia's production
Legumes	All SLAs which contain 5 % or more of state's production
Oilseeds	All SLAs which contain 5 % or more of state's production
Sugar cane	All SLAs which contain 1 % or more of Australia's production
Non-cereal forage crops	All SLAs which contain 1 % or more of state's production
Cotton	All SLAs which contain 1 % or more of Australia's production
Other non-cereal crops	All SLAs which contain 5 % or more of state's production
Other vegetables	All SLAs which contain 1 % or more of state's production
Potatoes	All SLAs which contain 1 % or more of state's production
Citrus	All SLAs which contain 1 % or more of Australia's production
Apples	All SLAs which contain 1 % or more of Australia's production
Pears	All SLAs which contain 1 % or more of Australia's production
Stone fruit	All SLAs which contain 1 % or more of state's production
Nuts	All SLAs which contain 1 % or more of Australia's production
Berry fruit	Not included as insufficient SLAs with 100 ha or more
Plantation fruit	All SLAs which contain 1 % or more of Australia's production
Grapes	All SLAs which contain 1 % or more of Australia's production

Number of commodities to be sampled

INCLUDE	Commodities which satisfy the criteria for inclusion (SS).
EXTRAS	Extra commodities which occur in a selected SLA under the inclusion criteria with greater than or equal to 100 ha of production (xx).
TOTAL	Total number of different agricultural commodities to be sampled - 3 replicates required for each different crop type.

1. For Pastures - please try and locate one control site in pure lucerne.

Data from AgStats 96/97 (ABS, 1999). Analysis performed by CSIRO Mathematical and Information Sciences.   SS - include (satisfies criteria); xx - extras (present in SLA)   1

Statistical Local Areas in QUEENSLAND where control sites are required
(for the National Land Use Mapping Project - a National Land and Water Resources Audit project)

Inset Map A

Inset Map B

Inset Map C

Inset Map D

Inset Map E

See Inset Map A

See Inset Map C

See Inset Map D

See Inset Map E

See Inset Map B

Total Number of Different Agricultural Commodities to be Sampled

1 3 5 7 9 11 13
2 4 6 8 10 12

Source : Australian Bureau of Statistics (1999). AgStats : Small Area of Agricultural Commodity Data 1996-97.
Analysis performed by CSIRO Mathematical and Information Sciences.

See table 'Statistical Local Areas (SLAs) in which control sites are to be located and the crop type to be sampled - QUEENSLAND'
for names of SLAs selected and the agricultural commodities to be sampled.

June 1999

Figure A7.2.   Example of the sampling map. This is a reproduction of the Queensland sampling map provided
with the original control site data form instructions document.

Control site data form

The control site data form is reproduced on the following pages.

Control Site Data Form

Agricultural Commodity Production Control Sites
for the National Land Use Mapping Project
(part of the National Land and Water Resources Audit)

00449-01

Instructions

1. Please refer to Table 1 for the list of agricultural commodities to be sampled in each Statistical Local Area (SLA) for your State.

2. For each commodity listed against a SLA the objective is to obtain information from 3 different sites.

3. Please select a site located in the centre of a paddock or orchard which grew the particular commodity in 1996-97. Try to avoid sites close to roads or other features such as remnant stands of vegetation or large dams. Ideally the site chosen should be situated in the centre of an area at least 4 km^2 planted with the commodity. Where this is not possible, please indicate the area in which the particular commodity dominates.

4. Complete this form with as many details as possible. The minimum is the "Site location details" and "Agricultural commodity harvested at site in 1996/97". The form should be returned as a Microsoft Excel Workbook (preferably 97 or 5.0/95) via ftp or as an email attachment to **landuse@brs.gov.au**.

5. Respondents are to be provided with background to the National Land and Water Resources Audit and the National Land Use Mapping Project.

6. Please refer to the "Instructions for Completing the Control Site Data Form" for further details.

7. To print this form print pages 1 to 13 only.

Details of person completing form

Name

Organisation

Address

Telephone Number

Fax Number

Email Address

Name of control site

Indicate file name prefix ⟶
(follow convention of state, SLA number, agricultural commodity and control site number e.g. vic01pa1 as given in "Return of the Control Site Data Form" in the Instructions handout)

Site location details

1. Provide location

Give as latitude and longitude. Use Attachment C and D if need to convert from grid coordinates.
Preferred datum is the World Geodetic System 1984 (WGS84) reference system.

	Longitude (decimal degrees)	Latitude (decimal degrees)
1a. Latitude and Longitude	E	S

	Preferred options	See Attachment C for common options if not preferred option (give as abbreviation)
1b. Projection (tick box or write in box alongside)	☐ Universal Transverse Mercator	
1c. Coordinate System (tick box or write in box alongside)	☐ WGS84	
1d. Ellipsoid (tick box or write in box alongside)	☐ WGS84	

1e. Source of coordinates :   ☐ GPS

☑ Hardcopy map   ⟶   Scale   1 :

Sheet number

☐ Other
(please specify)

2. Describe location

2a. State (select from list or write in box)   NSW ▼

2b. Statistical Local Area (SLA)
(select from list or see Attachment A and
write in box)   Wollondilly (A) ▼

2c. Nearest town

2d. Distance and direction from nearest town

2e. Property Address

2f. Brief description of site
(e.g. control site in centre of 100 ha square paddock
of gently undulating land on a wheat/sheep property.
Surrounding paddocks/properties similar land use.)

2g. Current (1999) land use
(select from list or see Attachment B and write in box)

AGROFORESTRY ▼

ABS Level 3 Classification (118 classes)

Other (please specify)

2h. Photograph of site taken (tick box)

☐ YES   ☐ NO

Film #, Shot #

2i. Date site visited

☐ Not visited

Principal (by area) agricultural commodity harvested at site in 1996/97 :

*This is the agricultural commodity for which the control site has been chosen and coordinates of location provided. The following questions relate to the crop harvested in the period **1st April 1996 - 31st March, 1997**. If double cropping or strip cropping occurred please indicate the other commodity or commodities harvested in 1996/97 under "Cropping system" below.*

3a. Commodity harvested in 1996/97
(Select from list or see Attachment B and write in box)

AGROFORESTRY ▼

ABS Level 3 Classification (118 classes)

Other (please specify)

3b. For annual crops indicate :

Month sown

Month harvested

3c. Indicate crop age in 1996/97 for orchards, berry/plantation fruit and grapes

☐ < 6 years   ☐ Not yet bearing fruit
☐ 6 years and over   ☐ Bearing fruit

3d. Was the pasture or crop irrigated?

☐ YES   ☐ NO

Cropping system at site in 1996/97 :

Were other crops grown at the site besides the selected agricultural commodity during 1996/97? If no, tick "Monoculture" and note additional comments, then go on to complete "Cropping management". Otherwise indicate the cropping system used and the commodities grown. "Site" refers to the control site and coordinates of the location provided, not the property as a whole.

☐ Monoculture (crop as given above)

☐ Double cropping (please specify other crop grown)

Select commodity from list or see
Attachment B and write in box

AGROFORESTRY ▼

ABS Level 3 Classification (118 classes)

Month sown

Month harvested

☐ Strip cropping (please specify other crop/s grown)

Next dominant crop   AGROFORESTRY ▼

Select commodity from list/s or see
Attachment B and write in box/es

Other crop   AGROFORESTRY ▼

	Next dominant crop	Other crop
ABS Level 3 Classification (118 classes)		
Month sown		
Month harvested		

☐ Other (please specify and list crops involved)

Next dominant crop   AGROFORESTRY ▼

Select commodity from list/s or see
Attachment B and write in box/es

Other crop   AGROFORESTRY ▼

	Next dominant crop	Other crop
ABS Level 3 Classification (118 classes)		
Month sown		
Month harvested		

4b. Additional comments
(e.g. typical cropping system for property,
sowing and harvesting dates typical,
unusually wet/dry season)

Crop management at site in 1996/97 :

*Tillage practices, stubble management, fallow type and fallow length relate to the **preparation** of the site for the commodity or commodities grown in 1996/97. Irrigation type and frequency relate to the commodity or commodities **harvested** at the site in 1996/97. Refer to "Points of Clarification" in the Instructions handout for further details.*

5a. Tillage practices (tick one box only)

☐ Not relevant

☐ Conventional tillage
☐ Minimum tillage
☐ Direct drill
☐ Other (please specify) ➝ [ ]

5b. Stubble management (tick one box only)

☐ Not relevant

☐ Burnt - early
☐ Burnt - late
☐ Incorporated
☐ Retained
☐ Other (please specify) ➝ [ ]

5c. Fallow type (tick one box only)

☐ Not relevant

☐ Cultivated
☐ Uncultivated / herbicide
☐ Pasture topping
☐ Other (please specify) ➝ [ ]

5d. Fallow length (tick one box only)

☐ Not relevant

☐ > 12 months
☐ 6 - 12 months
☐ 1 - 6 months
☐ < 1 month

5e. Irrigation type (tick one box only)

☐ Not relevant

☐ Flood
☐ Ditch
☐ Spray
☐ Trickle
☐ Other (please specify) ➝ [ ]

5f. Irrigation frequency
(e.g. daily, weekly, monthly, at particular growth stages)

[ ]

5g. Additional comments
(e.g. typical rotations, tillage implements used,
stock type and stocking rate)

Principal (by area) agricultural commodity harvested at site in 1997/98 :

*This is the agricultural commodity for which the control site has been chosen and coordinates of location provided. The following questions relate to the crop harvested in the period **1st April 1997 - 31st March, 1998**. If double cropping or strip cropping occurred please indicate the other commodity or commodities harvested in 1997/98 under "Cropping system" below.*

6a. Commodity harvested in 1997/98
(Select from list or see Attachment B and write in box)

AGROFORESTRY ▼

ABS Level 3 Classification (118 classes)

Other (please specify)

6b. For annual crops indicate :

Month sown

Month harvested

6c. Indicate crop age in 1997/98 for orchards, berry/plantation fruit and grapes

☐ < 6 years   ☐ Not yet bearing fruit
☐ 6 years and over   ☐ Bearing fruit

6d. Was the pasture or crop irrigated ?

☐ YES   ☐ NO

Cropping system at site in 1997/98 :

Were other crops grown at the site besides the selected agricultural commodity during 1997/98? If no, tick "Monoculture" and note additional comments, then go on to complete "Cropping management". Otherwise indicate the cropping system used and the commodities grown. "Site" refers to the control site and coordinates of the location provided, not the property as a whole.

☐ Monoculture (crop as given above)

☐ Double cropping (please specify other crop grown)

Select commodity from list or see
Attachment B and write in box

| AGROFORESTRY | ▼ |

ABS Level 3 Classification (118 classes)

| |

Month sown | |

Month harvested | |

☐ Strip cropping (please specify other crop/s grown)

Next dominant crop | AGROFORESTRY | ▼ |

Select commodity from list/s or see
Attachment B and write in box/es

Other crop | AGROFORESTRY | ▼ |

	Next dominant crop	Other crop
ABS Level 3 Classification (118 classes)		
Month sown		
Month harvested		

☐ Other (please specify and list crops involved)

| |

Next dominant crop | AGROFORESTRY | ▼ |

Select commodity from list/s or see
Attachment B and write in box/es

Other crop | AGROFORESTRY | ▼ |

	Next dominant crop	Other crop
ABS Level 3 Classification (118 classes)		
Month sown		
Month harvested		

7b. Additional comments
(e.g. typical cropping system for property,
sowing and harvesting dates typical,
unusually wet/dry season)

| |

Crop management at site in 1997/98 :

*Tillage practices, stubble management, fallow type and fallow length relate to the **preparation** of the site for the commodity or commodities grown in 1997/98. Irrigation type and frequency relate to the commodity or commodities **harvested** at the site in 1997/98. Refer to "Points of Clarification" in the Instructions handout for further details.*

8a. Was crop management the same as for 1996/97?　　☐ YES (go to Question 9)　　☐ NO (go tor Question 8b)

8b. Tillage practices (tick one box only)
☐ Not relevant

☐ Conventional tillage
☐ Minimum tillage
☐ Direct drill
☐ Other (please specify) ⟶ [   ]

8c. Stubble management (tick one box only)
☐ Not relevant

☐ Burnt - early
☐ Burnt - late
☐ Incorporated
☐ Retained
☐ Other (please specify) ⟶ [   ]

8d. Fallow type (tick one box only)
☐ Not relevant

☐ Cultivated
☐ Uncultivated / herbicide
☐ Pasture topping
☐ Other (please specify) ⟶ [   ]

8e. Fallow length (tick one box only)
☐ Not relevant

☐ > 12 months
☐ 6 - 12 months
☐ 1 - 6 months
☐ < 1 month

8f. Irrigation type (tick one box only)
☐ Not relevant

☐ Flood
☐ Ditch
☐ Spray
☐ Trickle
☐ Other (please specify) ⟶ [   ]

8g. Irrigation frequency
(e.g. daily, weekly, monthly, at particular growth stages)

[   ]

184

8h. Additional comments
(e.g. typical rotations, tillage implements used,
stock type and stocking rate)

Principal (by area) agricultural commodity harvested at site in 1998/99 :

*This is the agricultural commodity for which the control site has been chosen and coordinates of location provided. The following questions relate to the crop harvested in the period **1st April 1998 - 31st March, 1999**. If double cropping or strip cropping occurred please indicate the other commodity or commodities harvested in 1998/99 under "Cropping system" below.*

9a. Commodity harvested in 1998/99
(Select from list or see Attachment B and write in box)

AGROFORESTRY ▼

ABS Level 3 Classification (118 classes)

Other (please specify)

9b. For annual crops indicate :

Month sown

Month harvested

9c. Indicate crop age in 1998/99 for orchards, berry/plantation fruit and grapes

☐ < 6 years ☐ Not yet bearing fruit
☐ 6 years and over ☐ Bearing fruit

9d. Was the pasture or crop irrigated ?

☐ YES ☐ NO

Cropping system at site in 1998/99 :

Were other crops grown at the site besides the selected agricultural commodity during 1998/99? If no, tick "Monoculture" and note additional comments, then go on to complete "Cropping management". Otherwise indicate the cropping system used and the commodities grown. "Site" refers to the control site and coordinates of the location provided, not the property as a whole.

☐ Monoculture (crop as given above)

☐ Double cropping (please specify other crop grown)

Select commodity from list or see
Attachment B and write in box

AGROFORESTRY ▼

ABS Level 3 Classification (118 classes)

Month sown

Month harvested

☐ Strip cropping (please specify other crop/s grown)

Next dominant crop AGROFORESTRY ▼

Select commodity from list/s or see
Attachment B and write in box/es

Other crop AGROFORESTRY ▼

	Next dominant crop	Other crop
ABS Level 3 Classification (118 classes)		
Month sown		
Month harvested		

☐ Other (please specify and list crops involved)

Next dominant crop AGROFORESTRY ▼

Select commodity from list/s or see
Attachment B and write in box/es

Other crop AGROFORESTRY ▼

	Next dominant crop	Other crop
ABS Level 3 Classification (118 classes)		
Month sown		
Month harvested		

10b. Additional comments
(e.g. typical cropping system for property,
sowing and harvesting dates typical,
unusually wet/dry season)

186

Crop management at site in 1998/99 :

*Tillage practices, stubble management, fallow type and fallow length relate to the **preparation** of the site for the commodity or commodities grown in 1998/99. Irrigation type and frequency relate to the commodity or commodities **harvested** at the site in 1998/99. Refer to "Points of Clarification" in the Instructions handout for further details.*

11a. Was crop management the same as for 1997/98? ☐ YES (go to Question 12) ☐ NO (go tor Question 11b)

11b. Tillage practices (tick one box only)
☐ Not relevant

☐ Conventional tillage
☐ Minimum tillage
☐ Direct drill
☐ Other (please specify) ⟶ ▭

11c. Stubble management (tick one box only)
☐ Not relevant

☐ Burnt - early
☐ Burnt - late
☐ Incorporated
☐ Retained
☐ Other (please specify) ⟶ ▭

11d. Fallow type (tick one box only)
☐ Not relevant

☐ Cultivated
☐ Uncultivated / herbicide
☐ Pasture topping
☐ Other (please specify) ⟶ ▭

11e. Fallow length (tick one box only)
☐ Not relevant

☐ > 12 months
☐ 6 - 12 months
☐ 1 - 6 months
☐ < 1 month

11f. Irrigation type (tick one box only)
☐ Not relevant

☐ Flood
☐ Ditch
☐ Spray
☐ Trickle
☐ Other (please specify) ⟶ ▭

11g. Irrigation frequency
(e.g. daily, weekly, monthly, at particular growth stages)

11h. Additional comments
(e.g. typical rotations, tillage implements used,
stock type and stocking rate)

Degradation management at site

12a. Indicate the 3 most important degradation types which have management implications at the site *(tick box)*.

☐ No degradation

☐ Only 1 degradation type (indicate which one below and its present state)

☐ Only 2 degradation types (indicate which ones below and their present state)

☐ 3 degradation types (indicate which ones below and their present state)

Degradation type (tick up to 3 boxes)	Present state (tick a box)		
☐ Wind erosion	☐ Improving	☐ Stable	☐ Worsening
☐ Water erosion	☐ Improving	☐ Stable	☐ Worsening
☐ Dryland salinity	☐ Improving	☐ Stable	☐ Worsening
☐ Salinity under irrigation	☐ Improving	☐ Stable	☐ Worsening
☐ Soil acidity	☐ Improving	☐ Stable	☐ Worsening
☐ Soil structural decline	☐ Improving	☐ Stable	☐ Worsening
☐ Waterlogging	☐ Improving	☐ Stable	☐ Worsening
☐ Sodicity	☐ Improving	☐ Stable	☐ Worsening
☐ Woody weed infestation	☐ Improving	☐ Stable	☐ Worsening
☐ Non-woody weed infestation	☐ Improving	☐ Stable	☐ Worsening
☐ Vertebrate pests	☐ Improving	☐ Stable	☐ Worsening
☐ Invertebrate pests	☐ Improving	☐ Stable	☐ Worsening
☐ Other (please specify below)	☐ Improving	☐ Stable	☐ Worsening

188

12b. Additional comments
(e.g. typical degradation types for region, proportion
of property affected, costs in lost production and/or
amelioration, methods used to combat degradation)

NOTES :

189

Control site database

Figures A7.3 to A7.8 illustrate the control site database.
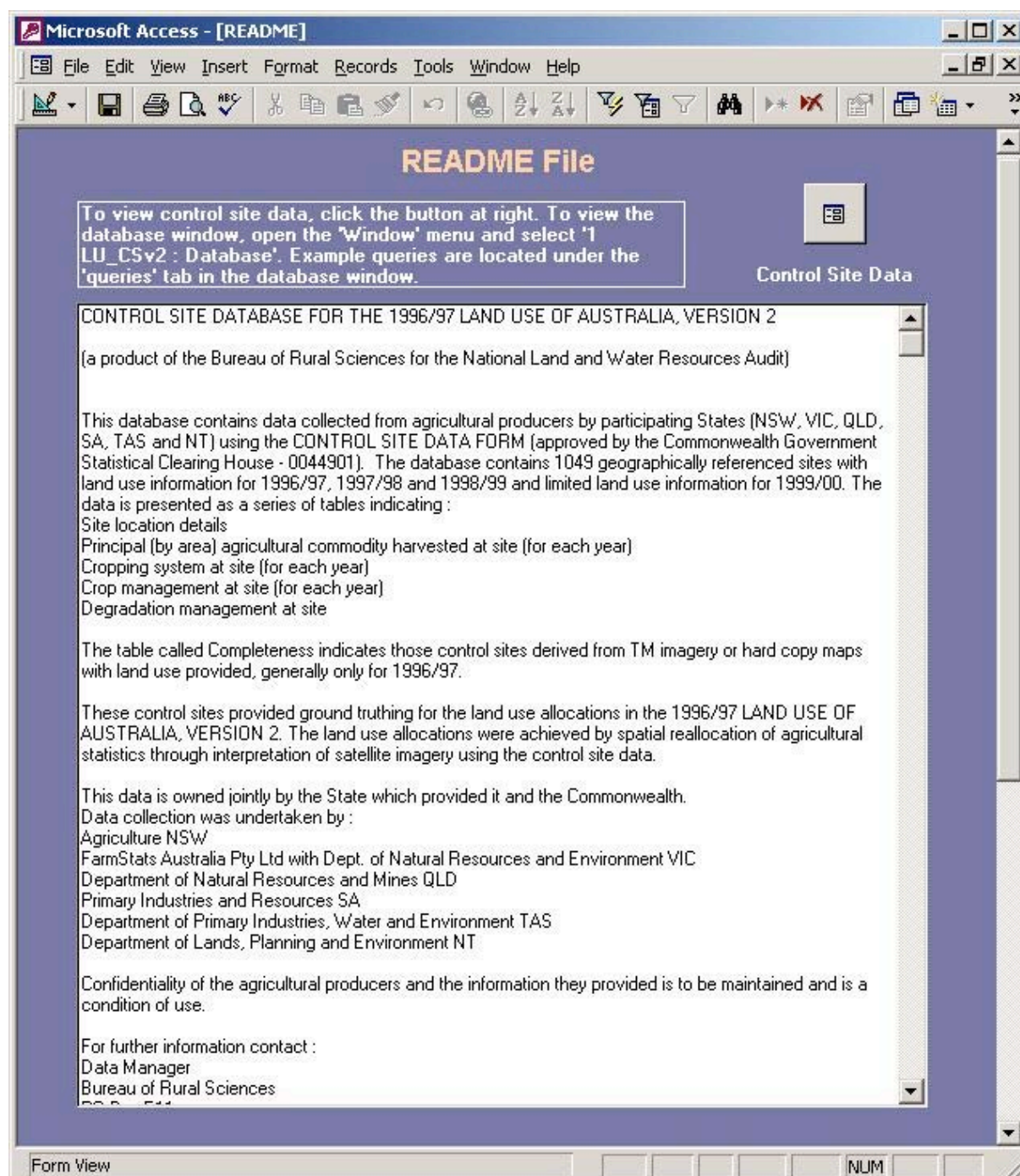
Figure A7.3. Readme of control site database for the 1996/97 Land Use of Australia, Version 2.

Figure A7.4. Control tab of control site database using control site qld50co3 as an example.

Figure A7.5. Principal agricultural commodity tab of control site database using 1996/97 land use of control site qld50co3 as an example.

Figure A7.6. Cropping system tab of control site database using 1996/97 land use of contol site qld50co3 as an example.
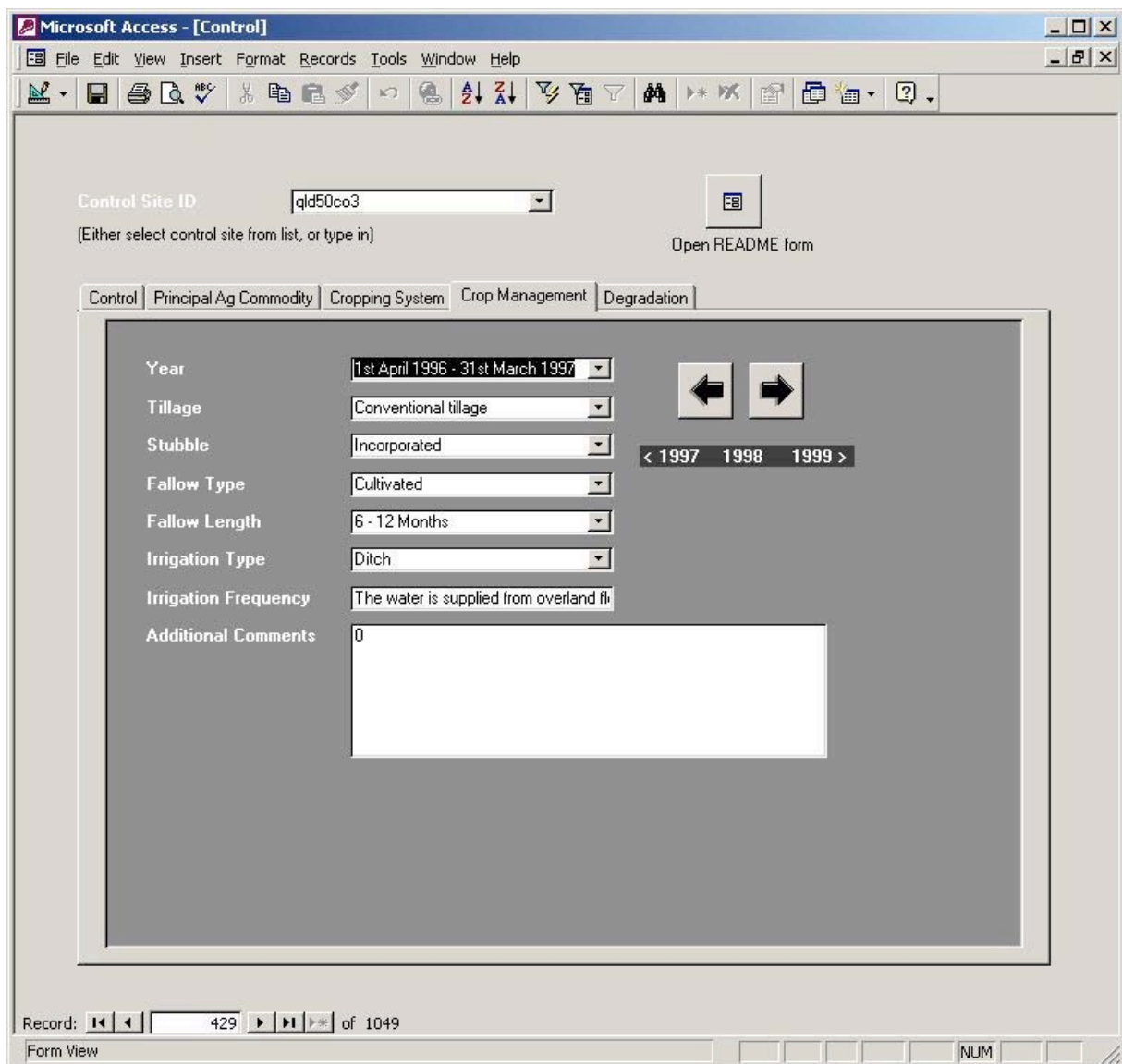
Figure A7.7. Crop management tab of control site database using 1996/97 land use of control site qld50co3 as an example.

Figure A7.8. Degradation tab of control site database using 1996/97 land use of control site qld50co3 as an example.

Querying of control site database

The following examples illustrate the types of information that can be obtained from the Control Site Database.

Tillage practices by State for cereals excluding rice

Considering crop management, the range of tillage practices undertaken for a crop type can be shown by State. Tillage practices have been considered for the 3 years available to maximise sample size. Figure A7.9 indicates that for the sites sampled, tillage practices differ between States for the Audit commodity 'cereals excluding rice'. Queensland and Tasmania predominantly undertake conventional tillage. In New South Wales, conventional tillage and minimum tillage are equally the main tillage practices undertaken. In South Australia and Victoria, minimum tillage was the most common practice. Direct drilling was undertaken in all States except Tasmania. If best practice is not to undertake conventional tillage (more than 2 passes with discs, tines, ploughs etc for weed control or seedbed preparation prior to sowing), then this data would suggest establishing why this practice is common in Queensland and Tasmania for 'cereals excluding rice' as a starting point for any initiative to change tillage practices.
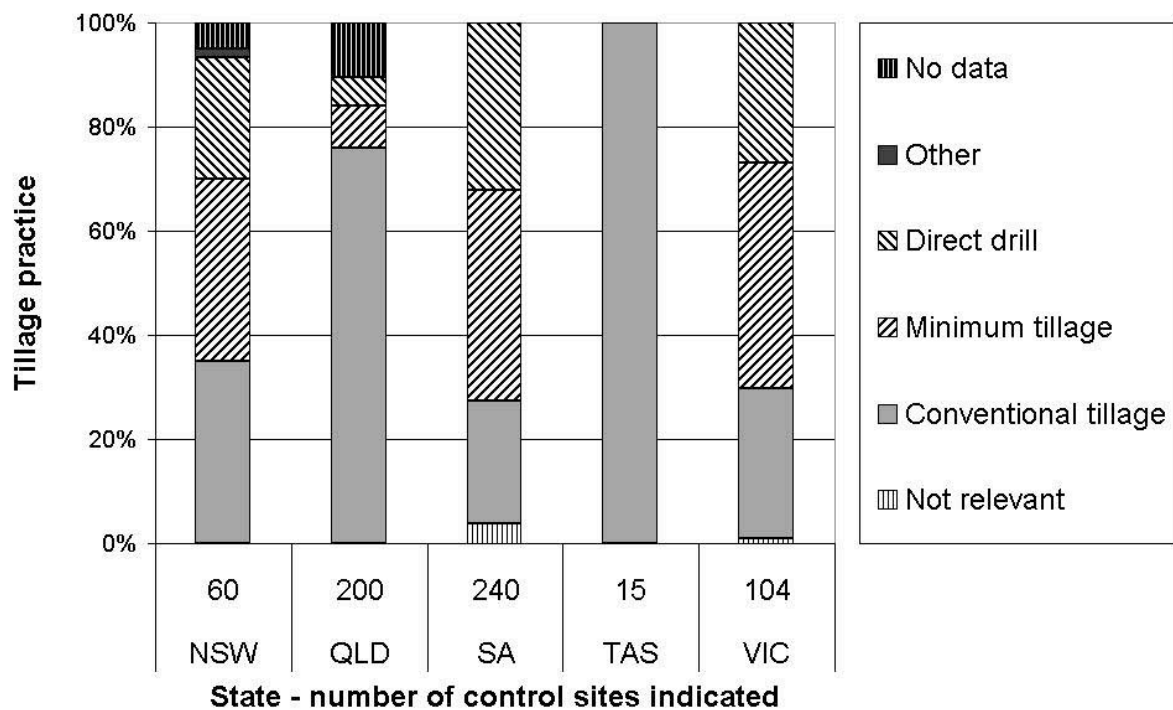
Figure A7.9. Tillage practices undertaken by States for control sites growing 'cereals excluding rice' in the years 1996/97 – 1998/99.

Types of irrigation practices by State for other vegetables

Another crop management example is to consider the types of irrigation practices undertaken by crop types by State. The Audit commodity 'other vegetables' was selected as this is generally irrigated. Again data was used for the 3 available years. Figure A7.10 shows for the States considered, spray irrigation is the most common method used followed by trickle irrigation. These methods tend to be more efficient in water use compared to the methods more commonly employed for broadacre cropping (i.e. flood or ditch).
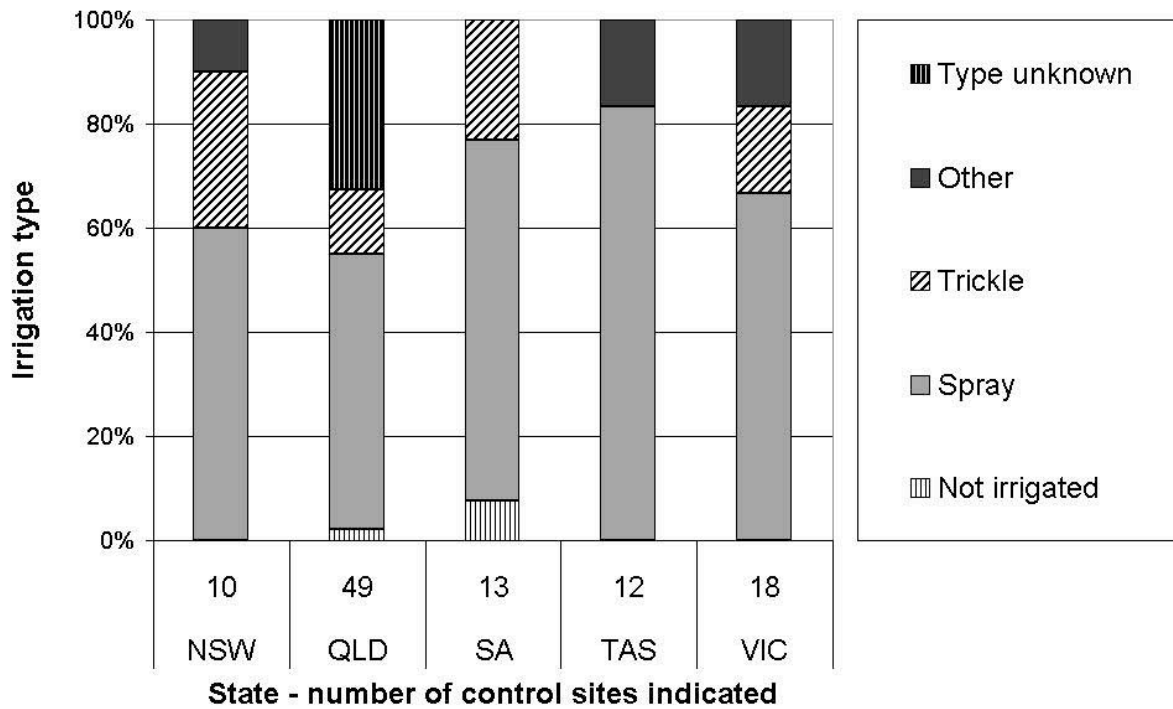
Figure A7.10. Type of irrigation undertaken by States for control sites growing 'other vegetables' in the years 1996/97 – 1998/99.

Degradation types with management implications

Respondents were asked to indicate the 3 most important degradation types with management implications at the site. Generally only 1 degradation type was an issue and the most common degradation types and combinations are listed in order of response in Table A7.2. The 3 main degradation types considered to be worsening are soil acidity, vertebrate pests and non-woody weeds. However, the small sample size needs to be considered when interpreting these results. Only 50% of respondents indicated any degradation issues requiring management, with 74% of Queensland's respondents having no degradation issues.

Of the respondents with degradation requiring management, invertebrate pests was the most important for Queensland; the combination of wind erosion, soil structural decline and non-woody weeds for South Australia and non-woody weeds for Victoria. The small sample size for the other States makes it difficult to draw conclusions.

Most respondents regard that they are successfully managing degradation on their properties with 'stable' the most common response.

Table A7.2.   Most common degradation types with management implications to control site respondents.

| Degradation type	No. respondents[a]	Present state		
		Improving	Stable	Worsening
No degradation	520			
Invertebrate pests	41	9.5	71.6	18.9
Non-woody weeds	37	21.6	58.0	20.5
Vertebrate pests	36	5.4	70.5	24.1
Water erosion	32	32.3	61.5	6.3
Wind erosion	28 (another 20 in combination with non-woody weeds)	37.4	61.9	0.7
Woody weeds	26 (another 13 in combination with vertebrate pests)	12.5	75.0	12.5
Soil structural decline	23 (in combination with wind erosion and non-woody weeds)	59.3	38.3	2.5
Waterlogging	12	37.7	56.6	5.7
Soil acidity	11	34.7	38.8	26.5

[a] Total number of respondents was 1049 (i.e. number of control sites)

Figures showing location of control sites by State

Figures A7.11 to A7.16 are maps showing locations and agricultural commodity of control sites by state (for 1996/97 land use).
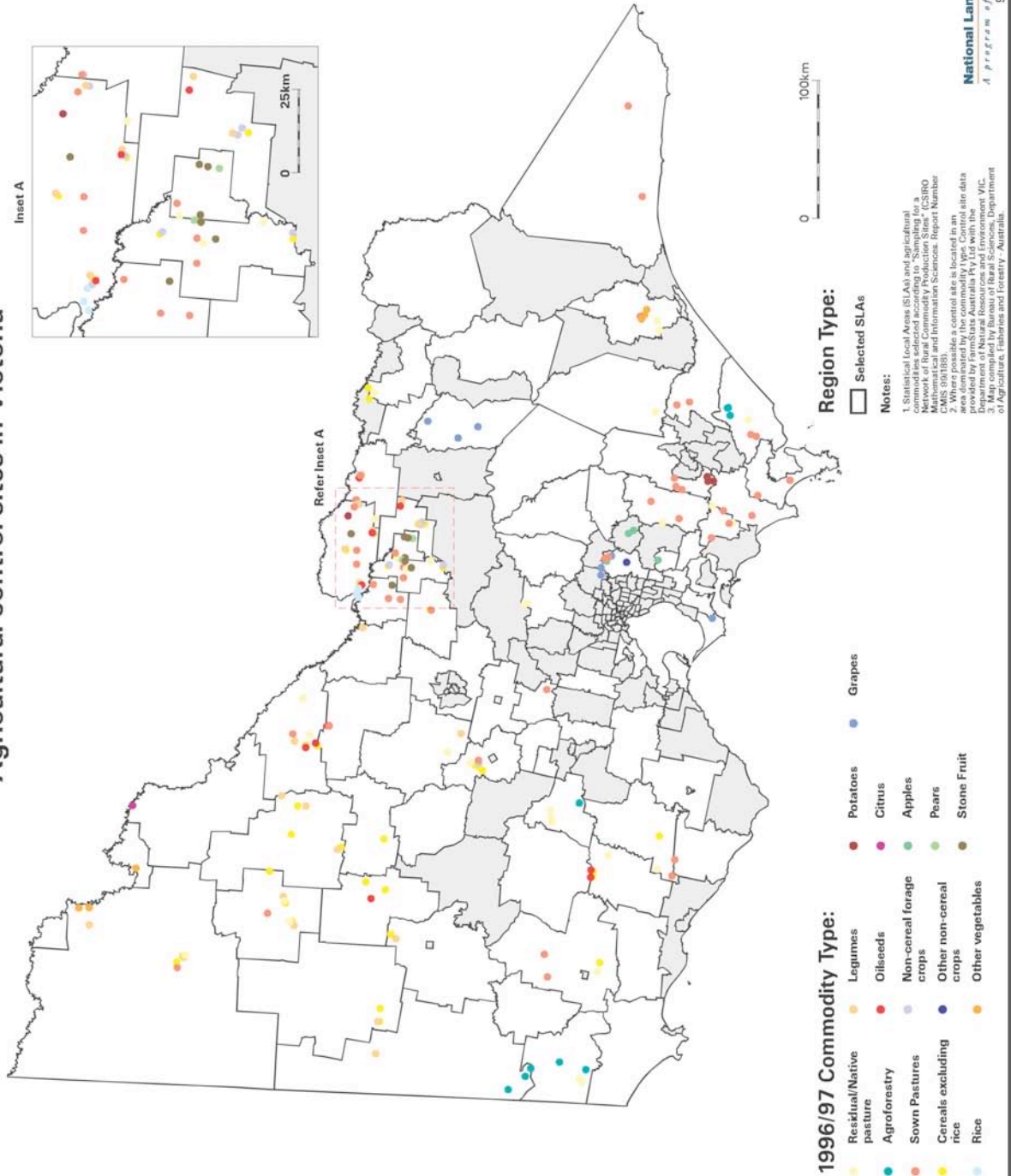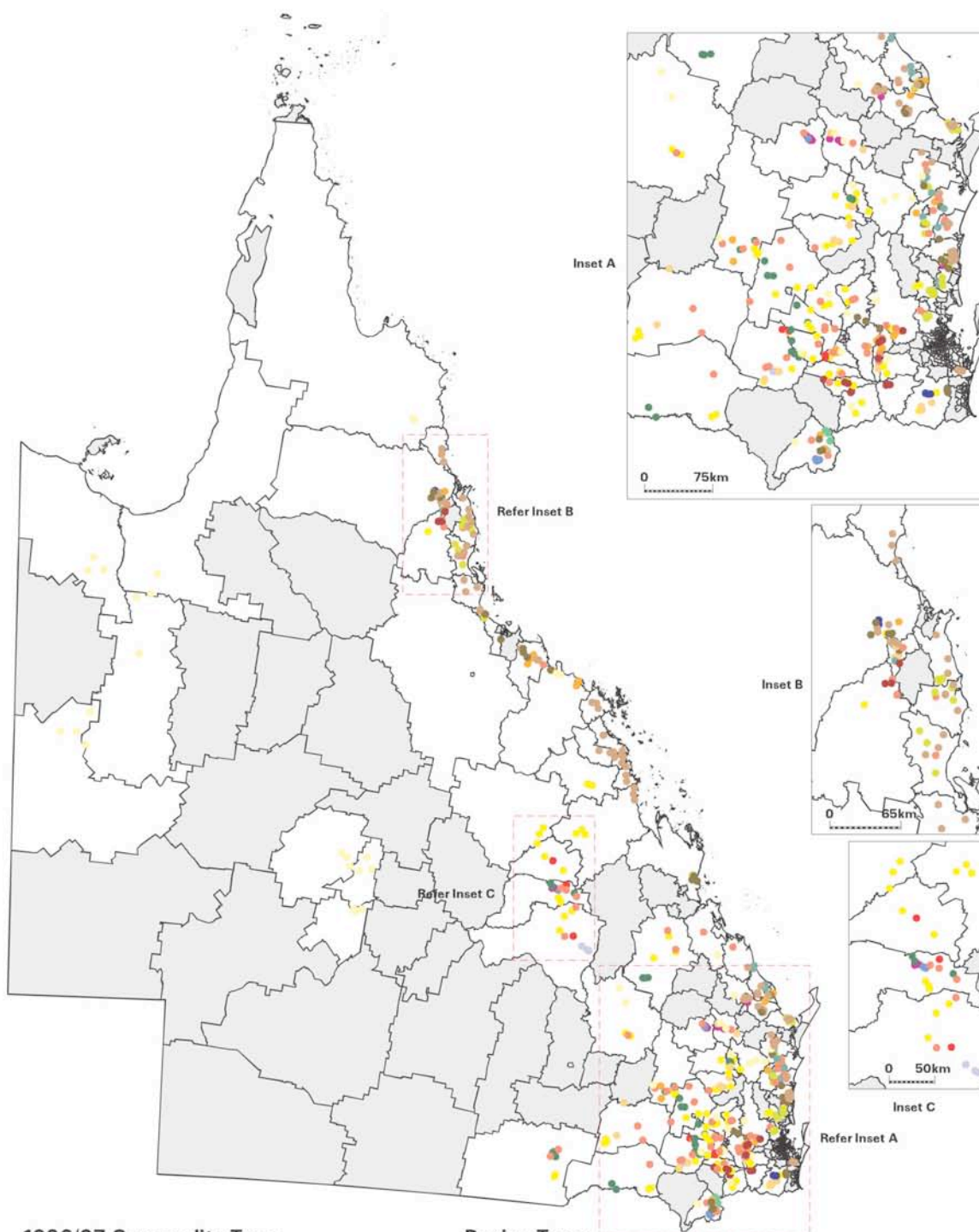
Figure A7.11.   (Facing page.) Agricultural control sites in NSW.

Agricultural control sites in New South Wales
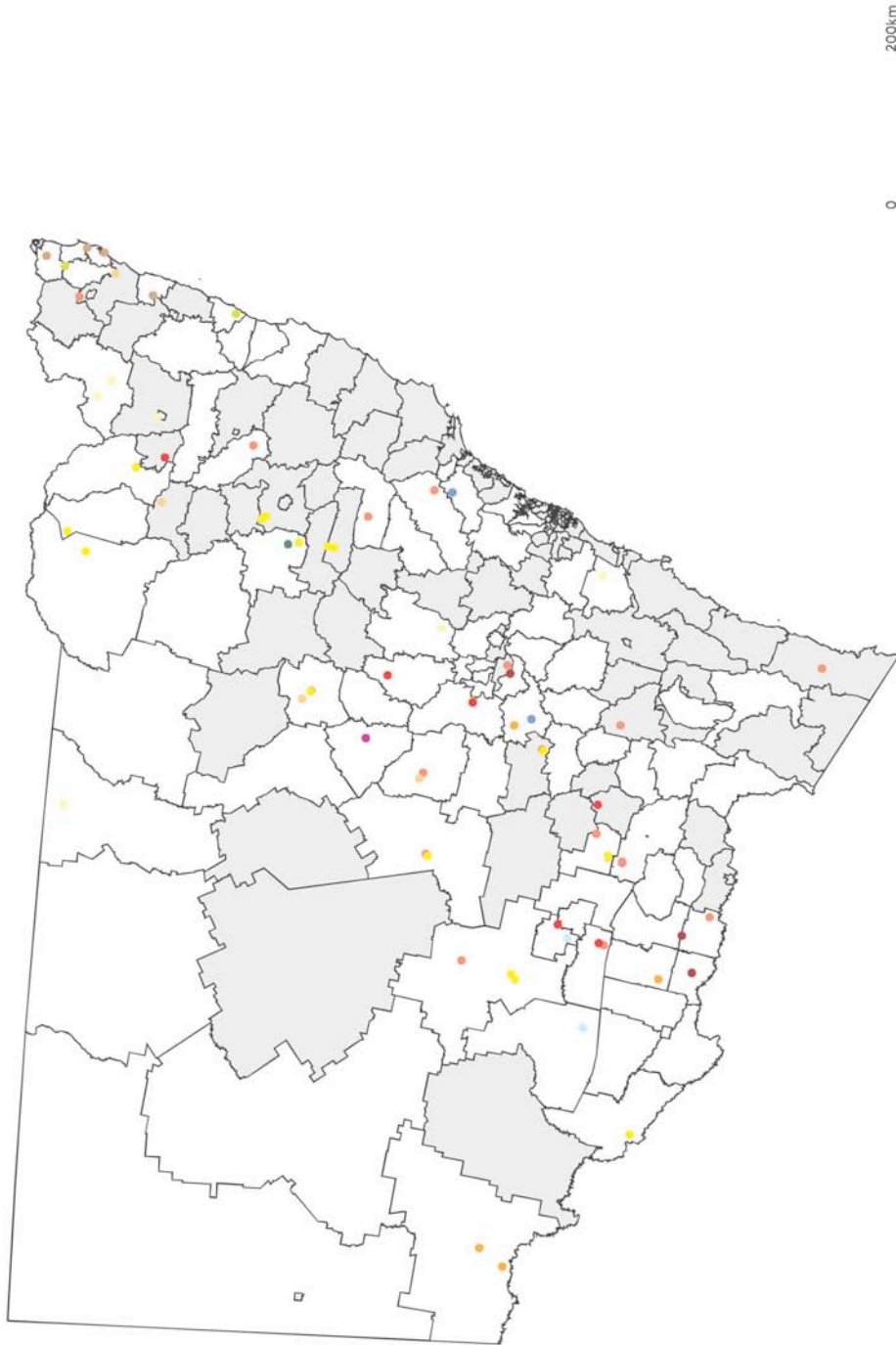
1996/97 Commodity Type:

- Residual/Native pasture
- Sown Pastures
- Cereals excluding rice
- Rice
- Legumes
- Oilseeds
- Sugar Cane
- Cotton
- Other vegetables
- Potatoes
- Citrus
- Plantation Fruit
- Grapes
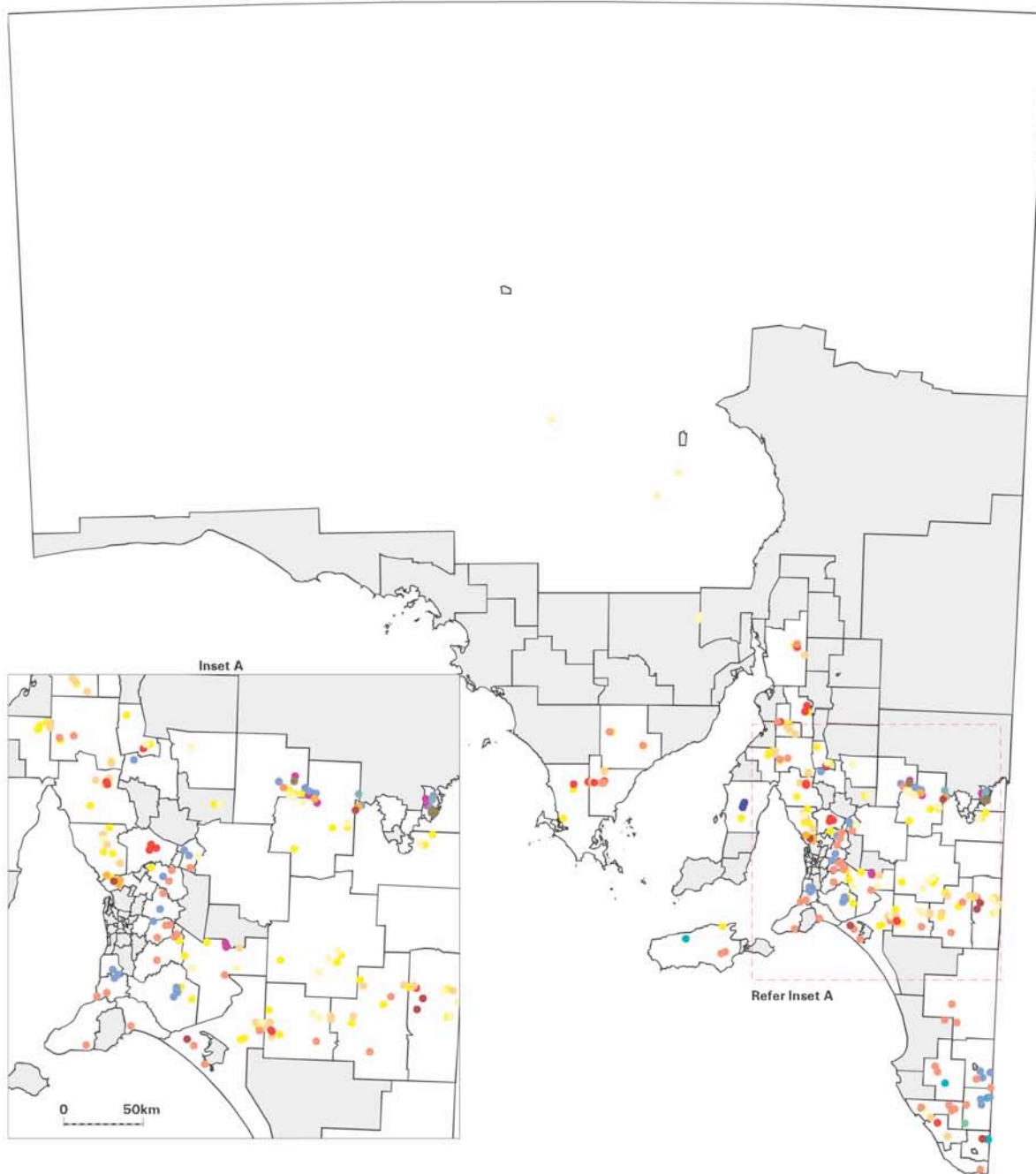
Region Type:

- Selected SLAs

Notes:

1. Statistical Local Areas (SLAs) and agricultural commodities selected according to "Sampling for a Network of Rural Commodity Production Sites" (CSIRO Mathematical and Information Sciences. Report Number CMIS 99/88).

2. Where possible a control site is located in an area dominated by the commodity type. Control site data provided by New South Wales Agriculture.

3. Map compiled by Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry - Australia.

0   200km

Figure A7.12.   (Facing page.) Agricultural control sites in Victoria.

Agricultural control sites in Victoria

Inset A

Refer Inset A

25km

0

1996/97 Commodity Type:

Residual/Native pasture

Agroforestry

Sown Pastures

Cereals excluding rice

Rice

Legumes

Oilseeds

Non-cereal forage crops

Other non-cereal crops

Other vegetables

Potatoes

Citrus

Apples

Pears

Stone Fruit

Grapes

Region Type:

Selected SLAs

Notes:

1. Statistical Local Areas (SLAs) and agricultural commodities selected according to 'Sampling for a Network of Rural Commodity Production Sites' (CSIRO Mathematical and Information Sciences. Report Number CMIS 98/188).
2. Where possible a control site is located in an area dominated by the commodity type. Control site data provided by FarmStats Australia Pty Ltd with the Department of Natural Resources and Environment VIC.
3. Map compiled by Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry Australia.

0   100km

National Land & Water Resources Audit
A program of the Natural Heritage Trust
9 December 2000

Figure A7.13. (Facing page.) Agricultural control sites in Queensland.

Agricultural control sites in Queensland

Inset A

0   75km

Refer Inset B

Inset B

0   65km

Refer Inset C

Inset C

0   50km

Refer Inset A

0   220km

1996/97 Commodity Type:

- Residual/Native pasture
- Sown Pastures
- Cereals excluding rice
- Legumes
- Oilseeds
- Sugar Cane
- Non-cereal forage crops
- Cotton
- Other non-cereal crops
- Other vegetables
- Potatoes
- Citrus
- Apples
- Pears
- Stone Fruit
- Nuts
- Plantation Fruit
- Grapes

Region Type:

- Selected SLAs

Notes:
1. Statistical Local Areas (SLAs) and agricultural commodities selected according to "Sampling for a Network of Rural Commodity Production Sites" (CSIRO Mathematical and Information Sciences. Report Number CMIS 09/188).
2. Where possible a control site is located in an area dominated by the commodity type. Control site data provided by the Department of Natural Resources QLD.
3. Map compiled by Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry - Australia.

National Land & Water Resources Audit
A program of the Natural Heritage Trust
9 December 2000

203

Figure A7.14.   (Facing page.) Agricultural control sites in South Australia.

Agricultural control sites in South Australia

Inset A

0   50km

Refer Inset A

1996/97 Commodity Type:

- Residual/Native pasture
- Agroforestry
- Sown Pastures
- Cereals excluding rice
- Legumes
- Oilseeds
- Other non-cereal crops
- Other vegetables
- Potatoes
- Citrus
- Apples
- Stone Fruit
- Nuts
- Grapes

Region Type:

Selected SLAs

0   220km

Figure A7.15.   (Facing page.) Agricultural control sites in Western Australia.

Agricultural control sites in Western Australia

1996/97 Commodity Type:

- Residual/Native pasture
- Sown Pastures

Region Type:

Selected SLAs

Notes:
1. Statistical Local Areas (SLAs) and agricultural commodities selected according to "Sampling for a Network of Rural Commodity Production Sites" (CSIRO Mathematical and Information Sciences. Report Number CMIS 99/188).
2. Where possible a control site is located in an area dominated by the commodity type. Control site data provided by Department of Agriculture Western Australia.
3. Map compiled by Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry - Australia.

0   240km

National Land & Water Resources Audit
A program of the Natural Heritage Trust
9 December 2000

Figure A7.16. (Facing page.) Agricultural control sites in Tasmania.

Agricultural control sites in Tasmania

Inset A

0   5km

Refer Inset A
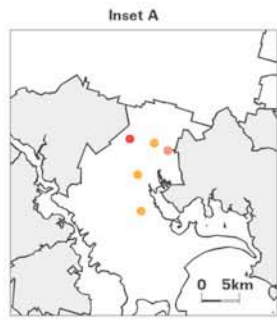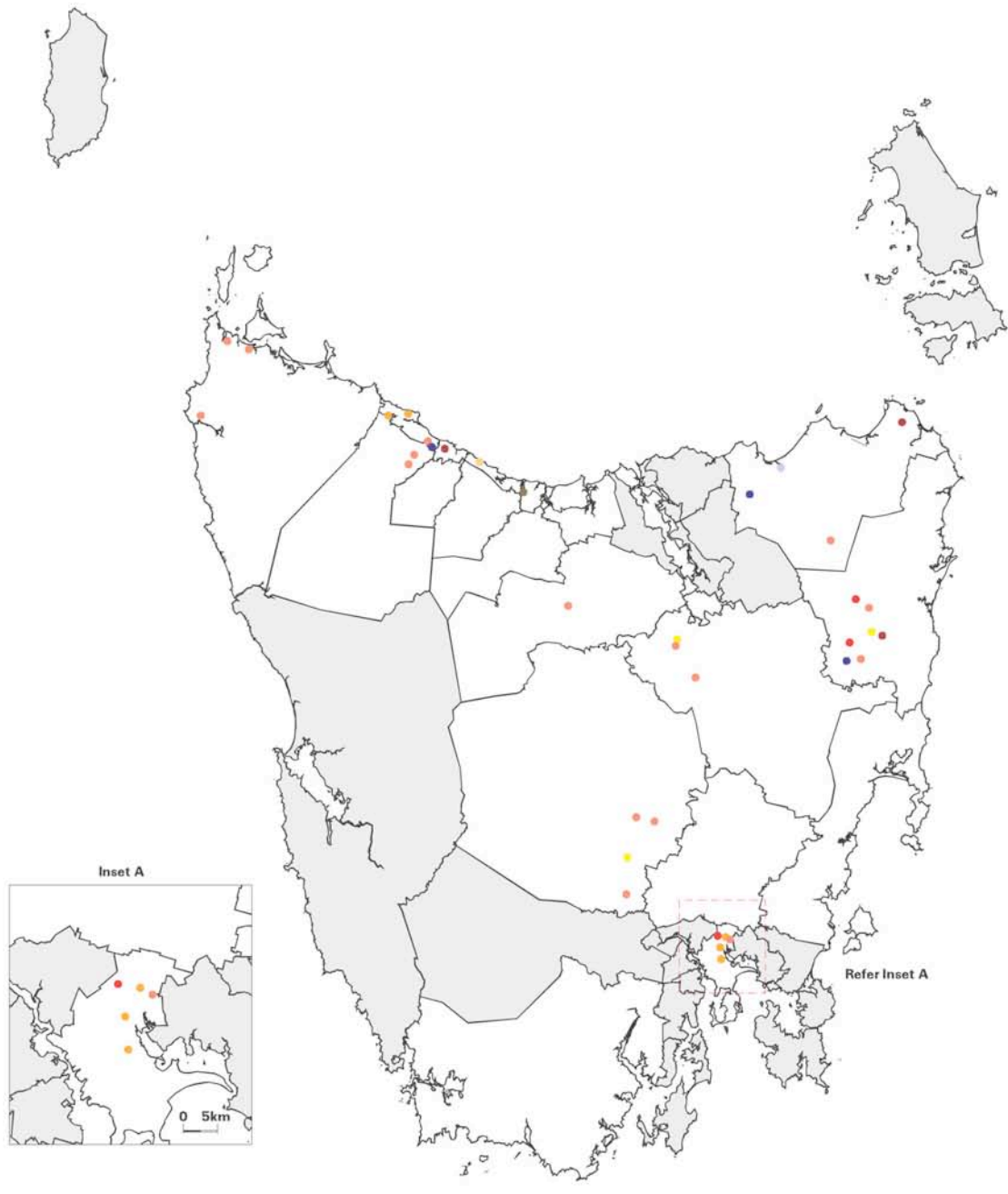
1996/97 Commodity Type:

- Sown Pastures
- Cereals excluding rice
- Legumes
- Oilseeds
- Non-cereal forage crops
- Other non-cereal crops
- Other vegetables
- Potatoes
- Stone Fruit

Region Type:

Selected SLAs

0   50km

Notes:
1. Statistical Local Areas (SLAs) and agricultural commodities selected according to "Sampling for a Network of Rural Commodity Production Sites" (CSIRO Mathematical and Information Sciences. Report Number CMIS 99/188).
2. Where possible a control site is located in an area dominated by the commodity type. Control site data provided by the Department of Primary Industries, Water and Environment TAS.
3. Map compiled by Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry - Australia.

National Land & Water Resources Audit
A program of the Natural Heritage Trust
9 December 2000

Appendix 8. NDVI profiles for control sites used for selected SLAs

A selection of control site NDVI profiles is presented. The SLAs were selected from SLAs requested for Queensland in Table A7.1 with their location given in Figure A7.2. These have been chosen from the dryland and irrigated inputs for the 790 SLAs given to SPREAD to allocate agricultural land use. The complete set of control site profiles for each SLA solved by SPREAD is available from the authors.

NDVI profiles used for allocation of irrigated agricultural land use for indicated SLAs in Queensland (SLA # as in Table A7.1 and Figure A7.2)

1. Redland (S) Bal – SLA # 4

2. Esk (S) – SLA # 11

3. Laidley (S) – SLA # 14

4. Maroochy (S) Bal – SLA # 15

5. Wondai (S) – SLA # 29

6. Emerald (S) – SLA # 50

Agricultural land uses presented in Figures A8.1 - A8.6 from left to right for row 1:

Cotton, Sugar cane, Rice, Potatoes, Non-cereal forage crops, Cereals excluding rice, Legumes

For row 2:

Oilseeds, Citrus, Sown pasture, Native pasture, Other vegetables, Other non-cereal crops, Apples

For row 3:

Plantation fruit, Nuts, Stone fruit, Pears, Grapes

NDVI profiles used for allocation of dryland agricultural land use for indicated SLAs in Queensland (SLA # as in Table A7.1 and Figure A7.2)

7. Redland (S) Bal – SLA # 4

8. Esk (S) – SLA # 11

9. Laidley (S) – SLA # 14

10. Maroochy (S) Bal – SLA # 15

11. Wondai (S) – SLA # 29

12. Emerald (S) – SLA # 50

Agricultural land uses presented in Figure A8.7 - A8.12 from left to right for row 1:

Apples, Other vegetables, Citrus, Potatoes, Other non-cereal crops, Cotton, Non-cereal forage crops

For row 2:

Sugar cane, Oilseeds, Legumes, Cereals excluding rice, Sown pasture, Agroforestry, Native pasture

For row 3:

Grapes, Plantation fruit, Nuts, Stone fruit, Pears

Figure A8.1. (Facing page.) NDVI profiles for irrigated agricultural land uses in Redland (S) Bal. See text for explanation.
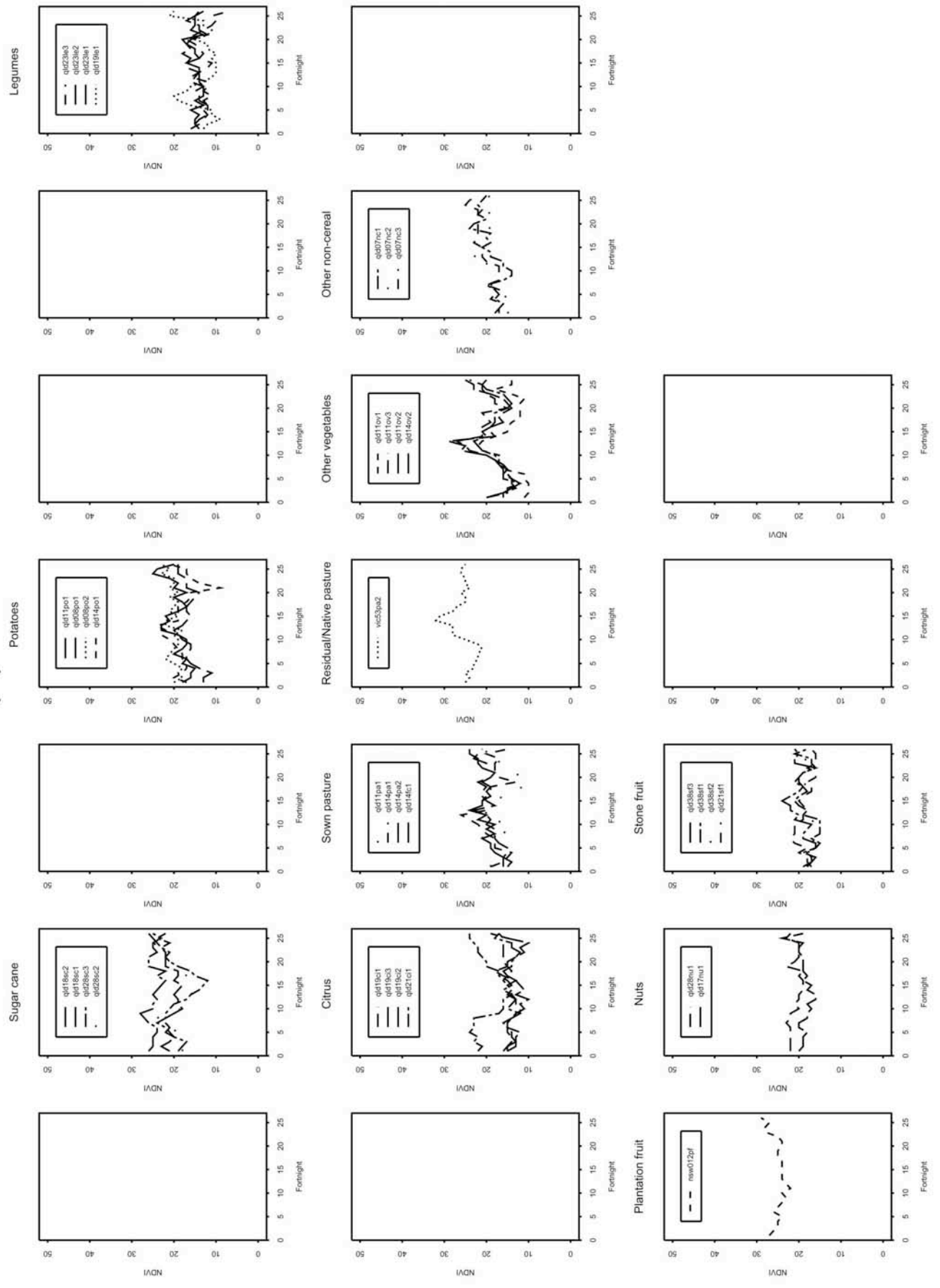
'Redland(S)Bal'-305506283

Figure A8.2. (Facing page.) NDVI profiles for irrigated agricultural land uses in Esk (S). See text for explanation.
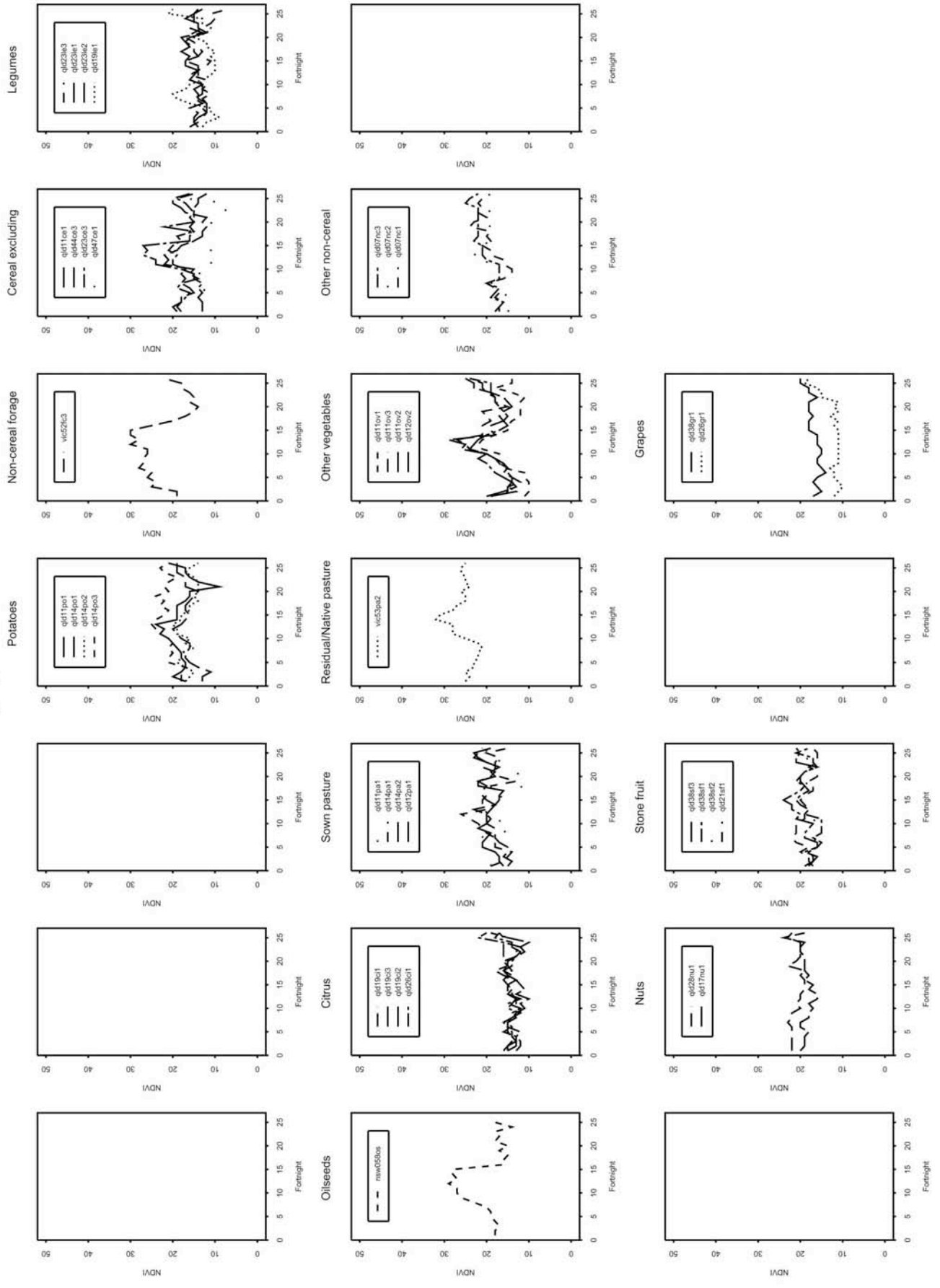
'Esk(S)'-3102203050

Figure A8.3. (Facing page.) NDVI profiles for irrigated agricultural land uses in Laidley (S). See text for explanation.
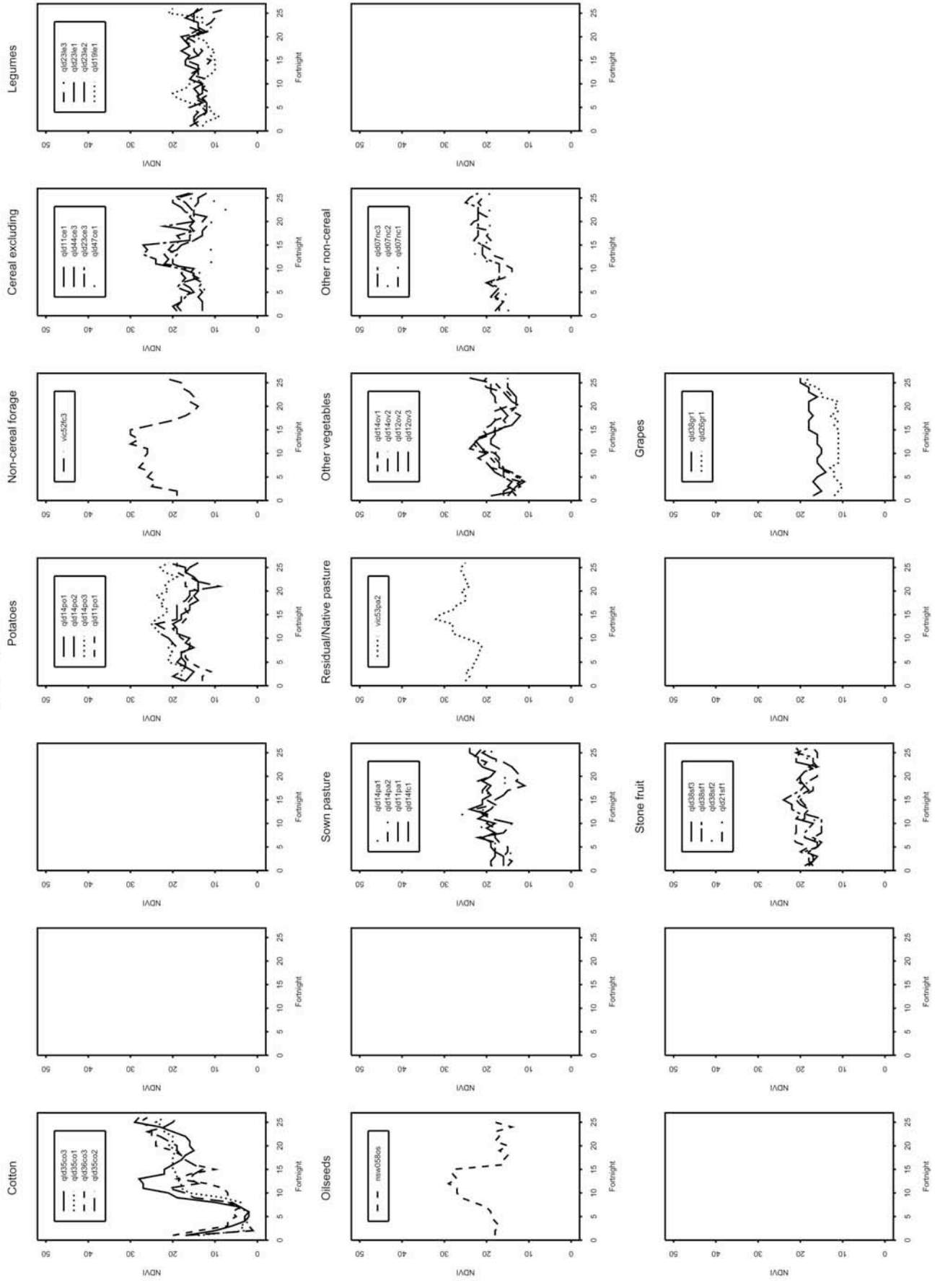
'Laidley(S)'-3102044450

Figure A8.4. (Facing page.) NDVI profiles for irrigated agricultural land uses in Maroochy (S) Bal. See text for explanation.
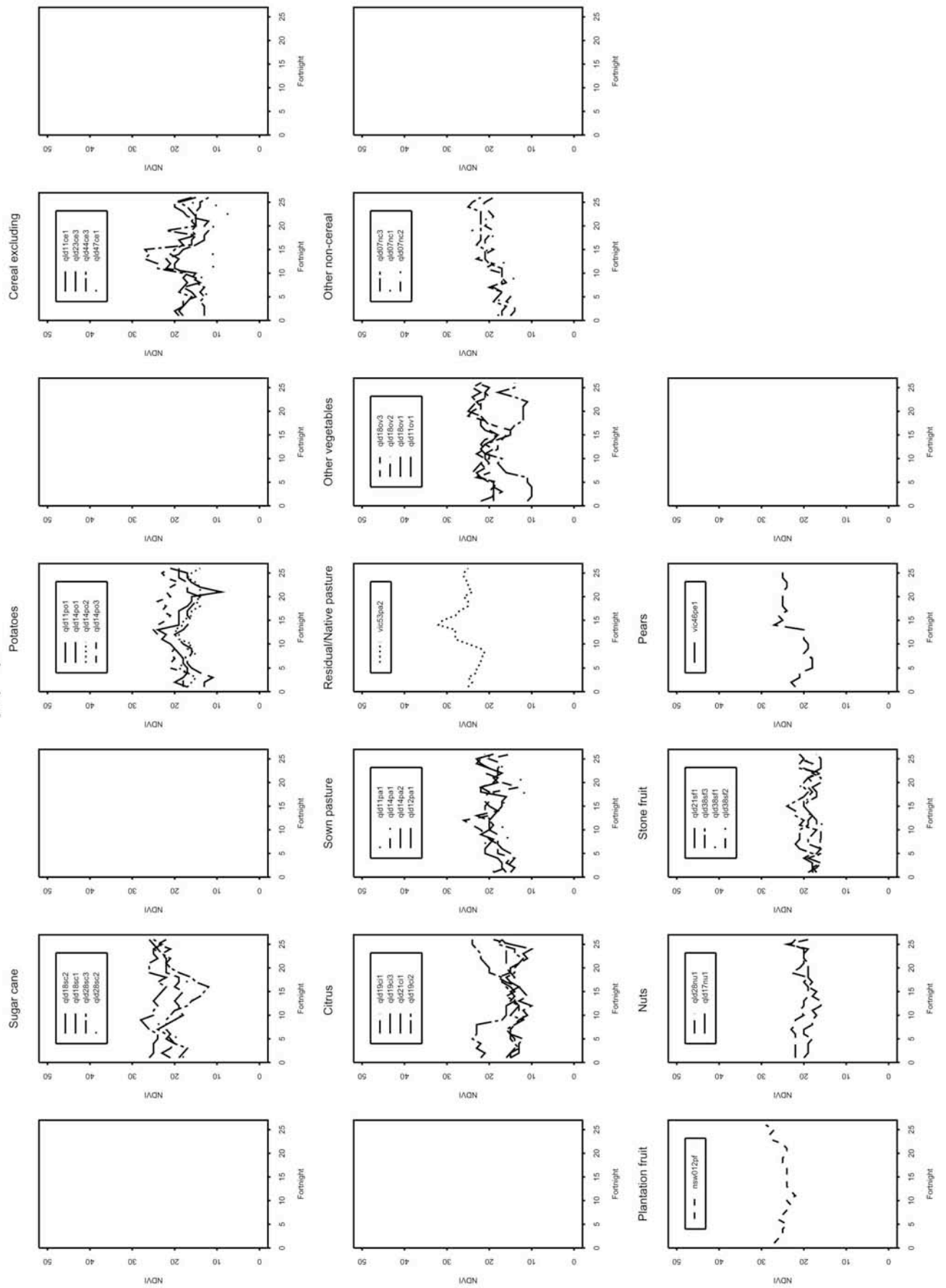
'Maroochy(S)Bal'-310204918

Figure A8.5.   (Facing page.) NDVI profiles for irrigated agricultural land uses in Wondai (S). See text for explanation.
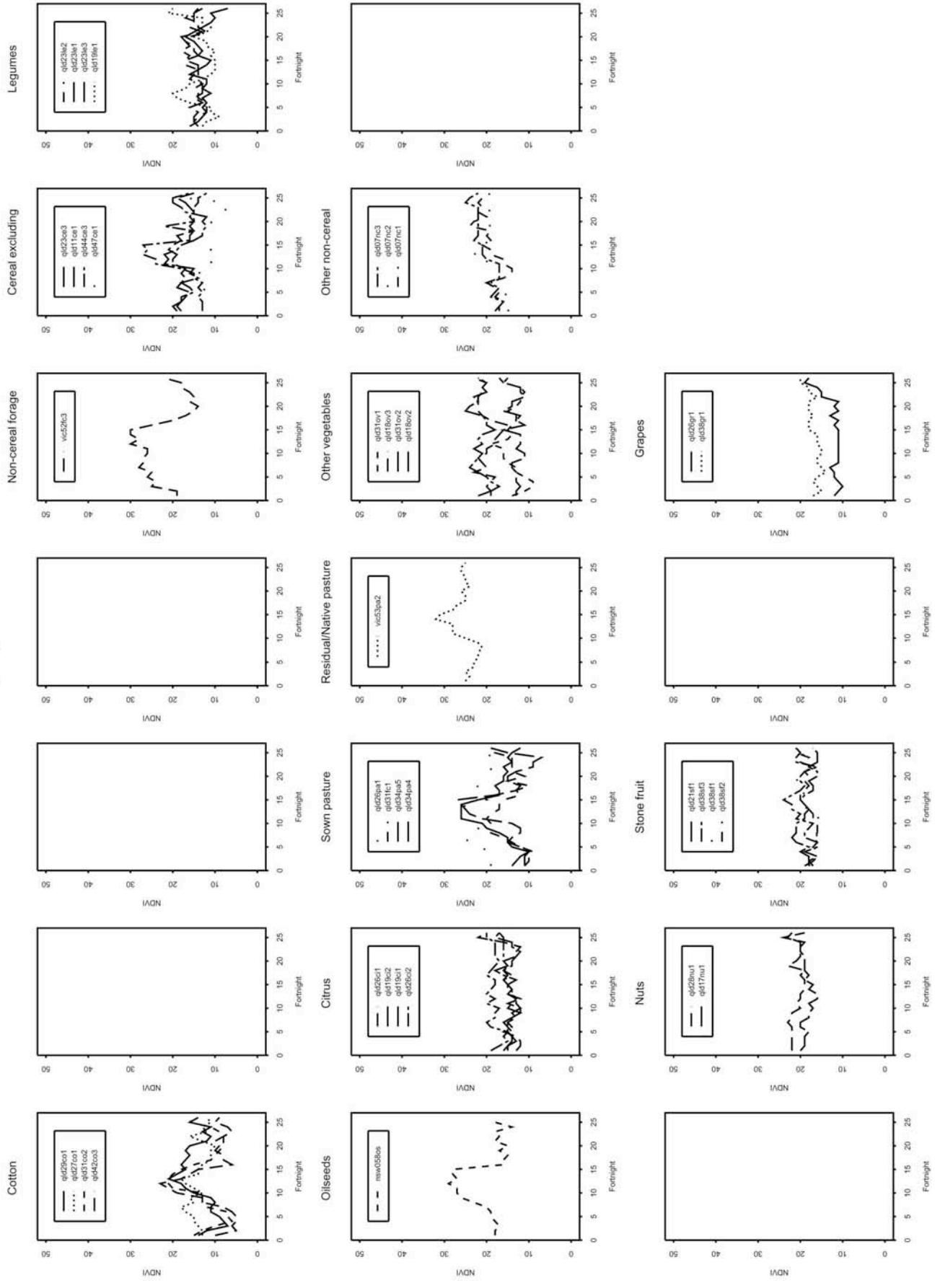
'Wondai(S)'-31510745O

Figure A8.6. (Facing page.) NDVI profiles for irrigated agricultural land uses in Emerald (S). See text for explanation.
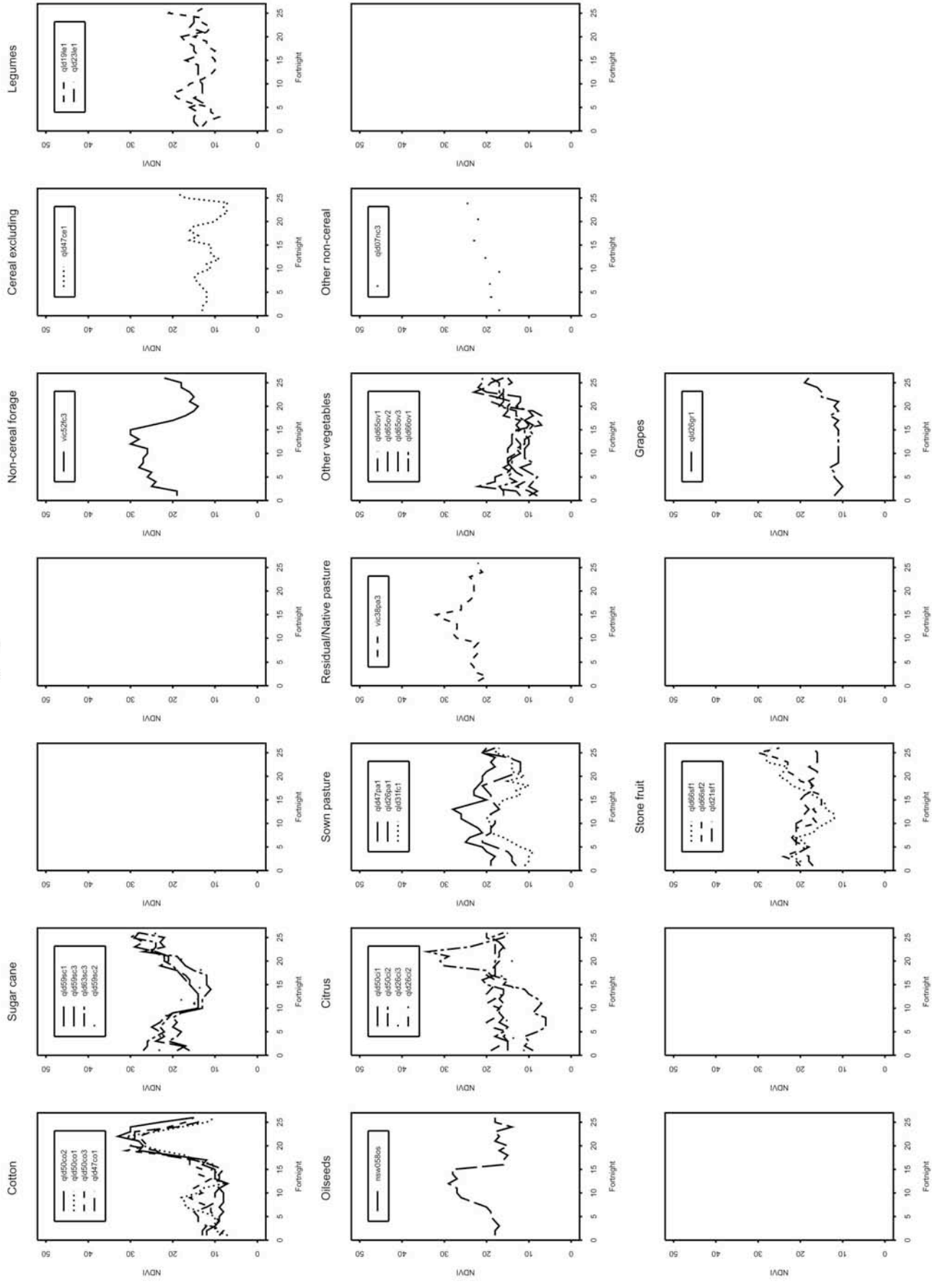
'Emerald(S)'-330153000

223

Figure A8.7. (Facing page.) NDVI profiles for dryland agricultural land uses in Redland (S) Bal. See text for explanation.
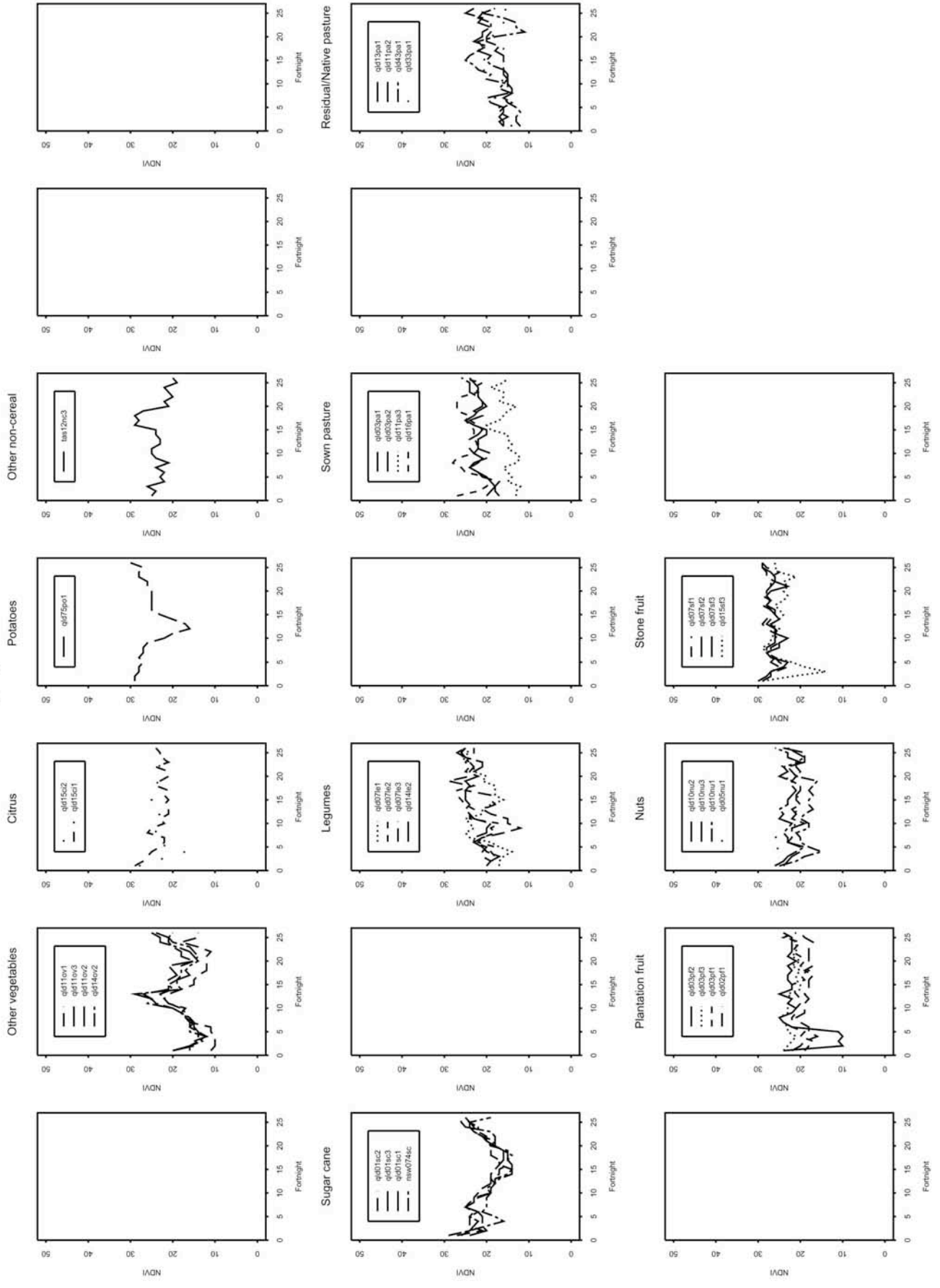
'Redland(S)Bal'-305506283

225

Figure A8.8. (Facing page.) NDVI profiles for dryland agricultural land uses in Esk (S). See text for explanation.

'Esk(S)'-310203050
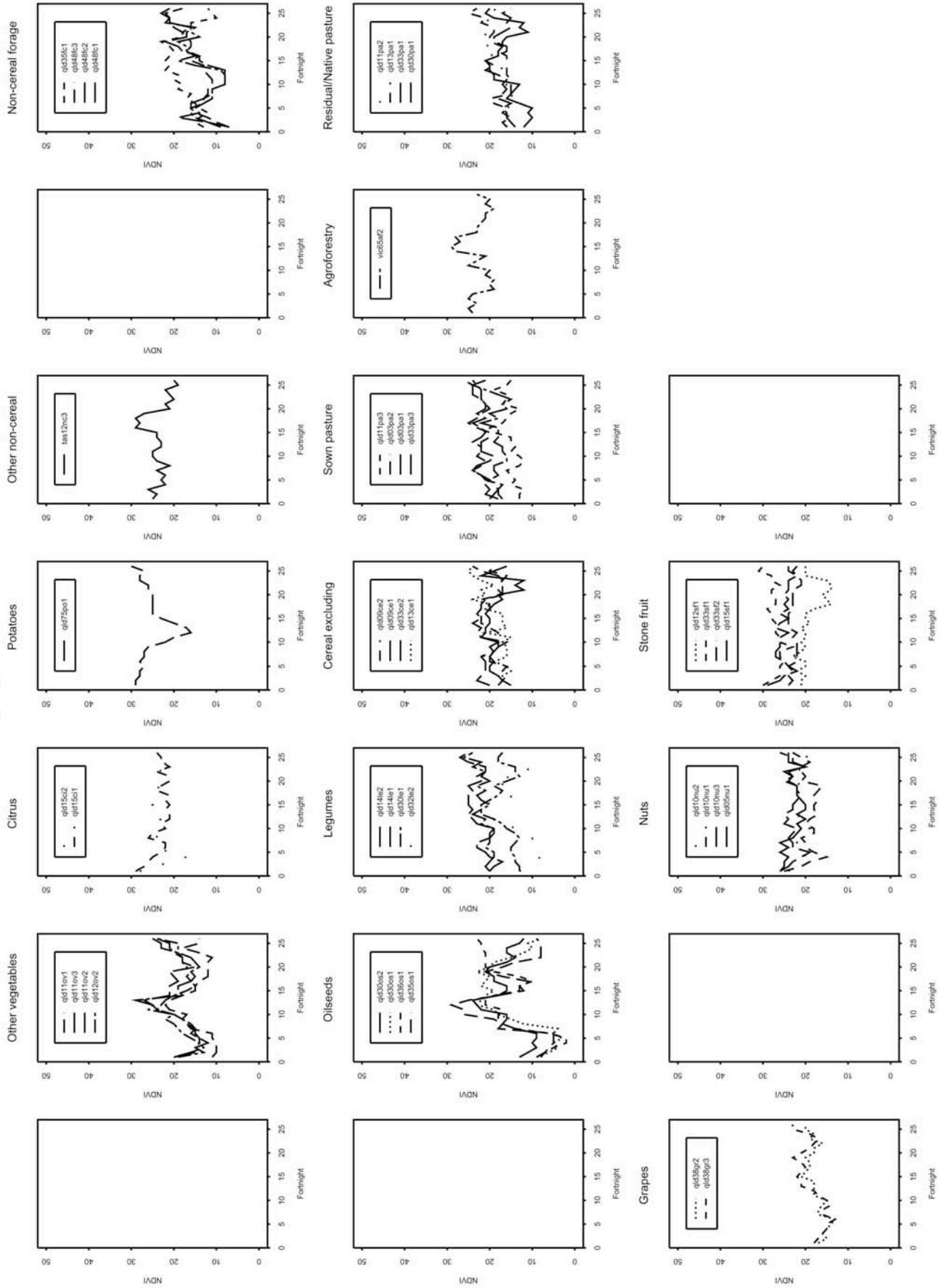
Figure A8.9. (Facing page.) NDVI profiles for dryland agricultural land uses in Laidley (S). See text for explanation.

'Laidley(S)'-310204450

Figure A8.10.   (Facing page.) NDVI profiles for dryland agricultural land uses in Maroochy (S) Bal. See text for explanation.

'Maroochy(S)Bal'-310204918

Figure A8.11.   (Facing page.) NDVI profiles for dryland agricultural land uses in Wondai (S). See text for explanation.

'Wondai(S)'-31510 7450

Figure A8.12.   (Facing page.) NDVI profiles for dryland agricultural land uses in Emerald (S). See text for explanation.

'Emerald(S)'-330153000
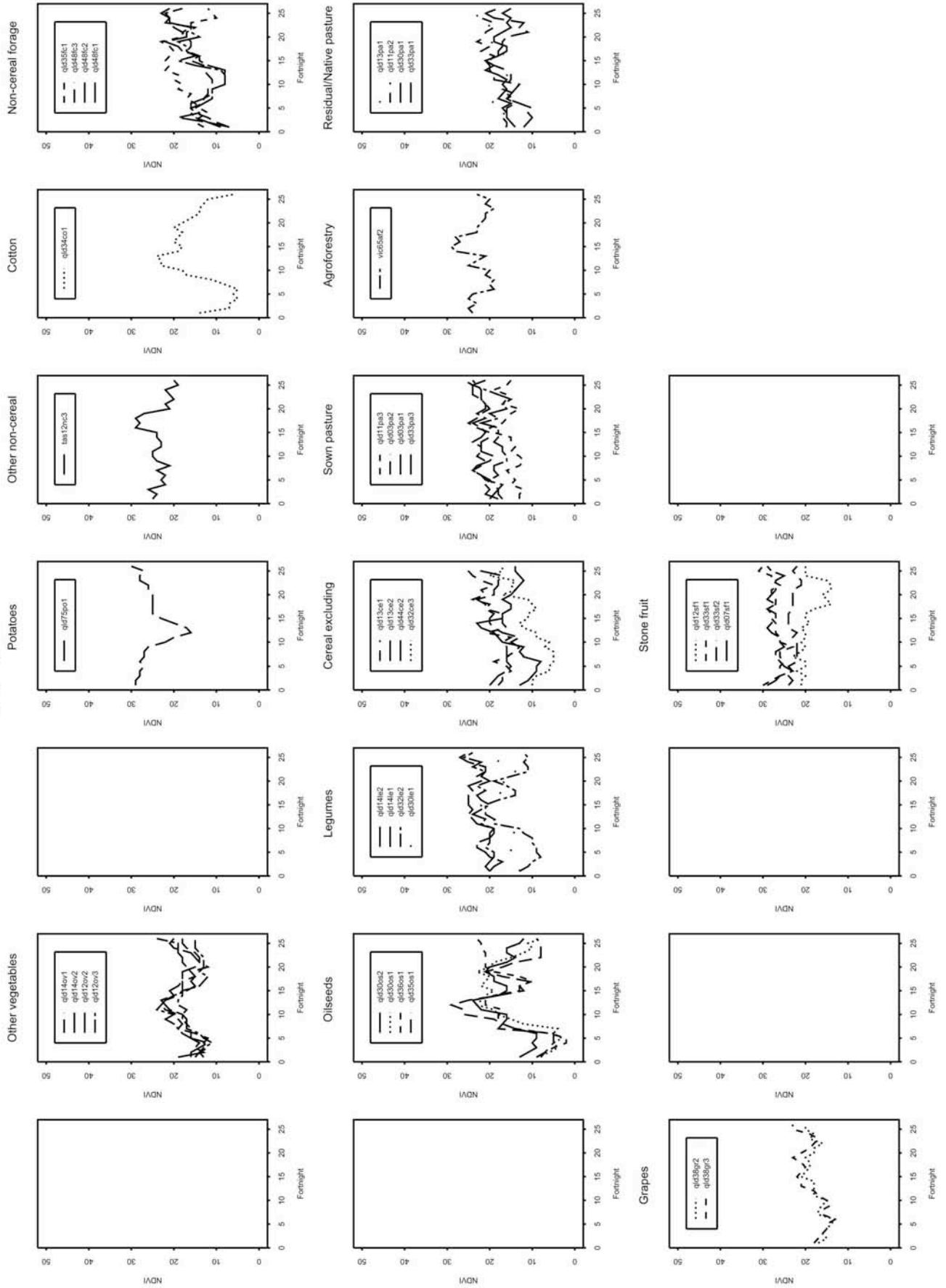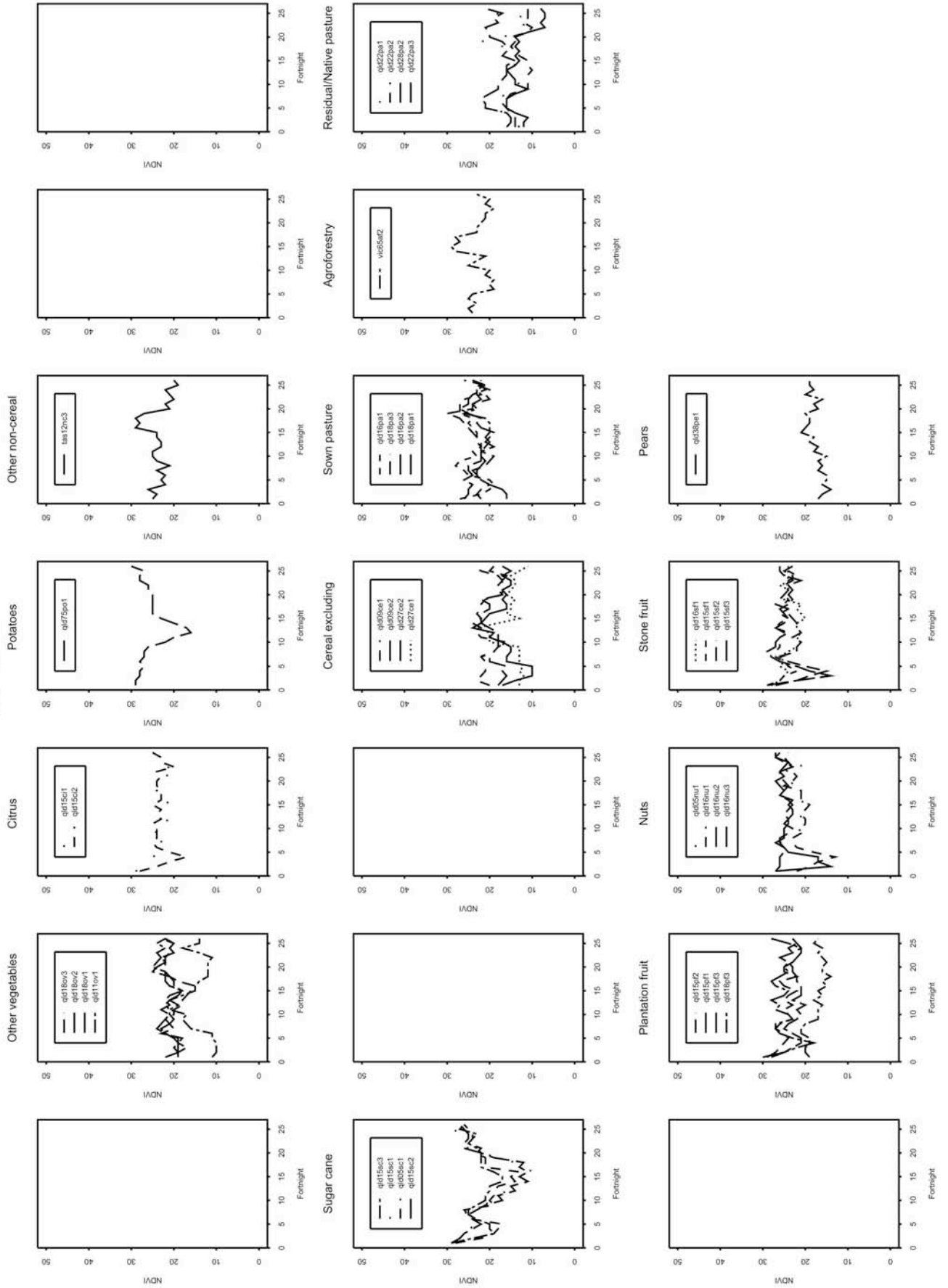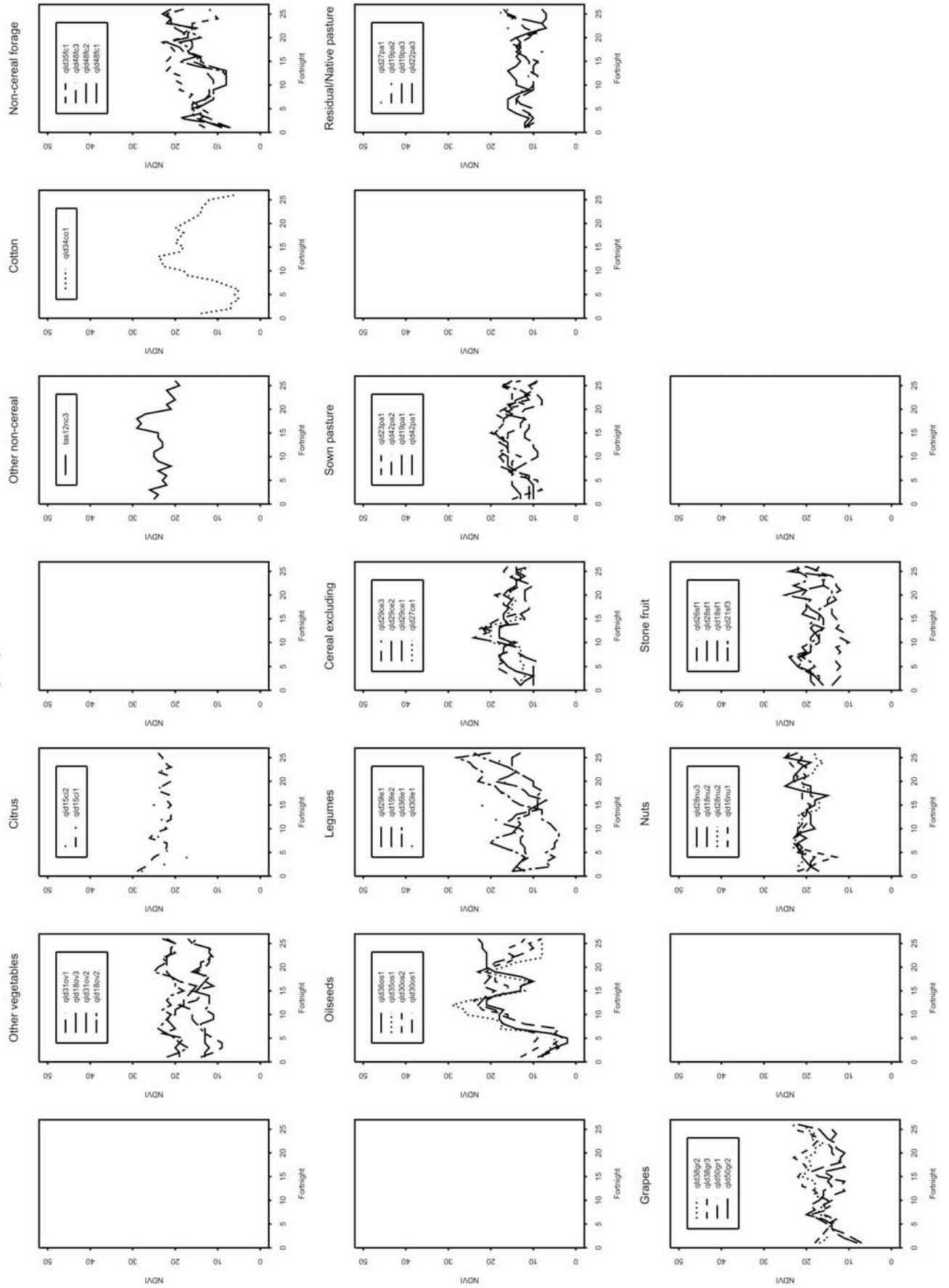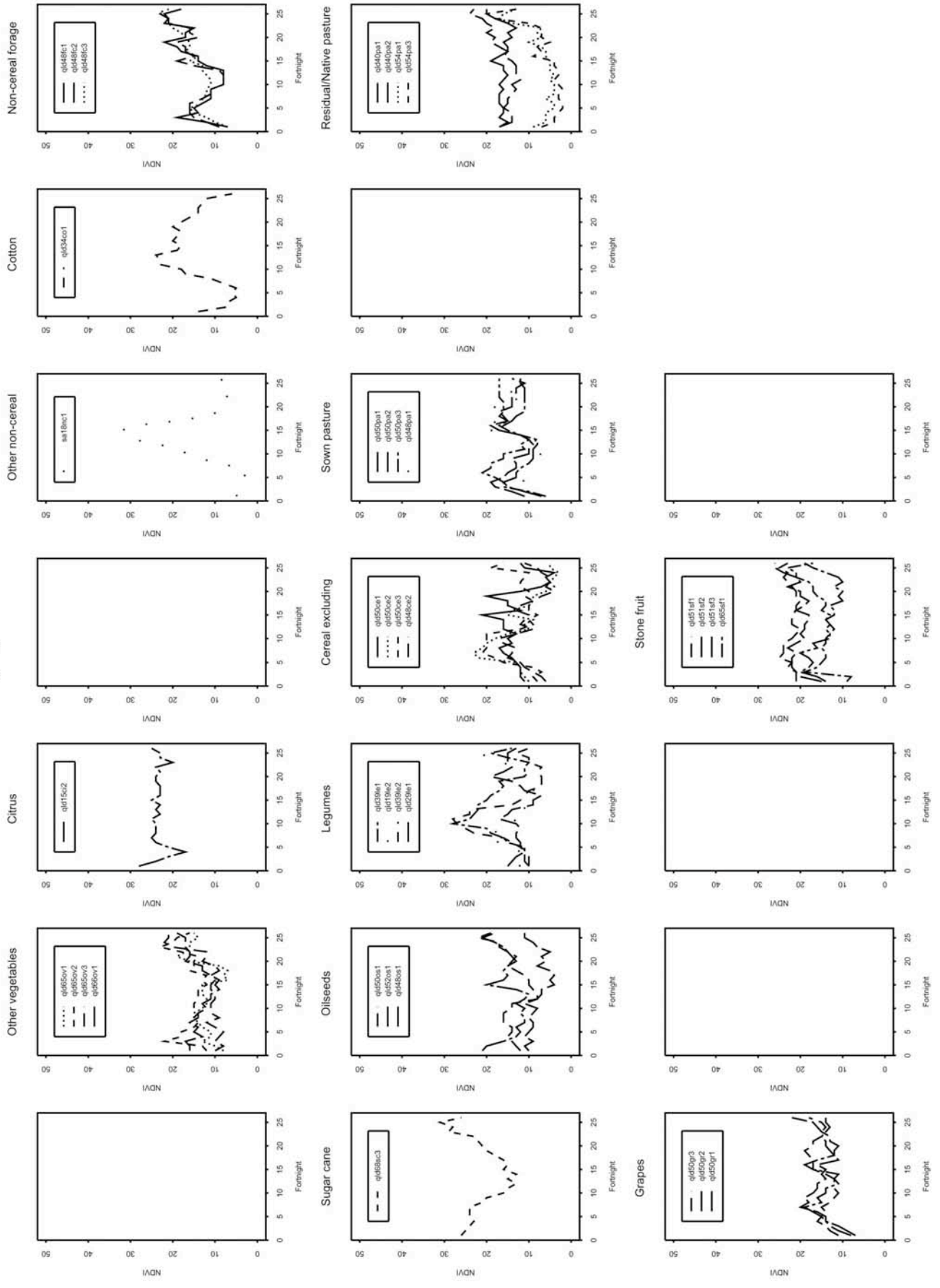
Appendix 9. Analysis of the SPREAD approach

Discrimination power of profiles

The ability of the NDVI profiles to discriminate between land uses is investigated. Two competing features of the problems must be taken into account. First, because of variations in climate and husbandry practices, control sites for the same commodity that are geographically distant from each other are not necessarily expected to have similar profiles. Thus only the discrimination power of control sites that are "close" in some sense are considered. The second feature is that due to the sparseness of data, the number of control sites that can be considered close is limited. Thus the results of the individual analyses will have large sampling error fluctuations.

For a given SLA and commodity, the closest control sites may be some distance from each other so care must be taken when interpreting the results. In addition, the control sites used for the analysis of a particular SLA will often be common across a range of SLAs. Thus a classification rate can potentially reflect the contribution of a single poor control site and the actual map may perform considerably better. Given this, these calculations should provide an approximate (if perhaps pessimistic) lower bound for the classification rate.

The following methodology is proposed. First, error rates within each SLA are estimated. These estimates are then averaged over the SLAs to smooth small sample fluctuations and to provide an estimate of error at the region level. This approach is justified by arguing that there should be some consistency in true error rate across a region for each commodity.

The analysis is carried out as follows. For each SLA a control site file for the dryland commodities only is generated, consisting of the three closest control sites for each commodity.

For each SLA the following two calculations are performed.

Analysis 1: Overall misclassification rate

1. For the *i*th control site its distance (based on the Gower metric) to the other control sites used for the SLA is calculated, restricting the calculation to control sites of commodities that are recorded as present in the SLA. Then create a prediction $\hat{L}_i$ for the *i*th control site based on the other control site with the minimum distance.

2. For commodity *j* the error rate is calculated as

$$Error\ Rate_j = \frac{1}{n} \sum_{sites} I(L_i, \hat{L}_i)$$

   where the summation is over the control sites belonging to the *j*th commodity class, *I()* is the indicator function taking the value one if the land uses are different and zero otherwise, and *n* is the number of control sites for the *j*th commodity in the SLA. This measure effectively counts the number of mismatches and expresses this as a proportion.

   The analysis output gives estimates of the misclassification rate within the SLA for each commodity.

Analysis 2: Pairwise misclassification rate

1. For the *j*th and *k*th commodity present in the SLA a control site frame F_{jk} that contains only control sites for these two commodities is constructed.

2. For the *i*th control site in the frame F_{jk} constructed in (1) its distance (based on the Gower metric) to the other control sites in the SLA is calculated. The create a prediction $\hat{L}_i$ for the *i*th control site based on the other control site with the minimum distance.

3. Calculate

$$Error\,Rate_{jk} = \frac{1}{n}\sum_{sites} I(L_i, \hat{L}_i)$$

where the summation is over all the control sites in F_{jk}, $I()$ is the indicator function taking the value one if the land uses are different and zero otherwise, and n is the number of control sites in frame F_{jk}. This measure effectively counts the number of mismatches and expresses this as a proportion of the elements in the frame.

The output of the analysis is a 21 by 21 matrix of estimates of the pairwise misclassification rate within the SLA for each commodity.

Amalgamation of analyses

The analyses are amalgamated to produce estimates over larger regions than the SLA. This is done to smooth local variation. Averages are calculated across the SLAs for analysis 1 as:

$$Mean\,error_j = \frac{1}{\#SLA}\sum_{SLA's} Error\,Rate_j$$

where the summation is over the relevant SLAs and #SLA is the number of SLAs that have valid estimates (i.e. the commodity was present) of the error rates. There are thus 21 estimates at the end of the analysis.

For analysis 2 we have

$$Mean\,error_{jk} = \frac{1}{\#SLA}\sum_{SLA's} Error\,Rate_{jk}$$

where the summation is over the relevant SLAs and #SLA is the number of SLAs that have valid estimates (i.e. both commodity j and k was present) of the error rates. This produces a 21x21 matrix of misclassification estimates.

The final part of the analysis is to consider the error rate for individual pixels. There are two ways to correctly predict a pixel. First, discriminate it correctly. Secondly, fail to discriminate it correctly but get it correct by chance.

Straightforward calculations via Bayes theorem lead to the identity

Pr(classify correctly) = Pr(Classify correctly|discriminate correctly)Pr(discriminate correctly)
        + Pr(Classify correctly|discriminate incorrectly)Pr(discriminate incorrectly)

For a single pixel, and assuming that a misclassified pixel is assigned randomly to the remaining target zones (which is a very rough assumption) we have:

$$Pr(\text{Classify correctly}|\text{discriminate correctly}) = 1$$

$$Pr(\text{discriminate correctly}) = 1 - Mean\,error_j$$

$$Pr(\text{Classify correctly}|\text{discriminate incorrectly}) = \frac{A_j}{\sum_j A_j}$$

$$Pr(\text{discriminate incorrectly}) = Mean\,error_j$$

Where A_j is the area in the SLA of commodity j and the $\sum_j A_j$ is the total area of commodities in the SLA.

This leads to

$$\text{Pr(classify correctly)} = (1 - \textit{Mean error}_j) + \frac{A_j}{\sum_j A_j} \textit{Mean error}_j \quad \text{--(1)}$$

The results of the analysis are presented in Tables A9.1 – A9.3. Table A9.1 gives the results of analysis one averaged to the state level (excluding NT due to lack of sufficient data). Table A9.2 gives the results of analysis 2 averaged over all SLA's. Table A9.3 gives the estimated probability of discriminating commodities correctly calculated in Equation (1) above.

Table A9.1. Classification error rates for the 21 commodities in each state.

Agricultural commodity	State					
	NSW	**VIC**	**QLD**	**SA**	**WA**	**TAS**
Residual/Native pastures	0.55	0.53	0.50	0.56	0.59	0.32
Agroforestry	0.72	0.59	0.24	0.38	0.99	0.35
Sown pastures	0.86	0.76	0.62	0.67	0.37	0.64
Cereals excluding rice	0.58	0.71	0.63	0.64	1.00	0.74
Rice	N/A	N/A	N/A	N/A	N/A	N/A
Legumes	0.72	0.77	0.81	0.73	1.00	1.00
Oilseeds	0.79	0.87	0.80	0.76	1.00	0.98
Sugar cane	0.61	N/A	0.33	N/A	1.00	N/A
Non-cereal forage crops	0.78	0.43	0.26	0.93	1.00	0.80
Cotton	1.00	N/A	1.00	N/A	N/A	N/A
Other non-cereal crops	1.00	0.71	0.29	0.09	1.00	0.53
Other vegetables	0.60	0.49	0.62	0.40	1.00	0.88
Potatoes	1.00	1.00	1.00	1.00	1.00	1.00
Citrus	1.00	1.00	0.47	1.00	1.00	N/A
Apples	0.76	0.42	0.33	0.98	1.00	0.73
Pears	1.00	1.00	1.00	1.00	1.00	1.00
Stone fruit	0.78	1.00	0.67	1.00	1.00	1.00
Nuts	0.94	1.00	0.82	1.00	1.00	1.00
Berry fruit	N/A	N/A	N/A	N/A	N/A	N/A
Plantation fruit	0.87	1.00	0.78	1.00	1.00	1.00
Grapes	0.88	1.00	0.51	1.00	1.00	1.00

Table A9.2. Average pairwise classification error rates for the commodities.

Agricultural commodity	Residual/ Native pastures	Agroforestry	Sown pastures	Cereals excluding rice	Rice	Legumes	Oilseeds	Sugar cane	Non-cereal forage crops	Cotton	Other non-cereal crops	Other vegetables	Potatoes	Citrus	Apples	Pears	Stone fruit	Nuts	Berry fruit	Plantation fruit	Grapes
Residual/Native pastures	N/A	0.22	0.33	0.31	N/A	0.30	0.30	0.11	0.28	0.32	0.19	0.35	0.25	0.23	0.27	0.35	0.27	0.29	N/A	0.23	0.33
Agroforestry	0.22	N/A	0.27	0.21	N/A	0.20	0.20	0.13	0.15	0.27	0.22	0.26	0.29	0.21	0.29	0.26	0.27	0.30	N/A	0.23	0.36
Sown pastures	0.33	0.27	N/A	0.36	N/A	0.34	0.33	0.25	0.27	0.30	0.17	0.33	0.24	0.23	0.32	0.30	0.29	0.26	N/A	0.30	0.35
Cereals excluding rice	0.31	0.21	0.36	N/A	N/A	0.40	0.44	0.03	0.30	0.30	0.19	0.25	0.23	0.23	0.19	0.31	0.26	0.26	N/A	0.24	0.32
Rice	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Legumes	0.30	0.20	0.34	0.40	N/A	N/A	0.49	0.30	0.39	0.32	0.11	0.24	0.30	0.23	0.23	0.32	0.30	0.34	N/A	0.30	0.27
Oilseeds	0.30	0.20	0.33	0.44	N/A	0.49	N/A	0.00	0.36	0.63	0.18	0.20	0.29	0.14	0.21	0.27	0.25	0.28	N/A	0.19	0.29
Sugar cane	0.11	0.13	0.25	0.03	N/A	0.30	0.00	N/A	0.12	0.25	0.16	0.09	0.23	0.19	0.07	0.25	0.28	0.46	N/A	0.33	0.00
Non-cereal forage crops	0.28	0.15	0.27	0.30	N/A	0.39	0.36	0.12	N/A	0.41	0.21	0.23	0.32	0.19	0.31	0.43	0.27	0.27	N/A	0.25	0.29
Cotton	0.32	0.27	0.30	0.30	N/A	0.32	0.63	0.25	0.41	N/A	0.40	0.24	0.50	0.33	0.25	NA	0.26	0.30	N/A	0.25	0.29
Other non-cereal crops	0.19	0.22	0.17	0.19	N/A	0.11	0.18	0.16	0.21	0.40	N/A	0.28	0.36	0.27	0.37	0.35	0.54	0.29	N/A	0.33	0.23
Other vegetables	0.35	0.26	0.33	0.25	N/A	0.24	0.20	0.09	0.23	0.24	0.28	N/A	0.29	0.13	0.36	0.37	0.33	0.35	N/A	0.28	0.34
Potatoes	0.25	0.29	0.24	0.23	N/A	0.30	0.29	0.23	0.32	0.50	0.36	0.29	N/A	0.46	0.23	0.50	0.42	0.28	N/A	0.39	0.45
Citrus	0.23	0.21	0.23	0.23	N/A	0.23	0.14	0.19	0.19	0.33	0.27	0.13	0.46	N/A	0.13	0.33	0.28	0.48	N/A	0.37	0.21
Apples	0.27	0.29	0.32	0.19	N/A	0.23	0.21	0.07	0.31	0.25	0.37	0.36	0.23	0.13	N/A	0.32	0.38	0.24	N/A	0.30	0.34
Pears	0.35	0.26	0.30	0.31	N/A	0.32	0.27	0.25	0.43	NA	0.35	0.37	0.50	0.33	0.32	N/A	0.49	0.36	N/A	0.43	0.75
Stone fruit	0.27	0.27	0.29	0.26	N/A	0.30	0.25	0.28	0.27	0.26	0.54	0.33	0.42	0.28	0.38	0.49	N/A	0.49	N/A	0.46	0.37
Nuts	0.29	0.30	0.26	0.26	N/A	0.34	0.28	0.46	0.27	0.30	0.29	0.35	0.28	0.48	0.24	0.36	0.49	N/A	N/A	0.55	0.40
Berry fruit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Plantation fruit	0.23	0.23	0.30	0.24	N/A	0.30	0.19	0.33	0.25	0.25	0.33	0.28	0.39	0.37	0.30	0.43	0.46	0.55	N/A	N/A	0.11
Grapes	0.33	0.36	0.35	0.32	N/A	0.27	0.29	0.00	0.29	0.29	0.23	0.34	0.45	0.21	0.34	0.75	0.37	0.40	N/A	0.11	N/A

Table A9.3. Estimated lower bound for the probability of correct classification in each state.

Agricultural commodity	State					
	NSW	VIC	QLD	SA	WA	TAS
Residual/Native pastures	0.88	0.78	0.91	0.78	0.74	0.85
Agroforestry	0.28	0.41	0.76	0.62	0.01	0.65
Sown pastures	0.24	0.49	0.42	0.44	0.71	0.64
Cereals excluding rice	0.46	0.34	0.40	0.49	0.17	0.27
Rice	N/A	N/A	N/A	N/A	N/A	N/A
Legumes	0.29	0.24	0.20	0.28	0.04	0.00
Oilseeds	0.21	0.14	0.20	0.24	0.00	0.03
Sugar cane	0.39	N/A	0.68	N/A	0.00	N/A
Non-cereal forage crops	0.22	0.57	0.74	0.07	0.00	0.21
Cotton	0.00	N/A	0.00	N/A	N/A	N/A
Other non-cereal crops	0.00	0.29	0.71	0.91	0.00	0.48
Other vegetables	0.40	0.51	0.39	0.60	0.00	0.13
Potatoes	0.00	0.00	0.00	0.00	0.00	0.00
Citrus	0.00	0.00	0.53	0.00	0.00	N/A
Apples	0.24	0.58	0.67	0.02	0.00	0.27
Pears	0.00	0.00	0.00	0.00	0.00	0.00
Stone fruit	0.22	0.00	0.33	0.00	0.00	0.00
Nuts	0.07	0.00	0.18	0.00	0.00	0.00
Berry fruit	N/A	N/A	N/A	N/A	N/A	N/A
Plantation fruit	0.13	0.00	0.22	0.00	0.00	0.00
Grapes	0.12	0.00	0.49	0.01	0.00	0.00

Background on SPREAD's performance

To explore the impact of variables on the discrimination power of our estimator we consider several cases.

1. The effect of the constraint on the discrimination power.

2. The effect of the sample size on the power of discrimination.

3. The effect of the use of the Gower metric as a discriminator.

Methodology

To explore the power of the discrimination several situations were investigated. Without loss of generality the simple model defined as follows was considered. It was assumed there were only two categories (e.g. land uses) that we wished to discriminate between and that observations (e.g. NDVI profiles) were distributed as

$$\text{Population 1}: Normal(\mu_1, \sigma^2)$$

$$\text{Population 2}: Normal(\mu_2, \sigma^2)$$

Without loss of generality it is assumed that $\sigma^2 = 1$. This model lets us explore a variety of situations. For example, if $\mu_1 \gg \mu_2$ then discrimination is very good. Alternatively if $\mu_1 = \mu_2$ then the data provides no information to discriminate between the populations. The behaviour of the techniques for a range of values of $\mu_1 \, and \, \mu_2$ can be explored and thus a range of difficulties in discrimination.

In all the examples considered the procedure followed was:

1. Given $\mu_1 \; and \; \mu_2$ draw a sample of size *n* from population 1 and 2. Denote these samples $y_{11}, \mathrm{K} \; y_{1n}$ and $y_{21}, \mathrm{K} \; y_{2n}$ respectively.

2. Calculate a discriminator from the sample. The standard, and "optimal" technique in this case is to set the point of discrimination mid way between the sample mean of population 1 and population 2, i.e. if the mean of population 1 is less than that of population 2

    $$if \; y' < \bar{y}_1 + \frac{\bar{y}_2 - \bar{y}_1}{2} \; then \; assign \; y' \; to \; population \; 1, else \; assign \; to \; population \; 2.$$

    with the obvious adjustments for the converse.

3. Draw a sample *N* from both population 1, $y^*{}_{11}, \mathrm{K} \; y^*{}_{1n} \; ,$. Use the discriminator created in 2 to assign the new sample and calculate the misclassification rate

    $$Error \; Rate_j \; = \; \frac{\sum_{i=1}^{N} y^*{}_{1i}}{N}$$

4. Repeat (1) to (3) reps (reps>1000, say) times and calculate the expected error rate.

    $$Expected \; Error \; Rate = \frac{\sum_{j=1}^{reps} Error \; Rate_j}{reps}$$

We now consider the particular cases.

The effect of the constraint on the discrimination power

To explore the effect of the constraint we compared the error rate for the optimal estimator calculated from the standard methodology against the optimal strategy for use with the constraint. Under the constraint, the optimal strategy in this case is to augment the validation sample with a set of observations drawn from population 2. The number of observations added will depend on the constraint. For example if the constraint is 2:1 pop1:pop2 the data would be augmented by .5N observation. This complication is necessary because the performance depends on the nature of the constraint. The validation sample is then sorted to assign the lowest N values to one population and the remainder to the other population.

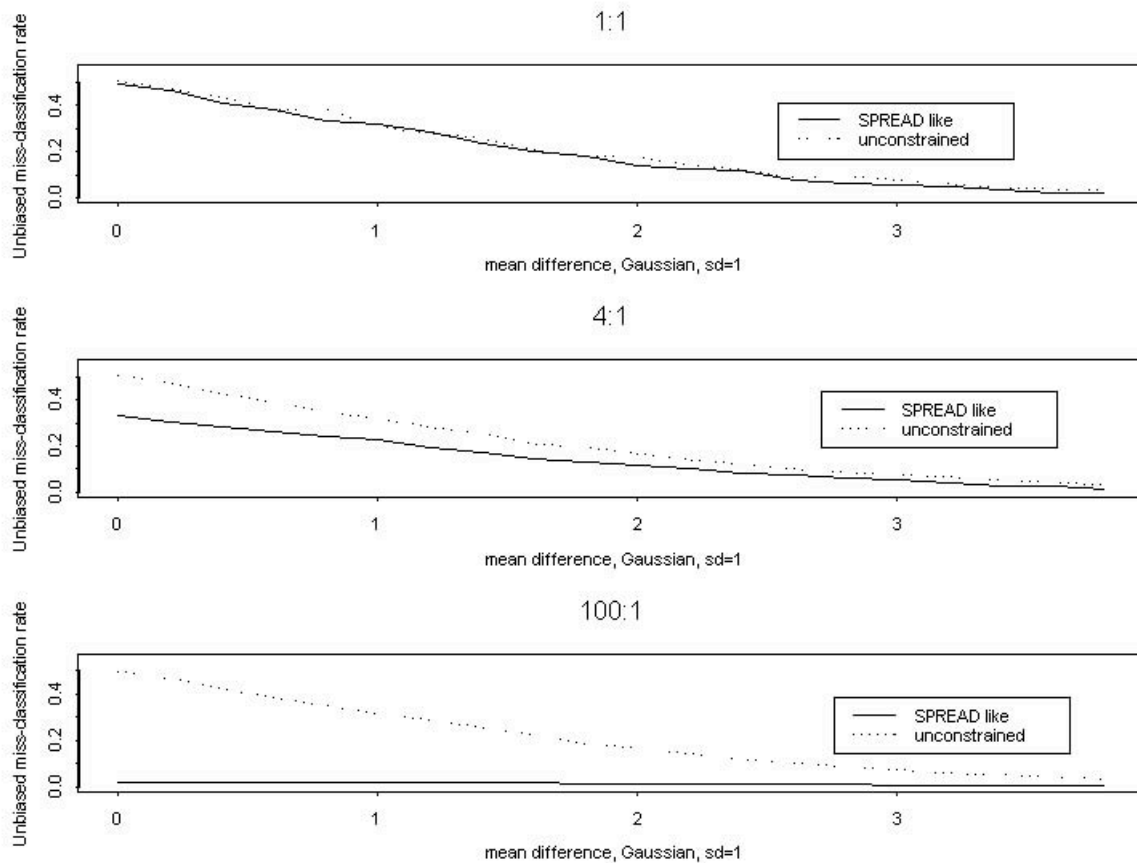The results of the analysis are shown in Figure A9.1.

Figure A9.1. Comparison of constrained and unconstrained classification.

The effect of using a sub-optimal discriminator

In this section the effect of using a sub-optimal discriminator is explored. The Gower metric is sub-optimal in the sense that it weights each of the elements of the profile equally. In practice, only parts of the profile may show useful discrimination and the remaining elements add noise. To see this the distance between the control site and a target zone is written as

$$D(c,t) = \frac{1}{p} \sum_{i=1}^{p} \frac{|c_i - t_i|}{Range(i)} = \sum_{some\,i} \frac{w_i |c_i - t_i|}{Range(i)} + \sum_{i=1}^{p} \frac{w^{\#}_i |c_i - t_i|}{Range(i)} = \text{discriminator} + \text{noise}$$

where c_i and t_i are the ith NDVI values for the control site and target zone respectively. *Range(i)* is the range of NDVI values for the ith season, and the w_i and $w^{\#}_i$ are weights chosen for optimal discrimination and equality respectively. Intuitively, the equation divides the distance measure into an optimal component for discrimination and a component that adds noise, blurring the discriminator's power.

To simulate this effect, data was constructed where additional noise is added onto the $y^*_{11}, K\ y^*_{1n}$ sample used to estimate the discriminator. It is assume that the noise is Gaussian with mean zero and variance 1. Theoretically this specification means there is increased noise in the population and therefore discrimination is harder.
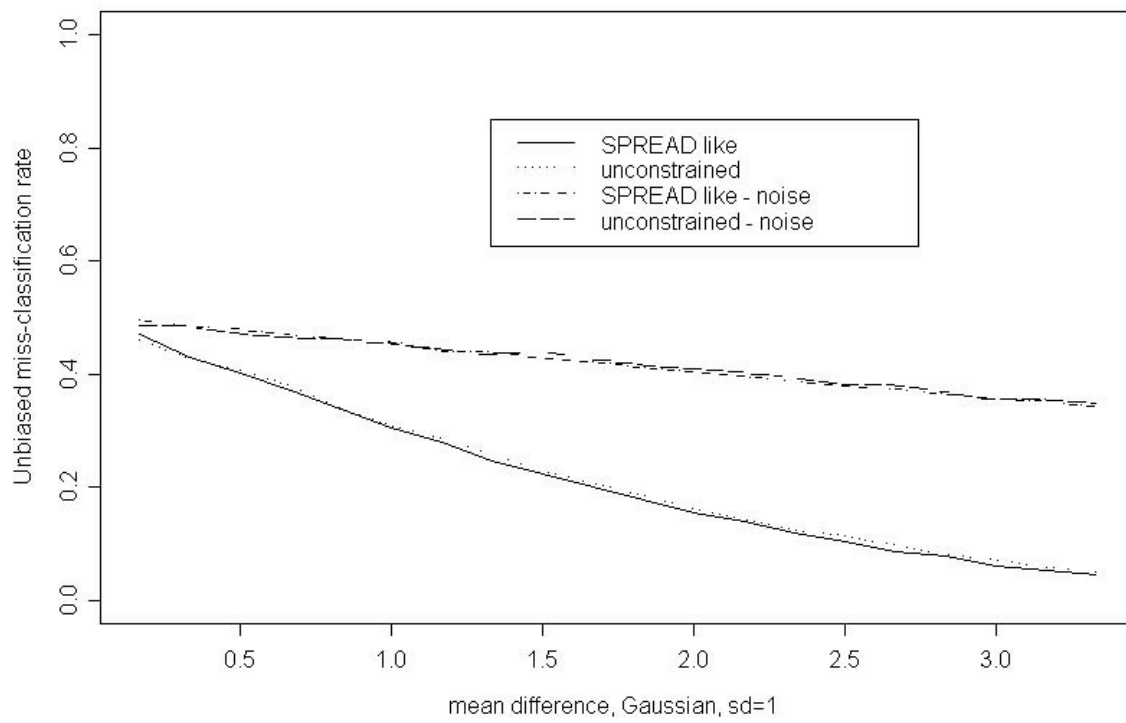
The effect is given in Figure A9.2.

Figure A9.2. Effect of a sub-optimal discriminator.

Appendix 10. Comparison with other data sources

The Audit, AFFA and the Murray Darling Basin Commission have funded a number of land use mapping exercises undertaken by the States and coordinated by BRS. The Audit refer to their products as Key Implementation Areas (KIAs) and encompass the Fitzroy Catchment (Qld), East and West Gippsland Catchment Management Authority Regions (Vic), Mount Lofty Ranges (SA) and Western Australia.

For the purpose of comparison, regional land use data sets were selected that mapped (as near as possible) 1996/97 land use. When comparing results it is important to consider if the land use classification has been interpreted differently for the different products. Where this is apparent or stated in the regional reports this has been noted.

The comparison of the national land use data set with other regional land use mapping exercises was undertaken for the Fitzroy Catchment (Qld), Mount Lofty Ranges (SA) and East and West Gippsland Management Authority Regions (Vic) (Figure A10.1).

The KIA vector products were converted to grids with the same cell size and cell alignment as the national land use grid. The national grid was clipped to the extent of the KIA and pixel by pixel comparisons undertaken at the primary, secondary and tertiary (where possible) level of the Australian Land Use and Management Classification, Version 4. Consideration was also given to the areal extent of the land uses represented in the 2 products at the same scale and the land uses lost in the KIA product on converting to the coarser scale of the national product.

All KIAs compared with the national land use grid were originally mapped according to Version 2 of the ALUMC. The KIA coordinating team within BRS converted ALUMC, Version 2 to Version 4 based on available data and talking to the State groups who undertook the mapping. The success of this conversion depended very much on the level of detail mapped in the original data. Copies of the classification and its versions are available at http://www.affa.gov.au by searching for ALUMC.

Fitzroy, Queensland

Background on the KIA

The Fitzroy Catchment in Central Queensland covers an area of ~14.3 Mha. The study area includes the Fitzroy Catchment as well as the western and northern portions of the Central Highlands lying within the upper Belyando catchment adjacent to the western watershed of the Fitzroy Basin. The study area contains 10% of the agricultural productive land in Queensland. Grazing is the major land use in the catchment, with livestock sales representing 57% of the value of agricultural production. Other major industries include irrigated agriculture (cotton), dryland cropping and coal mining.

Methodology undertaken by KIA

The Queensland Department of Natural Resources (QDNR)[1] undertook mapping of the 1997 land use in the Fitzroy Catchment. Satellite imagery interpretation (Landsat TM) and extensive fieldwork were used to collect the data. The majority of the data was mapped at a scale or 1:100 000 with the Emerald and Dawson Valley Irrigation Areas mapped at 1:25 000. From this were produced 8 hardcopy maps at 1:250 000.

Version 2 of the Australian Land Use and Management Classification (ALUMC) was applied to mapping the land use within the Fitzroy KIA. Version 2 of the classification was converted to Version 4 to allow comparison with the national land use product to the secondary level. Some key interpretations of the classification as applied in this mapping exercise are given below:

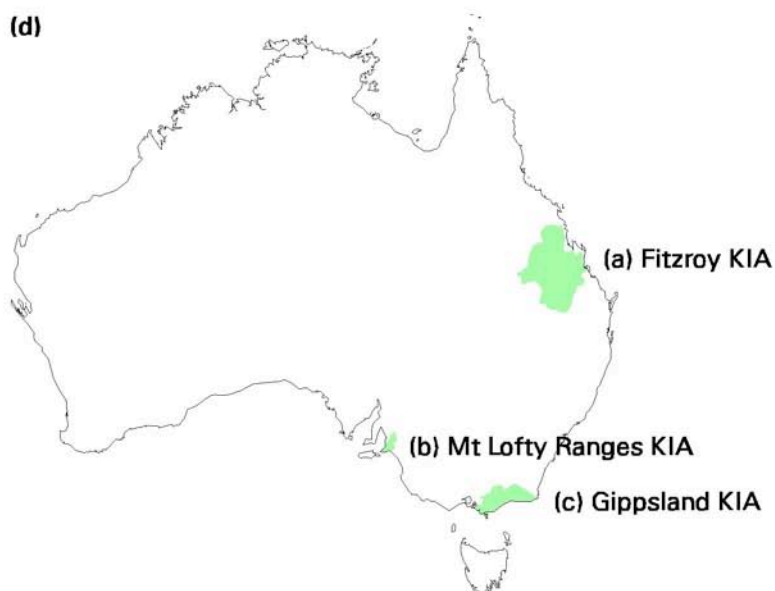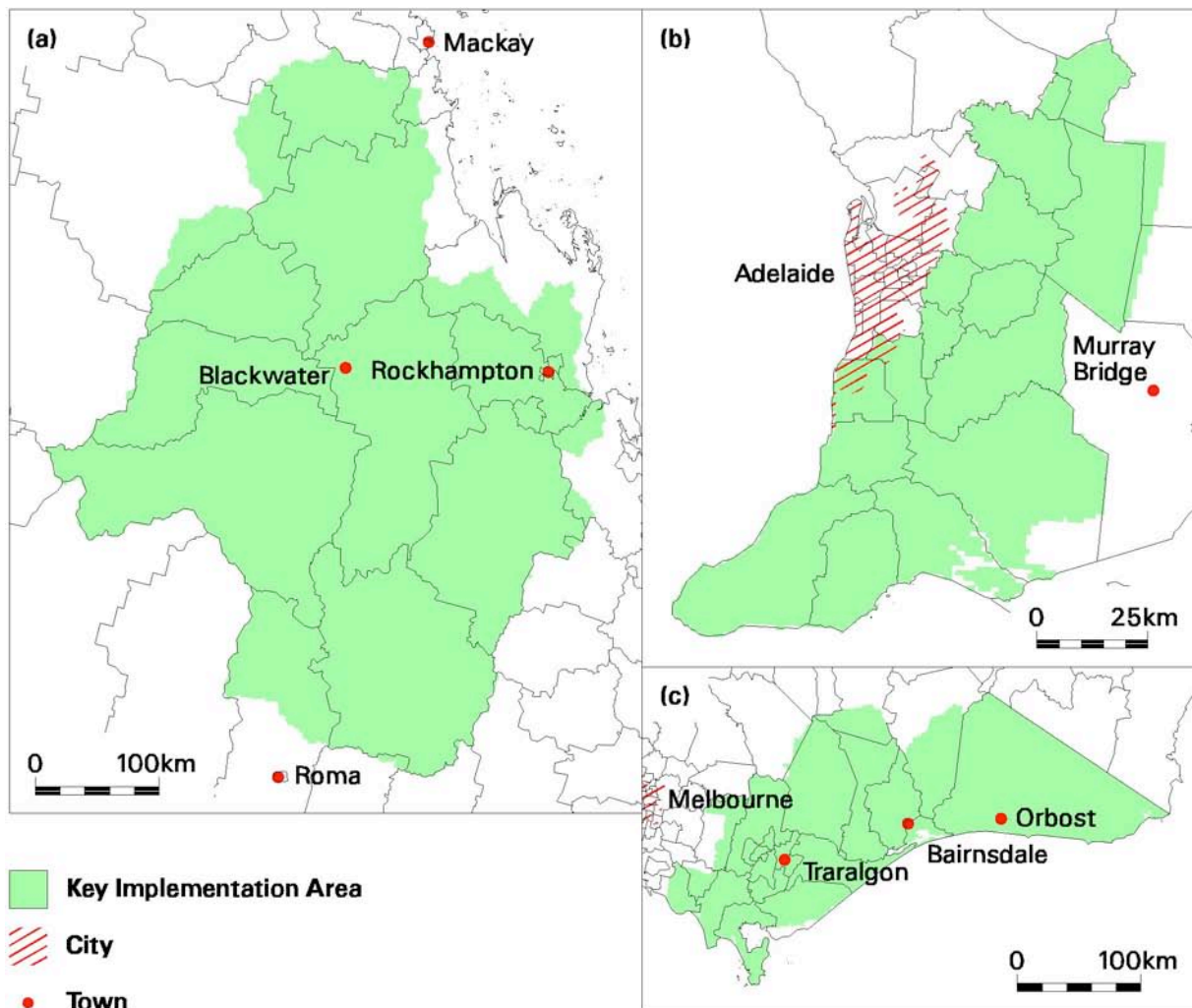[1] now the Queensland Department of Natural Resources and Mines

Figure A10.1. Location of the Key Implementation Areas (KIAs) mapped by the States for the National Land and Water Resources Audit. (a), (b) and (c) show the Fitzroy, Mt Lofty Ranges and Gippsland KIAs with the boundaries of Statistical Local Areas (SLAs) overlaid. (d) indicates where in Australia each KIA is located.

- 2.1 Livestock grazing includes grazing on native and improved pastures (more appropriate term mosaic). 3.3 Grazing modified pastures is only used for leucaena as it could be positively identified.

- 'Crop/pasture rotation' assigned to those areas where crop pasture rotation has occurred between the years 1991, 1995 and 1997 based on interpretation of TM satellite imagery. (This category does not exist in Version 4 of the ALUMC and has been assigned to 3.4 Cropping for comparison with the national land use product.)

- 5.4.2 Rural residential assigned to those areas as classified by a Shire Council's by-laws as rural residential (the definition differed for each local authority).

- 'Water bodies' – man-made water storage bodies designated, according to Version 2 of the ALUMC, as 5.5 Utilities (for 1:100 000 data) and 5.5.2 Water storage/treatment (for 1:25 000 data).

Comparison of KIA with national land use product

When the regional product was gridded to the same cell size as the national land use map, the following land uses were lost:

- 3.1 Plantation forestry;

- 5.1 Intensive horticulture; and

- 5.9 Waste treatment and disposal.

These land uses represent 0.005% of the total land use in the area mapped (~640 ha). In addition, there were changes in the proportion of land uses (Table A10.3). The major changes were:

- 1.2 Managed resource protection decreased from 0.3% to 0.1% (decrease of ~23200 ha)

- 3.5 Perennial horticulture decreased from 0.007% to 0.002% (decrease of ~770 ha)

- 5.7 Transport and communication decreased from 0.009% to 0.002% (decrease of ~980 ha)

- 6.0 Water decreased from 0.08% to 0.03% (decrease of ~7600 ha)

Figure A10.2 allows a visual comparison between the Fitzroy KIA and national product at the primary level of the ALUMC. Table A10.1 shows a 94% or higher match between the KIA and national product for primary classes 1 and 6 and a >75% match for primary class 2 on a pixel by pixel comparison. The high matching rate for primary class 1 is due to the high matching rate of secondary class 1.1 Nature conservation (Table A10.2), which the Fitzroy KIA mapping only categorizes as 1.1.3 National park. The national product has more tertiary classes in 1.1 as 6 of the 7 available classes are derived from CAPAD. For the Fitzroy KIA mapping, National Parks were extracted from the Queensland Digital Cadastral Data Base (QDCDB) rather than using CAPAD and hence the fewer tertiary classes under 1.1. For primary class 2, 2.2 Production forestry was extracted from the QDCDB by the Fitzroy KIA and is tenure based as it is in the national grid giving rise to the 96% match (Table A10.2).

Table A10.1. Percentage of matching pixels at 0.01 degree cell size between the Fitzroy KIA and the 1996/97 Land Use of Australia, Version 2, at the primary level of the Australian Land Use and Management Classification, Version 4.

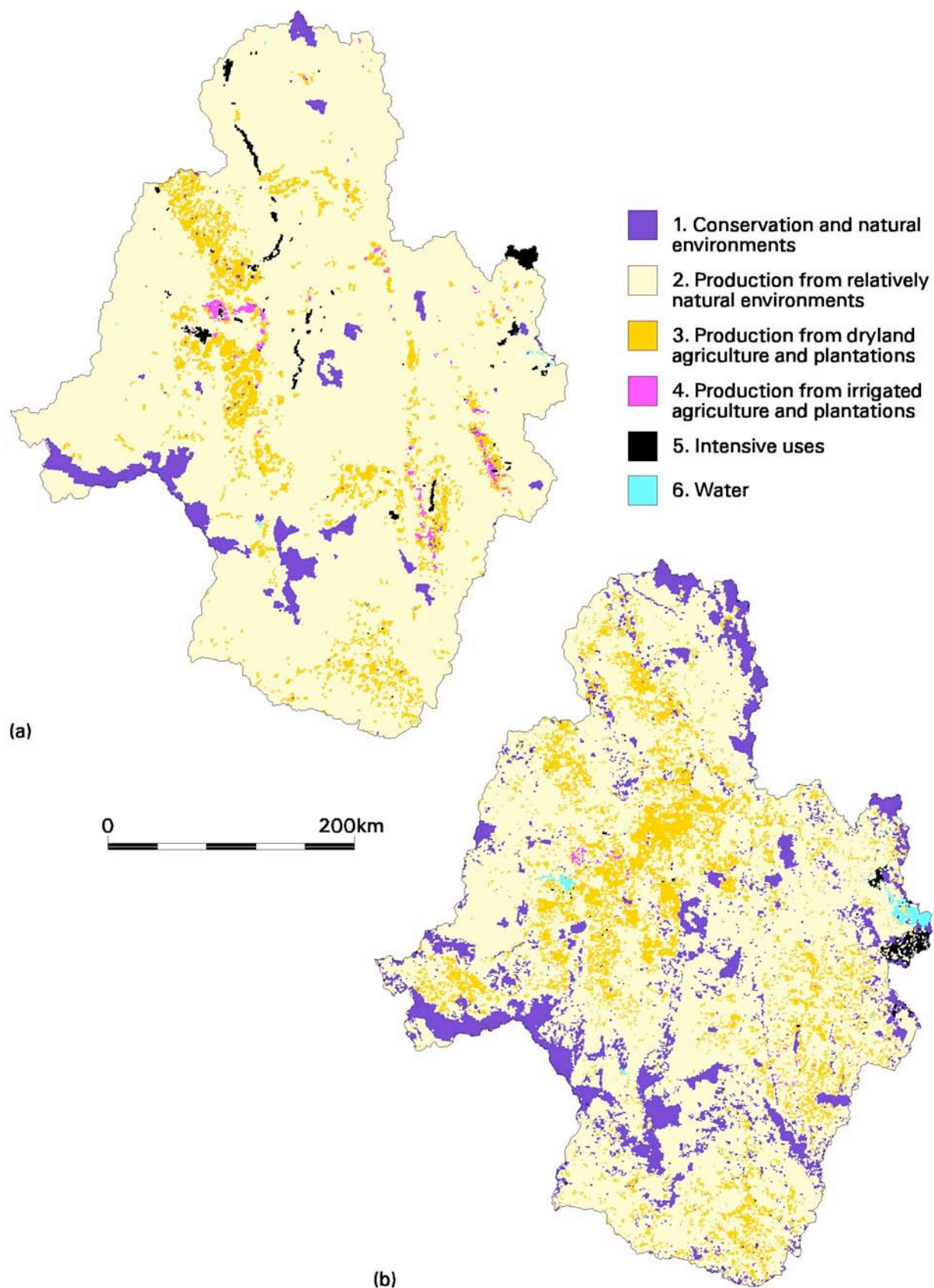| Primary classification	% pixel to pixel match
1. Conservation and natural environments	97
2. Production from relatively natural environments	76
3. Production from dryland agriculture and plantations	31
4. Production from irrigated agriculture and plantations	17
5. Intensive uses	5
6. Water	94

Figure A10.2. Primary land use classes occurring in the Fitzroy KIA. (a) Fitzroy KIA converted to the same resolution as the national land use data set (0.01 degree cell size). (b) the national land use data set clipped to the Fitzroy KIA.

248

Table A10.2. Pixel to pixel comparison between the Fitzroy KIA grid and the 1996/97 Land Use of Australia, Version 2, at the secondary level of the Australian Land Use and Management Classification, Version 4.

Secondary classification	% of total area	% pixel to pixel match	Comments in relation to national land use product
1.1 Nature conservation	4	97	Largest difference (15000 ha) assigned to managed resource protection
1.2 Managed resource protection	0.1	0	68% assigned to livestock grazing (10690 ha), 15 % to cropping and 7% to nature conservation
1.3 Other minimal use	0.005	0	50% assigned to estuary/coastal waters
2.1 Livestock grazing	83	73	11% (~1.3 Mha) assigned to other minimal use and 11% assigned to grazing modified pastures.
2.2 Production forestry	6	96	Largest difference (15160 ha) assigned to livestock grazing.
3.3 Grazing modified pastures	0.08	8	82% assigned to livestock grazing
3.4 Cropping	6	25	67% assigned to livestock grazing
3.5 Perennial horticulture	0.002	50	50% assigned to grazing modified pastures
4.3 Irrigated modified pastures	0.002	0	All assigned to livestock grazing
4.4 Irrigated cropping	0.5	16	63% assigned to livestock grazing, 16% to cropping
4.5 Irrigated perennial horticulture	0.01	0	80% assigned to livestock grazing, 13% to irrigated cropping
5.3 Manufacturing and industrial	0.006	0	Not a land use within the national product, assigned to intensive uses, largely undifferentiated intensive uses (86%)
5.4 Residential	0.09	37 (42 if include undifferentiated intensive uses)	44% assigned to livestock grazing, 12% assigned to grazing modified pastures
5.5 Services	0.2	0	Not a land use within the national product, 99% assigned to other minimal use
5.6 Utilities	0.09	0	Not a land use within the national product, 90% assigned to water features mostly lake
5.7 Transport and communication	0.002	67	The remainder assigned to undifferentiated intensive uses
5.8 Mining	0.4	0	Not a land use within the national product, 71% assigned to livestock grazing
6.0 Water	0.03	94	

Table A10.3. Comparison of different land uses as represented in the original Fitzroy KIA data (1:250 000), the gridded Fitzroy KIA data and the national grid.

Classification	% in original regional data	% in regional grid	% in national grid
1. Conservation and natural environments	**3.8**	**3.7**	**13.7**
1.1 Nature conservation	3.6	3.6	3.7
1.2 Managed resource protection area	0.3	0.1	0.4
1.3 Other minimal use	0.008	0.005	9.6[a]
2. Production from relatively natural environments	**87.9**	**88.9**	**72.3**
2.1 Livestock grazing	82.3	83.2	65.6
2.2 Production forestry	5.6	5.6	6.7
3. Production from dryland agriculture and plantations	**6.8**	**6.2**	**12.8**
3.1 Plantation forestry	0.0001	0	0
3.2 Farm forestry	0	0	0.009
3.3 Grazing modified pastures	0.1[b]	0.08[b]	9.4
3.4 Cropping	6.7[c]	6.1[c]	3.3
3.5 Perennial horticulture	0.007[d]	0.002[d]	0.006
4. Production from irrigated agriculture and plantations	**0.5**	**0.5**	**0.2**
4.3 Irrigated modified pastures	0.004	0.002	0.03
4.4 Irrigated cropping	0.5	0.5	0.2
4.5 Irrigated perennial horticulture	0.02	0.01	0.004
4.6 Irrigated seasonal horticulture	0[d]	0[d]	0.002
5. Intensive uses	**0.9**	**0.8**	**0.5**
5.1 Intensive horticulture	0.003	0	N/A
5.3 Manufacturing and industrial	0.006	0.006	N/A
5.4 Residential	0.1	0.09	0.04
5.5 Services	0.2	0.2	N/A
5.6 Utilities	0.1	0.09	N/A[e]
5.7 Transport and communication	0.009	0.002	0.01
5.8 Mining	0.4	0.4	N/A
5.9 Waste treatment and disposal	0.002	0	N/A
6. Water	**0.08**	**0.03**	**0.4**
6.1 Lake	N/A	N/A	0.1
6.2 Reservoir	0.08[e]	0.03[e]	0.005
6.3 River	N/A	N/A	0.05
6.5 Marsh/wetland	N/A	N/A	0.03
6.6 Estuary/coastal waters	N/A	N/A	0.2

[a] For the national grid, other minimal use includes remnant native cover on private land.

[b] For the Fitzroy cover and grid, grazing modified pastures only includes leucaena. All other modified pastures for grazing are included in 2.1 Livestock grazing.

[c] For the Fitzroy cover and grid, cropping includes crop/pasture rotation, where the national grid only indicates those areas cropped in 1996/97.

[d] For the Fitzroy cover and grid, horticulture is not separated into perennial and seasonal. For comparison with the national grid, horticulture has been assigned to perennial horticulture.

[e] For the Fitzroy cover and grid, dams on properties and large reservoirs like Lake Maraboon have been assigned to 5.6 Utilities. In the national grid, reservoirs are separately represented in 6.2 Reservoir.

Although the Fitzroy KIA was mapped for the same period as the national product, a different version of the ALUM classification was used (version 2 rather than version 4). Without the underlying data and decision rules used to allocate land use to version 2, conversion to version 4 is at best crude (and only undertaken to the secondary level). For instance, non-agricultural aboriginal land is classified as 1.2 Managed resource protection under version 4 in the national product and 1.3 Other minimal use in the converted Fitzroy KIA as it was classified as 'unmanaged land' in version 2 of ALUMC. Some mangroves and salt marshes within the confines of the lower Fitzroy River and Lake Maraboon were classed 'unmanaged land' and so on conversion are classed as 1.3 Other minimal use rather than 6.6 Estuary/coastal waters as in the national product (see Table A10.2). Other differences in approach and assumptions made to convert from version 2 to version 4 of ALUMC have already been indicated (i.e. crop/pasture rotation, horticulture, modified pastures).

Some conclusions that can be drawn for the national product are:

- Irrigated agriculture is under-represented. However, this may reflect mapping of the presence of irrigation infrastructure as opposed to its use in the Fitzroy KIA mapping rather than an under-reporting in AgStats of the area irrigated in 1996/97 and thus a difference in interpretation of the classification.

- Better representation of conservation and natural environments. This is due to conversion of the Fitzroy KIA from version 2 to version 4 of ALUMC without access to the underlying data and decision rules. Remnant native cover on private land is a large contributing factor in the national product.

- Direct comparison with the Fitzroy KIA is difficult and misleading without consideration of the different methods and version of the ALUMC originally used.

Mt Lofty Ranges, South Australia

Background on the KIA

The Mt Lofty Ranges comprise 600,000 hectares of hinterland of Adelaide/Elizabeth lying up to 50km to the south and east of the city. The main urban centres are Gawler and Crafers-Bridgewater. Livestock grazing is the dominant land use as well as the most valuable agricultural land use representing 49% of the value of agricultural production. Horticulture also is a major contributor to the total value of agricultural production with apple and stone fruit orchards, seasonal fruit and vegetables in the northern part of the study area and vineyards in the vicinity of McLaren Vale and Adelaide Hills.

Methodology undertaken by KIA

The region referred to as the Mount Lofty Ranges was mapped in 1993 and updated and validated in 1999. This time sequence allows consideration of land use change and indicates the region has undergone considerable change during this period. Areas have come into agriculture and other areas have changed agricultural land use to a diversity of other agricultural uses. Of note is the increase in grapevines, and decline in vegetable growing (Flavel and Ratcliff, 2000). Irrigated agriculture is important for the dairying and horticultural industries in the region.

The updating of the 1993 coverage to 1999 involved use of other spatial data sets, aerial photography and satellite imagery (25m Landsat TM images and 1998 PanAiRama CD) and field checking of 45% of the cadastre polygons. Assumptions were made in determining whether some areas were irrigated based on management practices. Areas mapped as grazing land include not only grazing land but other small anomalous areas like road and rail reserves. The categorisation of grazing land into native and modified pasture proved difficult and errors will include both native pasture classified as modified and modified classified as native (Russell Flavel, pers comm).

For comparison with the national land use data set, the land use of Mount Lofty Ranges in 1999 was used.

Comparison of KIA with national land use product

When the regional product was gridded to the same cell size as the national land use map, the following land uses were lost:

- 5.5.0 Services

- 5.7.1 Airports/aerodromes

- 5.7.4 Ports and water transport

- 5.9.3 Solid garbage

- 5.9.5 Sewage

- 6.2.3 Evaporation basin

- 6.6.0 Estuary/coastal waters

These land uses represent < 0.1% of total land uses in the area mapped (~570ha). In addition, there were changes in the proportion of land uses (Table A10.6). The major changes were:

- 2.1.0 Livestock grazing increased from 59% to 67% of total area (increase of ~46500ha)

- 5.4.2 Rural residential decreased from 3% to 1% (decrease of ~10700ha)

- 5.5.2 Public services decreased from 0.1% to 0.02% (decrease of ~620ha)

Figure A10.3 shows a visual comparison between the regional and national scale land use mapping of the Mount Lofty Ranges KIA at the primary level of the ALUMC. Table A10.4 shows the results of a pixel by pixel comparison of the two maps at the primary level of the ALUMC. Table A10.5 shows the results of a pixel by pixel comparison at the secondary level of the ALUMC.

Table A10.4. Percentage of matching pixels at 0.01 degree cell size between the Mount Lofty Ranges KIA and the 1996/97 Land Use of Australia, Version 2, at the primary level of the Australian Land Use and Management Classification, Version 4.

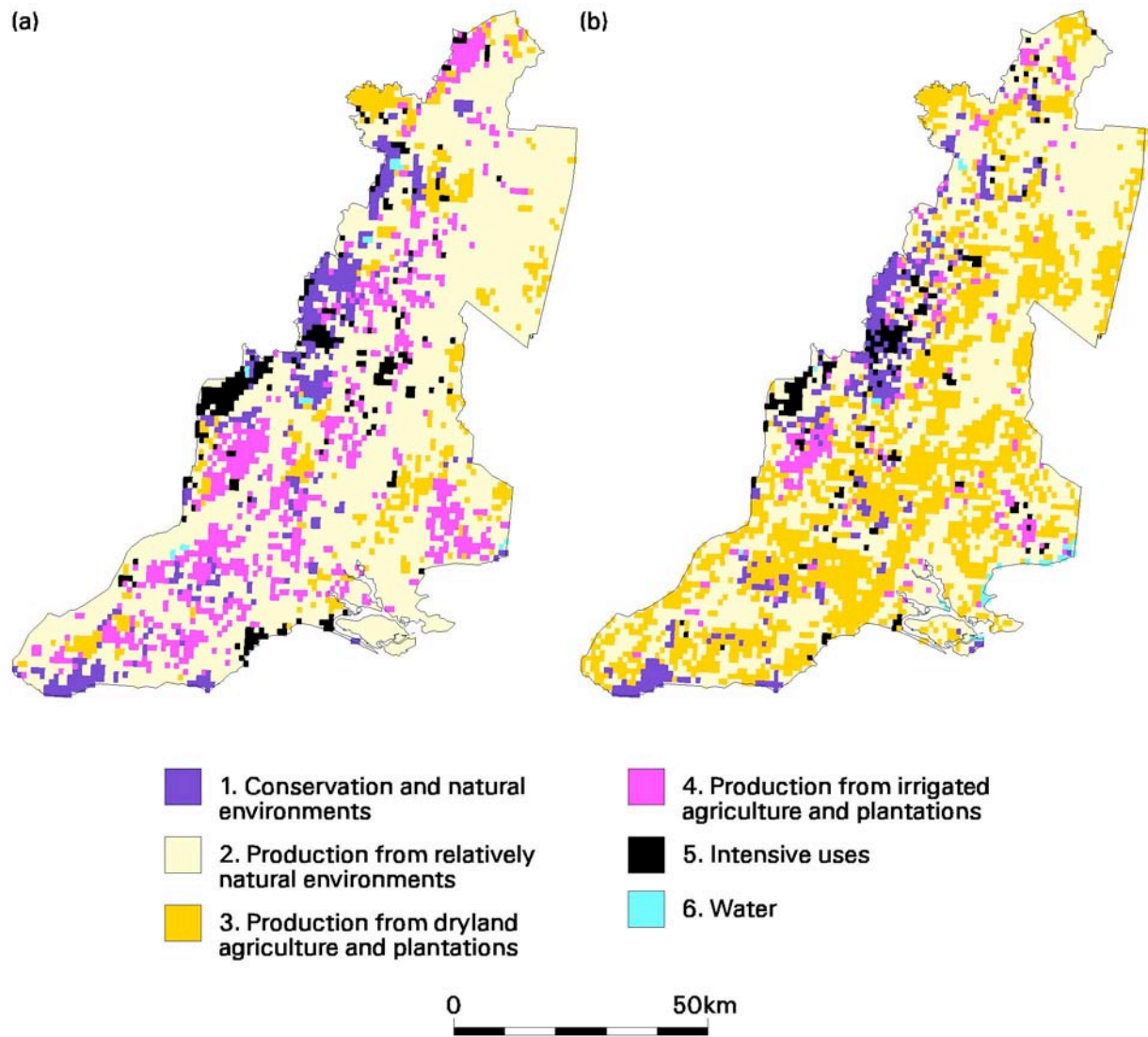| Primary classification	% pixel to pixel match
1. Conservation and natural environments	58
2. Production from relatively natural environments	55
3. Production from dryland agriculture and plantations	54
4. Production from irrigated agriculture and plantations	13
5. Intensive uses	34
6. Water	56

Figure A10.3. Primary land use classes occurring in the Mt Lofty Ranges KIA. **(a)** Mt Lofty Ranges KIA converted to the same resolution as the national land use data set (0.01 degree cell size). **(b)** the national land use data set clipped to the Mt Lofty Ranges KIA.

Table A10.5. Pixel to pixel comparison of Mount Lofty Ranges KIA grid and the 1996/97 Land Use of Australia, Version 2 at the secondary level of the Australian Land Use and Management Classification, Version 4.

Secondary classification	% of total area	% pixel to pixel match	Comments in relation to national land use product
1.1 Nature conservation	2	75	8% assigned to other minimal use and 7% to livestock grazing
1.3 Other minimal use	5	33	Assigned to a range of land uses, the major ones being production forestry (16%), nature conservation (15%) and livestock grazing (13%)
2.1 Livestock grazing	67	55	26% assigned to grazing modified pastures, 11% to cropping
3.1 Plantation forestry	3	56	37% assigned to production forestry
3.4 Cropping	5	46	All assigned to agricultural land, the majority (44%) to livestock grazing
4.3 Irrigated modified pastures	8	2	46% assigned to livestock grazing and 42% to grazing modified pastures
4.4 Irrigated cropping	0.4	0	73% assigned to livestock grazing, 15% to irrigated modified pastures and 11% to cropping
4.5 Irrigated perennial horticulture	5	26 (30 for all horticulture)	96% assigned to agricultural land, the majority (27%) to livestock grazing
4.6 Irrigated seasonal horticulture	0.2	0	57% assigned to grazing modified pastures, 43% to livestock grazing
5.3 Manufacturing and industrial	0.2	0	Not a land use in the national product, assigned to livestock grazing (44%), grazing modified pastures (33%) and residential (22%)
5.4 Residential	4	32	Most (37%) assigned to livestock grazing
5.5 Services	0.2	0	Not a land use in the national product, 46% assigned to livestock grazing
5.8 Mining	0.008	0	Not a land use in the national product, 60% assigned to livestock grazing
6.2 Reservoir	0.3	45 (55 for all water features)	22% assigned to production forestry

Table A10.6. Comparison of different land uses as represented in the original Mount Lofty Ranges KIA data, the gridded Mount Lofty Ranges KIA data and the national grid.

Classification	% in original regional data	% in regional grid	% in national grid
1. Conservation and natural environments	**8.7**	**6.9**	**6.7**
1.1 Nature conservation	1.8	2.0	2.3
1.3 Other minimal use	6.9	4.9	4.4
2. Production from relatively natural environments	**58.8**	**66.9**	**49.7**
2.1 Livestock grazing	58.8	66.9	47.8
2.2 Production forestry	N/A	N/A	1.9
3. Production from dryland agriculture and plantations	**9.0**	**7.9**	**35.8**
3.1 Plantation forestry	2.6	2.6	1.9
3.2 Farm forestry	N/A	N/A	0.02
3.3 Grazing modified pastures	N/A	N/A	22.7
3.4 Cropping	6.4	5.3	10.4
3.5 Perennial horticulture	N/A	N/A	0.7
3.6 Seasonal horticulture	N/A	N/A	0.07
4. Production from irrigated agriculture and plantations	**16.4**	**13.8**	**4.1**
4.3 Irrigated modified pastures	9.9	8.3	1.2
4.4 Irrigated cropping	0.6	0.4	0.07
4.5 Irrigated perennial horticulture	5.6	4.8	2.6
4.6 Irrigated seasonal horticulture	0.3	0.2	0.2
5. Intensive uses	**6.8**	**4.2**	**3.2**
6. Water	**0.3**	**0.3**	**0.5**

Some conclusions that can be drawn for the comparison of the national land use map with the Mt Lofty Ranges KIA land use map are:

▪ Table A10.6 shows that the national land use map, relative to the regional, under-represents 2.1 Livestock grazing and over represents 3.3 Grazing modified pastures. The pixel to pixel comparison in Table A10.5 shows that 81% of the land mapped as 2.1 Livestock grazing in the regional map is shown as either 2.1 Livestock grazing or 3.3 Grazing modified pastures in the national map. Further, 88% of the land mapped as 4.3 Irrigated modified pastures in the regional map is shown as either 2.1 Livestock grazing or 3.3 Grazing modified pastures. The regional map has no 3.3 Grazing modified pastures. The gridded version version of the regional map shows 75% pasture, while the national map shows 72%. The two maps are in broad agreement on the distribution and abundance of pastures but disagree on the distribution of pasture types. This disagreement needs to be considered in the context of the difficulty experienced during the regional mapping exercise in distinguishing different types of pasture. The national map shows less native pasture and less irrigated modified pasture but more dryland modified pasture than the regional map.

▪ The national land use map, relative to the regional, over-represents cropping (3.4 Cropping and 4.4 Irrigated cropping) and under-represents the proportion of cropping that is irrigated. The relative errors in these representations are large but the absolute errors are not excessive.

▪ The area of perennial horticulture – mainly grapevines – increased in the Mt Lofty KIA between 1993 and 1999. The national land use map shows approximately the expected area of perennial

horticulture though the proportion irrigated appears to be under-represented relative to the regional map. For the area covered by the regional map, the area under grapevines increased from 9000 ha to 23000 ha between 1993 and 1999 (Flavel and Ratcliff, 2000). Assuming a constant rate of increase, around 16000 ha of grape vines might have been expected in the Mt Lofty KIA in 1996 representing 2.7% of the mapped area. The national land use map has 3.3% of the area under perennial horticulture.

- The area of seasonal horticulture – mainly vegetables – decreased in the Mt Lofty KIA between 1993 and 1999. The national land use map shows half the area that might have been expected in 1996 assuming a constant rate of decrease. The national land use map shows a significant proportion of the seasonal horticulture not irrigated whereas the regional map shows it all irrigated. In the regional map, the area under vegetables decreased from 5200 ha to 2000 ha between 1993 and 1999 (Flavel and Ratcliff, 2000). Assuming a constant rate of decrease, around 3600 ha of vegetables might have been expected in the Mt Lofty KIA in 1996 representing 0.6% of the mapped area. The national land use map has 0.3% of the area under seasonal horticulture.

- The national land use map under-represents irrigated agriculture relative to the regional map. This is particularly so for modified pastures (mostly used for dairying). This could be due to errors in the regional mapping resulting from the original data not always specifing whether the land use was irrigated meaning that assumptions had to be made as to whether a land use was irrigated or not (Flavel and Ratcliff, 2000). It could also be due to errors in the AgStats-based data used in the national mapping, either inherent in the original AgStats data or introduced during its processing.

Gippsland, Victoria

Background on KIA

The Gippsland KIA comprises the Tambo, Mitchell, Thomson, La Trobe, East and South Gippsland, and Snowy catchments in Victoria. The area covers 3.9 Mha and lies 80 kilometres east of Melbourne. The study area contains about 1.2% of the agriculturally productive land in Victoria. The area is intensively farmed for dryland and irrigated dairying with milk contributing 49% to the total value of agricultural production for the region. Forestry is also a large land use in the region with both native and plantation forests. Agriculture and mining are the major employers with brown coal mines found in the La Trobe Valley, near Yallourn-Morwell and Loy Yang.

Methodology undertaken by KIA

Land use in the East and West Gippsland Catchment Management Authority Regions in Victoria was mapped for 1996/97. Twenty-six mapsheets at 1:100 000 were produced for the KIA. The methods employed were:

1. For classification of primary classes 1, 2, 5 and 6 - geospatial resource information using the Department of Natural Resources and Environment (NRE) Corporate Geospatial Data Library and CAPAD99;

2. For classification of primary classes 3 and 4 - satellite imagery acquired from Landsat 5 and SPOT 2 satellites for the summer of 1996-97, geocoded ABS agricultural statistics and irrigation infrastructure.

Field verification of the classification accuracy was undertaken for 15.5% of the area representing 3 high intensity land use areas of Gippsland around Sale, Maffra and Stratford.

NRE considered the difference between the geocoded ABS statistics and the area of crops and pastures as determined by the Land Cover Change Project (BRS) based on classification of remote sensing imagery. They found the geocoded ABS statistics only represented 48% of the agricultural area in the KIA.

With the satellite imagery used, NRE had difficulty distinguishing between irrigated and non-irrigated areas. Also there was difficulty distinguishing between native and improved/fertilised pastures and these were assigned to 3.3 Grazing modified pastures.

Other key interpretations of the ALUM classification were:

- Grazing leases on State Forest assigned to 2.1 Livestock grazing.

- Lakes and Marshes/Wetlands with IUCN category 'managed resource protection' assigned to 1.2.2. Surface water supply. (The national grid has assigned these to 6.1.1 Lake – conservation and 6.5.1 Marsh/wetland – conservation)

- Information on 3.2 Farm forestry was not available to spatially distinguish it from 2.2 Production forestry or 3.1 Plantations.

Comparison of KIA with national land use product

When the regional product was gridded to the same cell size as the national land use map, the following land uses were lost:

- 1.2.4 Landscape;

- 5.6.1 Electricity generation/transmission;

- 5.6.2 Gas treatment, storage and transmission;

- 5.7.3 Railways; and

- 5.7.4 Ports and water transport.

In total these land uses represented 1151 hectares or 0.03% of the KIA. In addition, there were changes in the proportion of land uses (Table A10.9). The major changes were:

- 3.3.0 Grazing modified pastures increased from 23% to 26% of total area (increase of ~97800 ha)

- 3.4.0 Cropping decreased from 0.2% to 0.07% (decrease of ~3400 ha)

- 3.6.0 Seasonal horticulture decreased from 0.02% to 0.005% (decrease of ~620 ha)

- 5.7.2 Roads decreased from 1.6% to 0.005% (decrease of ~59800 ha)

When converting the Gippsland KIA from Version 2 to Version 4 of the ALUMC, BRS had access to ancillary data providing comments on the land use allocated. This helped with re-assigning land parcels classified as crop/pasture rotations, allowing some to be assigned to 3.4 Cropping and others to 3.3 Grazing modified pastures or 2.1 Livestock grazing.

Figure A10.4 shows a visual comparison between the regional and national scale land use mapping of the Gippsland KIA at the primary level of the ALUMC. Table A10.7 shows > 80% match between the KIA and national product for primary classes 1, 2 and 6 with a pixel by pixel comparison. Primary classes 1, 2, 5 and 6 were derived from the NRE Corporate Geospatial Data Library (CGDL) and CAPAD99. CAPAD99 was the data set used in the national product for assignment of the bulk of primary class 1 and hence the pixel matching of 95%. Production forestry (2.2) in the national product was derived from tenure information and thus as the major land use in primary class 2 it is not surprising that there is high pixel matching (98%) for this secondary class (Table A10.8).

Table A10.7. Percentage of matching pixels at 0.01 degree cell size between the Gippsland KIA and the 1996/97 Land Use of Australia, Version 2, at the primary level of the Australian Land Use and Management Classification, Version 4.

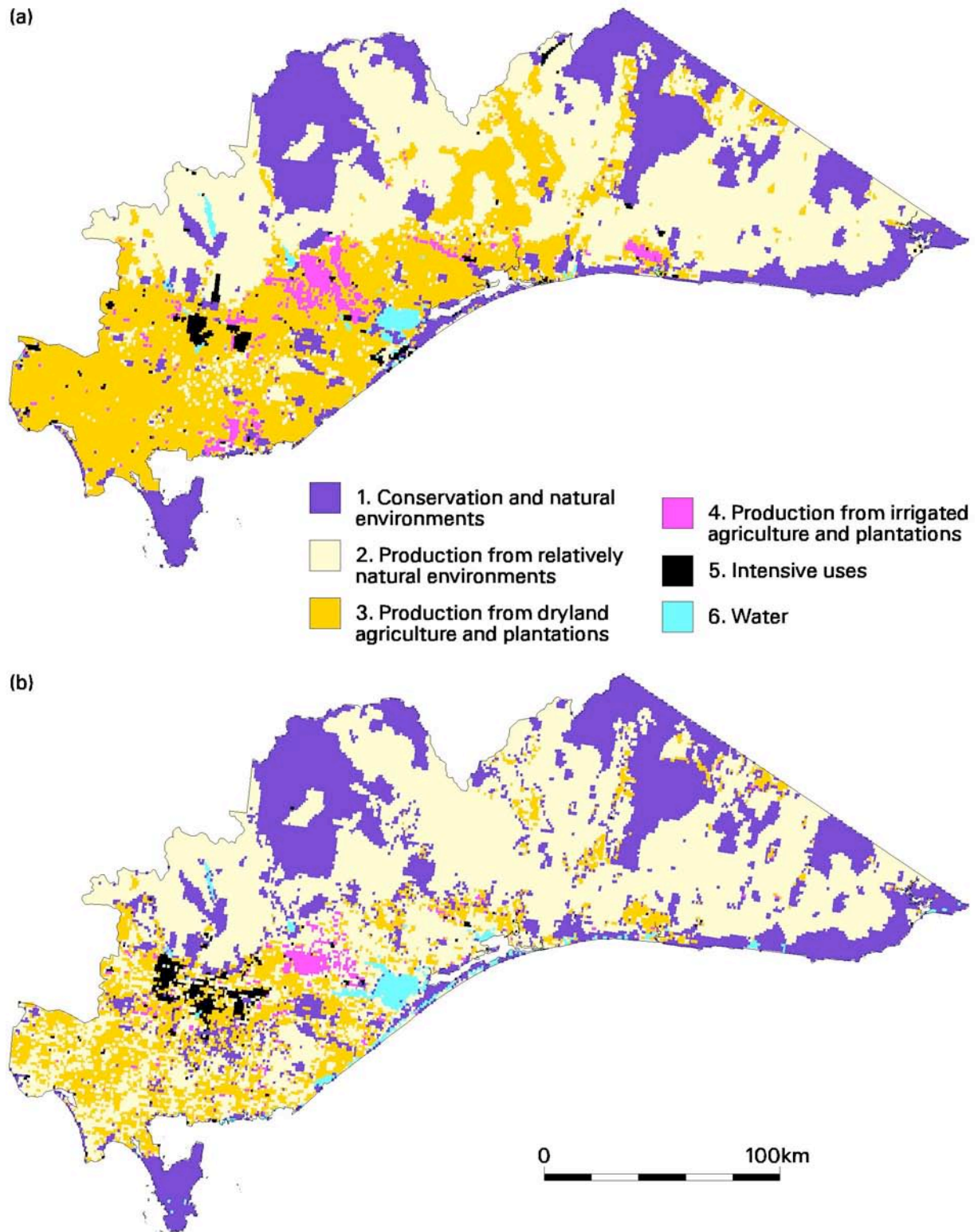| Primary classification	% pixel to pixel match
1. Conservation and natural environments	95
2. Production from relatively natural environments	88
3. Production from dryland agriculture and plantations	36
4. Production from irrigated agriculture and plantations	24
5. Intensive uses	41
6. Water	83

Figure A10.4. Primary land use classes occurring in the Gippsland KIA. **(a)** Gippsland KIA converted to the same resolution as the national land use data set (0.01 degree cell size). **(b)** the national land use data set clipped to the Gippsland KIA.

Table A10.8. Pixel to pixel comparison of Gippsland KIA grid and the 1996/97 Land Use of Australia, Version 2 at the secondary level of the Australian Land Use and Management Classification, Version 4.

Secondary classification	% of total area	% pixel to pixel match	Comments in relation to national land use product
1.1 Nature conservation	20	98	Largest difference assigned to production forestry (4220 ha), then water features (3600 ha)
1.2 Managed resource protection	1	47	42% assigned to water features (18790 ha)[a]
1.3 Other minimal use	1	10	64% assigned to nature conservation (31480 ha)
2.1 Livestock grazing	10	8	50% assigned to production forestry[b], 39% assigned to other minimal use (mostly remnant native cover)[c]
2.2 Production forestry	30	98	
3.1 Plantation forestry	7	25	70% assigned to production forestry[d]
3.3 Grazing modified pastures	26	40	49% assigned to livestock grazing[e]
3.4 Cropping	0.1	0	Assigned grazing modified pastures (74%) or livestock grazing (26%)
3.6 Seasonal horticulture	0.005	0	All assigned to modified pastures
4.3 Irrigated modified pastures	2	26	45% assigned to livestock grazing and 25% to grazing modified pastures
4.4 Irrigated cropping	0.1	0	62% assigned to grazing modified pastures, 30% to livestock grazing
4.6 Irrigated seasonal horticulture	0.05	5	37% assigned to grazing modified pastures, 32% to livestock grazing
5.4 Residential	0.3	61	29% assigned to livestock grazing
5.5 Services	0.1	0	Not a land use in the national product, 40% assigned to other minimal use, 11% to intensive uses (residential and undifferentiated intensive uses)
5.7 Transport and communication	0.01	0	60% assigned to other minimal use, the remainder to intensive uses (residential and undifferentiated intensive uses)
5.8 Mining	0.5	0	Not a land use in the national product, 44% assigned to undifferentiated intensive uses and 30% to production forestry
5.9 Water treatment and disposal	0.1	0	Not a land use in the national product, 82% to other minimal use
6.1 Lake	0.8	62	16% assigned to reservoirs, 6% to marsh/wetland
6.5 Marsh/wetland	0.01	20	The remainder split between nature conservation, other minimal use, livestock grazing and grazing modified pastures[f]

[a] For the Gippsland grid, lakes and marshes/wetlands with IUCN category 'managed resource protection' assigned to 1.2 rather than 6.1 or 6.5 as in national grid.
[b] For the Gippsland grid, grazing leases in State Forest assigned to livestock grazing.
[c] For the national grid, remnant native cover is largely open and closed forest on private land with unknown use.

[d] In the Gippsland cover and grid, some plantations are identified north-east of Bairnsdale. According to the National Forestry Inventory, these areas are most likely hardwood state forest. In the national grid, these areas are shown as 2.2 Production forestry as they have the tenure of multiple use forest and from the data used are not plantations.

[e] For the Gippsland grid, native pastures often assigned to grazing modified pastures due to difficulty distinguishing native and modified pastures.

[f] Land subject to inundation available for agricultural activities (particularly grazing) in national product.

Table A10.9. Comparison of different land uses as represented in the original Gippsland KIA data (1:100 000), the gridded Gippsland KIA data and the national grid.

Classification	% in original regional data	% in regional grid	% in national grid
1. Conservation and natural environments	**23.4**	**22.8**	**27.0**
1.1 Nature conservation	20.2	20.3	20.9
1.2 Managed resource protection area	1.2	1.2	0.6
1.3 Other minimal use	1.9	1.3	5.5[a]
2. Production from relatively natural environments	**40.8**	**40.5**	**54.8**
2.1 Livestock grazing	11.5	10.3	14.7
2.2 Production forestry	29.3	30.2	40.0[b]
3. Production from dryland agriculture and plantations	**29.7**	**32.6**	**13.9**
3.1 Plantation forestry	6.5[b]	6.9[b]	2.2 (plus 0.05 for farm forestry)
3.3 Grazing modified pastures	23.0	25.6	11.3
3.4 Cropping	0.2	0.07	0.3
3.6 Seasonal horticulture	0.02	0.005	0.05
4. Production from irrigated agriculture and plantations	**2.3**	**2.2**	**1.3**
4.3 Irrigated modified pastures	2.1	2.1	1.1
4.4 Irrigated cropping	0.2	0.09	0.03
4.6 Irrigated seasonal horticulture	0.08	0.05	0.1
5. Intensive uses	**2.8**	**1.1**	**1.5**
6. Water	**1.0**	**0.8**	**1.4 (incl 0.6 conservation)**

[a] For the national grid, other minimal use includes remnant native cover on private land.

[b] In the Gippsland cover and grid, some plantations are identified north-east of Bairnsdale. According to the National Forestry Inventory, these areas are most likely hardwood state forest. In the national grid, these areas are shown as 2.2 Production forestry as they have the tenure of multiple use forest and from the data used are not plantations.

Some conclusions that can be drawn for the comparison of the national land use map with the Gippsland KIA land use map are:

- The national land use map and the regional land use map are in good agreement for land uses in primary classes 1, 2 and 6.

- In the Gippsland KIA mapping, alternative interpretations of prime use have resulted in grazing within forested areas being classified with grazing by livestock of native or improved pasture. The national product has assigned these areas to 2.2 Production forestry and 1.3 Other minimal use (remnant native vegetation). However, when allowance is made for this there appears to be general agreement between the two products on the total areas occupied by these land uses.

- In the regional KIA mapping, difficulty was experienced in distinguishing between native and modified pasture. If allowance is made for this, the national land use map and the regional land

use map are in good agreement as the only major land use assigned to classes 3 or 4 by the regional map is 3.3 Grazing modified pastures.

Overview of pixel by pixel comparison at the secondary level of the ALUMC

In assessing the results of the pixel to pixel match between the national and regional land use maps, allowances need to be made for differences in interpretation of the land use classification. Table A10.10 summarises such an approach. It shows an appropriate alignment of land use codes at the secondary level of the ALUMC Version 4 between the national land use map and the regional land use maps for the Fitzroy, Mt Lofty Ranges and Gippsland KIAs.

Table A10.10. Alignment of land use codes at the secondary level of the ALUMC Version 4 between the national land use map and the regional land use maps for the Fitzroy, Mt Lofty Ranges and Gippsland KIAs making allowances for differences in interpretation of land use classification.

Secondary codes used in the regional land use maps	Allowed 'matches' in the national land use map
1.1	1.1
1.2	1.2, 6.1[G], 6.5[G]
1.3	1.2, 1.3, 6.6[F]
2.1	2.1, 3.3, 4.3, 2.2[G]
2.2	2.2
3.1	3.1
3.3	2.1[MG], 3.3, 4.3
3.4	3.3[FM], 3.4, 4.3[FM], 4.4
3.5	3.5, 3.6[F], 4.5, 4.6[F]
3.6	3.6, 4.6
4.3	2.1[MG], 3.3, 4.3
4.4	3.3[FM], 3.4, 4.3[FM], 4.4
4.5	3.5, 3.6[F], 4.5, 4.6[F]
4.6	3.6, 4.6
5.3	5.4
5.4	5.0, 5.4
5.5	5.0, 5.4
5.6	5.0, 5.4, 6.2[F]
5.7	5.0, 5.4, 5.7
5.8	5.0
5.9	5.0, 5.4
6.1	6.1
6.2	6.2
6.5	6.5

[G] Gippsland KIA only
[F] Fitzroy KIA only
[MG] Mt Lofty Ranges and Gippsland KIAs only
[FM] Fitzroy and Mt Lofty Ranges KIAs only

These alignments are based on the following factors previously discussed:

- In the Fitzroy, Mt Lofty Ranges and Gippsland KIA mapping:

    (i)   non-agricultural aboriginal land mapped as 'unmanaged land', which converts to 1.3 Other minimal use in ALUMC Version 4; non-agricultural aboriginal land mapped as 1.2 Managed resource protection in the national land use map.

(ii)   land mapped as native pasture includes some modified pasture. In the Gippsland KIA mapping, it also includes land mapped as 2.2 Production forestry in the national product.

(iii)   dryland and irrigated land uses have not been distinguished with certainty

- In the Fitzroy and Mt Lofty Ranges KIA mapping, after conversion to ALUMC Version 4, crop/pasture rotations are shown as 3.4 Cropping (and irrigated crop/pasture rotations as 4.4 Irrigated cropping). In the Gippsland KIA mapping, during conversion to ALUMC Version 4, crop/pasture rotations have been reclassified as cropping or pasture as appropriate.

- In the Fitzroy KIA mapping:

  (i)   after conversion to ALUMC Version 4, estuary and coastal waters are mapped as 1.3 Other minimal use; this land use is mapped as 6.6 Estuary/coastal waters in the national product.

  (ii)   land mapped as modified pasture is largely leucaena, the other modified pasture types having been mapped as native pasture.

  (iii)   after conversion to ALUMC Version 4, season and perennial horticulture are both classified as perennial horticulture.

  (iv)   some reservoirs are shown as 5.6 Utilities; mapped as 6.2 Reservoir in the national product.

- In the Mt Lofty Ranges and Gippsland KIA mapping, land mapped as modified pasture includes all types of modified pasture and also native pasture.

- In the Gippsland KIA mapping, after conversion to ALUMC Version 4, lake and marsh/wetland with IUCN category VI are mapped as 1.2 Managed resource protection. In the national land use map these land uses are mapped as 6.1 Lake and 6.5 Marsh/wetland.

- In the national land use map, built-up areas have been classified using the tertiary class, 5.4.1 Urban residential; and peri-urban intensive land uses (mainly rural residential and mining) have been classified using the primary class, 5 Intensive uses.

Table A10.11 summarises the extent of agreement between the national land use map and the regional land use maps, separately and combined, subject to matching at the secondary level of the ALUMC Version 4 using the alignments shown in Table A10.10.

Table A10.11. Agreement between the national land use map and the regional land use maps, separately and combined, subject to matching at the secondary level of the ALUMC Version 4 using the alignments shown in Table A10.10.

Regional land use map	Area (km^2)	Extent of agreement with national land use map (%)
Fitzroy KIA	142 000	80.6
Mt Lofty Ranges KIA	6 000	72.9
Gippsland KIA	38 000	84.9
All of the above combined	187 000	81.2

Summary of comparisons

Due to the scale of mapping, the national product will over-represent native pasture (2.1. Livestock grazing) as is generally the dominant (by area) land use in a grid cell. Fragmented land uses will tend to be lost in converting from the scale mapped to the cell size of the national product. Linear features like roads and railway lines are lost on conversion to a coarser grid-based product. This particularly applies to classes in intensive uses.

Comparison is made difficult by differences in land use classification:

- More irrigation is reported in the regional products than in the national product. This may be due to under-reporting in the AgStats data used to compile the national product but may also be due to over-reporting in the regional products through use of assumptions as to what is irrigated or through mapping of irrigation infrastructure rather than use of irrigation.

- Use of the crop/pasture rotation land use category in the regional land use mapping entails loss of specificity in comparing with the national land use map since the national product does not use this combined category.

- The distinction between native and modified pasture is not well defined. Making this distinction in the regional mapping proved particularly difficult. No doubt this distinction has not been well handled by the national product either. The extent of agreement between the national and regional maps is significantly worse if no allowance is made for the difficulties encountered in making this distinction.

The currency of the Mt Lofty Ranges KIA land use mapping (1999) is significantly different from the currency of the national land use map (around 1996). This must account for some of the disagreement between the two maps. Information on the land use changes that occurred in the Mt Lofty Ranges KIA between 1993 and 1999 is available and confirms this.

Primary classes 1, 2 and 6 have the best match between the national product and the three KIA maps with which it was compared. This arises as these classes tend to be derived from existing data sources and often the same data source (e.g. CAPAD).

The extent of agreement between the national land use map and the three KIA land use maps considered was about 81%. This is based on comparison at the secondary level of the ALUMC Version 4 using the alignments shown in Table A10.10.

References

Calvert, M. Simpson, J. and Adsett, K. 2000, *Land Use Mapping of the Fitzroy Catchment. Fitzroy Catchment Implementation Project Final Report QNR17*, Queensland Department of Natural Resources and the National Land and Water Resources Audit, Canberra.

Flavel, R. and Ratcliff, C. 2000, *Evaluating Regional Change. Mount Lofty Ranges Implementation Project Final Report DAS18*, National Land and Water Resources Audit, Canberra and Primary Industries and Resources South Australia.

Sposito, V, Abuzar, M and Morris, M. 2000, *Land Use Mapping: East and West Gippsland Catchment Management Authority Regions Implementation Project Final Report DAV30*, Department of Natural Resources and Environment, Victoria and National Land and Water Resources Audit, Canberra.

Data sets

Land Use of the Fitzroy River Catchment 1996-7, Queensland. The Queensland Department of Natural Resources and Mines and National Land and Water Resources Audit.

Land use in Gippsland 1996-7, Victoria. Victorian Department of Natural Resources and Environment and National Land and Water Resources Audit.

Land Use in the Mount Lofty Ranges 1999, South Australia. Primary Industries and Resources South Australia and National Land and Water Resources Audit.