CHAPTER 5

DEVELOPING LAND COVER AND LAND USE DATA SETS FOR THE AUSTRALIAN CONTINENT – A COLLABORATIVE APPROACH

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ABSTRACT
Nine Australian state/territory and federal government agencies have cooperated to complete mapping of land cover and land use for the Australian continent. The United States, Canada and Mexico are currently considering the joint development of a land cover data set for North America; this paper describes the issues encountered in establishing a similar collaborative mapping program for Australia. In Australia’s mapping programs we have distinguished between land cover, the physical surface of the Earth, and land use, the purpose to which the land cover is committed. This collaboration has produced high quality data sets which are being used to establish where in the landscape government investments in land and water management will provide the best returns. The data are also being used to develop effective responses to major natural resources management problems, including water scarcity and water quality decline at national, regional and local levels. The development of the data sets is briefly described, their uses identified, the factors which have contributed to a successful model for collaboration discussed and future plans outlined. This collaborative model underpins the national coordination arrangements now being established in Australia to ensure development of nationally consistent data on natural resources.

Key words: land cover mapping, land cover change, land use mapping, land management practices

INTRODUCTION

Land cover, land use and land management practices play a significant role in mediating the movement of carbon, nutrient, sediment and water through the landscape, affecting both rates and size of fluxes (Meyer and Turner 1996; Foley et al 2005). Australia’s need for spatially explicit data to describe the continent’s land cover, land uses and management practices has been driven by recognition
of the heterogeneity of our land, water and vegetation resources and the need to characterise this if we are to improve resource management. Capacity to quantify and predict these fluxes in relation to changes in climate, land cover, land use and land management practices is fundamental to improving natural resources management in Australia. Improvements in process modelling have increased our ability to quantify fluxes, but our ability to make practical use of these models in the 1990s was limited by the lack of spatially explicit land cover, land use and land management practice information at suitable scales.

Australia covers an area of 766 million hectares, approximately the area of the coterminous states of the United States, its latitudinal extent ranges from about 10° to 43° south. Australia experiences a wide range of climate zones, soil and vegetation types; recognition and accommodation of this diversity has been an important factor in developing and applying remote sensing methods for mapping land cover and land use. Within Australia land management is the responsibility of the six state and two territory governments (hereinafter “states”); mapping land cover and land use has been a collaborative effort between these state agencies responsible for natural resources management and or agriculture and the Australian Government Department of Agriculture, Fisheries and Forestry.

The initial focus of our collaborative mapping programs was land cover and land cover change in the intensively managed land use zone (Figure 1) which represents approximately thirty eight percent of the Australian continent. Outside this zone in the Australian outback, the land cover is disturbed but relatively intact (Graetz, Wilson, and Campbell, 1995). The land cover data sets were developed from Landsat Thematic Mapper (TM) data to provide the information on rates of clearing and replanting of woody vegetation and the implications for carbon fluxes needed for Australia’s first national greenhouse gas inventory (Barson, Randall, and Bordas, 2000).

The changes in land cover brought about by clearing of native vegetation undertaken since European settlement, predominantly to establish much of Australia’s agriculture, have led to an acceleration of sediment and water transport processes and significant changes in landscape function, particularly in relation to catchment (watershed) hydrology, hydrogeology and sediment movement (Graetz, Fisher, and Wilson, 1992). The 1:100,000 land cover data sets have been especially useful
for quantifying the impacts of changes in the distribution of forest vegetation such as plantation development on water resource availability (e.g. Bressard and Vertessy, 1999). However, quantifying processes within landscapes that are no longer forested requires information on current land use. Two data sets at national (1:2,500,000) and catchment scales (1:25,000 – 1:250,000 depending on land use intensity) have been developed for this purpose through the Australian Collaborative Land Use Mapping Programme (ACLUMP).

Observation, experimental work and simulation modelling have demonstrated that the choice of land management practices (for example tillage and stubble management methods) can also have a significant impact on water quality, as well as on the status of the farm resource base and farm productivity (Barson and Lesslie, 2004). Governments and agricultural industries are funding programs to encourage farmers to adopt the most sustainable land management practices. The Land Use and Management Information System (LUMIS) is being developed collaboratively by Australian, state and territory government agencies to meet the need to capture and standardise information on a very
Land cover

Land cover refers to the physical surface of the earth, including various combinations of vegetation types, soils, exposed rocks and water bodies as well as anthropogenic elements, such as agriculture and built environments. Land cover classes can usually be discriminated by characteristic patterns using remote sensing.

Land use

Land use means the purpose to which the land cover is committed. Some land uses, such as agriculture, have a characteristic land cover pattern. These usually appear in land cover classifications. Other land uses, such as nature conservation, are not readily discriminated by a characteristic land cover pattern. For example, where the land cover is woodland, land use may be timber production or nature conservation.

Land management practice

Land management practice means the approach taken to achieve a land use outcome — the ‘how’ of land use (eg cultivation practices, such as minimum tillage and direct drilling). Some land management practices, such as stubble disposal practices and tillage rotation systems, may be discriminated by characteristic land cover patterns and linked to particular issues.

Land capability and land suitability

Land capability assesses the limitations to land use imposed by land characteristics and specifies management options. Land suitability (assessed as part of the process of land evaluation) is the fitness of a given type of land for a specified kind of use.

Commodity

A commodity is usually an agricultural or mining product that can be processed. Commodity information may relate to land use and land cover, particularly at finer divisions of classification. Agricultural commodity data are available through the ABS Agricultural Census.

Tenure

Tenure is the form of an interest in land. Some forms of tenure (such as pastoral leases or nature conservation reserves) relate directly to land use and land management practice.
wide range of management practices. LUMIS will provide the data needed to identify the agricultural industries and regions which would most benefit from investment in changed management practices, as well as information to evaluate the success of these investments.

Table 1 defines the terms land cover, land use and land management practice used in the Australian mapping programs.

**MAPPING LAND COVER AND LAND COVER CHANGE**

Australia’s first national greenhouse gas inventory suggested that clearing for agricultural development could contribute as much as a quarter of Australia’s total greenhouse gas emissions (Department of Environment, Sport and Territories 1994). These estimates were regarded as very uncertain, as little information was available on the rates of clearing or the type of vegetation cleared. It was agreed that a nationally consistent approach to monitoring rates of land clearing was needed. In 1994 the Australian and states’ governments agreed to jointly fund and undertake land cover and land cover change mapping coordinated through the Bureau of Rural Sciences (BRS), the science agency within the Australian Government Department of Agriculture, Fisheries and Forestry.

The participating agencies reviewed the greenhouse gas inventory information requirements, the availability of existing data held by state agencies and the remote sensing data sources and methods for mapping land cover and detecting change. It was agreed that four digital data sets at a scale of 1:100,000 would be produced using Landsat Thematic Mapper (TM) data: Land cover 1990 and 1995, Structural Vegetation 1990 and Land Cover Change 1990 – 1995.

The Land cover data sets provided the information needed to establish the type of land cover present in 1990 prior to change, and to assign 1995 land cover categories to those areas of change. The major land cover category of interest for this project, woody vegetation, was defined as all vegetation, native or exotic, with a height of ≥ 2m and a crown cover density of ≥ 20 percent (McDonald et al 1990). This is the definition of forest agreed by state and Australian Government agencies for Australia’s National Forest Inventory (National Forest Inventory 1998) and the definition used for Australia’s first national greenhouse gas inventory (National Greenhouse Gas Inventory 1999). The
definition includes vegetation usually referred to as forest (50 – 100 percent crown cover) as well as woodlands (20 – 50 percent crown cover) and plantations (silviculture operations), but not open woodlands where crown cover is ≤ 20 percent.

Land cover change was defined as increases (planting or regeneration) or decreases (clearing or burning) in woody vegetation. The reason for each change was also recorded. The Structural vegetation data were developed by combining existing digital vegetation data and the 1990 land cover data set; these data provided the basis for calculating biomass losses due to clearing.

Participating agencies jointly developed the specifications (Kitchin and Barson 1998) for these outputs. This work was Australia’s first operational use of satellite remote sensing other than for meteorological purposes, and it was recognised that the remote sensing experience, computer processing capacity and ancillary data available and the skills of the nine contributing organisations varied greatly. The jointly developed project specifications included an agreed *a priori* land cover classification (Table 2); the cover types comprising features that could be reliably identified on Landsat TM images. Classification of these land cover types from TM imagery had been undertaken previously in south eastern Australia by four of the participating agencies (Ritman 1995).

<table>
<thead>
<tr>
<th>Land Cover Classes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not classified</td>
</tr>
<tr>
<td>1</td>
<td>Pasture/Crop including herbfields, grasslands and open woodlands</td>
</tr>
<tr>
<td>2</td>
<td>Urban</td>
</tr>
<tr>
<td>3</td>
<td>Bare Ground</td>
</tr>
<tr>
<td>4</td>
<td>Water</td>
</tr>
<tr>
<td>5</td>
<td>Plantation</td>
</tr>
<tr>
<td>6</td>
<td>Orchard</td>
</tr>
<tr>
<td>7</td>
<td>Native or exotic woody vegetation (excluding plantations, orchards) where height ≥2m and crown cover ≥20 percent</td>
</tr>
</tbody>
</table>

Table 2. The land cover classes attributed from Landsat TM data for the Australian Land Cover Change project
specifications also set out the methods for data set development, data formats, attribute and positional accuracy standards, attributes for the information tables accompanying the raster data sets, methods for quality control and metadata requirements.

One hundred and fifty six pairs of TM scenes were chosen for 1990 and 1995. Criteria for scene selection included the driest time of the year (to maximise discrimination between the ground layer and tree canopies) and matching of scene dates to reduce differences in illumination and minimisation of cloud cover. Pre-processing of the Landsat TM data included geo-correction and co-registration of the 1990 and 1995 images, fixing of data dropouts, some radiometric calibration and the preparation of image masks for water, shadow, smoke and fire. State agencies tested their proposed image processing methods; the methods were chosen to give the best results for the vegetation, soils and wild fire patterns in their regions, as well as the resources they could contribute to the project. Details of the image processing methods are available in Barson, Randall, and Bordas (2000), and are summarised in Table 3.

<table>
<thead>
<tr>
<th>State</th>
<th>Land cover themes</th>
<th>Land cover change</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>Unsupervised classification (100 classes) of 1991 images</td>
<td>Unsupervised classification of combined 1991 and 1995 images</td>
</tr>
<tr>
<td>NT</td>
<td>Unsupervised classification (100 classes) of 1990 images</td>
<td>Band 5 subtraction of 1990 and 1995 images</td>
</tr>
<tr>
<td>QLD</td>
<td>Classification of band 5 and NDVI using 1991 TM images</td>
<td>Thresholding of band 2, 5 and NDVI difference images</td>
</tr>
<tr>
<td>SA</td>
<td>Unsupervised classification (150 classes) of combined 1990 and 1995 images</td>
<td>Unsupervised classification (150 classes) of combined 1990 and 1995 images</td>
</tr>
<tr>
<td>TAS</td>
<td>Supervised classification of 1990 images</td>
<td>Thresholding of NDVI difference data</td>
</tr>
<tr>
<td>VIC</td>
<td>Unsupervised classification (150 classes) of 1990 images</td>
<td>Unsupervised classification of combined 1990 and 1995 images to create woody, non-woody, woody increase and woody decrease</td>
</tr>
<tr>
<td>WA</td>
<td>Combined 1990 and 1995 images and carried out canonical variant analysis based on biogeographic regions to identify indices and bands to classify land cover themes and land cover change</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Image processing methods used by agencies participating in the Australian Land Cover Change project
Some field checking for the land cover data sets and comparison with existing vegetation and forestry data sets was undertaken to ensure that the image processing techniques used discriminated forest and woodland land cover (height of ≥ 2m and a crown cover of ≥ 20 percent) from open woodland (crown cover of ≤ 20 percent).

The land cover change data were filtered to remove individual pixels and clumps of two to three pixels that could have been erroneously identified as change. All areas identified as change on the imagery were checked against another data source such as aerial photography, other TM or Satellite Pour l’Observation de la Terre (SPOT) imagery, ancillary information such as forest management data sets or field verified where no independent sources of information were available. The data source used to check each change pixel was recorded.

State agencies supplied the Land cover, Land cover change and Structural vegetation data to BRS as 1:100,000 map sheets with a 1km overlap. The data sets were checked to ensure they complied with the output specifications. Positional and attribute accuracy were checked and the change tables were checked by assigning a logical code to the change data incorporating the four main attributes, type of change, land cover 1990, cause of change and replacement land cover 1995 to test whether the combination of change attributes was appropriate. As agreed with participating agencies at the beginning of the project, data which did not meet the agreed output specifications were returned for reprocessing.

A summary of the amount of change by type of change and cause of change per map sheet was supplied to state agencies for verification. The state data sets were produced by merging the map sheet tiles by Australian Map Grid zone, then projecting the zone into Albers Equal Area. The zones were merged to form the state data sets (25 metres, 1:100,000 scale) and clipped to the state boundaries. Subsequently these data were resampled to produce data sets at 100 metres (1:250,000) and 250 metres (1:500,000) cell sizes.

A method to assess the reliability of the change data for areas where no suitable reference data were available was developed by Lowell (2001) and applied to half of the images in the study area. Sample based estimates of change were prepared by independent consultants for comparison with the
results produced by state agencies and the differences between states’ and consultants’ estimates of change evaluated. Of the sixty seven scenes evaluated, ninety seven percent met the acceptance criteria – the differences between the two estimates were not significant at the ninety five percent confidence interval. Overall the assessment demonstrated that the process of detecting land cover change from TM data provided repeatable and reliable results although the collaborating agencies used different change techniques and approaches to radiometric calibration (Barson et al 2004).

The land cover data have proved particularly useful for hydrological modelling and have been resampled to 1km and incorporated into the Australia’s main hydrological modelling toolkit (Western 2005).

The total cost of the land cover and change mapping and collation of the Structural vegetation data set was $A 5.7 million. The four digital data sets produced, together with the project specifications and the final report are available on CD ROM at 25, 100 and 250m resolution from the authors, and can be downloaded from http://adl.brs.gov.au

Land cover change monitoring has continued in Queensland where land clearing contributes a significant proportion of Australia’s greenhouse gas emissions (Department of Natural Resources and Mines 2006). The resulting data help quantify the state’s emissions, assist in vegetation management and compliance checks for land clearing permits and provide information for regional ecosystem mapping. The Australian Greenhouse Office within the Australian Government Department of Environment and Water Resources is now responsible for monitoring land clearing at the continental scale.

**MAPPING LAND USE**

The availability of the seven class high resolution (1:100,000) land cover data set for 1995 improved our capacity to model the impacts of clearing and planting of forests and woodlands on water resource availability. However, additional information on the purposes to which the land cover is committed (the land use) and how the land use is undertaken (the land management practices) was required to improve our capacity to quantify and predict fluxes of carbon, nutrients sediments and to identify where changes in landscape management were needed to improve soil condition, water
quality and habitat.

Land use mapping activities in Australia have focussed on developing nationally consistent coverage at catchment (watershed) (1:25,000 – 1:250,000) and continental scales (1:2,500,000), the establishment of technical standards including a national land use classification system and web based delivery to facilitate user and community access to land use information and national and regional reporting of conditions and trends. Different approaches have been adopted for the preparation of catchment and continental scale mapping, although they use the same classification (Lesslie, Barson, and Smith, 2006).

CATCHMENT SCALE LAND USE MAPPING

Building on the success of the Land Cover Change project, state agencies and BRS agreed in 1999 to collaborate on the mapping of land use at catchment scale. State agencies have operational responsibilities for the natural resource management issues affecting soils, water and vegetation. These agencies need information on the processes operating at the catchment scale to help evaluate natural resource condition and trends, and aid the development of cost effective on–ground solutions to water quality, soil erosion and acidification problems. At the national level these data are being used to help identify where the best returns on investments in natural resources management can be made.

The collaborating agencies recognised that many natural resources management issues are cross – jurisdictional, and that a nationally consistent although not necessarily uniform, approach to land use mapping was highly desirable. A model for the Australian Collaborative Land Use Mapping Program (ACLUMP), similar to that developed for the Australian Agricultural Land Cover Change project was adopted, with joint funding provided by Australian and state government agencies, and the land use classification and project specifications being developed jointly. The mapping has been done by state agencies, with BRS coordinating and collating the work and completing the quality assurance processes.

The agreed technical specifications have played an important role in developing consistent and reliable data sets. These output specifications cover the coding and attribution of land use and source
information (including scale, date, source and reliability), data formatting, spatial referencing, data resolution, spatial precision, topological integrity and attribute accuracy (Bureau of Rural Sciences 2006a). The agreed procedure for coding and attribution, the Australian Land Use and Management (ALUM) Classification (Figure 2) is an *a priori* classification with a three-tiered hierarchical structure. The primary, secondary and tertiary classes broadly reflect the degree of modification and impact on native land cover, and provide a structure for attaching attributes describing the land use, commodities produced and land management practices used.

Six primary levels are distinguished in the ALUM classification in order of generally increasing levels of intervention in the landscape.

1. Conservation and natural environments: land used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems present.
2. Production from relatively natural environments: land used primarily for primary production with limited change to the natural vegetation.
3. Production from dryland agriculture and plantations: land used mainly for primary production, based on dryland farming systems.
4. Production from irrigated agriculture and plantations: land mostly used for primary production based on irrigated farming.
5. Intensive uses: land subject to extensive modification, generally in association with closer residential settlement, commercial or industrial uses.
6. Water: water features – both natural and human made. Water is a land cover type, but is regarded as an essential part of the classification because of its importance to natural resource management.

Figure 3 outlines the catchment scale mapping process which has been developed to make the best use of existing spatial data resources, including Landsat Enhanced Thematic Mapper (ETM), SPOT satellite imagery, aerial photography and the digital cadastre which identifies land tenure boundaries. The mapping procedures are described in Bureau of Rural Sciences (2006a). Significant emphasis is given to verification of the draft maps in the field by personnel familiar with local land uses and to the
Validation of the draft data is undertaken by independent assessors who assess attribute accuracy by locating a sample of land use features from high quality data (usually large-scale aerial photography) not used in the mapping process, classifying these features and comparing them with the classes depicted in the land use data set. The required attribute accuracy for catchment scale land use mapping is eighty percent. In the final quality assurance phase BRS checks that all the output specifications have been met, and produces a data quality statement which remains with the data set.

Cartographic scales vary according to the intensity of land use activities, ranging from 1:25,000 scale for irrigated and peri urban areas, to 1:100,000 for broadacre agriculture (cropping and grazing) regions and 1:250,000 for the semi arid and arid pastoral zone (Figure 4). The size of the Australian continent (766 million hectares) and the modest resources available to the mapping program resulted in mapping being conducted over the period 1997 – 2006. The digital data sets have been compiled to produce a mosaic for the continent which can be updated when new information becomes available. The use of pre-existing input data has been important in controlling the mapping costs; these are
approximately $A3 - $A5.00 per square kilometre (depending on land use intensity) for 1:100,000 scale mapping.

**NATIONAL SCALE LAND USE MAPPING**

BRS undertakes national scale mapping to provide synoptic level land use assessments needed by Australian government agencies for strategic planning and evaluation and national scale modelling applications such as carbon accounting. Gridded data at 1.1km resolution are prepared by linking the phenological characteristics of crops and pastures (Figure 5), the Normalised Difference Vegetation Index (NDVI) annual time series from NOAA Advanced Very High Resolution Radiometer (AVHRR) data, ground control point data, the national agricultural statistics and spatial data on non agricultural land use (Walker and Mallawaarachi 1998; Bureau of Rural Sciences 2004). The resulting probability...
surfaces for each mapped agricultural commodity are combined to produce a map of most likely land uses.

The input data for national scale mapping relate to agricultural commodities, the tertiary level attributes for the Australian Land Use Management Classification (Figure 2). As this classification is hierarchical, the commodity attributes can be amalgamated to present land uses at the primary or secondary levels (Figure 6) of classification as required by the user. National scale mapping has been completed for 1992–1993, 1993–1994, 1996–1997, 1998–1999, 2000–2001 and 2001–2002 using ground control data collected by state agencies. The catchment scale data are used to check the veracity of the national scale outputs. Figure 7 shows the differences in scale and information captured in the national (1:2,500,000) and catchment scale (1:100,000) mapping.

The national scale data have proved to be an inexpensive way of capturing changes in the agricultural landscape, with the time series costing approximately $A 300,000 to produce. Analysis of the time series has identified regions where farmers practise crop/pasture rotations, and the expansion and contraction of irrigated agriculture.

**MAPPING LAND MANAGEMENT PRACTICES**

In Australia, land used for agriculture represents about sixty per cent of the total land area (Figure 6) making farmers the largest group managing Australia’s natural resources. Management practices at farm scale impact on Australia’s land, water and biodiversity resources as well as on the profitability and
Figure 6. Land use mapping at the national scale.
Figure 7. Differences in scale and information contained in the national (1:2,500,000) and catchment scale (1:100,000) land use maps of an area near Hobart, Tasmania.
sustainability of agriculture (Kokic, Davidson, and Boero Rodriguez, 2006). In 2004, state agencies, Australian government departments, industry groups and scientific organisations convened to discuss the need for a national approach to the collation and mapping of land management practices. It was agreed to develop a national categorisation and information system for land management practices, (Land Use Management Information System – LUMIS) for testing by state agency partners.

The LUMIS categorisation is a hierarchical system that moves from the object of management at the highest level through to generalised practices then specific actions. The primary components of the landscape (plants, animals, soil, water, and potentially air) and the managerial components (business and infrastructure) are the highest level of the categorisation. Figure 8 demonstrates how the management practice of liming would be categorised. Details relating to the action of liming such as the amount applied, characteristics of the liming material used and the application method can also be accommodated. LUMIS will also have a spatial locator to link the management practices information with land use and other data sets. Initially the categorisation focuses on agricultural practices, but it is structured to enable inclusion of practices associated with other land uses such as forestry, conservation and mining.

Figure 8. The Land Use Management Information System (LUMIS) is a hierarchical system that moves from the object of management at the highest level through to generalised practices and then specific actions. An example is given for the action of liming to maintain or improve soil condition.
An analysis of needs (Stewart, Yapp and Lesslie, forthcoming) was undertaken to prioritise the demand for land management practices information. Key management practices identified for initial data collection include protection of native vegetation, soil conservation methods, irrigation scheduling and application methods, controlling weeds and pest animals and crop rotation systems. State agency partners will undertake pilot studies in 2007 to develop methods for mapping these practices. These projects will collate and map land management practices from surveys of land managers, information from local experts, existing data from agencies, industry and local groups; field mapping and interpretation of aerial photography or satellite imagery.

One pilot study is exploring the potential high resolution imagery (e.g. SPOT 5) may offer for the use of object-classification algorithms to identify specific features such as contour banks in the landscape. Others will examine how remote sensing using standard pixel-based classifications and manual image interpretation can be used for sampling or mapping practices such as tree clearing or thinning, crop rotations, strip cropping, centre – pivot irrigation, fencing of riparian vegetation, and wildlife corridors or the impact of management (e.g. groundcover as an indicator of grazing management).

The results of these projects will contribute to a nationally agreed categorisation for land management practices and specifications for mapping these practices. Further work is planned to explore the appropriate scales and frequency for mapping land management practices.

A number of the state agency partners are investing in information systems which bring together spatial data on land management practices, land use, land cover and other data (such as social and economic information) to improve natural resource management decision making. Interagency collaboration is making the best use of the limited resources available for developing a land management practices categorisation and efficient data collection methods, as well as providing a nationally consistent approach to this issue.

**SUCCESS FACTORS FOR COLLABORATIVE MAPPING PROGRAMS**

The land cover and land use mapping programs have produced high resolution, high quality data sets that provide consistent information across jurisdictional boundaries. The data sets are used
routinely by government agencies and researchers for modelling the impact of land cover changes on water availability (Brown et al forthcoming), water quality (Sherman et al 2007) and sediment budgets (Lu et al 2004; Wilkinson et al 2005). State agencies have used the catchment scale land use information to plan locust control programmes and for preparedness exercises for Foot and Mouth and Newcastle diseases (Western Australia); manage sediment and nutrient loads in the Gippsland Lakes and undertake surface water resources modelling in the Macalister Irrigation District (Victoria); support regional integrated natural resource planning and investment and develop regional strategies for industry development (South Australia); model sediment and nutrient transport across catchments associated with the Great Barrier Reef and define the extent and sizes of sub-divisions for residential expansion in south-east Queensland and to develop a horticulture database and plan pest and disease responses for the Northern Territory (Bureau of Rural Sciences 2006b).

A number of factors have contributed to the success of the programs. These include the partners in the mapping programs having a significant interest in using the resulting data for natural resource management in their own jurisdictions and their enthusiasm for sharing experience and expertise with other agencies. For example, the Queensland Department of Natural Resources and Water developed an improved validation technique for catchment scale land use datasets (Denham 2005) which is now part of the national standards (Bureau of Rural Sciences 2006a). Queensland have also developed a method for semi-automating the production of a draft land use map for field checking which is being trialled by other agencies. The state agencies are also custodians of or can readily access ancillary data sets such as aerial photography, which has helped to contain the costs of mapping.

Early in the development of the mapping programs agencies recognised the great diversity of environments being mapped and the varying levels of skills and resources available to the projects, and decided that these could best be used by agreeing on output specifications rather than standardising inputs and methods. The output specifications were formalised in manuals (Kitchin and Barson, 1998; Bureau of Rural Sciences, 2006a), with all collaborating agencies contributing to their development. Agencies were then free to develop mapping methods appropriate to their environments which they tested in pilot projects to ensure that the agreed output specifications could be met.
It was agreed that one agency, BRS, would take overall responsibility for quality assurance testing for the final products, and that data sets not meeting the agreed specifications would be returned for reprocessing. The arrangements were formalised through contracts with each partner agency which established the costings, the contributions to be made by the Australian Government and the state government agency, project milestones and payments and the agreed products to be delivered.

The Australian Government is currently promoting improvement in natural resource management in fifty six regions around the continent through the Natural Heritage Trust programme. Well informed investment decisions and the assessment of outcomes requires the collation of nationally consistent information on natural resource condition and trend, including land cover, land use and land management practices.

These needs and the success of the collaborative land cover, land use and other natural resources data coordination processes, have led to the formalising of national coordination arrangements for vegetation, water and salinity as well as for land use and soils. National coordination groups are now responsible for promoting the development of nationally consistent information, facilitating national assessment of natural resources condition and trend as well as meeting the needs of major information users in the natural resource sciences community, industry, state governments and regional groups. A key challenge for the national coordination groups is to provide data that can be integrated for analysis of landscape processes affecting water quantity and water quality, soil erosion and nutrient loss needed to examine the trade offs required to provide acceptable environmental, social and economic outcomes. Increasing demand for information to support integrated assessment has also led to recent plans for the establishment of an expanded nationally coordinated land cover mapping program.

**FUTURE DEVELOPMENTS**

As land use mapping at the catchment scale nears completion, the focus of the program is shifting to the detection and reporting of change over time. An ability to measure, analyse and report on land use change is critical to effectively addressing key sustainability questions associated with processes such as salinity, habitat change, and water quality and soil loss. A capacity to measure and report
change in land use over time is also critical to evaluating trends in agricultural productivity and natural resource condition, the effectiveness of public investment in natural resource management and reporting on industry performance initiatives such as environmental management systems and market-based instruments.

Several state agencies have assessed land use change by comparing catchment scale land use datasets from different years and creating a change data set (Jamieson et al 2006; van den Berg and Jamieson 2006). Pilot projects are now being undertaken to investigate the use of Moderate Resolution Imaging Spectroradiometer (MODIS) time series data to detect and report land use changes. Land cover changes detected from MODIS are being used to identify sites of likely land use change for further investigation. It is anticipated that the projects’ results will provide the information needed to specify the outputs for mapping and reporting land use change consistently at the national level.

Land use information is also needed to implement water allocation and efficiency measures. For example, the National Water Initiative (Council of Australian Governments 2004) has recognised the potential for certain land use changes to have a significant impact on the interception of ground and surface waters and affect the subsequent availability of water for other purposes. Irrigated agriculture is a major user of water resources, and farm dam developments and large-scale plantation forestry intercept significant volumes of surface and ground water. Digital data sets are being developed to meet the technical requirements in this area, and substantial progress is being made in integrating land use and water management data to support water use analysis. For example, water use efficiency for cropping in the Central Goulburn Irrigation District in Victoria has been assessed in terms of total water supplied as a proportion of crop water requirements, indicating spatially where there are deficits and surpluses of supply (Figure 9).

Ensuring effective dissemination of land use, land management and land cover information to the users of information is also a priority. Land Use Mapping for Australia, a DVD and website (www.brs.gov.au/landuse) provide easy access to land use data, enabling users to view land use data online, download datasets and see the latest applications of the data to natural resource management issues. An online reporting system is currently being prepared to present synoptic change and trend
Figure 9.
information for land use and land management practices at a national level. Land use information will be presented with other environmental, social and economic data to give an integrated picture of a particular region.

CONCLUSIONS

Collaborative mapping programs which have brought together resources, skills and experience across jurisdictions are proving to be an effective and efficient way of developing high quality data sets fundamental to natural resources management in Australia. The availability of consistent data sets which have identical mapping categories irrespective of jurisdiction is of paramount importance in addressing water resources and other intra state issues. These data sets will also help identify where the Australian Government’s funding for natural resource management should be provided to give the best returns on investment.

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REFERENCES


