CATCHMENT SCALE LAND USE MAPPING IN QUEENSLAND

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Abstract

Land uses have major impacts on Australia's natural resources. Soil salinity, acidification, rates of erosion, carbon losses and nutrient and water quality decline pose serious threats to land productivity. The provision of land use information is essential for the implementation of effective assessment and management solutions for these problems.

The Queensland Department of Natural Resources and Mines (NR&M) has been working with the Commonwealth Bureau of Rural Sciences (BRS) to develop catchment scale land use datasets since 1999, as part of the Queensland Landuse Mapping Program (QLUMP). Mapping has been completed for major catchments such as the Fitzroy, Upper Condamine and Lower Balonne and is in progress for coastal catchments in southeast and central Queensland.

This paper provides an overview of the methods developed by the Land & Environmental Assessment Group within NR&M for land use mapping of the Upper Condamine catchment in southern Queensland undertaken in 2001. The technique described is similar to earlier work undertaken in the Fitzroy, Don and Balonne catchments and has been enhanced for current work in coastal catchments. It can be applied to land use mapping at a range of scales, dependent on land use intensity and available data. Independently assessed classification accuracies approaching 90% have been demonstrated using the method described.

The methodology utilises a data integration approach. The broad steps involved in this process include acquisition of satellite imagery, aerial photography and spatial datasets containing land use information from a wide range of sources as well as information and expert knowledge from landowners, managers, government agencies and others. These are collated, merged and interpreted in image analysis and geographic information systems` (GIS). Land use is categorised according to the Australian Land Use and Management Classification, a national classification scheme developed by state agencies and the BRS, and a draft map produced. The draft map is verified by field checking and final attribution and editing performed. The final land use dataset is then produced and independently validated. A classification accuracy of at least 80% must be achieved prior to quality assurance checking.

Forty land use classes covering 1.55 million hectares were identified in the Upper Condamine catchment. Cropping was the predominant land use type accounting for 45% of total catchment area. Livestock grazing (38%) and production forestry (12%) were other major land use types. All other land uses cover 5% of the catchment. Demonstrated classification accuracy was 87.5%.

Recent coastal catchment mapping has highlighted the benefits of ongoing development and refinement of the methodology. Draft land use datasets have been produced by collation of existing data using spatial modelling based on a decision matrix. This automation has considerably increased the mapping efficiency and reduced the subjectivity of interpretation.

The costs and benefits of using existing data compared to creating new datasets have been highlighted as issues requiring careful consideration. Other limitations identified primarily stem from a lack of coordination of land use mapping approaches and classification schemes. Future developments will focus on improvements to these as well as more effective reporting, publishing protocols and improved data sharing.

Introduction

Land uses have a profound impact on Queensland's natural resources including its soil, water, plants and animals. Land use information at catchment scale is a key requirement in the development of effective responses to natural resource issues such as catchment salinity and water quality, rates of soil erosion, acidification, nutrient decline and carbon losses. It is also contributing to the assessment of agricultural productivity and opportunities for agricultural diversification, the costs and benefits of major natural resources investments and trade-offs arising from land use change (BRS, 2002).

Land use and land management practices are among the key factors controlling regional or catchment scale spatial and temporal heterogeneity in the Australian landscape. It is increasingly recognised by policy makers and management agencies that these factors need to be accounted for in developing solutions for sustainable land management (BRS, 2000). Furthermore, land use and land management practice datasets are the most important information requiring development for application in integrated modelling which is considered to offer the best opportunity to predict the behaviour of a catchment under different management options (BRS, 2000).

Until recently land use mapping approaches at national and regional levels have focused on assessing the suitability/capability of land for agricultural uses and land use information was generally derived from land systems and soils mapping (BRS, 2000). For example, information contained within the Atlas of Australian Soils (Northcote *et al*, 1960-68; Northcote *et al*, 1975) and the Western Arid Region Land Use Study conducted by the Queensland Department of Primary Industries and published between 1976 and 1984, has been use to attribute land use.

A joint Commonwealth-State workshop convened in February 1999 was the genesis for development of a national land use classification scheme and methodology appropriate for catchment scale land use mapping. The Australian Land Use and Management Classification (ALUM) is based on a land use classification developed by Baxter & Russell (1994) for land use mapping in the Murray-Darling Basin and has been refined in collaborative Commonwealth-State review processes (BRS, 2002). The methodology makes best use of available information including State cadastre, public land databases, satellite imagery, medium-scale aerial photography, other land cover and use data, expert knowledge as well as information collected in the field.

The Queensland Department of Natural Resources and Mines (NR&M) has been collaborating with the Bureau of Rural Sciences (BRS), National Land and Water Resources Audit (NL&WRA) and State agencies to develop digital land use datasets for Australia. The Queensland Landuse Mapping Program has been established to progress this work in Queensland and has as its primary objective the production of baseline land use datasets (as at 1999) for the entire state. Scales of mapping should be appropriate to land use intensity using a nationally agreed methodology and classification scheme. The baseline data for 1999 needs to have spatial and attribute accuracy suitable for monitoring land use change at the catchment scale.

Land use mapping in the Upper Condamine catchment in southern Queensland was undertaken by NR&M as part of the Murray-Darling Basin Commission's (MDBC) Landmark project which is assessing the future of dryland broadacre farming in the Basin. Task 6 of the project aims to develop cost-effective methods to map land use change and measure changes in management practices to assess whether long term economic and environmental goals are being achieved. It is being undertaken in two phases. Phase 1 focused on the development and testing of cost-effective methods for land use mapping as a basis for future monitoring of land use changes. Pilot land use mapping at 1:100,000 scale has been undertaken for the St George (Queensland), Cootamundra (New South Wales) and Swan Reach (South Australia) areas. Phase 2 involved applying the methods developed and tested in Phase 1 to mapping three key catchments of the Basin – Upper Condamine (Queensland), Billabong Creek (New South Wales) and Goulburn-Broken (Victoria).

This paper briefly reviews progress in the Queensland Land Use Mapping Program (QLUMP) and focuses on recent work in the Upper Condamine catchment to highlight development of the methodology and results. It also identifies limitations in the approaches as well as opportunities for improvements and future directions.

Study Area

Catchment scale land use mapping in Queensland has been underway since 1999 with 15.26 million hectares (8.7%) of the state completed or in progress (Figure 1). Areas for which mapping has been completed at a nominal scale of 1:100,000 include the St George 1:100,000 mapsheet (completed in 1999), Fitzroy (2000), Lower Balonne (2001) and Upper Condamine (2001) catchments. Mapping of coastal catchments primarily at 1:50,000 scale began in 2001 and is currently in progress. It is anticipated that future initiatives will extend mapping to cover the entire state.

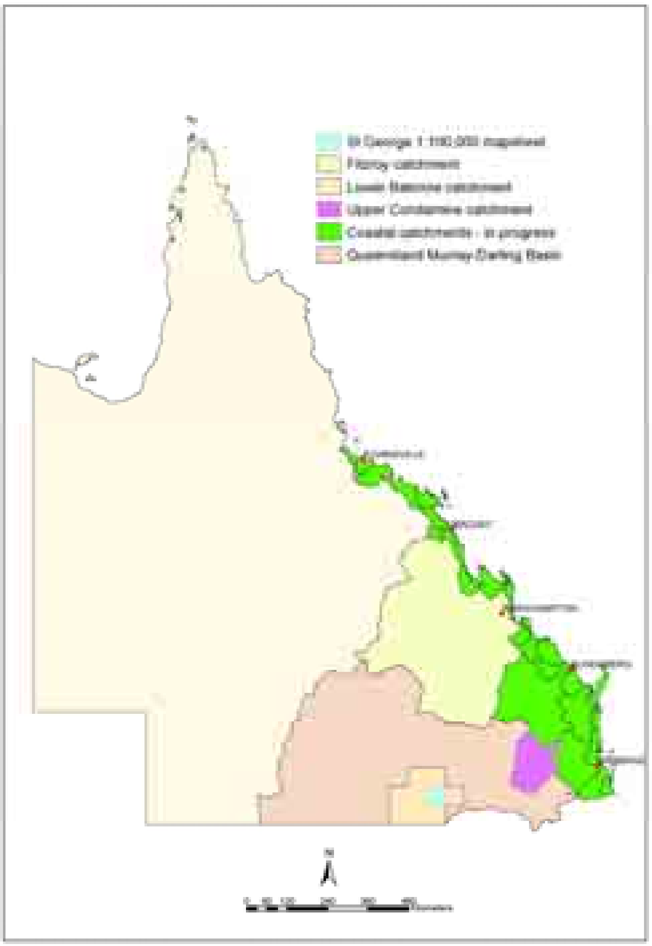

Figure 1. Current extent of catchment scale land use mapping in Queensland

The Condamine River is a major component of the upper Murray-Darling Basin system and is recognised as one of the most significant catchments in Queensland, primarily due to the high intensity of land and water use along much of its length. The catchment is centred approximately 150 kilometres west of Brisbane in the Brigalow Belt South bioregion and covers an area of 1.56 million hectares. Principal land use types are cropping, livestock grazing and timber production. Much of the cotton and a significant proportion of the grains and cereals produced in Queensland are grown in the catchment.

Methods

The procedures used in this study were developed from experience gained by NR&M, BRS and its State agency partners in land use mapping completed for MDBC Landmark Phase 1, NL&WRA and the National Action Plan for Salinity and Water Quality. Projects in Queensland include the St George 1:100,000 mapsheet, Lower Balonne and coastal catchments land use mapping.

The methodology makes best use of available information and balances the requirements for accurate and reliable data, practicality and cost effectiveness. It involves successive stages of data collation, interpretation, verification, validation, quality assurance and production of final outputs (Figure 2). BRS (2002) provides detailed information on both the mapping procedure and the ALUM classification scheme.

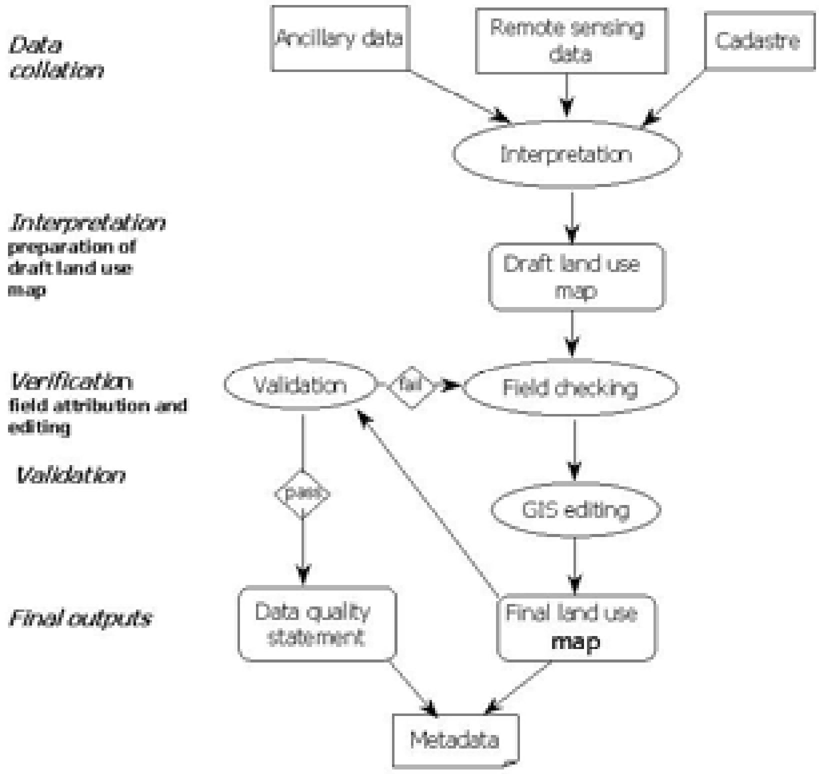

Figure 2. Land Use Mapping Procedure

Mapping in the Upper Condamine was undertaken at a nominal scale of 1:100,000. This is consistent with project requirements, available datasets and nationally agreed scales for mapping medium intensity land use such as broadacre cropping. Coastal regions and areas where land use intensity is high, such as irrigation areas, are being mapped at a scale of 1:50,000 whilst low intensity land use, such as rangelands, are mapped at a scale of 1:250,000.

Land Use Classification Scheme

The ALUM is based on a classification developed by Baxter & Russell (1994) for the MDBC and emphasises level of intervention into the landscape. Together with nationally agreed land use mapping procedures, it was the major outcome from a joint Commonwealth-State workshop on land use mapping in 1999 and has subsequently undergone substantial revision based on work undertaken by Commonwealth and State agencies.

ALUM has a three-tiered hierarchical structure with primary, secondary and tertiary classes (Figure 3). Five primary levels are identified in order of increasing levels of intervention or potential impact on the natural landscape. Primary and secondary classes relate to land use, that is, the principal use of the land defined in terms of the management objectives of the land manager. Tertiary classes include commodities or vegetation data, for example, crops such as cereals and oil seeds. (Lesslie *et al*, 2000).

The minimum attribution level for land use mapping in Queensland is shown in grey shadings (Figure 3). Where necessary and possible the attributing is taken to tertiary classes.

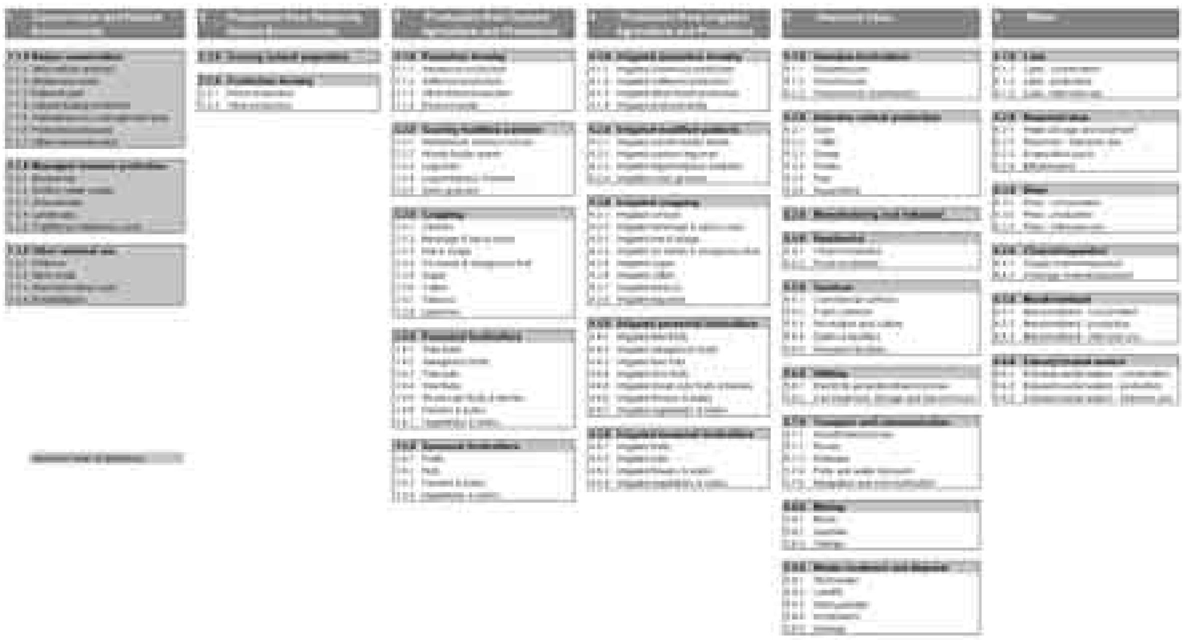

Figure 3. Australian Land Use and Management Classification (ALUM) Version 5

Data collation

Primary datasets acquired included 1999 land cover produced by the Statewide Landcover and Tree Study (SLATS) group within NR&M (Kuhnell *et al*, 1999) and 1999 Landsat ETM imagery which had been radiometrically corrected, rectified and re-sampled to a resolution of 12.5 metres by SLATS. Cadastral information was sourced from the Queensland digital cadastral database (DCDB). Ancillary data included Queensland protected areas; state forests and timber reserves; plantations; dams and weirs; Condamine River floodplain irrigation infrastructure; and AUSLIG 1:250,000 scale Geodata (waterbodies, built up areas and aeronautical). Additional verbal and hardcopy information and expert knowledge regarding land uses and their locations was obtained from regional DNR&M officers, land owners and managers as well as from field observations.

Interpretation

This stage involved interpreting land use from remotely sensed, cadastral, and ancillary data, creating a land use mask dataset from these source datasets, assigning appropriate land use codes and preparing draft land use maps for verification and field checking.

The primary dataset on which the draft land use mapping was built is the SLATS 1999 land cover raster image. This provided land cover information in six broad classes. Using ERDAS Imagine image processing software, a copy of the land cover image together with a range of ancillary datasets containing land use information was overlayed on 1999 Landsat ETM images of the catchment. Land use features were extracted and interpreted from the datasets and the land cover image edited to reflect these features thereby creating a raster land use map. Land use features were assigned classes according to ALUM Version 4. The output from this process was a raster draft land use image. This was converted to vector format in preparation for field checking and editing.

Interpretation, preparation of the draft dataset and subsequent editing to produce the final land use map was performed using raster images rather than vector coverages. The authors believe this approach is justified from two perspectives. Firstly, the land cover dataset supplied by SLATS and from which land use datasets are derived was originally produced and supplied in raster format. To preserve the spatial and attribute integrity of this dataset, it was considered desirable to perform all enhancements and editing in raster format, converting only the final dataset to vector. Secondly, it is widely recognised that editing a thematic raster image is inherently simpler than editing a complex vector polygon coverage.

Verification and Editing

This involved annotation and enhancement of draft maps using field checking, expert knowledge and editing of land use polygons. Regional NR&M staff as well as land owners and managers made a significant contribution to this process.

Field checking involved loading the vector draft land use dataset, Landsat imagery, DCDB and roads coverage of the catchment onto a field laptop computer and preparing an Arcview GIS project using these datasets. The project included a theme highlighting land use polygons with unknown or uncertain land use type. A global positioning system (GPS) receiver connected to the laptop running Geographic Tracker positioning software and Arcview GIS provided a real-time ‘moving map’ display to facilitate navigation to the polygons requiring checking. Attribute information was entered for polygons as they were visited.

Additional anecdotal expert knowledge and data obtained from regional NR&M staff, land owners and land managers was incorporated to enhance the land use dataset. This included a highly accurate coverage of irrigation infrastructure on the Condamine floodplain. This dataset provided valuable information on the locations of areas planted to irrigated cotton, an economically and ecologically important crop in the Upper Condamine.

Following the completion of a map a set of GIS procedures are followed to ensure the data meets the required spatial and attribute standards.

Validation

An independent validation was undertaken comparing the attributes of the land use dataset with information obtained from field survey and large-scale aerial photography. This was carried out shortly after completion of mapping using a modified version of the procedure described by BRS (2002). Validation points were assigned randomly to those land use classes that occupied an area greater than 0.5% of the catchments. The number of points assigned to a class is proportional to the area that particular class occupies in the catchment.

Final outputs

This stage included the finalisation of land use datasets, preparation of metadata, validation reports and quality assurance. Metadata was entered into NR Meta, NR&M's web enabled metadata entry and storage tool which is linked to the Australian Spatial Data Directory. Quality assurance checks were performed on the final dataset to ensure compliance with data specifications.

Results and Discussion

Of forty land use classes identified, three major land use types characterised the study area. Dryland and irrigated cropping is dominant, accounting for 46% of the catchment (not including irrigated cotton). Livestock grazing on native and modified pasture (38%) occurs primarily in the northern, western and southern areas. Production forestry in native forests (12%) mainly occurs in the northern, western and southern parts.

Irrigated cotton, an important crop both economically and environmentally, is the most significant (1.6%) of the remaining classes. Other land uses occupying less than 1% of the catchment area include plantation forestry, water storage and treatment, national parks, conserved areas and built up areas. Intensive land uses include horticulture, animal production, utilities and services, manufacturing, transport and communication, mining and waste treatment and disposal. Table 1 and Figure 4 provide a summary of the results.

Table 1. Land Use Summary – Upper Condamine Study Area

Land Use Class	ALUM code	Proportion of catchment
Cropping	3.3.0	46%
Livestock grazing	2.1.0	38%
Production forestry	2.2.0	12%
Irrigated cotton	4.3.6	2%
Residential	5.4.0	1%
National Park	1.1.3	1%
Other uses		< 1%

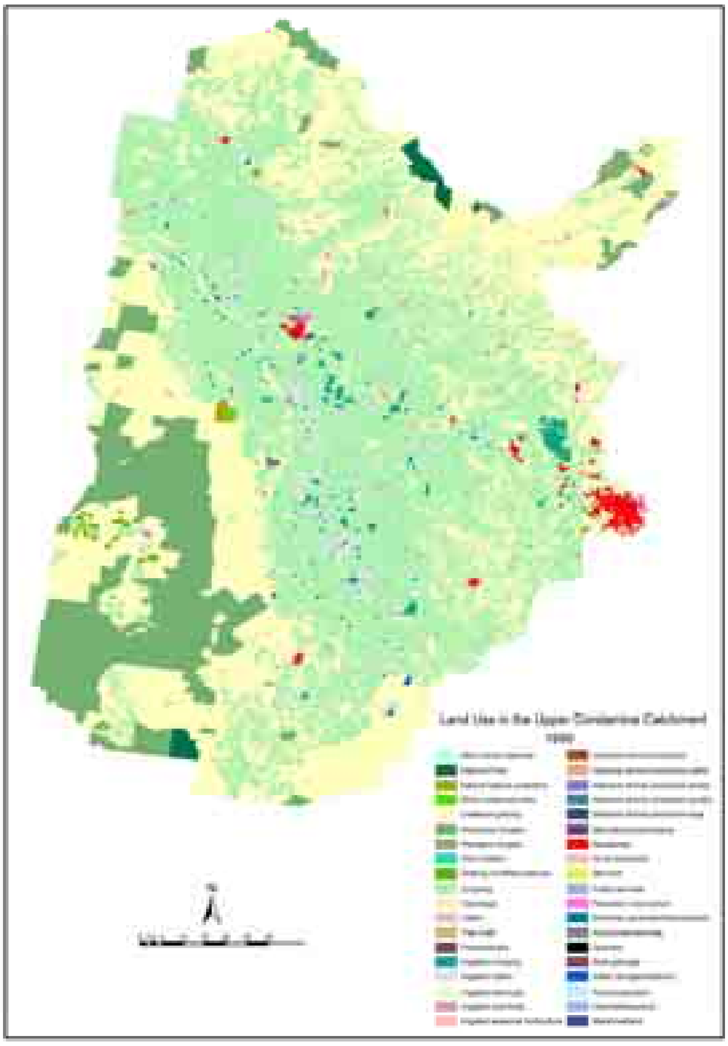

Figure 4. Land use map of the Upper Condamine catchment, southeast Queensland

The overall classification accuracy for the Upper Condamine 1999 land use map was 87.5%. Results of the accuracy assessment are provided in Tables 2 and 3. The number of points for each class was proportional to the area of that class within the catchment. Therefore a large number of points occurred in the major land uses Livestock Grazing, Cropping and Production Forestry.

Table 2 provides details on the reliability of the mapping for each major land use class. For example 49 points were randomly selected in areas classed as Livestock Grazing. 47 out of the 49 points were identified as Livestock Grazing with 2 points occurring in misclassified areas, which were actually cropping. That equates to an error of commission of 95.92% for Livestock Grazing.

Table 2. Error matrix for Upper Condamine land use classification

CLASSIFIED DATA	REFERENCE DATA									
	1.1.3 National Park	2.1 Livestock Grazing	2.2 Production Forestry	3.3 Cropping	4.3 Irrigated Cropping	4.3.6 Irrigated Cotton	5.4 Residential	5.5 Services	6.2 Reservoir	**Total**
1.1.3 National Park	**6**	0	0	0	0	0	0	0	0	**6**
2.1 Livestock Grazing	0	**47**	0	2	0	0	0	0	0	**49**
2.2 Production Forestry	0	0	**25**	0	0	0	0	0	0	**25**
3.3 Cropping	0	6	0	**39**	0	5	0	0	0	**50**
4.3 Irrigated Cropping	0	1	0	0	**4**	1	0	0	0	**6**
4.3.6 Irrigated Cotton	0	0	0	2	0	**9**	0	0	0	**11**
5.4 Residential	0	0	0	0	0	0	**5**	2	0	**7**
5.5 Services	0	1	0	0	0	0	0	**0**	0	**1**
6.2 Reservoir	0	0	0	0	0	0	0	0	**5**	**5**
Total	**6**	**55**	**25**	**43**	**4**	**15**	**5**	**2**	**5**	**160**

Overall Classification Accuracy = 87.50%

Discussion of Approach to Coastal Catchment Mapping

The coastal catchments program is currently mapping 27 catchments from the Queensland – New South Wales border to Townsville, a distance of approximately 1,350 kilometres. This covers an area of approximately 11.3 million hectares or 6.4% of the state and includes the major southeast Queensland catchments of the Brisbane, Mary and Burnett Rivers. The coastal catchments exhibit a diverse range of land use types with extensive areas of highly intensive land use associated with agriculture and the major coastal populations centres. Given the size of this task considerable effort went into further automating the mapping procedure. A model of the data collation stage of the land use mapping procedure was developed using the modeller module in ERDAS Imagine. This incorporated a decision matrix that allocated the most appropriate land use class for all possible combinations of pixels from the input data layers. The model output is a draft land use map for the entire extent of the coastal catchments. Individual catchments were clipped from the model output and mapping refined using Landsat ETM imagery and aerial photography. Multi-temporal imagery and colour aerial photography was used wherever available as this often provided seasonal information useful for the identification of crop types not readily discernable in single date imagery.

Conclusions

Accurate and detailed information on land use is very important for a broad range of planning and assessment activities. For example, catchment-scale land use maps are a key datasets for predicting water quality attributes, soils erosion and salinity risk. The need for a standardised approach to provide land use maps of high quality and suitable for a broad range of applications has been increasing rapidly in recent years.

The methodology described in this paper produces accurate and well-described land use maps at scales appropriate for the intensity of the land use. In the case of the Upper

Condamine catchment the mapping scale was 1:100,000. The independent accuracy assessment showed a classification accuracy of 87.5%. The quality of this data is suitable for monitor land use change using Landsat or other imagery and landcover datasets produced by the SLATS project. The methodology utilises both image analysis and GIS software. The focus is on evaluating and integrating existing digital datasets and enhancing this information through further image and airphoto interpretation and field assessment. A key component is accessing expert knowledge in regional state government offices, local councils and also community groups and directly from land holders.

The research focus of the land use mapping program has been on further automating the production of draft land use maps. Effort in this area has already improved the mapping efficiency and reduced the level of manual interpretation. This minimises the level of subjectivity and hence operator variation and increases the ability to monitor change accurately. Future research will continue to look at this issue, however other areas including data acquisition, management and documentation will also be reviewed.

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