MAPPING QUEENSLAND LAND COVER ACCORDING TO FAO LCCS USING MULTI-SOURCE SPATIAL DATA

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ABSTRACT:

Recent developments in the application of high-resolution satellite data for extracting spatial information have encouraged land cover mapping activities throughout Australia. Together with the increase of these mapping activities, the need for standardizing land cover classification schemes for maps has been emphasized. In 2000, FAO published a widely accepted land cover classification system based on priori (pre-decided) approach, which can be applied to any area of the world. This study examined land cover features of the geographically diverse state of Queensland, Australia, with a special emphasis on dynamic land cover differences, and applied fundamentals of FAO LCCS to classify land cover of two different regions. These two regions; 1) the arid Mt. Isa region in northern Queensland; and 2) the urbanized southeast region including Brisbane and the Gold Coast, cover a diversity of landscape types. The combination of these regions is representative of a large portion of other regions of the Australian continent. Improving the resolution of national land cover maps is of a national priority as it required to address a wide range of environmental and natural resource issues. Classifications were conducted on SPOT 10m satellite data, supported by 2.5m high resolution SPOT true colour images, ASTER, and some Landsat scenes. Other GIS data layers including SLATS 2001-2003 (Statewide Land cover and Trees Study) data and extensive field survey information collected from both areas were also utilized. Both regions were classified initially into three levels (dichotomous phase) of the FAO LCCS and then spectral features, field investigations, and other image attributes were used to generate 4th level (Modular-Hierarchical phase) land cover categories. Results show a very satisfactory land cover map at 10m resolution compared to existing land cover products. The standard FAO classification scheme provides a standardised system of classification that can be used to analyse spatial and temporal land cover variability throughout the country. This approach also has the advantage of facilitating the integration of Australian land cover mapping products with global land cover datasets.

1. INTRODUCTION

When human interaction with the land increases, understanding the land changes becomes an integral part of any environmental plan. In general terms, "Land" is a part of the earth, or the ground, not covered by water. According to some definitions in law, "Land" is described as a three dimensional space consisting of Land and space below and above it (Butt, 2001). But, environmental engineers are paying more attention to the land surface since investigating the land and its resources is critical to their work. The FAO document defines the land according to its contribution to productivity. The main resource controlling primary productivity for terrestrial ecosystems can be defined in terms of land: the area of land available, land quality and the soil moisture characteristics (Di Gregorio and Jansen, 2000). This main resource or the Land further explains by its physical appearance as "Land Cover" and "Land Use". The Australian institute under the Natural Heritage Trust, the National Land and Water Resources Audit, agrees with the FAO definition of the land cover, which is describes as observed biophysical cover on the earth's surface including vegetation and manmade surfaces (Di Gregorio, 2005). Further, the National Land and Water Resources Audit defines Land Use as the purpose to which the land cover is committed (National Land and Water Resources Audit, 2007).

This is explained further by the FAO definition, for example, "grassland" is a land cover type, while "rangeland" or "tennis court" refers to the "use" of respective "grassland". Hence, it's clear that the geographical feature of the land or land cover determines the land use. With ever increasing human interaction, agriculture has become the primary land use activity which alters the land cover. Within last 50 years, the gross value of Australian agricultural sector expanded dramatically from $4.5 billion in 1960/61 to $46.5 billion in 2007/08 (Australian Bureau of Statistics, 2008). Due to its massive scale of activities, Australia has a significant obligation to act in this field of research to fulfill its local and global responsibilities in food production and environmental conservation. Table 01 shows few noteworthy features of Australian agriculture and land cover against world.

Table 01. Some characteristics of Australian agriculture and land cover (source: Agro data, 2006)

Component	Australia	World
Per Capita Cereal Production (tons per person), 1999 - 2001	1794	343
Percent change of Cereal production since, 1979-81	62%	32%
Hectares of Cropland per 1,000 population, 1999	2547	251
Forest area as a percent of total land area, 2000	20%	29%

Land cover information is vital for the sustainable use of land. A standardized and up-to-date land cover dataset is required to; assess the condition of the natural resource base, modeling water quality, soil erosion, soil health and the sustainable production of food and fiber (DAFF, Australia, 2007). Data generation must be conducted to satisfy the logical approaches of standard land cover classification systems to compare with multi-temporal inter-state and international data. Here, the priori Land Cover Classification System (LCCS) adopted by the FAO can be used as the standard to build a local land cover classification system for Australia.

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2. CONSTRUCTING THE CLASSIFICATION SCHEME

Earth surface mapping was given a tremendous boom with the introduction of earth observation satellites in 1972. Land cover and land use maps at various scales were generated to address specific needs or local areas, but none of the classification schemes became internationally recognized or standardized. Under this context, the Land cover classification system (LCCS) adopted by the FAO can be considered as an approach with logical definitions which apply all land cover types of the world (Di Gregorio and Jansen, 2000). FAO and UNEP gathered in 1993 to establish a land cover classification system to match the wider spectrum of global land cover types and so by 2000 the FAO LCCS became fully operational.

2.1 Basics considered in FAO LCCS

The FAO LCCS system is consider as the only such approach available today which can be applied to any region of the world regardless of the economic conditions and data source. Initially, the FAO method is a "*priori*" classification system, which defines all the classes before the classification is conducted. The advantage of this approach is the possibility to maintain standardisation of classes. For this propose, LCCS developed pre-defined classification criteria, or *classifier* to identify each class, instead of identifying the class itself. This concept is based on the idea that a land cover class can be defined without considering its location or its type, using a set of pre-selected classifiers. Therefore, when the user requires a large number of classes, a large number of classifiers are required. To organize the classification more easily, FAO system used a *dichotomous* (divide into sub categories), approach in hierarchical levels and used eight classifiers to group all land cover types at the third level. In other words, any location on the earth surface can be categorized into one of the eight classes without having a conflict. Up to this third level, FAO used the presence of vegetation, edaphic (plant conditions generated by soil and not by climate), and artificiality of land cover for classification. Additionally, the third level of FAO classification can be considered as a concept based on visual classification, which uses the directly visible and knowledge based components on the ground.

In practical conditions, a further breakdown of the third level eight classes must be conducted to obtain a detailed level of land cover classes. For that purpose, FAO uses a *hierarchical approach*, or the *Modular-Hierarchical Phase*, to build additional classifiers, but strictly within one of eight classes identified in third level of the dichotomous phase. Under this 4th phase, the system uses a set of pre-defined pure land cover classifiers, different from the eight classes in the dichotomous phase presented in Table 02.

Table 02. Dichotomous approach to build primary classes in FAO LCCS

First level	Second level	Third level
A. Primarily vegetated	**A1.** Terrestrial	**A11.** Cultivated and managed terrestrial areas
		A12. Natural and semi-natural terrestrial vegetation
	A2. Aquatic or regularly flooded	**A23.** Cultivated aquatic or regularly flooded
		A24. Natural and semi-natural aquatic or regularly flooded
B. Primarily non-vegetated	**B1.** Terrestrial	**B15.** Artificial Surfaces and Associated Areas
		B16. Bare Areas
	B2. Aquatic or regularly flooded	**B27.** Artificial water bodies, snow and ice
		B28. Natural water bodies, snow and ice

The pure land cover classifiers are defined by **Environmental Attributes** (e.g., climate, soil, and etc) or by **Specific Technical Attributes** (specific details like crop type and soil type) (africover, 2008). In both cases, the user gets the freedom to add these classifiers with their own research interests, scale of the classification, and the physical and climatological conditions of the field. The FAO LCCS document presents a large number of classifiers to use in this level and the user can use only a selected set from the list to match with the scope of their own mapping project.

2.2 Australian vegetation and its recent changes

The Australian flora and fauna is a composite of Gondwanan elements, and has evolutionary lines shared with South America. About 80% of the flora of Australia is endemic to the country and most of the species are extremely restricted in geographic and climatic range. For example, 53% of the about 800 species of eucalypts have climatic ranges spanning less than 3˚C mean annual temperature, and 25% span less than 1˚C (Hughes, 2005). Also, about 23% have adapted to less than 20% of mean annual rainfall changes (Barrie, 2003). The recent global warming may have influenced these flora (and fauna), since the largely flat Australian geography offers only a little space to escape naturally.

The millions of years old unique Australian landscape has faced a rapid change within last two centuries with the arrival of European settlers. The native vegetation cover or plants present in Australia before European settlement has declined to 87% of the country (State of Environment, 2006). Most of the native forest change has occurred through clearing of forests and woodlands, which originally covered 54% of the country and now covers only 42%. Within this period, an excessive loss occurred in rainforest and vine thickets, eucalyptus woodland, Mellee woodlands, and low closed forest categories by over 30%. According to overall assessments, about 22% of the forest and woodland have been lost due to burning and farming by settlers (State of Environment, 2006). These recent manmade and other climatic influences on the land surface have attracted the attention of researchers.

2.3 Applicability of FAO LCCS system in Australian terrain

Australian land cover is greatly influence by climate rather than it's near flat terrain with 99% of its land area below 1000m (Hughes 2003). Figure 1 compares the annual rainfall and topography of the country, which shows heavy rainfall along the east and north coastal areas. Within Queensland, the central region receives extremely low rainfall (Birdsville, mean annual rainfall is less than 200mm), while northeast coast receives heavy monsoon rains (Innisfail, mean annual is over 3200mm) (see locations on figure 1). Vegetation types throughout the state have adapted to these climatic variations. When classifying land cover of Australia, the priori classification approach of FAO LCCS, provides a logical approach to separate land cover types. It helps to ignore differences in land surface of Australia at the initial three levels of the classification (see Table 02). However, for the construction of the 4th level of the classification system, regional environmental features and field information must be considered.

When building the land cover map through these four levels of FAO LCCS, the near-flat terrain of Australia requires a focus on climate and soil characters rather than topology. The other elements to consider for the classification are spectral characteristics and the resolution of original data, final mapping resolution and the quality of supporting data (including ground truth data). In this study we used SPOT 10m satellite data and a set of GIS data for the mapping. Also extensive ground surveys and SPOT 2.5m color composite images were used to build the classifiers.

3. THE CASE STUDY

The land cover of Queensland varies from semi-desert barren lands and huge farm lands in the vast hinterland to some of Australia's largest remnant tropical rainforests including a world heritage site (Department of the Environment, 2008) and urban environments in east coast. Mapping the land cover characteristics covering all these land cover diversities is a challenging task. The present study focuses on the classification of two selected locations of Queensland (see figure 2), that represent significantly different land cover types of the state. The paper presents two selected areas from originally classified full scenes of SPOT, with only one area (area No. 1, Mt. Isa) in details

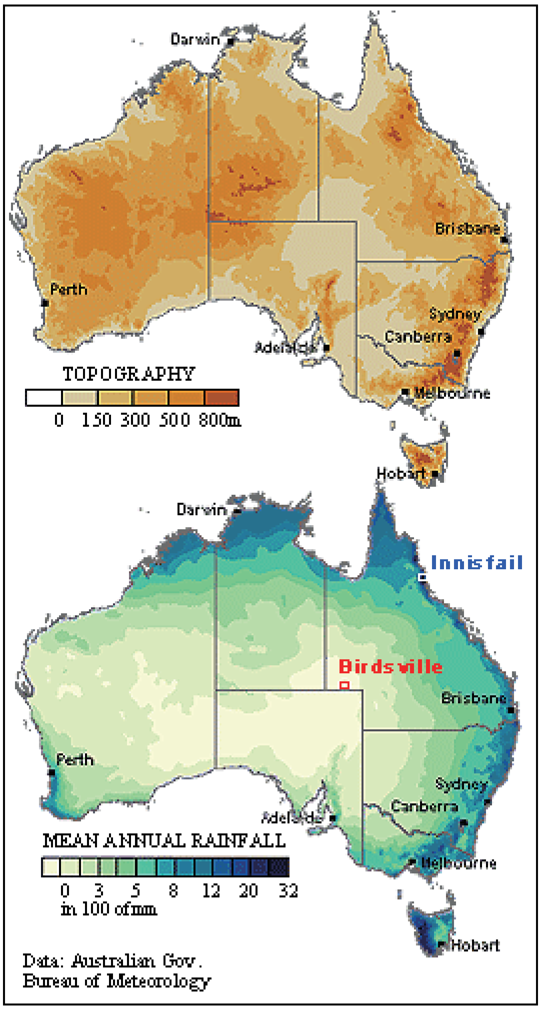


Figure 1. Elevation and annual rainfall of Australia.

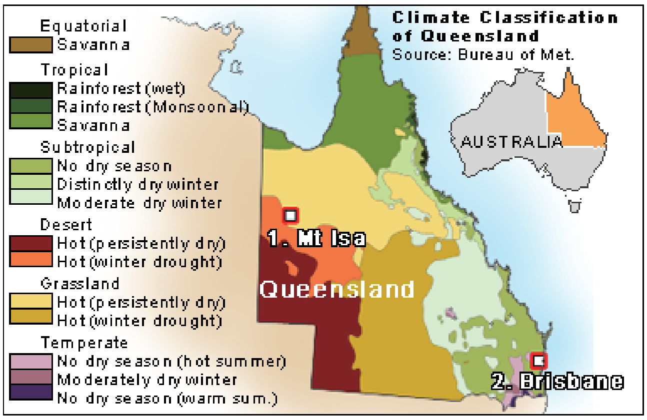


Figure 2. Locations of study areas on QLD Climatic Zone map.

The locations of study sites are over 1,500 kilometres apart from each other (figure 2). The selected locations lie in the arid and subtropical climatic zones respectively. The land cover classification of these two areas with contrasting geo-climatic characteristics makes the approach suitable to apply to other Australian regions with appropriate modifications. As tabulated in Table 03, the two selected study areas are considerably distinct from each other by various geo-climatic aspects. The 1st area, just south to Mt Isa city in central Australia has arid climate with relatively an unproductive soil layer for farming. Brisbane area (2nd study area) in southeast Queensland is the main urban region of the state. Its sub-tropical climate has warmer and wetter conditions with no clear dry season while the 1st area in north inland has a semi-aired climate with less potential for farming (Michael F. H and et al, 2005). Naturally, the Brisbane region has the highest population density, while Mt. Isa (43,338 km²) is sparsely populated where the entire population has just over 23,000 people concentrated in the mining city, Mt Isa. For this study, we extracted 1000 km² sections from each region.

Table 03. Main features of study areas.

Element	**1. Mt. Isa**	**2. Brisbane City**
1. Selected area	1000 km²	1000 km²
2. Mean annu. rainfall	389.75mm	1149.1mm
3. Mean annual maximum temperature	32.3˚C (at post office)	25.5˚C (at regional office)
4. Climatic zone (based on KÖppen)	Semi-arid, hot climate	Subtropical - No dry season
5. Elevation	530 – 300 m	280 – 0m
6. Population density	0.05 (2006)	115 (SEQ) (2004)
7. Main land cover feature	Woodlands and bare lands with grass	Urban and settlements

4. DATA AND DATA PROCESSING

4.1 Used data

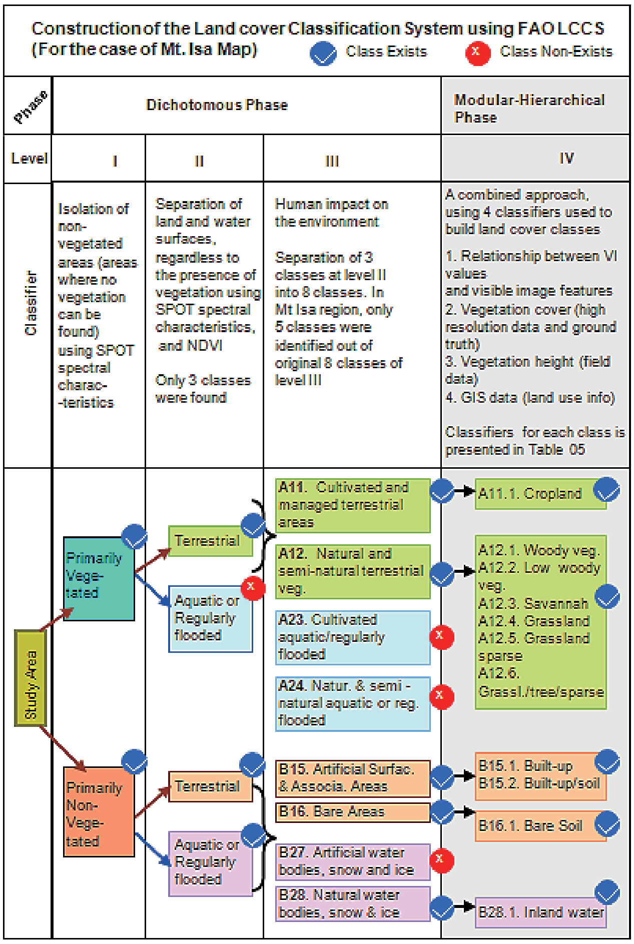
The Table 04 summarized the data sets used for the study.

Table 04. Used data in the study

Data type	**Data set identifier**	**Date**
For Mt. Isa		
SPOT 2.5m	sthn_gulf_2p5m_nc.tif	20052006
SPOT 10m	sp5xi10_358391_30072005.tif sp5xi10_358392_30072005.tif	30072005 30072005
ASTER	1397_203_130900.img	16102006
Landsat	l5tmre_mtis_20051005_ba7m4.img	05102005
Field Survey		Dec/Jan 2008
For Brisbane		
SPOT 10m	390/405	06072006
SPOT 2.5m	sp5col2p5_SG5614.ecw sp5col2p5_SG5615.ecw	20052006 20052007
Field Survey		Apr 2008

4.2 Building the classification for study areas

To limit the length of the paper, the methodology of building the classification scheme focuses on one of the mapped areas, Mt Isa in north-west Queensland. Micro Image TNT software package (TNTmips 2008:74) was used for all aspects of the image processing. The construction of first three levels of the classification was completed by strictly following the FAO LCCS structure. For these initial three levels, spectral characteristics of SPOT images and vegetation index image were used extensively. We also used different levels of spectral information to isolate broad classes at each level of the LCCS. A new set of training sites were selected from each level to perform the next level classification. Those training sites were selected with the help of 2.5m SPOT images, field investigations, different image indexes of SPOT, Landsat, and ASTER data, and general knowledge of the region. Under the dichotomous approach (see table 2) of FAO LCCS, the accuracy of each initial level is permanently affected by the accuracy of following levels of the classification.


Construction of the Land cover Classification System using FAO LCCS (For the case of Mt. Isa Map)

Level I: Isolation of non-vegetated areas (areas where no vegetation can be found) using SPOT spectral charac--teristics

Level II: Separation of land and water surfaces, regardless to the presence of vegetation using SPOT spectral characteristics, and NDVI

Only 3 classes were found

Level III: Human impact on the environment

Separation of 3 classes at level II into 8 classes. In Mt Isa region, only 5 classes were identified out of original 8 classes of level III

Level IV: A combined approach, using 4 classifiers used to build land cover classes

1. Relationship between VI values and visible image features
2. Vegetation cover (high resolution data and ground truth)
3. Vegetation height (field data)
4. GIS data (land use info)

Classifiers for each class is presented in Table 05

Figure 3. Building the classification scheme according to the FAO LCCS.

4.2.1 Classification Level I: A supervised classification to isolate non-vegetated lands was conducted through careful selection of training sites from 100% non-vegetated areas. Spectral values of each SPOT band and NDVI image together with 2.5m SPOT images were used to identify these training sites, precisely. All other areas under different levels of vegetation (from vegetated area to a mix of bare ground and grass) were classified into vegetated areas.

4.2.2 Classification Level II: The re-classification was carried out with two classes of level I to generate four classes. After observing the NDVI, image classification was conducted through selecting training sites using the 2.5m and 10m SPOT images. Only 3 classes were found out of four, and the class A2 ("aquatic or regularly flooded areas under primarily vegetated category") (see figure 3) were not found in Mt Isa region.

4.2.3 Classification Level III: At this level, FAO LCCS has 8 sub classes to represent all land surface features on the earth. The availability of the area under each class is directly depending on the regional features of land cover of each respective area. A clear example is, in a remote desert region with no human settlements or any vegetation, it may just comprise of only one class (B16, A6: Loose and Shifting Sand) from these 8 classes. The Mt Isa region has a predominantly dry climate and no vegetated lands under aquatic or regularly flooded conditions exit. We found five classes out of eight original classes at this level (see Level III in figure 3) with regard to Mt Isa region.

4.2.4 Classification Level IV: The 4th level of the classification is the challenging phase of the land cover mapping, which must identify classes closer to real world land cover with clearly demarcated boundaries. As an example, even after extensive studies, the LCC for Tasmania conducted in 2006 had 14 classes at local level, but one of them, "seabird rookery complex" found no matching class in FAO LCCS to be re-named (Atyeo and Thackway 2006). Fundamentally, the 4th level or local level class generation has to be conducted through applying more detail "classifiers" (Di Gregorio, 2005), as FAO LCCS requires. In this study we used very high resolution 2.5m satellite images and ground survey information to build classifiers for the 4th level. Additionally, spectral characteristics of SPOT 10m images played a strong role in the classification process. Figure 3 shows the simplified flow of this process which presents all four levels with regard to the Mt. Isa map. *Classifiers* used to generate each class in level IV for Mt Isa map are presented in Table 05.

Table 05. Land cover classes mapped in Mt Isa region under FAO LCCS system

Class Code	Class name	Classifiers	Corresponding FAO LCCS classif. Code
A11.3	Crop land	VIT(visually identified training sites using 2.5m images) + high NDVI value (around 0.6)	**A11** A3 Herbaceous D4 Surface irrigated
A12.1	Woody vege-tation	VIT + high NDVI value (higher than 0.3) + closed woodlands (> 60%) + tree height is over 2.5m	**A12** A1 Woody A1 A10 Closed A10 B1 Height 7 – 2 m
A12.2	Low Woody vege-tation	VIT + high NDVI value (higher than 0.3) + open woodlands (10 – 40%+ tree height is over 1m	**A12** A1 Woody A21 Open B14 Height 5 – 05m
A12.3	Savan-nah	VIT + areas under low NDVI value (below or around 0.3), and Shrubs (Sparse) + Graminoids observed from field investigation	**A12** A4 Shrub A6 Graminoids A14 Sparse (1% - 15% Shrubs and trees)
A12.4	Grass land (wetlan ds)	VIT + areas with moderate to high NDVI value (0.3 - 05), dominate by Graminoids observed from field investigation	**A12** A6 Graminoids C1Spatial distribution
A12.5	Grass land sparse	Visually identified training sites from areas under low NDVI value (below 0.3), with Sparsely distributed Graminoids, observed from field investigation	**A12** A6 Graminoids A14 Sparse
A12.6	Grass land /tree/ sparse	Special spectral feature of soil color caused by rocky terrain, identified by 10m and 2.5m data, verified by field investigations.	**A12**, A6 Graminoids A4 Shrubs, A14 Sparse A3 Tree Sparse
B15.1	Built-up	Visually identified training sites using 2.5m data and field investigation	**B15** Urban Areas A13
B15.2	Built-up/soil		**B15** A12 Industrial and other
B16.1	Bare soil		**B16** A5 Unconsolidated Bare soil
B28.1	Inland water	Visually identified training sites using 2.5m data	**B28**. A1 Water A1

5. RESULTS OF THE CASE STUDIES

This paper mainly emphasizes the characteristics of Australian land surface and the application of FAO LCCS to classify that into land cover classes. We produced land cover maps for the two test sites mentioned in previous sections.

5.1 Mt. Isa, the arid region

The vicinity of Mt Isa city significantly represents the vast inner Australian arid landscape. The centre of the mapped area (Mt Isa city) associates with a large mining complex, which is one of the largest in Australia. The built-up area of the city with 23,000 people is restricted to a small area, though its urban limits cover 43,310 square kilometres (moutisa.qld.gov web). Due to the harsh climate, no major farming areas can be seen closer to the city, except ranching activities. Figure 4 A and B, shows typical red-soil outback (Australian term for remote area) environment around Mt Isa.

Figure 4. Typical land cover types in Mt Isa area. Left area is about 7 km east and right area is 18 km south to the Mt. Isa city.

Through a careful observation of spectral characteristics of SPOT 10m images and vegetation index images as explained in section 3.3, a land cover map of Mt Isa was produced with 11 classes under the 4th level (figure 5). An accuracy assessment of the Mt Isa map was carried out using the 2.5m SPOT image. Using a systematic random sample, 128 points were selected from the area covered by 2.5m image and checked against the classified image data. Samples were under represented on land cover types with very low areas of coverage, but all major land cover types were counted. Results showed an overall accuracy of 82% for Mt Isa map.

5.2 Brisbane, the coastal urban region

Mapping urban environments using high resolution satellite data is a relatively an easy task, since spectral characteristics of urban surface show a clear discrimination against vegetation. Specially, Brisbane city stands out clearly against the surrounding mostly non-built-up areas of Queensland. The map shown here as Brisbane (figure 6), is a subsection of a larger map that covers whole southeast Queensland (SEQ) catchment. SEQ has a wide variety of land cover types and its Brisbane-Gold Coast coastal urban belt with over 1.5 million people (2007 Projected) (ABS, Australia) is the busiest urban region in the northern half of Australia. Table 06 presents land cover classes mapped in Brisbane area, under FAO LCCS.

An error matrix was used on the classified SEQ map to determine the percentage of land cover accuracy. The error matrix used a total of 190 points and found total class accuracy for the entire SEQ Catchments area was 90%. The selected subregion in this study may have a different accuracy, if a separate sample is administrated for the subregion only. Specifically, the accuracy of the separate built-up areas from vegetated lands is high, compared to finding boundaries amongst vegetation types. Also, the inclusion of GIS data layers into the final map of SEQ has forced the vegetation types into some mixed vegetation classes (e.g., Tree Plantations), which is not a typical land cover class able to be identified through spectral classifications only.

5.3 The qualitative aspects of new maps

This study was conducted to apply the FAC LCCS system for Australian land cover products. Initially, two full SPOT image scenes were classified and only sub-regions of 1000skm were presented in this study in order to present clearer maps. To maintain homogeneity within each land cover class, classes have to be built with broad and easy to understand classifiers. A large number of classes based on micro-level local information is appropriate for local level detail mapping, and such a scheme must be organized in order to be accommodated within the national level land cover maps.

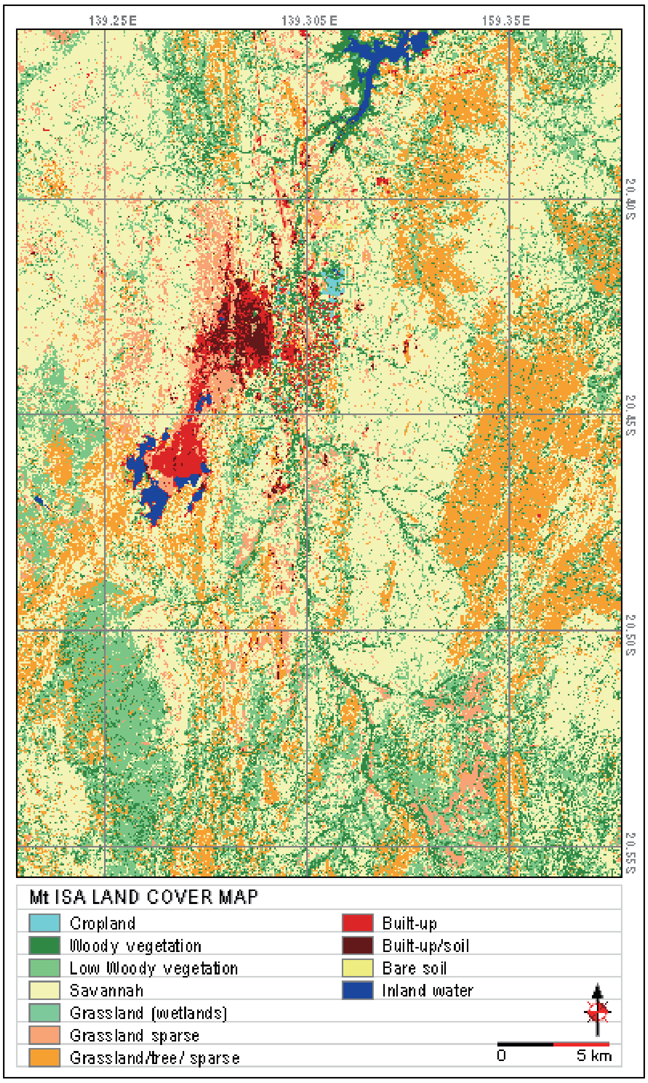


Figure 5. Land cover map of Mt Isa region.

Table 06. Land cover classes of Brisbane area under FAO LCCS.

Class Code (Arranged by FAO LCCS)	Class name **Brisbane** (South East Queensland)
A11.1.	Grassland - farm
A11.2.	Tree Plantation
A11.3.	Cropland - Dry land
A11.4.	Cropland - Irrigated
A11.5.	Cropland – Tree crop
A12.1.	Medium to tall woody veg.
A12.2.	Woody open
From A12.3. to A12.10	No class identified
B15.1	Built-up-Non-vegetated
B15.2	Built-up-Impervious road surface
B15.3	Non-built-up non vegetated
B15.4	Non-built-up-Mine/Quarry
B15.5	Non-built-up-Impervious road surface
B16.1	Bare rock (only in outside of selected area)
B16.2	Bare soil
B27.1	Canals
B28.1	Inland water
B28.2	Marine water

We have used an approach based on spectral values and visual observation of super-resolution (2.5m colour images), which are the basic needs for any classification. We then added field observation information to the training site selection and the refining process, which strengthens the classifiers used to break level 3 classes into the 4th or final level classes. As explained earlier, the classification gave satisfactory levels of accuracy with both maps being accommodated in a classification scheme based on FAO system. Figure 7 visually compares new map with existing SLATS 2001-2003 data set to indicate the improvement in land cover data when high resolution images were used.

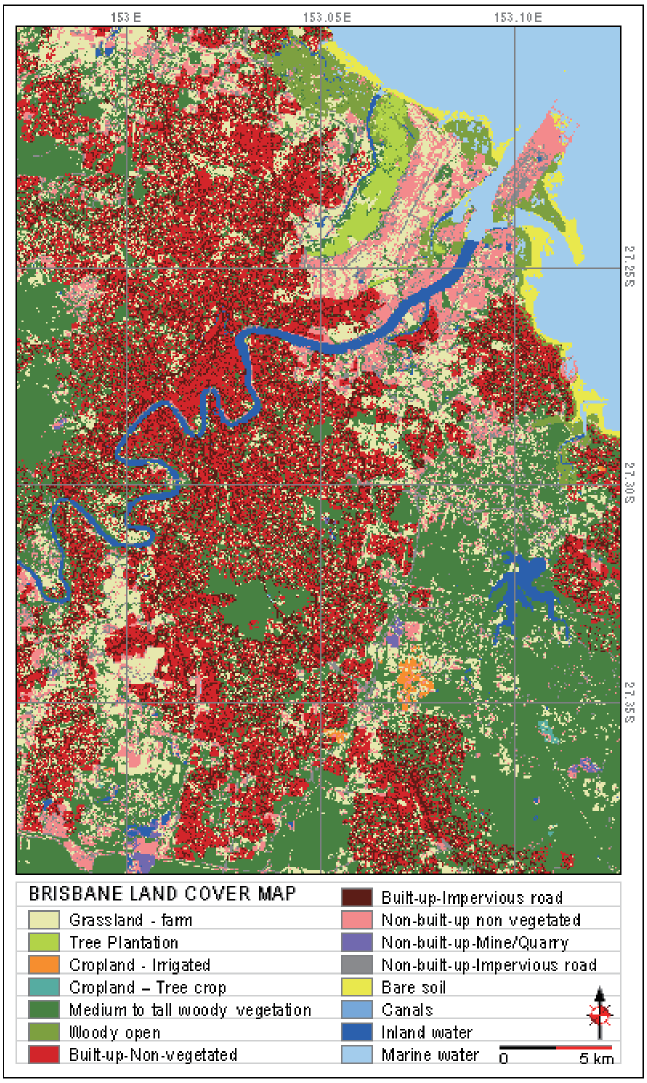


Figure 6. Land cover map of Brisbane urban region.

Figure 7. Comparison of land cover details of a sample area.

6. CONCLUSIONS

Australia's agriculture and mining based economy requires an accurate assessment of land use and land cover. However, mapping the country at 10m or finer resolution has just started and over 90% of the country is yet to be mapped. This study classified two distinctly different landscape plots from Queensland, Australia. The prime objective of the study was to build the classification system common for both regions using the fundamental approach of FAO Land Cover classification system. The FAO system has three initial class levels based on a priori (pre-defined) classification approach and the 4th detail level or the Modular-Hierarchical Phase. A careful observation of the spectral information against super resolution satellite data and ground survey information enabled classifiers for 4th level to be selected. For each map, different land cover types were identified in diverse geo-physical and climatic conditions for each respective region. Some classes ended with same name and same class identifier when the classifiers were similar to each other (i.e.; A12.2. woody open class in Brisbane map). The results showed a promising outcome for mapping different regions under a single classification scheme. The maps were completed with a high accuracy and 10m spatial resolution which will be a useful data source for regional and national level land cover planning.

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