Historical revision of the spatial data and methods used for land-use mapping in a dynamic urban area of NSW: the Sydney Basin case (*Feeding Sydney* project).

Piquer-Rodriguez, M.*[1], Crabtree, L.* and O'Neill, P.*

* Urban Research Centre. University of Western Sydney. Level 6. 34, Charles St. Parramatta NSW 2150 [1]: m.piquerrodriguez@uws.edu.au

ABSTRACT

The Urban Research Centre (UWS) is developing *Feeding Sydney*, a research prospectus focusing on the spaces and processes of Sydney's food systems. The interaction between urban development and agricultural land on Sydney's fringe is a core concern. The project requires the availability of a high quality, consistent and standardised source of land-use data to determine potential future challenges for policy, planning and governance in pursuing more sustainable land uses.

There currently exist gaps in land-use data for Sydney's greater metropolitan area. There is a lack of spatial, methodological and time consistency in land-use data that could otherwise be effectively used in the sustainable planning of the metropolis.

In this paper we introduce the first findings of the research on data availability and methodologies used to generate existing land-use maps of the region. We also propose the usage of automated methods to gain efficiency and consistency with international land-use maps.

Key-words: aerial photograph, agricultural lands, digitizing, remote sensing

Introduction

Land-use change detection is one of the basic pillars of global change towards sustainability. Landscape sustainability requires an understanding of the evolution and usage of land and the nature and extent of land resources (land cover). Analysis of historical and current land-use helps to determine potential future challenges for policy, planning and governance in pursuing more sustainable land uses.

There currently exist gaps in land use data for the Sydney greater metropolitan area. These data are inconsistent across agencies (state departments, councils, universities, etc) and over time. Current Sydney land-use data are a patchwork of different mapping techniques based on several sources with varying agendas. There is a lack of spatial, methodological and time consistency in land-use data that could otherwise be effectively used in the sustainable planning of the metropolis.

The Urban Research Centre is developing *Feeding Sydney*, a research prospectus for an innovative research program focusing on the spaces and processes of Sydney's food systems. The interaction between urban development and agricultural land on Sydney's fringe is a core concern of *Feeding Sydney*. Further, *Feeding Sydney* will combine and coordinate the investigation on numerous intertwined issues regarding urban food, such as: the significance and retention of urban and peri-urban agriculture; food, equity and health; patterns and cultures of consumption; holistic metropolitan planning; and future-proofing Sydney's food. In general, this project is significant at all levels of government as it relates to the management and sustainability of inter-related portfolios and sectors.

The success of the *Feeding Sydney* project, and any planning project, requires the availability of a high quality, consistent and standardised source

of land-use data. This would, first, give a coherent indication of current land use in Sydney and, second, act as a base on which to build ongoing analysis and track ongoing changes.

Some of the questions that need answers are:

1. Recent studies from DPI (Malcom & Fahd, 2008, unpublished) have proven that a substantial area that is used for agricultural production will be occupied by Sydney's north-west and south-west growth centres. Is this based on a planning framework inherited from the past?
2. Has the expansion of suburban Sydney into agricultural lands displaced agricultural activity into more isolated areas?
3. What are the spatial patterns of urban expansion through time in the Sydney Great Metropolitan Region?
4. Sydney's Natural Protected Areas surround and limit the growth of the metropolis. What has been the evolution of the human occupation of natural areas in the Sydney Great Metropolitan Region?

State of the Art

An extensive literature and data review was been carried out in order to generate a typology of the State of the Art of land-use mapping in the Sydney metropolitan region. A description of the main available production characteristics of the historical and current land-use maps for the Sydney metropolitan area and surroundings is presented below. A map showing the areas covered by the described land-use maps is located at the end of this section.

To assess land use changes in the Sydney Basin, we first need to define the Basin. From the perspective of land-use mapping—and taking into account the spatial extents of previous maps—we understand the Sydney Basin as the area surrounding the Sydney Great Metropolitan Region and itself (Figure 1). Our special interest focuses on the interaction of the dynamic urban system with its agri-natural environment.

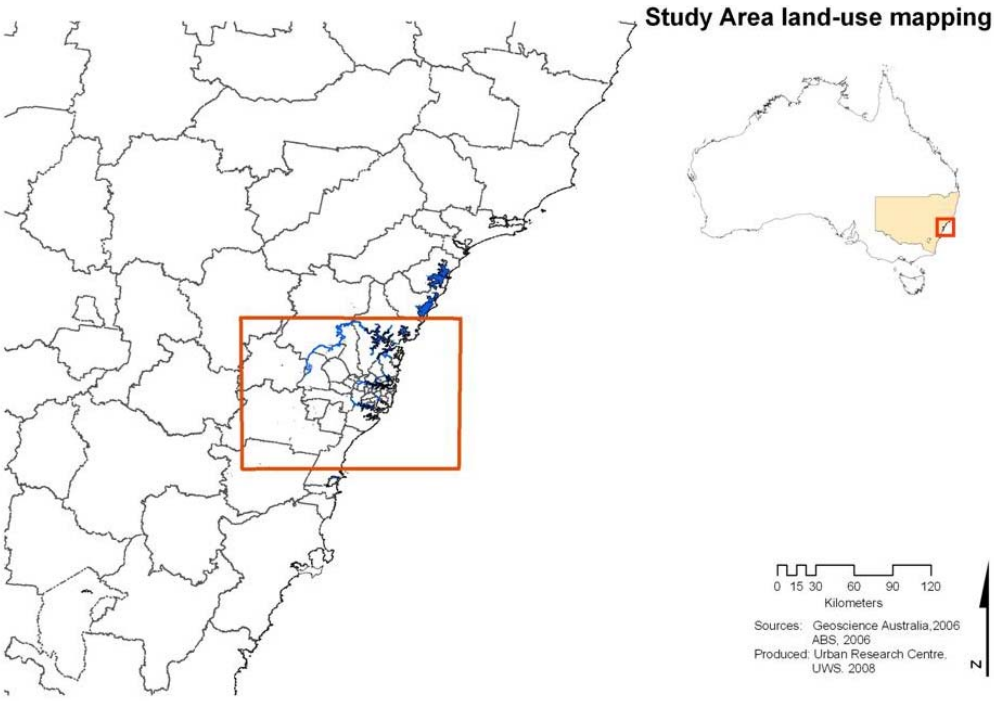

Figure 1: Study area for the land-use mapping exercise.

There are two main methodologies that have led the production of land-use maps from 1995 to date for the Sydney Basin area.

First is the visual recognition of land-use features with the help of remote sensing imagery. The recording of data is done by manual digitizing of each plot and its associated land-use. Teams of trained officers define the land-uses and populate the geographical databases where the use of each parcel is recorded. Plots requiring further clarification are visited and the land-use checked in-situ. Changes are made to the line work and the database when necessary. Most of the time, auxiliary ancillary data—such as natural protected areas, roads, rivers, indigenous land, property parcels, etc.—is overlaid over the remote sensing imagery. Variations of this method include the use of interviews with farmers, aerial or satellite imagery, or the use of a cadastral base that avoids the manual digitizing of plots.

The second method is an automated remote sensing imagery analysis. In this case, specialised imagery software depicts the land-use types based on the detection of energy reflectivity that different materials emit. This depiction can be unsupervised (when the remote sensing software groups the different energies received by the satellite by means of a predefined number of classes that the user sets) or supervised (the user gives the software a set of reference energies that belong to well-known land-uses). The satellite imagery might need several corrections prior to the mapping exercise. Once the maps are prepared, land-use results must be ground-truthed with sample field data to check for mapping accuracy.

List of the land-use mapping exercises developed for the Sydney Basin since 1995:

1995 – Agricultural Land Classification Atlas of Sydney Basin, including the Lower Nepean – Hawkesbury Catchment (Department of Primary Industries, NSW).

Area: North, south and Great Western Sydney.

Data processing for: *Agricultural sites*: field observation, air photo-interpretation and usage of topographic maps.

Other uses: auxiliary data from the Land Information Centre, Bathurst.

Scale: 1:50 000

1996/1997 – Land use Sydney Coast –Georges River Basin (Australian Natural Resources Atlas, Australian Government).

This dataset is part of the 1996/1997 Land Use of Australia, Version 2

Area: Sydney Great Metropolitan Region

Data processing for: *Agricultural sites*: automated process by satellite imagery

Other uses: auxiliary data from several sources (Environment Australia, Geoscience Australia, National Forestry Inventory)

Control sites: field visits and interviews to farmers

Resolution: 1km

Scale: State wide

1999/2000 – Land Use: Eastern New South Wales (Department of Infrastructure, Planning and Natural Resources, NSW).

Area: Extent enclosed between North of Sydney, North-East NSW state boundary, East of Bourke.

Data processing for: *Agricultural sites*: manual digital mapping based on recognition of patterns from satellite images (Landsat 7)

Other uses: several sources (aerial photographs, field checks, local knowledge, cadastre, native vegetation data, DIPNR)

Control sites: field visits.

Scale: 1:50 000

Accuracy of the mapping: 92-99%

2000 – South Creek Catchment (EPA)

Area: South Creek Catchment, South-West Sydney.

Data processing for: *All land use classes*: automated process by satellite imagery analysis combined with interpretation of the digital aerial photography. Help of auxiliary data sources.

Control sites: field visits and interviews to farmers

Resolution: 25 m.

2003 – Western Sydney Rural Land Use Study (EDGE Rural and Environmental Planning Consultants for DIPNR, NSW).

Area: Sydney Great Metropolitan Area

Data processing: recognition of patterns of land uses based on aerial imagery. Manual GIS database population of cadastral parcels.

Control sites: field visits (driving through)

2006 – Distribution of major land-use types in NSW (in Chapter 4 Land. NSW State of the Environment 2006)

Area: NSW

Data processing: Adapted from NLWRA 2001, DNR, DPI and DEC data.

2008 – Land use maps of Western Sydney and Central Coast, NSW (DECC, NSW)

Area: Extent enclosed between: Glen Alice, Hanworth and the coast line.

Data processing: recognition of land use patterns based on aerial imagery. Manual digitizing of parcels for updating 2006 land use map.

Control sites: field visits

Local government is another source of land-use data that has an extensive property land-use catalogue of the Local Governmental Areas. Recommendations from state departments have been made to approach city councils and gather their land-use maps to gain 2008 coverage. At this point and considering the coherence in mapping set as a main goal, we have discarded this as an option. However, locally it is an invaluable tool for planning purposes.

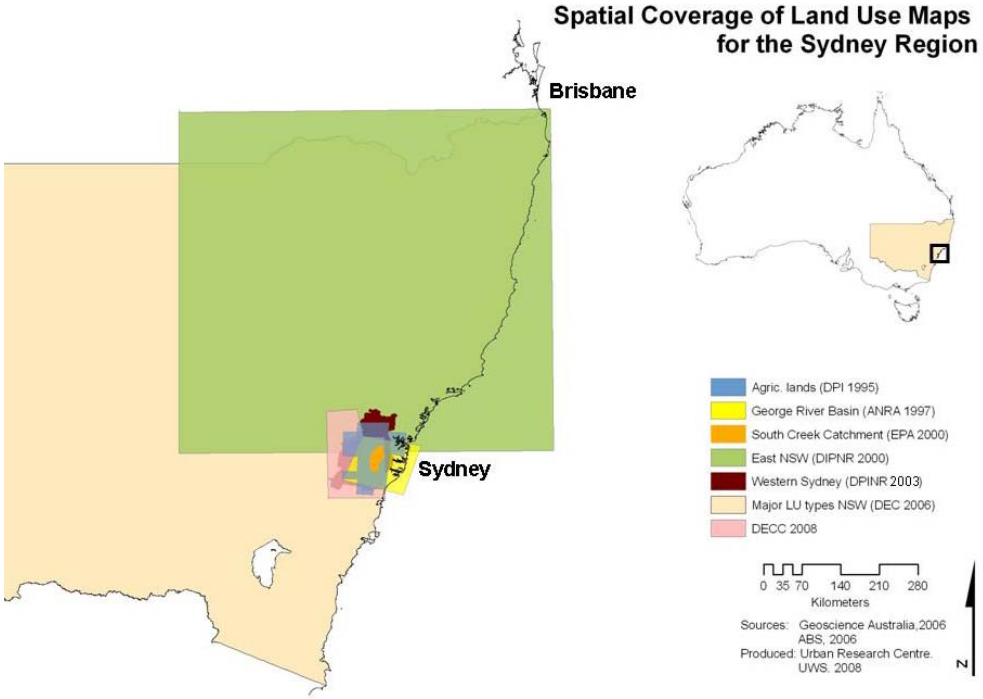

Figure 2: Land-use mapping coverage of the Sydney Area and surroundings. Sources: DPI, ANRA, CANRI, EPA, DIPNR , DEC

Although internationally some methodologies still interpret visually and digitize manually remote sensing imagery (e.g. CORINE project), land-use computer classification of remote sensing data is extending its use and applications worldwide in places such as Great Britain (Fuller et al., 1994), the Netherlands (Thunnissen et al., 1992) and Spain (Tapiador and Casanova, 2003). It has also been proved to be the most cost effective and timely approach (Whistler et.al. 1995).

Proposed methodology and outcomes

At this stage of the research, a need for an automated and consistent methodology in scale, spatial and time extent in land-use mapping production

for Sydney metropolitan area has been detected. This is where our attempt to map land-uses through time and space in the Sydney Area and surroundings will make an innovative contribution to the land-use mapping and the decision maker's tools.

We aim to develop a methodology for the generation of historical and current land-use maps that can be easily reproduced for other areas, is reliable and consistent. For this purpose we will analyse and produce 6 land-use maps for the Sydney Basin region dating from 1986, 1991, 1996, 2001, 2006 and 2009. The dates have been chosen to coincide with the ABS Census data releases and to provide a 2009 study to show changes since the last census. The sequence allows extra socio-economic comparisons in the study and enriches and broadens the study components and results. The imagery will be processed using specific remote sensing imagery software. In order to achieve a standardized mapping process, the guidelines for land-use mapping in Australia (ACLUMP, Bureau of Rural Sciences 2006) will be followed. The imagery to be used will be a fusion of two different image sources: one that allows a broad range of spectral signatures to be detected (medium resolution: Landsat TM) and another that enhances the final resolution of the fused image (high resolution: SPOT). Reference parcels with pure spectral signatures for the supervised land-use classification will be depicted using the latest land-use map generated by DECC (2008) while aerial imagery will be used for earlier maps.

After processing the data, the accuracy of the generated maps must be carefully checked through ground-truthing. For this purpose, fieldwork will be carried out. Test samples that have been previously determined by stratified random sampling will be ascribed their current land-use with the help of General Positioning Systems (GPS) technology. The collected current land-use data will be cross-referenced with the generated 2008 land-use map.

Intended project outcomes include:

- Six land-use maps of the Sydney Basin for the years: 1986, 1991, 1996, 2001, 2006 and 2009.

- A standardized methodology for land-use mapping in one of the most dynamic areas of the Australian east coast. Once the basis for such a study is set, it can be used in the future by different governmental bodies, research entities and planners.

- A library of current and ground-truthed land-use data in 2009 for the Sydney Basin that offers the potential for its continued use for similar future field validations.

- Dynamic Web GIS application where the results will be made accessible to a broad audience and used as a base for sharing and transmitting data in the academic and planning environment as well as among stakeholders.

Concluding observations and discussion

At this point we have to highlight that consistent space and time parameters on the land-use mapping of the Sydney Great Metropolitan Region and surroundings has failed to be developed. Determining these is fundamental if we want to empower planners and decision makers to make informed and critical decisions on the future of our lands and food sources. Agricultural land is being displaced and occupied by growing urban centres (DPI, 2008) and future plans do not bring hope to the maintenance of areas of productive agricultural land on the eastern coast of NSW. Appropriate land-use planning is the gateway for sustainable living in a fast changing world in which future water supply and energy prices mean that agriculture west of the Great Dividing Range and further afield cannot be guaranteed as future options to feed Sydney.

Comparisons among—and therefore correct usage of—spatial data requires firstly, the right data covering the time lags and spatial zones and secondly, a consistent methodology. In this regard, the existence of the ACLUMP project is a very beneficial step forward for the development of a precise and common land-use mapping activity at a state or regional scale.

Automated methodologies save time and money and generate data at a faster rate than manual methodologies. Although an automated method might lead to a higher error generation than a manual one, for some purposes the detection of hot-spot areas on which to focus planning efforts by means of automated methods can be more valuable when time is getting on. We believe that once a standardized land-use mapping methodology has been developed for broad land-use classes, its continuity will be safeguarded due to the ease of reproducibility. We understand that manual land-use mapping processes have their importance at local scales once the priorities of where to focus planning efforts have been determined at broader scales.

In the support of remote sensing methodologies for generating land-use data, we have found that stakeholders of land-use data have pointed out the benefits of using a remote sensing approach: it depicts objectively those current land-uses that the human eye sometimes fails to capture. However, human expertise on the land-uses of the area is still essential in order to train the remote sensing software and understand the land processes that take place over the years.

Acknowledgements

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