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MAPPING LAND COVER CHANGES (1947-2004) IN THE LANG LANG CATCHMENT, VICTORIA

Narsimha Swamy Garlapati, Shobhit Chandra and Jim Peterson

Centre for Geographic Information Systems (GIS)
School of Geography and Environmental Science, Monash University
Melbourne VIC 3800, Australia
Shobhit.Chandra@arts.monash.edu.au

ABSTRACT

The Lang Lang river catchment has been rated as having poor water quality even though it has the least urban sprawl of any catchment in the area controlled by Melbourne Water. The catchment is the largest under Melbourne Water jurisdiction and exhibits a wide variation in terms of geology and geography. Documented changes in the stream channels and sediment yield into the Westernport Bay have been monitored in the past twenty years and are said to be mainly due to clearance of the dense forests within the contributing catchment. This land cover change has progressed inexorably from the days of first European settlement about 150 years ago.

Previous studies of the Lang Lang catchment already published by Melbourne Water and CSIRO have linked the progress of soil erosion to the history of land clearance, but time series quantification of land cover change is lacking, as is any derivative with reference to geographical variation in the catchment. In this paper results of mapping canopy cover change by using time series orthorectified mosaics for the period 1947 to 2004 in the catchment are presented.

Land use after clearing in this catchment refers mainly to grazing, agriculture and dairying, all commendably viable in this area because of reliable rainfall and fertile soil. It is interesting to note that current and past attempts of reforestation by plantation have come nowhere near compensating for the amount of land cleared. By routine adoption of modern digital spatial data handling methods for change detection and by taking into account detailed geographical variation of the catchment, Water Managing Authorities and Catchment Management Authorities can facilitate their catchment restoration and rehabilitation programs.

BIOGRAPHY OF PRESENTER

A graduate of Cambridge University (PhD, 1994) and Lucknow University (MSc 1987), Dr. Shobhit Chandra joined the Centre for GIS at the School of Geography and Environmental Science, Monash University (Clayton) in 1997. Since then he has taught and supervised students for their research training. His research focus is on spatial modelling and analysis for sustainability of water resources, natural habitats and urban settlements. He is also working on applications of mobile Augmented Reality technology in real-time spatial visualisations.

INTRODUCTION

Some of the environmental, social and economic effects associated with increased land use and land cover changes have a significant impact on land sustainability. Some other consequences can be increased pressure on water resources, degradation of water quality, loss of highly productive agricultural land, clearance of native vegetation and biodiversity decline (Johnson *et al.* 2000, Barson *et al.* 2000, Lovett *et al.* 2004))

In Victoria the past 150 years of European settlement have profoundly transformed a landscape that had been comparatively stable for thousands of years. This is no more evident than for our changes in rivers, streams, lakes and all other surface water bodies and forest cover (Lunt 1997, Woodgate *et al.* 1988). From European settlement many of the wetlands were drained for agriculture and many rivers subject to flood mitigation works (Barton *et al.* 2004). Thus most of the Victoria's rivers and streams are now significantly modified, while over 30% of Victorian wetlands have been drained and many others are substantially altered for various purposes. Only a few catchments remain unaltered (Shapiro 1975). The Lang Lang river catchment (Figure 1a & b) has also been subject to significant modifications to its natural hydrology since European settlement. These changes are reflected in a generally degraded aquatic ecosystem, stream health issues (including severe bank erosion, in-stream sedimentation, poor in-stream flow, poor riparian vegetation cover) and increased sedimentation in Western Port Bay (Coleman 2001 and Wallbrink 2003). Prior to European settlement, the Lang Lang catchment was densely forested throughout and contained a series of swamps with thick tea-tree scrub. Native vegetation in this region was eucalyptus trees, shrubs, grasses, hedges, wild flowers and all other plants which occurred naturally in the region prior to European settlement (Lunt 1997; WPCCG 1984).

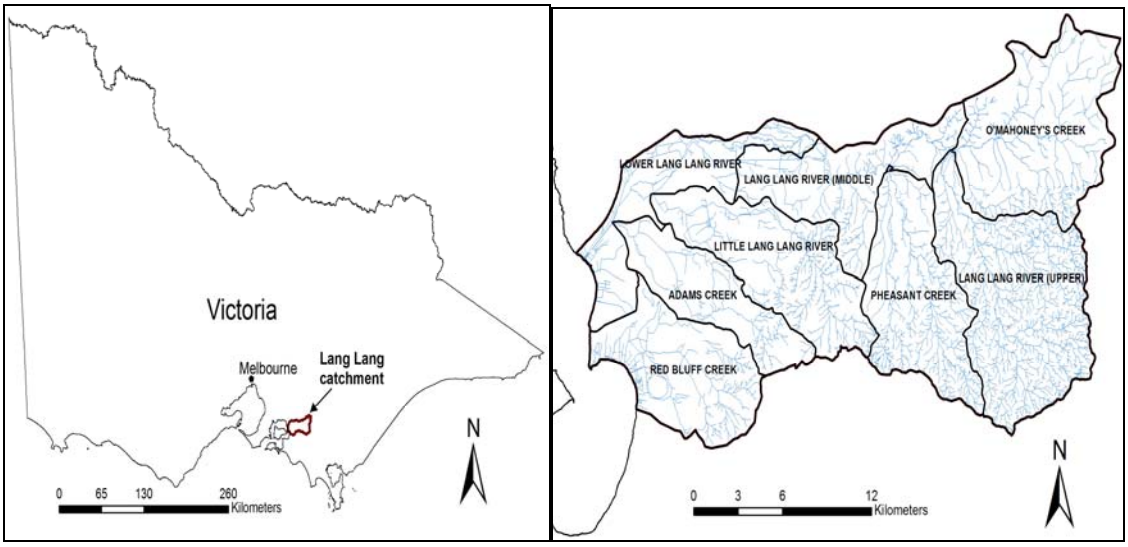

Figure 1 (a) Location Map of the Lang Lang River catchment in Victoria, Australia (b) Stream network and sub-catchment boundaries in the Lang Lang River Catchment (Source: VicMap Hydro (2006) for stream network and Melbourne Water for sub-catchment boundaries)

The land cover change history of the Lang Lang River catchment (492 km^2) (Figure 1(a) offers an interesting case study. It has undergone significant land cover changes over the last two centuries. Prior to European settlement, the slopes were densely forested and the lowlands occupied by a series of swamps with thick tea-tree scrub known as the ‘Kooweerup Swamps’. Much of the forest and swampland has now been cleared, with agricultural land use covering most of the area. Environmental values used as indicators for the health of the river system have changed significantly particularly in the middle reaches of the Lang Lang River and some sections of tributary creeks, such as Pheasant and O’Mahoney’s creeks (Figure 1(b)). As settlements intensified in the region the impacts were noticed in terms of river health becoming degraded (Melbourne Water 2004). The sub-catchments and the three sections for the Lang Lang River catchment are shown in Figure 1(b). The catchment is divided into Upper, Middle and Lower sections for administrative purposes by Melbourne Water. The latest Index of River Condition (IRC) rating for the Lang Lang River based on data in the past 5 years to 30th June, 2004 was compiled by Melbourne Water and is summarised as follows: Significance: *Low;* Current River Condition: *Poor* and Social Value: *Low* in terms of the Water quality, Aquatic life, Habitat and Vegetation

Melbourne Water's Index of River Condition (IRC) is designed to provide an overall integrated measure of the environmental condition of rivers. The IRC rating is based on the Index of Stream Condition (ISC) which is developed by Victorian Government, Department of Sustainability and Environment (DSE) for rural rivers and creeks. It has been modified however, to account for the urban rivers and creeks in Melbourne Water's operating area, and includes data for all of the rivers and creeks that Melbourne Water manages (Melbourne Water 2006). The vegetation and water quality has been rated as relatively poor in both the upper and lower catchments and is attributed in various reports to land clearance progressing into soil erosion (Hancock 2001; Wallbrink *et al.* 2003) but time series quantification of the rate and amount of canopy clearing is lacking, as is any derivative of it with reference to geographical variation in the catchment.

METHODOLOGY

Previous studies of Land use Land cover (LULC) change detection techniques have primarily used Remote Sensing data and many change detection techniques have been developed (Mas 1999; Lu *et al* 2004). A review of these change detection techniques by Lu *et al* (2004) has shown that spectral mixture analysis, artificial neural networks and integration of geographical information system and remote sensing data methods are important techniques in recently published change detection applications.

The Integrated GIS and Remote Sensing method is chosen for this study because available historical aerial photos are of different photo-scale, quality, completeness of coverage in the catchment and have different spatial resolutions. Automated change techniques cannot be used on such a spatial database. Our method allows the use of image overlay technique to be used in revealing, quantitatively, the change dynamics in each category of canopy cover. Building of this time series database of image mosaics for the Lang Lang Catchment required historical aerial photographs which were carefully chosen to cover the whole catchment. They were scanned from the aerial photo archives of Land Victoria at Laverton in Melbourne for the years 1947, 1967, 1975, 1985 and 1990. Melbourne Water sourced the coloured aerial orthomosaics for the years 2000 and 2004.

The time-series orthomosaics were made using the ERDAS-Imagine 8.6 Orthobase software module (Leica 2006). Ground Control Points (GCP's) were derived from field dGPS collection, the Victorian Spatial Data Infrastructure (VSDI) VicMap Roads and Property layers (VicMap 2006). A large part of the catchment constitutes a hilly terrain such that the 20mVicMap DEM layer could be called upon for some of the input data for the orthorectification process. All orthomosaics were registered to the MGAZone55 co-ordinate system. For this project a Root Mean Square Accuracy (RMSE error) of less than 3 was acceptable when triangulation was performed. Camera calibration reports were not available for years 1947 and 1965 and the methodology as derived by (Niwa 2004) was used. As there is lack of good quality ground control points covering the region in aerial photos for the year 1947 and 1965 due to lack of good quality road intersections in the region, the most recent orthomosaic of 2004 was used to perform the image-to-image rectification process for the year 1947 and 1965. All rectified images were clipped, colour balanced and mosaicked to the Lang Lang catchment boundary. The derived orthomosaics have different spatial resolutions which are given in Table 1. Figures 2 (a) & (b) show the 1947 and 2004 orthomosaics clipped to the catchment boundary.

The derived spatial database of orthomosaics had varying spatial resolution and spatial accuracies were acceptable at around +/- 10m to +/- 15m in relation to the VicMap vector layers of roads and property. The orthomosaics were brought into ArcGIS (ESRI, 2006) for visual interpretation and on-screen digitizing of the boundaries for the land cover classes. This method of interpretation made full utilisation of the analyst's experience in visual image interpretation and local geographic knowledge of the area. Attributes of texture, shape, size and patterns in the orthomosaics are the key elements for identification of the canopy cover. Even though this method involves a laborious process of digitizing and is a time consuming process for an area of approximately 492 kms^2, the key elements mentioned above cannot be used in automated digital change detection analysis because of the difficulty in extraction of these elements (Lu *et al.* 2004)

Table 1: Tabulation of the attributes for the derived orthomosaics and Canopy Cover

Dataset	***Spatial Resolution***	***Type***	***Status***	***Details***
1947 ortho-mosaic	0.73m	Raster	Derived	B/W Images
1967 ortho-mosaic	3.0m	Raster	Derived	B/W Images
1975 ortho-mosaic	2.0m	Raster	Derived	B/W Images
1985 ortho-mosaic	1.0m	Raster	Derived	B/W Images
1990 ortho-mosaic	0.67m	Raster	Derived	Coloured Image
2000 ortho-mosaic	0.77m	Raster	Derived	Coloured Image
2004 ortho-mosaic	0.35m	Raster	Derived	Coloured Image
Digitised Canopy Cover	1: 25000	Vector	Derived	Derived from time series orthomosaics

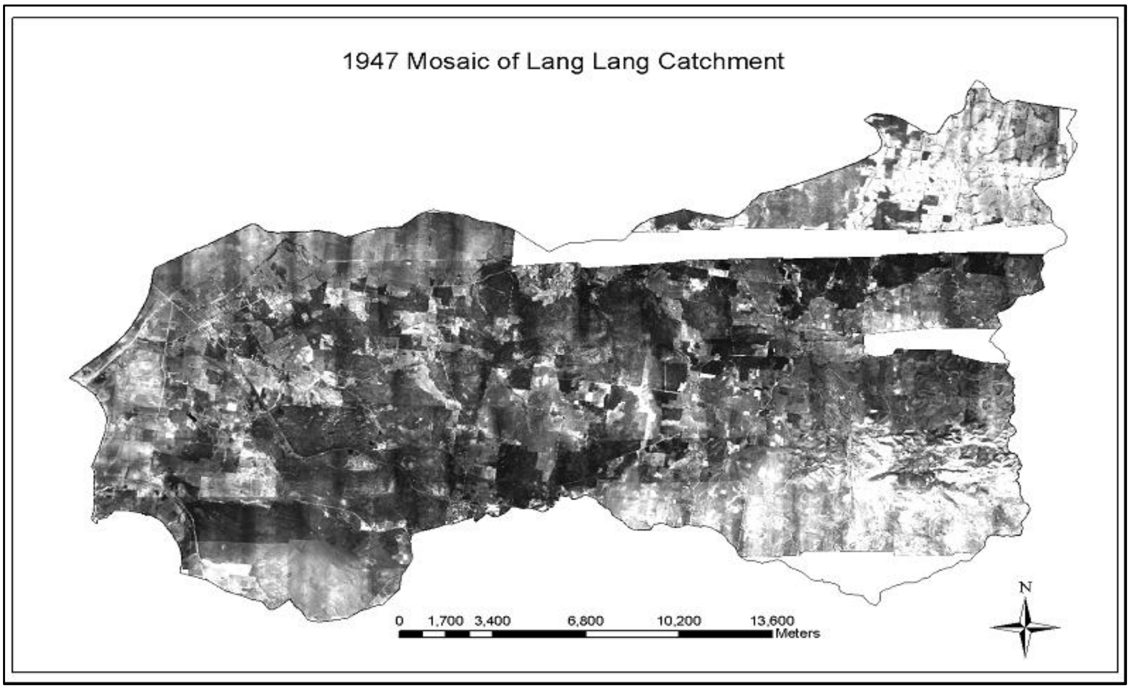

Figure 2(a) Derived orthomosaic from the1947 aerial photographs (Missing data in Land Victoria aerial photo archives for the southern & north-eastern parts of the catchment)

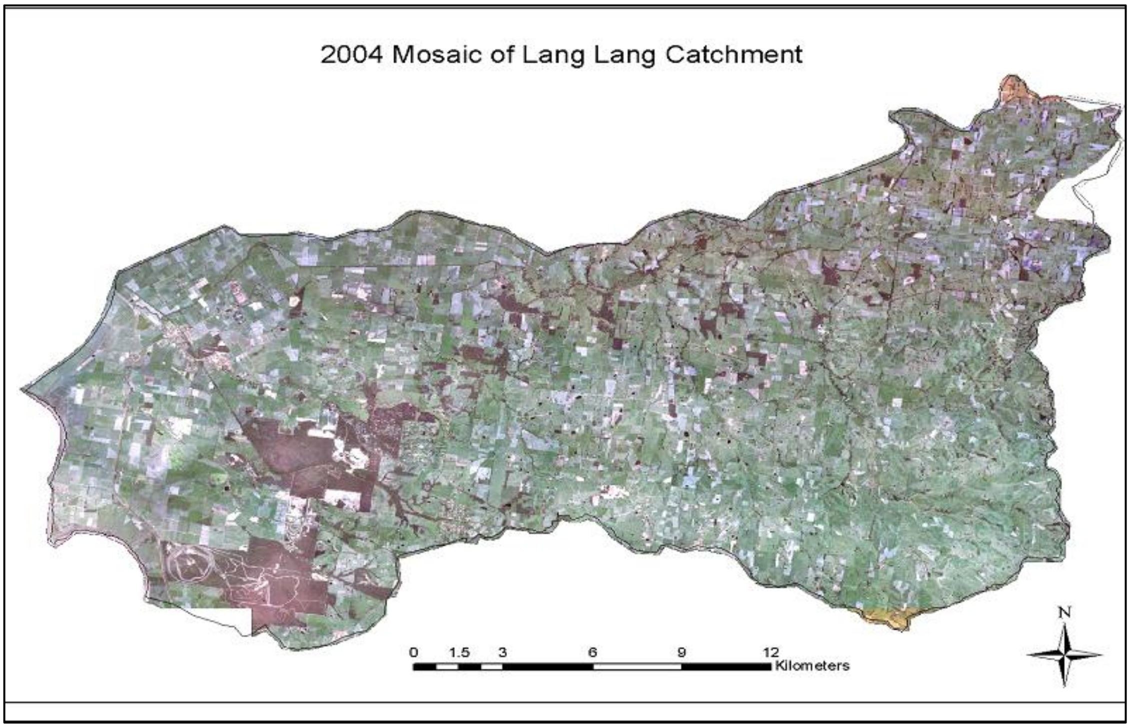

Figure 2(b) Orthomosaic for 2004 for Lang Lang Catchment (Source Melbourne Water)

The rules for visual image interpretation for digitising canopy cover were set as follows: Any woody vegetation (at least 5 m tall) that exists in the study area is classified as canopy cover; single trees are not accountable; grazing grasslands have been excluded; wind breaks have not been digitised as they do not play much of any significant direct part in the water balance, runoff filtering or habitat maintenance. The vegetation that exists inside the streams is also not taken into account, only the riparian vegetation is included. Copses (undergrowths) are accepted as canopy cover and have been digitised as they tend to have much impact on the water quality (Prosser *et al.* 1999). The canopy cover was classified into two types: Scattered and Continuous; 'Scattered' type included small and thin coverage of woody vegetation whereas 'Continuous' type included dense thick forests within the catchment. After digitisation of canopy cover polygons, area for each category was calculated using ArcGIS software program. The difference in the canopy cover, for both scattered and continuous categories for each orthomosaic was derived by subtracting vector overlays. The spatial accuracy of these digitised canopy polygons were assessed at several places in the catchment to be ranging from around +/-15m to +/-20m. The digitised polygons have the inherent spatial errors of the orthomosaics plus the human digitisation errors.

RESULTS AND DISCUSSION

The derived canopy cover change in both the Lower and Upper Lang Lang River catchments over the last 60 years (1947-2004) (Table 2 and Figure 3) clearly demonstrates a substantial reduction in the area of vegetation cover including native vegetation. The time period between 1947 and 1967 saw the most significant decrease in canopy cover.

With regard to interpreting the present results, is can be immediately noted that the loss of vegetation cover is more marked in some sub-catchments of the study area than in others (Figure 4). In the Pheasant Creek and Little Lang Lang river subcatchments (Figure 1(b)) a significant change in canopy cover loss can be observed. An interesting observation is also a non-significant improvement in total canopy cover took place between the periods 1990 to 2000 but again a slight decrease is noticed between the periods 2000 to 2004.

Table 2: Total Canopy of the Lang Lang Catchment from 1947–2004

Orthomosaic year	Lang Lang Catchment Area (492 km^2) Total Canopy Cover Area (km^2)	Percentage of Canopy Cover in the catchment
1947	160.10	32.54%
1967	59.85	12.17%
1975	47.98	9.76%
1985	39.33	7.99%
1990	40.27	8.19%
2000	44.31	9.00%
2004	41.89	8.52%

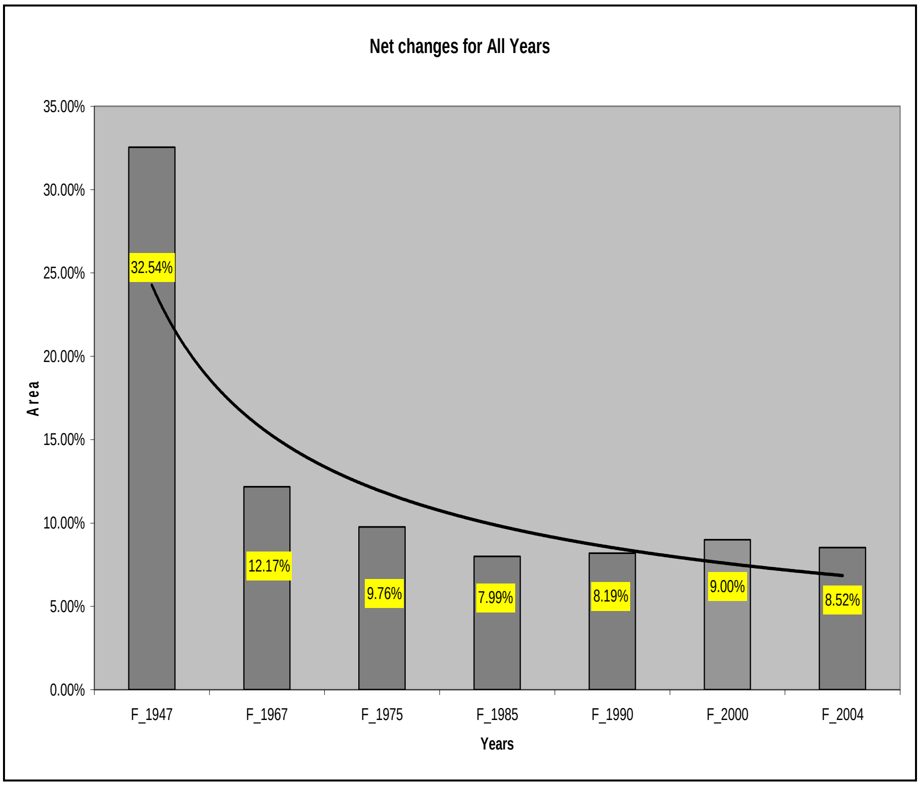

Figure 3: Graphical representation of the percentage change of total canopy cover in the catchment between 1947 and 2004.

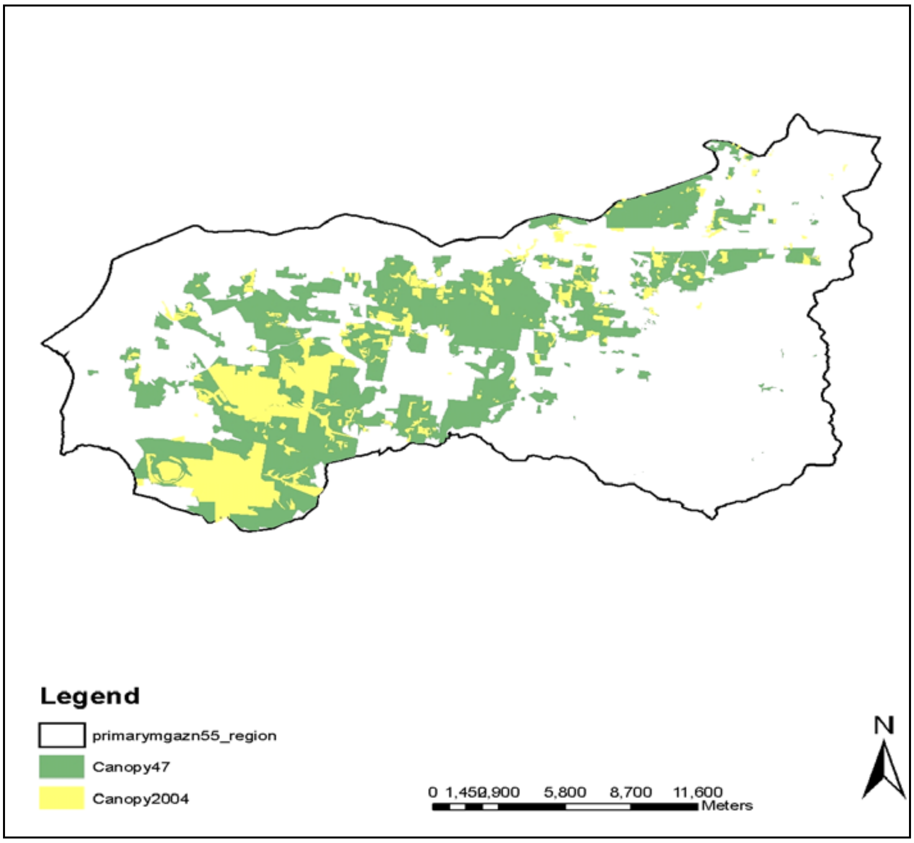

Figure 4: Spatial extent of canopy cover for the years 1947 and 2004.

The slight improvement in the canopy may be because of the revegetation plans actioned by the stakeholders like Melbourne Water, Port Phillip and Westernport Catchment management authority (PPWCMA 2006). Many other organisations like Greening Australia (2006), Landcare Victoria (2005) and EPA (2000) are concerned about the revegetation plans and that large amounts of money to revegetate the trees in this region have been spent, but the results have not been satisfactory. More research is needed to find out the likely cause of the hitherto poor results of such revegetation programs. The Canopy Cover has been classified into two types: Scattered and Continuous. Table 3 represents area of the existing canopy cover types and percentages for the years 1947 and 2004.

Table 3: Canopy cover area for Scattered and Continuous types in 1947 & 2004

Canopy Cover Type	Area in km^2	Percentage Cover
Continuous in 1947	64.99	13.22%
Scattered in 1947	95.09	19.33%
Continuous in 2004	29.17	5.93%
Scattered in 2004	12.71	2.59%

The decrease in area for scattered canopy cover was more than continuous cover for the period 1947 to 2004 and this trend was because of intense clearing of scattered canopy occurring for agricultural practices, particularly dairy farming in this period. Since 1967 the rate of decline in canopy cover is much less than for the period 1947-67. However, the catchment water quality has not improved since 1967 (Melbourne Water 2004). This constant decline in water quality may be attributed to intensification of dairy farming practices in the catchment and some future research work needs to be done to identify the most likely contributing factors. Particular attention should no doubt be paid to mapping dairy sheds and adjacent holding dams, as point-source pollution source and distributed hydrological modelling of grazing slopes, (weighted according to fertiliser application rates) for monitoring non-point source pollution.

The significant decline in canopy cover has promoted not only decline in water quality but also erosion and landslips. A limited assessment of water quality trends using data collected since 1990 from three sites on the lower Lang Lang River (Coleman and Pettigrove 2001) as well at twelve other sites was part of the water quality monitoring study. Elevated nutrient concentrations were thereby inferred as characteristic throughout streams draining grazed areas of the catchment. The possible dominant nutrient sources include fertilisers, dairy waste, sewage treatment plant discharges and suspended solids. Erosion control, riparian buffer strips, in-stream revegetation and fostering best-management practices on farms are practices which were recommended to reduce nutrient levels in streams. Such time series land-cover monitoring information derived from this study would be useful in scenario modelling during consensus building designed to engage the interests of land holders in adopting these recommendations.

The orthomosaics built for this study (1947, 1967, 1975, 1985, 1990, 2000 and 2004) do not offer snapshots at evenly timed intervals. From the results achieved it is documented spatially and proved that there is steady decline in the canopy cover of the Lang Lang catchment for the last 60 years (1947-2004). Water quality degradation would be predictable from such a history of canopy cover clearance, especially if, as is the case here, riparian vegetation is involved (Prosser *et. al* 1999)

CONCLUSIONS

This study has exemplified the use of historical time-series digital spatial database in documenting the total canopy cover changes of Lang Lang catchment between 1947 and 2004: a time during which concern for surface water quality maintenance and improvement has evolved (from a low base) to become reflected in public policy (EPA 2000, Melbourne Water 2004). As pointed in the Index of Stream Condition (Melbourne Water 2004) it is clear that ecosystem integrity in the Lang Lang catchment has been altered substantially. Accurate spatial mapping of the extent, nature and rate of vegetation clearance can provide a useful indicator of river health, nutrient loss and water quality in any catchment. As well as providing a direct indicator of the impact of agricultural development on native vegetation, vegetation clearance can also act as an indicator of general ecosystem disturbance, soil erosion, and thus show the pattern in potential for degradation in stream water quality. Studies such as this one can assist catchment decision-makers in assessing catchment vegetation resource condition (*vis-a-vis* the native vegetation replanting project records) and addressing the broader requirements of natural resource policy development and revegetation planning.

In response to these results, it is argued that time-series mapping of landcover patterns as part of digital spatial modelling for stakeholder consensus building can serve to bridge the policy-to-practice gap evident in the poor water quality data. By spatial data integration geographical variation (especially geology, terrain attributes and soils) in the catchment and extrapolation of findings according to the known interrelationships between land cover and water quality problems, the prime sites for canopy cover improvement and extension, with special reference to stream buffers, some of which are already being re-planted, can be identified.

The monitoring of the canopy-cover record will soon be routinely possible using high resolution satellite imagery in conjuction with aerial orthomoasics. If multi-spectral imagery is used, pixel classification trials for vegetation species mapping should be undertaken. The National Vegetation Plan (NVP) of the Port Philip and Western Port Catchment Management Authority PPWCMA (2006) has been implemented since 2004. All catchment managers in Victoria are responsible for pro-actively facilitating the restoration of native vegetation cover on both public and private land that is better re-vegetated for the sake of water quality improvement than kept in production. The detailed maps derived from such studies would also serve in the kind of data integration needed to allocate payments to land-holders for ecological services. Such a pilot trial of ecological services using time series spatial layers is being done in Victoria known as the EcoTender pilot project, where landholders in parts of northern Victoria were able to receive financial support to improve the environmental health of their catchment (DSE Conservation & Environment 2006).

Since 2004 in Victoria every Catchment Management Authority (CMA) has to reach an agreed re-vegetation targets, and report results to government. The time series aerial imagery used in this study exemplifies the utility of the historical aerial photography and of recently-available digital photogrammetric softwares designed to help in monitoring the results of canopy cover loss and revegetation. The results as quantified for over the last 60 years (1947-2004), have served to identify the need for native vegetation restoration, particularly riparian vegetation in aid of water quality improvement and conservation of vegetation associations especially in terms of constraining fragmentation.

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REFERENCES

Barson, M.M., Randall, L.A. and Bordas, V. 2000 Land Cover Change in Australia. Results of the collaborative Bureau of Rural Sciences- State agencies Project on Remote Sensing of Land Cover Change. *Bureau of Rural Sciences,* Canberra.

Barton, J. and Metzeling, L., 2004 The development of biological objectives for streams in a single catchment: a case study on the catchment of Western Port Bay, Victoria, Australia, *Environmental Monitoring and Assessment* 95, 239-256.

Coleman, R. and Pettigrove, V. 2001 The Health of the Lang Lang River Melbourne *Melbourne Water Technical Report.*

Department of Sustainability & Environment 2006 Native Vegetation - Incentives and Tradinghttp://www.dse.vic.gov.au/DSE/nrenlwm.nsf/LinkView/0BEDF7FB7A7EA6C9CA257126001338EE273EC4728399BE97CA25712B0004B22D. Accessed 6/11/06

EPA 2000 Protecting the Waters of Westernport and Catchment Melbourne, Policy Impact Assessment, *Environment Protection Authority of Victoria*.

ESRI 2006 *Environmental Systems Research Institute www.esri.com.* Accessed on: 2/07/06.

Greening Australia 2006 http://www.greeningaustralia.org.au/GA/VIC/ Accessed on 1/11/06

Hancock, G.J., Olley, J.M. and Wallbrink, P.J. 2001 Sediment transport and accumulation in Westernport. *CSIRO Land and Water Technical Report* 47/01

Johnson, A.K.L., Ebert, S.P., and Murray, A.E., 2000 Land Cover Change and its Environmental Significance in the Herbert River Catchment, North-east Queensland. *Australian Geographer,* Vol. 31, No. 1, pp. 75-86.

Landcare Victoria 2005 http://www.landcarevic.net.au/ Accessed on 5/11/05

Leica - ERDAS 2006 *Leica Geosystems http://www.leica-geosystems.com.* Accessed on: 01/11/06.

Lovett., S and Price. P, 2004 Fact Sheet 3: Improving Water Quality, *Land and Water Australia*. http://www.rivers.gov.au/publicat/factsheets.htm Accessed on 15/2/2006

Lu, D., Mausel, P., Brondizio, E., and Moran E., 2004 Change detection techniques. *International Journal of Remote Sensing*, Vol 25, No. 12, 2365-2407

Lunt, I. D. 1997 Tree Densities Last Century on the Lowland Gippsland Plain, Victoria. *Australian Geographical Studies,* Vol 35, (3), 342-348.

Mas. J. F. 1999 Monitoring land-cover changes: comparison of change detection techniques. *International Journal of Remote Sensing*, Vol.20, No. 1, 139-152

Melbourne Water 2004 Lang Lang River Health Strategy Melbourne Water http://www.melbournewater.com.au/content/rivers_and_creeks/our_rivers_and_creeks/lang.asp. Accessed on 18/05/2006

Melbourne Water 2006 Index of River Condition - Lang Lang River. *http://www.melbournewater.com.au/content/rivers_and_creeks/river_condition/index_of_river_condition.asp.* Accessed on: 12/01/2006.

Niwa, Y. 2004 Orthorectification without Camera Calibration *http://support.erdas.com/focus3/files/Aerial_photo.pdf.* Accessed on: 02/05/05.

PPWCMA 2006 The Regions Vegetation Resource *www.ppwcma.vic.gov.au.* Accessed on: 01/06/2006.

Prosser, I., Bunn, S., Mosisch, T., Ogden, R. and Karssies, L., 1999 The delivery of sediment and nutrient to streams In Riparian Land Management Technical Guidelines, Volume One: *Principles of sound management, Land and Water Australia*, Canberra. S.Lovett and P. Price (eds).

Shapiro, A. 1975 Western Port Bay Environmental Study, *Ministry for Conservation* Melbourne

VicMap 2006 VicMap Digital Spatial data products http://www.land.vic.gov.au/land/lcnlc2.nsf/alltitle/professions-spatial-vicmap+products. Accessed on 15/01/2006

Wallbrink, P. J., Hancock, G. J., Olley, J.M., Hughes, A., Prosser, I.P., Hunt, D., Rooney, G., Coleman, R and Stevenson J 2003 The Western Port sediment study, *CSIRO Consultancy repor*t.

Wallbrink, P. J and Hancock, G 2003 Western Port sediment study: Background and literature review. *Technical Report* 12/03 CSIRO Land and Water, Canberra

Woodgate, P., and Black, P., 1988 Forest Cover Changes in Victoria 1869-1987 *Department of Conservation Forests and Land,* Melbourne.

WPCCG 1984 A Case Study of the Upper Lang Lang River Catchment and a Proposal for a Full Scale Study of the Western Port Catchment Melbourne. *Western Port Catchment Co-ordinating Group*.