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The feasibility of extracting urban fringe land cover information from pixel-level fused TM and SPOT images

***Gang-Jun Liu*[1]*, Tony W Norton*[2]*, Christopher J Pettit*[3]**

Department of Geospatial Science, RMIT University, GPO Box 2476V Melbourne, VIC 3001, Australia

[1] Tel: +61 9925 53351, Fax: +61 9663 2517, Email: Gang-Jun.Liu@rmit.edu.au

[2] Tel: +61 9925 53279, Fax: +61 9663 2517, Email: Tony.Norton@rmit.edu.au

[3] Tel: +61 9925 3271, Fax: +61 9663 2517, Email: Chris.Pettit@rmit.edu.au

ABSTRACT

Given a set of remotely sensed images with different spatial and spectral resolutions, information preserving techniques of pixel-level image fusion can be used to generate a synthesised image that maximises the preservation of both the spectral and the spatial information available from the source images. These techniques have the potential for improving the quality of information on urban fringe land cover patterns, which are important to many applications. Here, we assess the feasibility of extracting useful land cover information in order to derive more accurate spatial information to inform sustainable land-use of the urban fringe. After a brief review of some existing pixel-level image fusion techniques, the results from applying a wavelet transform based pixel-level image fusion technique on subsets of TM and SPOT images over a portion of the eastern fringe of Melbourne are evaluated in terms of spectral fidality and spatial enhancement. We argue that the wavelet fusion technique demonstrated here may provide an efficient and cost-effective means to support enhanced land cover and land use assessment.

KEYWORDS: Urban-rural fringe land use, sustainable management, wavelet transformation, pixel-level image fusion, TM, SPOT

Introduction

Australia's cities and regional centres will continue to grow at more than twice the rate of smaller centres, producing enormous challenges for landuse zoning and environmental management including the protection of open space, natural environments and amenities at the urban fringe (Newton et al. 2002). The urban–rural fringe can be defined as the area extending from the edge of a city's contiguous urban development to the outer edge of the vehicular commuter belt (McKenzie 1996). The urban–rural fringe forms as businesses and individuals attempt to exploit the relative advantages afforded by access to both urban and rural settings (Davis et al. 1994). The rapid pace of change makes the urban–rural fringe a potential zone of competition and conflict (Troughton 1981). The urban-rural fringe is identified as one of the most significant points of land use conflict (Planning and Local Government Advisory Committee 1996). Management issues confronting the urban-rural fringe of Australian cities will continue and are likely to be intense (Cocks 1996).

Strategies to protect and enhance the quality of urban life must give greater emphasis to the sustainability of the urban-rural fringe. Fortunately, sophisticated technologies such as remote sensing systems are being developed to aid land-use planning and management and to support the sustainable use of natural resources in these situations (Li *et al*. 2001, Pettit 2003). Remote sensing systems can be used to efficiently characterise, monitor and manage land cover and land use, and human activities that may threaten sustainability. Complementary information about these regions can be obtained and/or derived from a variety of satellite and ground-based sources to help develop a comprehensive and dynamic understanding of land use and land cover change in the urban-rural fringe. Even so, issues remain with the integration of some technologies and data sources.

This paper assesses the feasibility of extracting useful urban fringe land cover information from pixel-level fused TM and SPOT satellite images in order to derive more accurate spatial information for the urban-rural fringe of Melbourne, Australia.

Study area

The urban-rural fringe of Melbourne (Figure 1) was chosen as a case study because this fringe includes a diverse range of land-uses where strategic planning and management is recognised as a major concern (DOI 2002).

Figure 1 **Metropolitan Melbourne and surrounds indicating the urban-rural fringe and study area (Map adapted from Department of Infrastructure, Victoria, 2001)**

Melbourne's population is expected to increase by over a 1 million by 2030, which translates to approximately 620,000 new households and much greater land-use pressures (DOI 2002). The Melbourne 2030 Plan (DOI 2002) provides a strategic vision for future urban growth based upon the concept of creating a liveable city, and addresses the long-term limits of urban development and where non-urban values and land uses should prevail in metropolitan Melbourne. Intrinsic to the implementation of this plan is the importance placed on the urban-rural fringe. The urban-rural fringe is the interface where urban related land uses such as residential, industrial and commercial development meet rural based activities such as agriculture and grazing. It is important that the urban–rural fringe areas be readily identifiable and mapped with a high degree of spatial precision and attribute accuracy.

Datasets

Dry season Landsat 7 ETM+ multispectral image data (06 March 2001) and SPOT panchromatic image data (03 February 2001) for the Dandenong Ranges were used. Both data sets were geo-referenced (to GDA94 _MGA55) and orthorectified with the 20 m resolution Vicmap Digital Elevation Model (Liu, 2001). Based on previous findings (Li *et al.* 2001, Liu 1996), TM bands 3, 4 and 5 were used as a composite in this study. The panchromatic SPOT data had a 10 m resolution and the multispectral TM data a 30 m resolution (Figure 2).

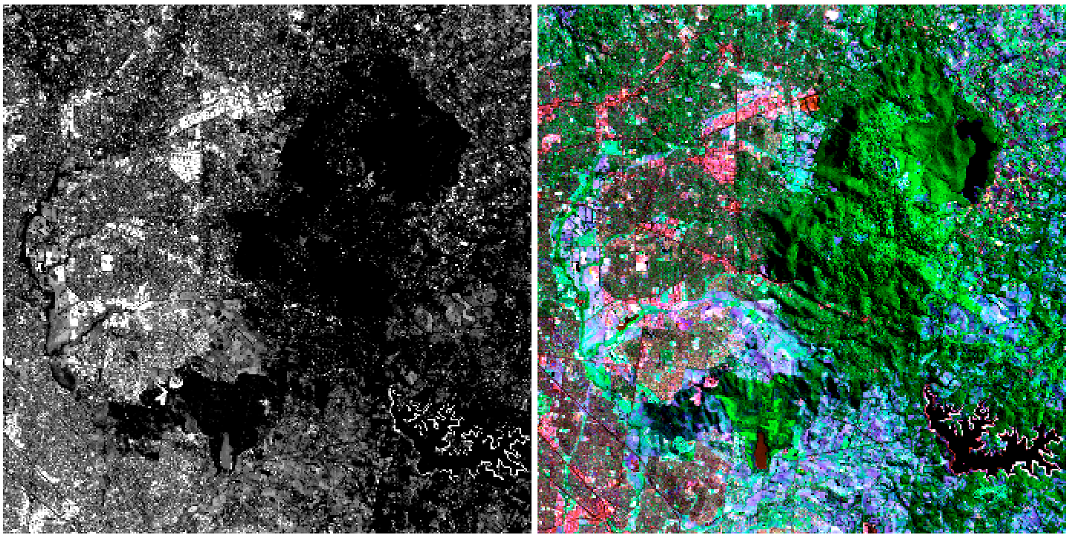


Figure 2 **Panchromatic SPOT data (left, displayed as gray scale image), and multispectral TM data (right, bands 3, 4 and 5 displayed as RGB composite image), used for the Melbourne urban-rural fringe study.**

Experiment design

Our general conceptual framework for deploying an integrated approach to spatial data analysis for the study of urban-rural fringe sustainability issues is illustrated in Figure 3. Key inputs to this framework include details of the spatial information requirements of stakeholders and decision makers and access to primary data sets maintained by government authorities. Integration of remotely sensed data sets is expanded here given the emphasis of this paper. Improved image analysis methods are required to more reliably evaluate land cover and land use changes.

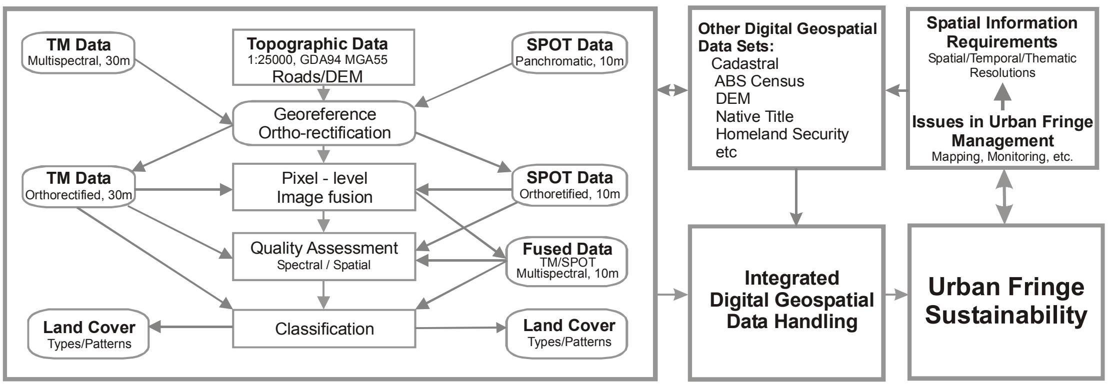


Figure 3 **Conceptual framework for the integration of spatial data to evaluate and monitor urban-fringe sustainability**

Land cover and land use data may be sourced from several satellites to inform the management of the urban-rural fringe. The data may be recorded by different sensors, by the same sensor scanning the same scene at different dates, by the same sensor operating in different spectral bands, and/or by the same sensor located on platforms orbiting or flying at different heights (Elachi 1987). For certain applications, the information available from individual sensors may be incomplete, inconsistent, or imprecise, and it is desirable to combine complementary information from multiple image sources for better understanding of the observed site (Clements *et al*. 1993, Varshney 1997, Hall and Llinas 1997). Image fusion provides a potential means to integrate data from disparate sources. Image fusion can take place at three different levels; vis. Pixel-level fusion works directly on the pixels obtained at the sensors' outputs; feature-level fusion works on image features extracted from the source images; and decision-level fusion works at an even higher level and merges the interpretations of different images obtained after image understanding (Pohl, 1998).

Many pixel-level image fusion methods have been proposed, and commonly used simple procedures to perform image fusion include intensity-hue-saturation (IHS) transform (Carper *et al*. 1990) and principal component analysis (PCA) (Chavez *et al*. 1991). The intensity-hue-saturation (IHS) method transforms the three multispectral bands of a low-resolution image from RGB colour space to the IHS colour space. Fusion then proceeds by replacing image intensity with the panchromatic high-resolution image information. The fused image is then obtained by performing an inverse transformation from IHS back to the original RGB space. The principal component analysis (PCA) method treats multispectral bands as correlated multivariate data, transforms them into uncorrelated variables as linear combinations of the original variables, then replaces the first principal component with the panchromatic high-resolution image information, and the fused image is finally obtained by inverting back to the original colour space (Liu 1996). The simple procedures does not preserve the detailed surface structures in the input images to be fused, and therefore, techniques that integrate the •ne details of the input data into the fused image are preferred (G. Simone et al. 2002). More complicated pixel level image fusion approaches that preserve the detailed surface structures in the input images to be fused include the discrete wavelet transform (DWT) (Mallet 1989, Li *et al*. 1995, Yockey 1995, Zhou *et al.* 1998, Nunez *et al*. 1999), constructed on the basis of the Daubechies wavelet family (Daubechies 1988, Cohen *et al*. 1992).

In the following sections, we demonstrate that, to a certain degree, the image fused from the lower spatial resolution multispectral TM image data and the higher spatial resolution panchromatic SPOT image data, using a wavelet transform method, does preserve some of the spatial details in the panchromatic SPOT data and exhibits little distortion in the spectral details of the TM data. The potential benefits of the fused images, especially when combined with other available digital geospatial data sets such as cadastral and digital elevation models, in supporting assessments of the sustainability of urban-rural fringes, will also be discussed.

Results

The fused image for the Melbourne case study region, as depicted in Figure 4, can be used to demonstrates that the wavelet fusion method has the potential to enhance spatial details and at the same time minimise spectral distortion. The ability of the wavelet fusion method in minimising spectral distortions can be illustrated with paired bi-spectral band scatter plots, as depicted in Figure 5. The almost identical scattering patterns between the paired corresponding scatterplots (ie. between 5a and 5b, between 5c and 5d, and between 5e and 5f) suggest that little spectral distortion has been introduced into the fused image. The component bands used for generating the respective pixel-value scatterplots are:

- 5a: TM image band 3 (x-axis) versus TM image band 4 (y-axis);
- 5b: fused image band 3 (x-axis) versus fused band 4 (y-axis);
- 5c: TM image band 3 (x-axis) versus TM image band 5 (y-axis);
- 5d: fused image band 3 (x-axis) versus fused image band 5 (y-axis);
- 5e: TM image band 4 (x-axis) versus TM image band 5 (y-axis); and
- 5f: fused image band 4 (x-axis) versus fused image band 5 (y-axis).

The amount of spatial details from the SPOT panchromatic image that has been incorporated into the fused image can be demonstrated by comparing the three edge images, as depicted in Figure 6, based upon the understanding that the spatial details of an digital image can be extracted by passing an edge enhancement filter over the original image. The following 3 by 3 high filter has been used as the edge enhancement filter in this study:

-0.7 -1.0 -0.7
-1.0 6.8 -1.0
-0.7 -1.0 -0.7

The SPOT edge image (Figure 6a) is generated by passing the high filter over the original SPOT panchromatic image. The fused edge image (Figure 6b) is generated by adding the three individual edge images that were derived from the three fused band, in the same manner as the SPOT edge image; and the TM edge image (Figure 6c) is generated in the same manner as the fused edge image, but from the three original TM bands. It can be seen that much spatial detail from the SPOT panchromatic image that is represented at the spatial resolution conditioned by the TM image data has been incorporated into the fused multispectral image data.

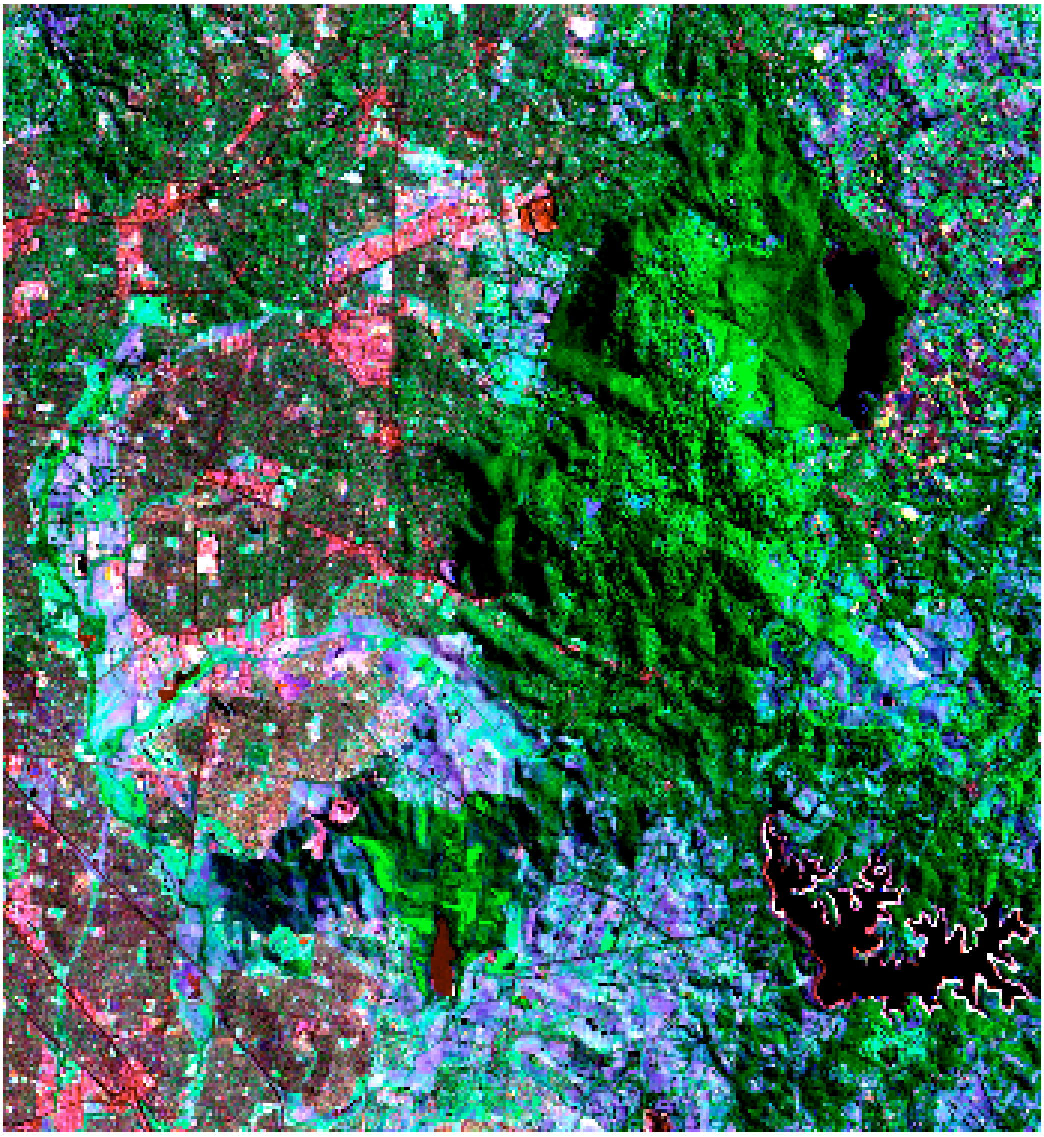
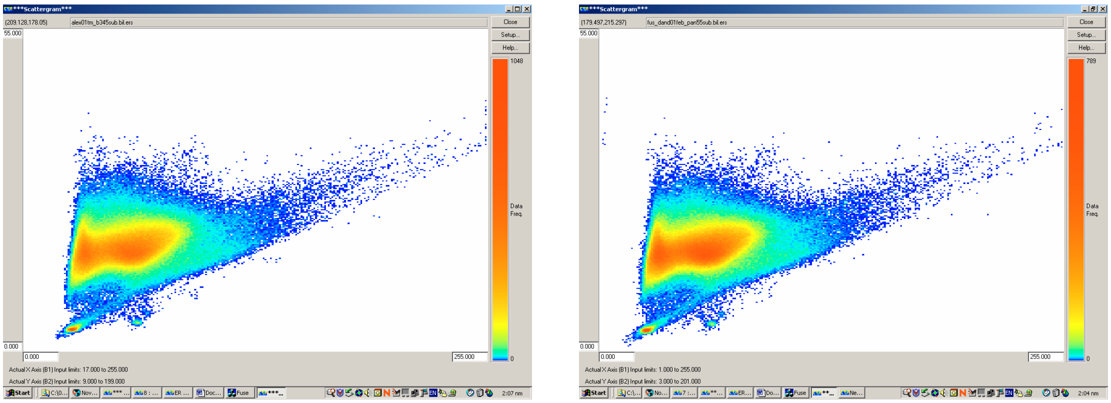
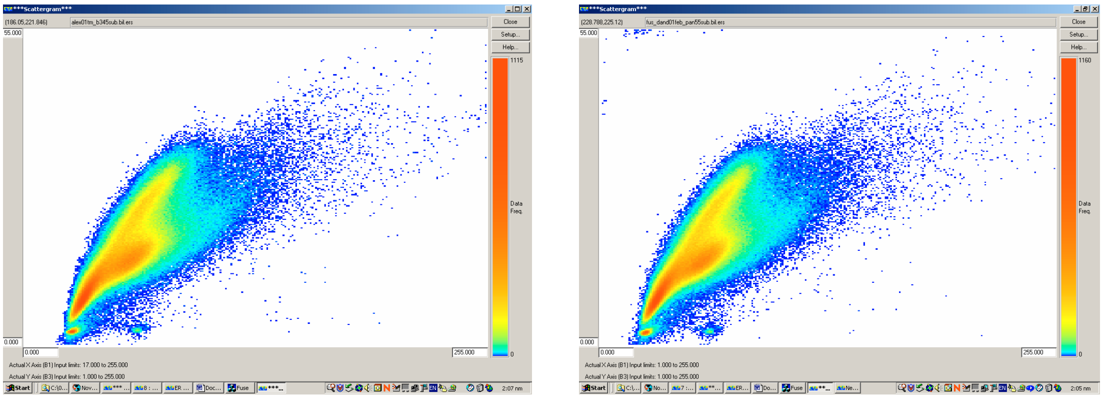


Figure 4 The fused image for the case study area in eastern Melbourne, displayed as a RGB composite image

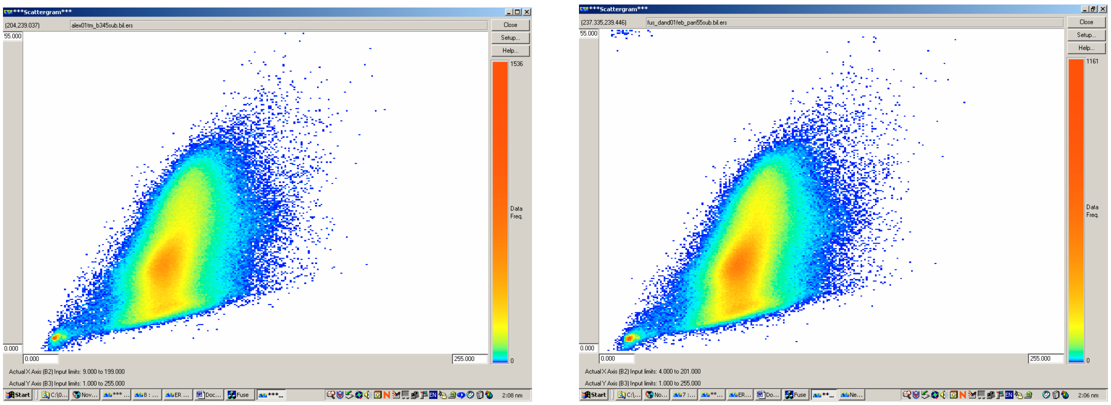
TM Image **Fused SPOT/TM Image**



5a. and 5b.

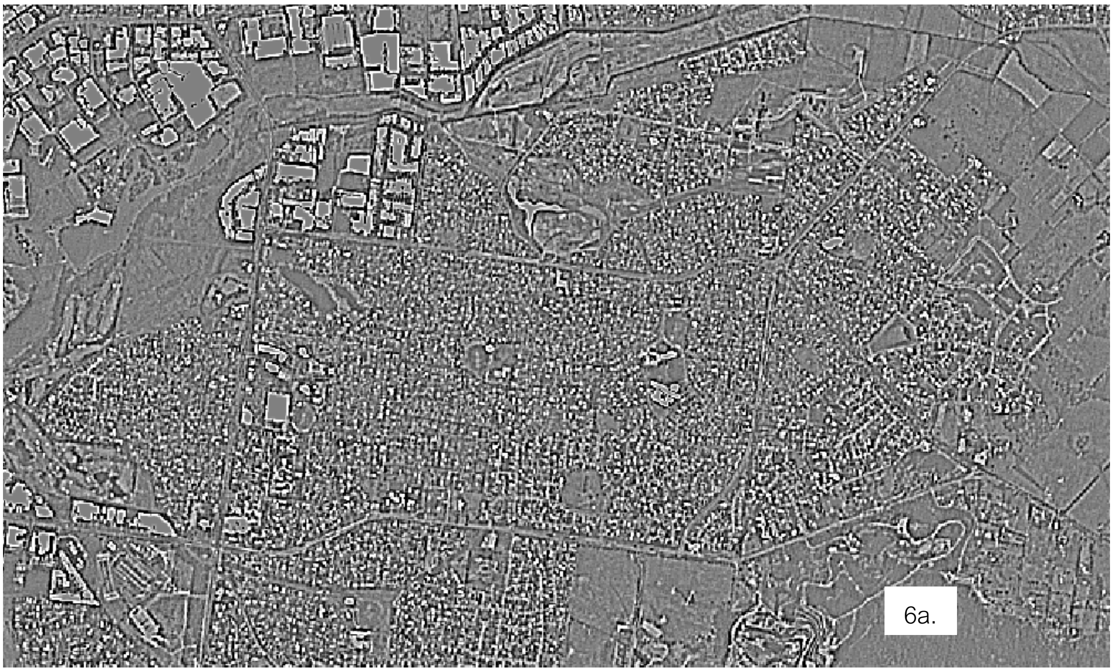


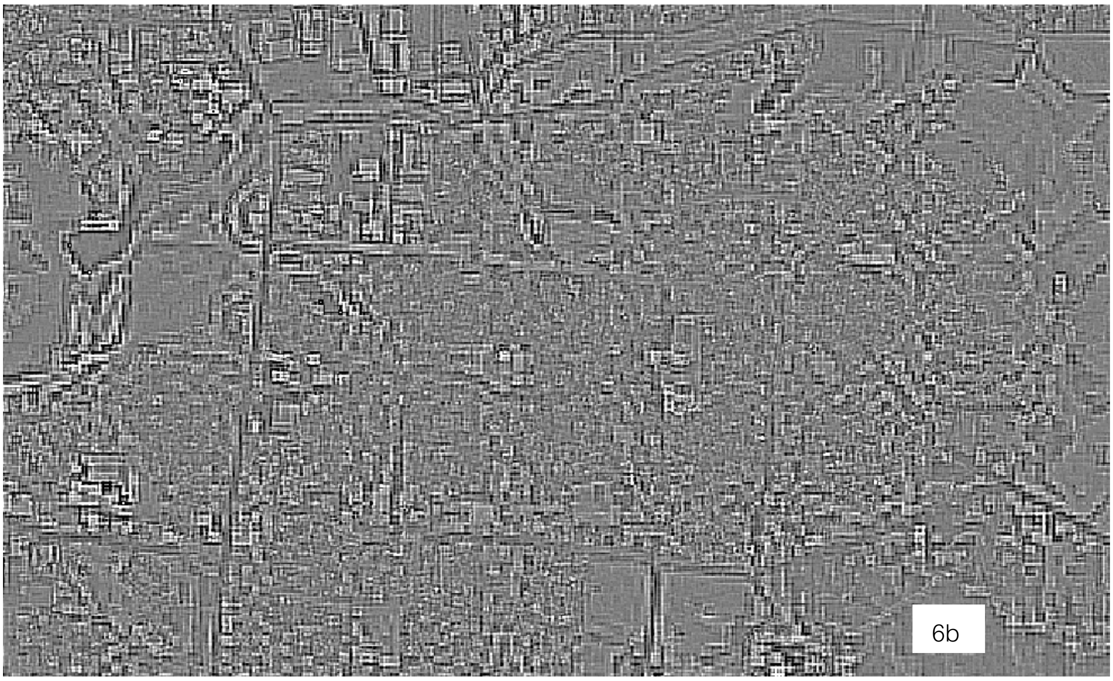
5c. and 5d.



5e. and 5f.

Figure 5 **The almost identical scattering patterns between the corresponding scatterplots suggest that little spectral distortion has been introduced into the fused image**


6a.


6b

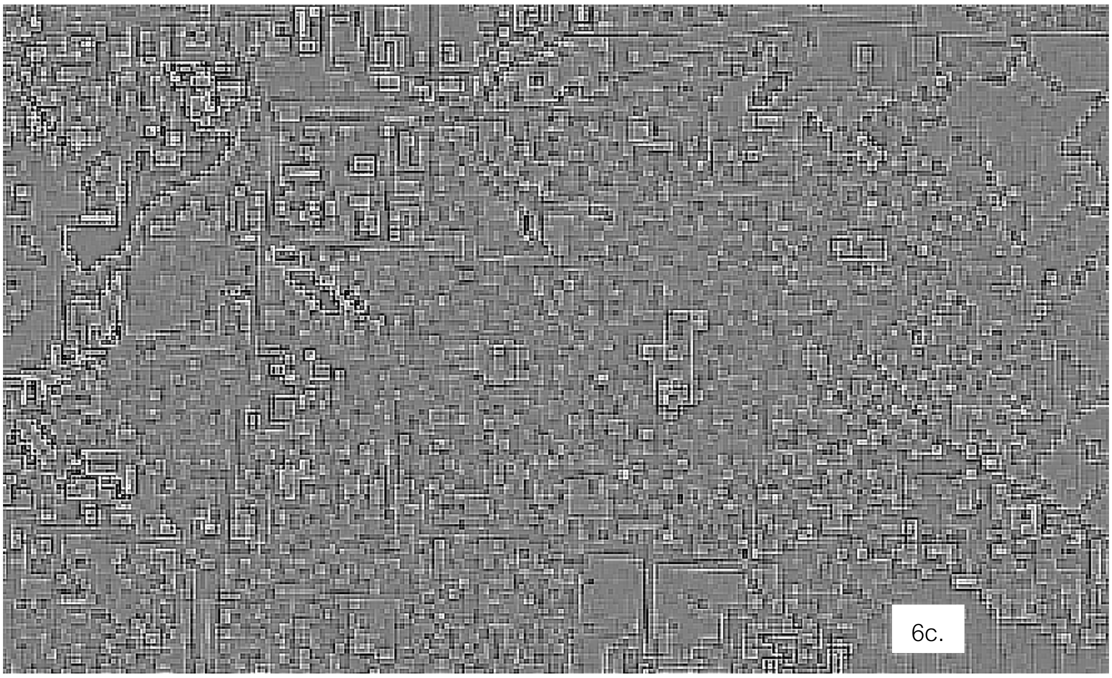


Figure 6 **The SPOT edge image (6a), fused edge image (6b) and TM edge image (6c). Certain amount of spatial detail from the SPOT Panchromatic image that has been incorporated into the fused image.**

Discussion

Accurate and timely geospatial information are important to a number of common planning tasks including managing and monitoring urban activities, site selection, impact assessment, and strategic/scenario planning (Pullar and McDonald 1999, Pettit and Pullar 2001, Klosterman 2001, Landis 2001, Pettit 2003).

The wavelet transform based image fusion, as demonstrated above, has the potential to maximises the preservation of both the spectral and the spatial information available from the source images. Further investigations are undertaken at the moment to evaluate its utility in enhance land cover information extraction. We attempt to derive accurate and timely spatial information from the fused image data in an efficient and cost effective manner to support a range of urban and regional planning tasks.

With the support of other digital spatial data sets such as cadastra (Figure 7) and digital elevation model (Figure 8), the wavelet based pixel-level image fusion techniques may be useful in evaluating and monitoring land use patterns in the urban fringe zones, especially for the growth areas identified in the Melbourne 2030 plan, which include the municipalities of Wyndham, Hume, Whittlesea, Casey and Cardinia.

Figure 7 **Overlay of land parcel data with Wavelet fusion technique data near the Dandenong Ranges. The green box indicates the areal extent shown in Figure 8.**

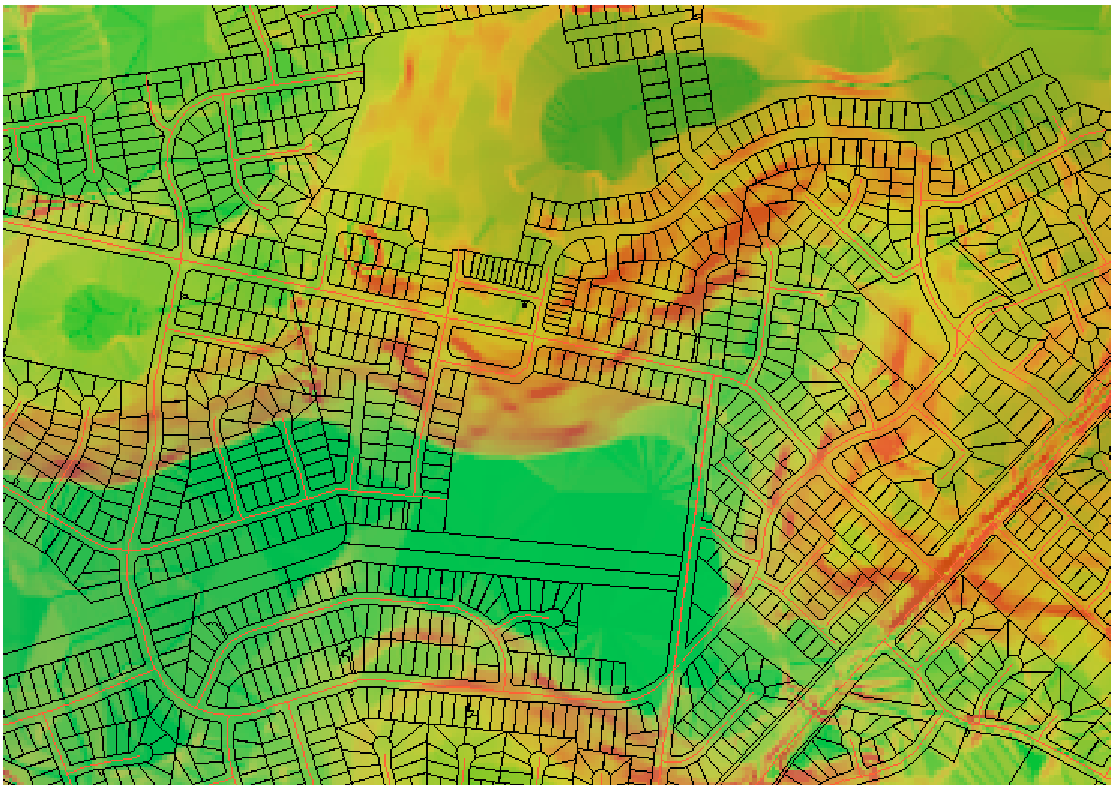


Figure 8 **Overlay of land parcel and road network data sets with a fine resolution digital elevation model**

In Victoria, a comprehensive state-wide high resolution digital spatial data sets, including TM and SPOT images, have been accumulated over the years. It is envisaged that by undertaking the wavelet based fusion of Landsat and SPOT imagery, more accurate spatial datasets including land use data can be produced and updated more cost effectively. The 10 m resolution fused image data can be used as a cost effective means for supporting activities in the mapping, measuring, monitoring and modelling of the urban growth process.

Acknowledgments

We are grateful to John White of Land Victoria for helping supply the orthorectified TM and SPOT images, and May Treloar and Renado Schnitzer of Geospatial Science @ RMIT for assistance with the presentation of the paper.

References

Australian Bureau of Statistics, 2003. Census data for Australia. AGPS, Canberra.

BRS. 2002. Land Use Mapping at Catchment Scale: Principles, Procedures and Definitions. Canberra, Bureau of Rural Science. Edition 2 February 2002.

Bureau of Rural Sciences. 2002. Land Use Mapping at Catchment Scale: Principles, Procedures and Definitions. Canberra, Bureau of Rural Science. Edition 2 February 2002.

Carper, W.J. et al., 1990. The use of Intensity-Hue-Saturation transformation for merging SPOT panchromatic and multispectral image data, Photogrammetric Engineering and Remote Sensing 56 (4) () 459–467.

Chavez, P.S. et al., 1991. Comparison of three different methods to merge multiresolution and multispectral data: Landsat TM and SPOT panchromatic, Photogrammetric Engineering and Remote Sensing 57 (3) : 295–303.

Clement, V *et al*. 1993. Interpretation of remotely sensed images in a context of multisensor fusion using a multispecialist architecture, IEEE Trans. Geosci. Remote Sensing 31 (4).

Cocks, D. 1996. People Policy: Australia's population choices. University of New South wales press, Sydney.

Cohen, A.I. *et al*. 1992. Biorthogonal bases of compactly supported wavelets, Communications on Pure and Applied Mathematics 45 (5) (1992) 485–560.

Davis, J., A. Nelson, and K. Dueker 1994 The New 'Burbs: The Exurbs and Their Implications for Planning Policy. Journal of the American Planning Association 60(1):45–59.

DOI. 2002. Melbourne 2030: Planning for Sustainable Growth. Melbourne, Victorian Department of Infrastructure. October 2002.

DOI. 2002. Melbourne 2030: Planning for Sustainable Growth. Melbourne, Victorian Department of Infrastructure. October 2002.

Elachi, C. 1987. Introduction to the physics and techniques of remote sensing, in: J.A. Kong (Series Ed.), Wiley Series in Remote Sensing, 1987.

Hall, D.L. and J. Llinas, 1997. An introduction to multisensor data fusion, Proc. IEEE 85 (1):6–23.

Klosterman, R. E. 2001. The What if? Planning Support System. In Planning Support Systems. (ed.) Brail, R. K. & Klosterman, R. E. Redlands, California, ESRI Press: 263–284.

Klosterman, R. E. 2001. The What if? Planning Support System. In Planning Support Systems. (ed.) Brail, R. K. & Klosterman, R. E. Redlands, California, ESRI Press: 263–284.

Lamb, R. 1983 The Extent and Form of Exurban Sprawl. Growth Change 14(1):40–47.

Landis, J. 2001. CUF, CUFII, and CURBA: A family of spatially explicit urban growth and land-use policy simulation models. In Planning Support Systems: Integrating geographic information systems, models, and visualisation tools. (ed.) Brail, R. K. & Klosterman, R. E. Redlands, California, ESRI Press: 157–200.

Landis, J. 2001. CUF, CUFII, and CURBA: A family of spatially explicit urban growth and land-use policy simulation models. In Planning Support Systems: Integrating geographic information systems, models, and visualisation tools. (ed.) Brail, R. K. & Klosterman, R. E. Redlands, California, ESRI Press: 157–200.

Li, H. et al., 1995. Multisensor image fusion using the wavelet transform, Graphical Models and Image Processing 57 (3) : 235–245.

Li, X., J.A. Peterson, G-J Liu, and L. Qian 2001. Assessing Regional Sustainability: The Case of Land Use and Land Cover Change in the Middle Yiluo Catchment of the Yellow River Basin, China. Applied Geography 21(1):87–106.

Liu, G-J. 2001. Vicmap Digital Elevation Model: Technical Specifications and Product Description. http://www.giconnections.vic.gov.au/menupage/products/vicmap_elevation_11.pdf.

Liu, G-J. 1996. Land cover mapping in a salinised dryland farming area in southeastern Australia using Landsat TM data. Geocarto International, 11(4):47–59.

McKenzie, F. 1996 Beyond the Suburbs: Population Change in the Major Exurban Regions of Australia. Canberra: Department of Immigration and Multicultural Affairs.

McKenzie, F. 1997 Growth Management or Encouragement? A Critical Review of Land Use Policies Affecting Australia's Major Exurban Regions. Urban Policy and Research 15(2):83–101.

Nelson, A. 1992 Characterizing Exurbia. Journal of Planning Literature 6:350–368.

Newton, P.W. et al., 2001. Human Settlements Theme Report. Australia State of the Environment Report 2001 (Theme Report) AGPS, Canberra.

Nunez, J. et al., 1999. Multiresolution-based image fusion with additive wavelet decomposition, IEEE Trans. Geosci. Remote Sensing 37 (3) : 1204–1211.

Pettit, C. & Pullar, D. 2001. Introduction to Urban and Regional Planning using ArcView 3.x. cited in: http://campus.esri.com/.

Pettit, C. 2003. Formulating a Sustainable Development Land Use Strategy for Hervey Bay 2021.In The 8th International Conference on Computers in Urban Planning and Urban Management, 27–29 May, Sendai, Japan, CUPUM.

Pettit, C. 2003. Formulating a Sustainable Development Land Use Strategy for Hervey Bay 2021.In The 8th International Conference on Computers in Urban Planning and Urban Management, 27–29 May, Sendai, Japan, CUPUM.

Pettit, C. & Pullar, D. 2001. Introduction to Urban and Regional Planning using ArcView 3.x. cited in: http://campus.esri.com/.

Planning and Local Government Advisory Committee. 1996. Review of Issues on the Urban Fringe. Melbourne, Department of Planning and Local Government. Final Report November 1996.

Planning and Local Government Advisory Committee. 1996. Review of Issues on the Urban Fringe. Melbourne, Department of Planning and Local Government. Final Report November 1996.

Pohl, C. 1998. Multisensor image fusion in remote sensing: concepts, methods and applications, International Journal of Remote Sensing 19 (5) :823–854.

Pullar, D. & McDonald, G. 1999. Geographical Information Systems: A tool for planning. Australian Planner 36: 216–222.

Pullar, D. & McDonald, G. 1999. Geographical Information Systems: A tool for planning. Australian Planner 36: 216–222.

Staley, S. R. & Mildner, C. S. 1999. Urban-Growth Boundaries and Housing Affordability: Lessons from Portland. Reason Public Policy Institute October, 1999: http://www.rppi.org/urban/pb11.html.

Troughton, M. 1981 The Rural–Urban Fringe: A Challenge to Resource Management. *In* The Rural–Urban Fringe: Canadian Perspectives, K. Beesley and L. Russwarm, eds., pp. 218–243. Toronto: York University Geographical Monographs No. 10.

USA Bureau of the Census, 2003. International Database. USA government, Washington DC., USA.

Varshney, P.K. 1997. Multisensor data fusion, Electron. Commun. Eng. J. 245–263.

Yockey, D.A. 1995. Image merging and data fusion by means of the discrete two-dimensional wavelet transform, Journal of Optical Society of America A 12 (9) () 1834–1841.

Zhou, J. et al., 1998. A wavelet transform method to merge Landsat TM and SPOT panchromatic data, International Journal of Remote Sensing 19 (4) : 743–757.