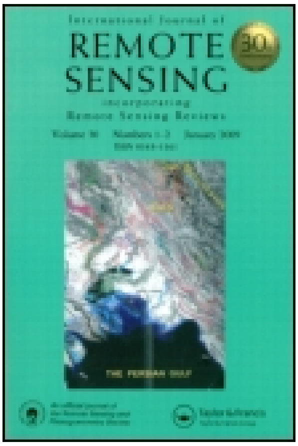


International Journal of Remote Sensing

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tres20

# Sustainable urbanization

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Version of record first published: 02 Oct 2012.

To cite this article: Janet E. Nichol, Bruce King & Xiaoli Ding (2013): Sustainable urbanization, International Journal of Remote Sensing, 34:3, 755-758

To link to this article: http://dx.doi.org/10.1080/01431161.2013.721284

*International Journal of Remote Sensing*
Vol. 34, No. 3, 10 February 2013, 755–758

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# GUEST EDITORIAL

## Sustainable urbanization

Although the science and technology of remote sensing as applied to observation and monitoring of the Earth's surface is quite mature, application areas such as urban studies are only beginning to exploit the recent advances in sensor spatial and spectral resolutions. To traditional automated pixel classifiers, the combination of increased spatial detail and spectral complexity within land-use and land-cover (LULC) types is often found to be more prominent than the difference between types, the result being less reliable classification than with imagery from the older lower resolution sensors. This has constituted a major setback in the application of remote sensing to urban areas at a time when worldwide urban growth is proceeding at increasingly faster rates which, in turn, creates increasingly serious environmental problems that require observation and monitoring. However, the perceived barriers to the application of automated classification technology have at the same time created a wealth of research opportunities. Now, recently developed image and data processing techniques, which exploit jointly the spatial and spectral properties of the new twenty-first century sensors and can be applied at multiple scales and in different contexts, are showing great potential to deal with the complexity of urban imagery.

This special issue on sustainable urbanization results from 11 articles on urban remote-sensing themes presented at the First International Conference on Sustainable Urbanisation held by the Faculty of Construction and Environment of the Hong Kong Polytechnic University in December 2010. In addition to these articles, three others have been selected from the wider community to complete the issue. The exciting developments in urban remote sensing referred to above are well illustrated in this issue of the journal, with articles at the cutting edge of urban LULC mapping, air and climate monitoring, building modelling, and environmental analysis. The range of remote-sensing systems used in the studies varies from airborne multispectral cameras (Li and Shao 2013; Hu and Wang 2013), airborne multispectral scanners (Thomas, Briottet, and Santer 2013), satellite-borne optical (Du et al. 2013; Kiran and Joshi 2013; Liang, Weng, and Tong 2013; Wong, Nichol, and Lee 2013) and thermal (Holderness et al. 2013; Wong and Nichol 2013) scanners, InSAR (Leighton et al. 2013), airborne Lidar (Hu and Wang 2013; Teo and Shih 2013), doppler Lidar (Chan and Li 2013), and sunphotometers (Wong et al. 2013), and some of the studies have used multiple sensors (Tack et al. 2013) and sensor types (Hu and Wang 2013).

Recent advances in the automated classification of high-resolution imagery are typified by Bakos et al. (2013). The article has two main themes; it first presents a useful classification of different methodologies (pixel-based, context-aware, and shape-based procedures) that may be applied to the analysis of high-resolution spectral and spatial data for automated urban land-use mapping. Secondly, it shows that the sequential application of all three procedures, when applied to a high-resolution hyperspectral image, can yield a classification accuracy of over 90% in a complex urban study area. The study also indicates that using such a complex approach is not useful for simple classes of land cover when compared to the use of a simple per-pixel classifier, and that high resolution data are necessary for the

ISSN 0143-1161 print/ISSN 1366-5901 online

http://dx.doi.org/10.1080/01431161.2013.721284
http://www.tandfonline.com

more complex approach including context and shape to function effectively. This is borne out by the study by Li and Shao (2013) of urban vegetation, where over 90% accuracy was obtained in identifying eight classes of urban vegetation with four-band digital aerial photography as the only data source by employing an object-based approach, with four different segmentation methods and a decision tree classifier.

In a complex urban environment, certain LULC classes are desirable to be known from a planning perspective but may be very difficult to accurately identify. Previous studies have shown that office, industrial, civic, and transportation classes fall into this group. Hu and Wang (2013) undertook an experiment that employs a multi-sensor approach to identify those classes and achieved an overall accuracy of 62% by combining lidar for building height and fine resolution colour aerial photography in a geographical information system (GIS) with building data, and applying a decision tree classifier. Their results show that the most difficult class to identify accurately was civic land uses and highlights the need for more work in applying remote-sensing technologies to the identification of increasingly specific land-use categories. An investigation of methods of fractal analysis of images of urban areas by Liang, Weng, and Tong (2013) exemplifies the less tangible type of enquiry that drives research in any discipline. They found that fractal dimensions (FDs) vary according to the image resolution, waveband, and the computational algorithm used, and recommend the use of the red or near-infrared (NIR) bands and the triangular prism method for computing FDs for discriminating the spatial complexity of LULC types. Sandhya Kiran and Joshi's (2013) application of spatial analysis to image-derived land-cover classes also addresses the spatial complexity of urban LULC in applying a range of spatial measurement indices to classified images. In analysing time-series land cover, they are able to compute the land consumption rate, which they recommend as a tool for sustainable urban planning.

While recent research in urban applications has focussed on algorithm development for the new fine resolution satellite sensors such as IKONOS, QuickBird, and WorldView, medium- and low-resolution sensors continue to have relevance, especially in environmental applications, as demonstrated by six other articles in this issue. Du et al. (2013) describe the use of Landsat Enhanced Thematic Mapper Plus (ETM+) images as the main data source to derive indicators of urban ecological security in Xuzhou City, China, where the transition from traditional coal mining to a modern economy threatens sustainable development. Holderness et al. (2013) use the 30 year archive of Advanced Very High Resolution Radiometer (AVHRR) thermal imagery now available to quantify the spatial temperature dynamics of London related to heat waves. They find that the use of individual images cannot represent either typical or extreme climatic conditions or trends due to local and diurnal effects, whereas monthly or seasonal averages provide a much better basis for inter-annual comparisons. The article also addresses some yet unresolved issues in the use of Earth observation for urban climatic analysis, such as the relationship between image estimates of surface temperatures and screen-level air temperatures. The comparison of satellite-derived surface temperatures with another parameter of urban climate, ventilation, is the subject of Wong and Nichol's (2013) article. They use the GIS metric frontal area index to depict ventilation corridors across the urbanized Kowloon Peninsula of Hong Kong and compare these with resolution-enhanced Advanced Spaceborne Thermal Emission and Reflection (ASTER) thermal images of heat island intensity, both parameters being generated at spatial resolutions ranging from 40 to 400 m. The enquiry suggests that in order to mitigate heat islands, ventilation corridors should be in the order of 100 m wide.

Since air pollution is now recognized almost universally as the most serious environmental problem faced by modern cities, it is encouraging to those in the discipline that remote sensing is increasingly able to address these concerns through retrieval of air quality parameters from satellite sensors with high temporal resolution. Whereas most previous studies have presented new or improved algorithms for retrieval of aerosol optical thickness (AOT), Wong et al. (2013) compare different sensors for retrieval of AOT over bright and heterogeneous urban surfaces. These sensors include the Moderate Resolution Imaging Spectrometer (MODIS), the Multi-Angle Imaging Spectrometer (MISR), the Ozone Monitoring Instrument (OMI), and the Cloud Aerosol Lidar (Calipso). Good correlations with multi-locational sunphotometers in Hong Kong suggest the robustness of AOT products over different surface types including bright urban surfaces and their use for daily air quality monitoring. An exciting development in the derivation of AOT at high spatial resolution for detailed urban air quality assessment is presented by Thomas, Briottet, and Santer (2013), who employ the observation of shadows for aerosol inversion over 3D scenes (OSIS). The method is based on the observation of shadow/sun transitions on airborne optical images of high-rise urban scenes. With the use of an appropriate aerosol model, accuracy in AOT derivation is found to be similar to that of MODIS land AOT products.

Fundamental to the validation of remotely sensed AOT estimates, the global network of sunphotometers operating under NASA's AERONET programme are essentially remote-sensing devices measuring AOT from the ground upwards through the atmospheric column towards the Sun. Wong, Nichol, and Lee (2013) exploit the 4 year data archive of multi-spectral AOT data from the Hong Kong PolyU AERONET station and employ the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to identify probable source areas of different aerosol types affecting Hong Kong. This addresses a long-standing controversy over the main emission sources, in a region with diverse pollutant types and source areas. Another non-imaging remote-sensing device demonstrated in this issue to be applicable to atmospheric measurement is Doppler lidar. The article by Chan (2013) describes its use for real-time mapping of visibility at the Hong Kong International Airport over an area of up to 10 km from the lidar location. This is a new technique for visibility measurement, which is traditionally estimated from a point in a single direction, and gives good results when compared with forward scatter sensors along the airport runways.

Accurate 3D modelling is increasingly important in research relating to urban environments. The more complex or detailed the research problem, the more detailed and comprehensive the 3D models need to be. Much research has gone into the automatic extraction of digital surface models (DSMs) of urban areas from airborne lidar sensors. Teo and Shih (2013) demonstrate a method using airborne Lidar, which in addition to modelling the existing urban infrastructure, can inform where changes have occurred and whether the change is due to the addition or subtraction of existing object types (e.g. addition or removal of buildings) or to changes in object type (replacing parkland with high-rise structures). Their method is based on object detection using multitemporal lidar data, thus enabling the detection of changes in object properties such as height and roughness over a time period.

In urban areas, the detection of change at an even more detailed level involving sub-metre movement of ground and buildings is vital for the safety of buildings and infrastructure. Leighton et al. (2013) present a study of land motion in the urban area of Nottingham, UK, over the period from November 2002 to February 2009 using persistent scatterer InSAR (PSI). The atmospheric effect on the PSI measurements, which is corrected with zenith wet delays (ZWD) determined with precise point positioning (PPP) GPS observations, is found to be effective. The PSI results are compared and validated with ground levelling measurements and provide a synoptic view of land motion at centimetre scale over the whole urban area.

The ability of modern sensors to identify features from centimetre to kilometre scales along with the creativity of remote-sensing specialists in extending applications through techniques and algorithm development assures the continued dynamism of the remote-sensing discipline for urban applications. The breadth of articles covered by this special issue on remote sensing for sustainable urbanization illustrates this responsiveness and bodes well for the future growth of the discipline.

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