Foreword to the Special Issue on Urban Remote Sensing by Satellite

THE MAJORITY of the world's population lives in cities or major urban areas. Densely populated urban areas are ones in which the quality of human life and the state of the natural and physical environment are inextricably linked. While city developments are often well-planned at the microscale (individual buildings and precincts), urban developments at the macroscale are not, frequently resulting from creeping outward growth (sprawl) and successive phases of randomized in-filling of green spaces. In order to optimize the health and quality of life of the population that lives in cities, there is a significant need for new strategic planning policies that take account of both local and regional land-use, as well as of short- and long-term trends in urban development and environmental change. The monitoring of the macroscale long-term changes to urban environments has been a difficult problem due to the lack of appropriate tools and technologies. Now we have the possibility to use space technology to understand and control the urban environment. However, the analysis and interpretation of urban remote sensed data, its integration with ancillary new technologies (such as temporal geographical information systems, precision navigation, mobile mapping technologies), and its exploitation by strategic planning agencies are still poorly developed.

As a matter of fact, satellite remote sensing has so far not been used extensively for analyzing and monitoring cities. There are a number of reasons for this, such as the following:

- wide variability in the spectral characteristics of built surfaces;
- inadequate spatial resolution of satellite sensor systems;
- lack of adequate tools to integrate remote sensing data of highly differing characteristics;
- complexity of the three-dimensional (3-D) structure of the urban landscape and "builtscape";
- inadequate techniques to understand patterns of land-use and to analyze structural features in remotely sensed imagery.

However, there have been a number of recent important technological and methodological developments, which can overcome these problems to a large extent. These recent developments are the main reason for this special issue, which includes 12 papers organized in three groups.

One of the key developments has been the operational deployment of very high resolution optical/infrared imaging sensors. However, while very high resolution (VHR) imagery has much potential in the urban context, analysis of imagery can no longer rely on the traditional multispectral classification approach that has been commonly used with lower resolution imagery over rural areas in the past. Most types of urban land-cover in VHR imagery are distinguishable on the basis of structure and morphology requiring new analytical techniques. The first group of papers of this special issue addresses these problems.

In particular, in the paper by Herold *et al.*, the spectral resolution requirements for accurately mapping urban land-cover are examined. Airborne Visible Infrared Imaging Spectrometer (AVIRIS) data were collected over a test area in the vicinity of Santa Barbara, CA. Comparisons were made of the accuracy of classifications of the urban land-cover using the four broadband IKONOS channels convolved from the AVIRIS data, five narrow bands in the same spectral region, and the four broadband IKONOS channels plus two additional shortwave infrared (SWIR) bands. The results clearly demonstrate the value of narrowband information and SWIR information in accurately discriminating urban land-cover types, and also highlight the restrictions of current satellite sensor systems for urban land-cover mapping. Similarly, the paper by Shackleford and Davis examines the use of combined spectral and spatial information derived from high-resolution IKONOS multispectral and pan-sharpened imagery to classify urban and suburban land-cover. Texture measures were investigated as a means to separate spectrally similar classes. For situations in which texture measures proved inadequate, a "length–width" spatial context measure was developed, and a hierarchical fuzzy classification approach was used. It initially determines membership values in separate pairs of urban land-cover classes using the spectral data plus an entropy texture measure and the length–width spatial contextual measure. The results indicate the superiority of the hierarchical fuzzy classification approach compared to the maximum-likelihood classifier and illustrate the importance of spatial information in urban class discrimination. The paper by Sugumaran *et al.*focuses instead on the issue of monitoring and preserving sensitive forests within urban areas. They use both a maximum-likelihood classifier and a rule-based classifier, based on the classification and regression tree (CART) algorithm, to classify urban forest areas in 4-m resolution multispectral IKONOS imagery and in 25-cm and 1-m resolution airborne imagery of Columbia, MO. They use the very high resolution images for the identification of eight different species of oak trees in the urban area. Their results demonstrate the utility of such imagery to separate urban tree species, but also indicate that the choice of seasonality and illumination condition of data acquisition is critical in optimizing the results. Finally, the paper by Benediktsson *et al.*examines the use of morphological features to provide urban area characterization in IKONOS panchromatic data at 1-m spatial resolution. It

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shows that the use of these features, together with feature reduction, provides an efficient way to improve classification maps using very fine spatial resolution sensors.

A further useful development of satellite sensors with respect to urban analysis has been the availability of remotely sensed data from the radar part of the spectrum, also at high resolution. This is the main topic of the second group of papers in this special issue, and we have six papers relating to it.

In particular, the paper by Dekker examines the possibility to discriminate among different urban environments in synthetic aperture radar (SAR) images by means of texture measures. The work compares texture measures and provides hints about the most useful ones. As a result, the author states that texture helps improving the results, but the accuracy values are still not useful for map updating purposes in urban conglomerates. The paper by Lombardo *et al.*focuses instead on multifrequency polarimetric data segmentation in urban areas, and investigates the efficiency of a new technique, based on a split–merge test, that shows superior performance with respect to the polarimetric test. The methodology is assessed by analyzing SIR-C data and extracting different urban blocks. From a different pint of view, the paper by Quartulli and Datcu examines a framework based on a probabilistic description of the scene for interferometric SAR (InSAR) data analysis in urban areas. The methodology is applied to data at different spatial scales, from 25 m of the Shuttle Radar Topography Mission to 2.5 m of an airborne SAR sensor. The work shows a way to improve the understanding of very complex InSAR scenes of urban or semiurban areas by facing the problem in a hierarchical way. Finally, the paper by Luckman and Grey focuses on the availability of height information from SAR multibaseline coherence values. The authors show that it is possible, at least to some extent, to exploit the relationship between the coherence values (even for very long baselines) and the height mean value. By this way it is possible to characterize the 3-D urban structure by inverting spatial decorrelation measures from satellite sensors.

To understand in advance the possibility offered by these data, we may need an efficient urban SAR simulator. The paper by Franceschetti *et al.* introduces such a tool. The paper discusses backscattering effects in an urban scene. It addresses in detail the backscattering of a model set of dielectric buildings placed over a random rough nonflat dielectric terrain. Interesting applications are also presented, such as defining parameters for new SAR systems suited for urban area analysis or training supervised feature extraction algorithms with artificial but precise data. Using such data it is possible, as shown in the paper by Dell'Acqua *et al.*, to test new approaches to improve urban characterization by means of SAR imagery using multitemporal and multiangle datasets. The authors propose a neurofuzzy procedure for multitemporal classification in order to improve the accuracy in classification land-cover classes. They also successfully use a multiangle dataset to improve the characterization of road networks in an urban area.

The third group of papers refers to the growing need for environmental management in urban areas, which represents an enormous scientific challenge. Currently, about 74% of the world's population in developed countries lives in urban regions. Many of these areas are tectonically active or located near the coast and/or within river floodplains, deltas, and alluvial systems and are vulnerable to the associated risks—some of which are actually increasing (e.g., due to the higher level of "extreme" weather events arising from global climate change). This can only be achieved by a significant improvement in our ability to monitor urban areas, to gain greater insight into environmental risks faced in urban areas, and to improve long-term planning for improved environmental quality and risk avoidance alongside sustainable development. To address these problems, the paper by O'Hara *et al.*focuses on the monitoring of urban growth in sensitive coastal environments by the detection of long-term changes in land-use and land-cover in Landsat images nine years apart. They develop spectral profiles of known land-use and land-cover types from seasonal vegetation "leaf-on" and "leaf-off" imagery for a test area along the Mississippi Gulf Coast. Thematic-change logic rules relating the "leaf-off" class to the "leaf-on" class are used to produce improved classifications of land-cover in a particular year. Comparisons of the Landsat data from different years then lead to estimates of changes in land-cover over the period 1991–2000. The results indicate that urban land-cover increased by more than 36% in the test area over the period concerned. The paper demonstrates the value of seasonal imagery and rules based on seasonal changes in establishing accurate land-cover classification in a particular year, and also the value of satellite imagery acquired many years apart in understanding regional growth in urbanization. Similarly, in the paper by Greenhill *et al.*, IKONOS-2 images are used to derive the spatial distributions of landscape ecological metrics within suburban areas. The obtained results indicate typical ranges of the used metrics in environmentally sustainable localities. It is demonstrated in the paper that the spatial distributions of the metrics provide new insight into landscape structure, which can be used in urban planning.

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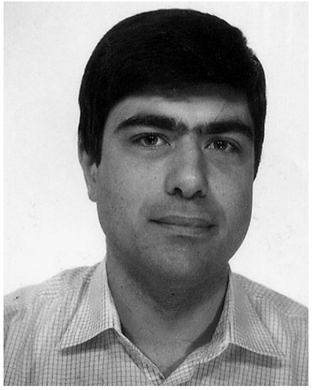
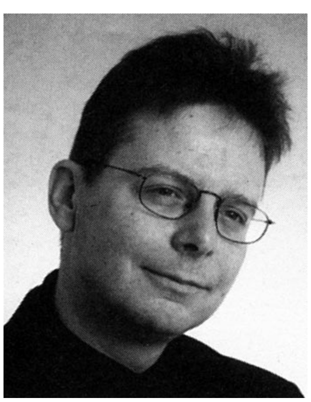


Paolo Gamba (S'91–M'93–SM'00) received the laurea (cum laude) and the Ph.D. degrees in electronic engineering from the University of Pavia, Pavia, Italy, in 1989 and 1993, respectively.

He is currently Associate Professor of telecommunications at the University of Pavia. From 1992 to 1994, he was a Research and Development Engineer in the Microwave Laboratory of Siemens Telecomunicazioni, Cassina de' Pecchi, Milano, Italy. In 1994, he joined the Department of Electronics, University of Pavia, first as a Teaching Assistant and later as an Assistant Professor and now as an Associate Professor. Since 1997, he has been teaching radiocommunications systems, electrical communications, and remote sensing image processing. He has been involved in a number of projects funded by the European Community, the Italian Ministry for Scientific Research, the Italian Space Agency (ASI), and the Italian Research Council (CNR). From 1998 to 2001, he has acted as a Consultant for the Radar Science and Technology Section, Jet Propulsion Laboratory (JPL), Pasadena, CA, concerning SAR over urban areas. He is the Guest Editor of a special issue of the *ISPRS Journal of Photogrammetry and Remote Sensing* on "Algorithm and Techniques for Multi-Source Data Fusion in Urban Areas" and a special issue of the *International Journal of Information Fusion* on "Fusion of Urban Remotely Sensed Features." His current research interests include remote sensing data processing for urban applications, especially SAR urban analysis, multitemporal/polarization/frequency and multispectral data classification by neural and fuzzy classification tools, satellite image interpretation for civil protection purposes, weather radar, and meteorological satellite data interpretation.

Dr. Gamba was the recipient (first place) of the 1999 ESRI Award for Best Scientific Paper in Geographic Information Systems. He was also awarded a Fulbright grant for the academic year 1999/2000. He was the Organizer and Technical Chair of the first IEEE/ISPRS Joint Workshop on "Remote Sensing and Data Fusion over Urban Areas," whose first issue was held in Rome, Italy, in November 2001, and the second is in Berlin, Germany, in May 2003. He is currently Chair of Technical Commette 7 "Pattern Recognition in Remote Sensing" of International Association for Pattern Recognition (IAPR) and is a member of the Data Fusion Committee of IEEE Geoscience and Remote Sensing Society.



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Dr. Benediktsson was a Fellow at the Australian Defence Force Academy (ADFA), Canberra, in August of 1997. In 1991, he received from Purdue University the Stevan J. Kristof Award as outstanding graduate student in remote sensing. In 1997, he was the recipient of the Icelandic Research Council's Outstanding Young Researcher Award, and in 2000, he was granted the IEEE Third Millennium Medal. He is Editor of IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING (TGARS) and was an Associate Editor TGARS from 1999 to 2003. In 2002, he was appointed Vice President of Technical Activities in the Administrative Committee of the IEEE Geoscience and Remote Sensing Society (GRSS). From 1996 to 1999, he was the Chairman of GRSS' Technical Committee on Data Fusion. He coedited (with Professor David A. Landgrebe) a Special Issue on Data Fusion of TGARS (May 1999). He is the current and founding Chairman of the IEEE Iceland Section.

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