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Geo-Spatial Technologies in Urban Environments

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with 45 Figures and 14 Tables

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Foreword

Using Geospatial Technologies in Urban Environments simultaneously fills two gaping vacuums in the scholarly literature on urban geography. The first is the clear and straightforward application of geospatial technologies to practical urban issues. By using remote sensing and statistical techniques (correlation-regression analysis, the expansion method, factor analysis, and analysis of variance), the authors of these 12 chapters contribute significantly to our understanding of how geospatial methodologies enhance urban studies. For example, the GIS Specialty Group of the Association of American Geographers (AAG) has the largest membership of all the AAG specialty groups, followed by the Urban Geography Specialty Group. Moreover, the Urban Geography Specialty Group has the largest number of cross-memberships with the GIS Specialty Group. This book advances this important geospatial and urban link.

Second, the book fills a wide void in the urban-environment literature. Although the *Annals of the Association of American Geographers* has recently established an editorship devoted to human environmental issues ("Nature and Society"), relatively few of the articles in this section of the journal have focused specifically on urban-environmental topics. Likewise, of the textbooks in urban geography published over the past decade (Knox, 1994; Pacione, 2001; Kaplan, Wheeler, and Holloway, 2004), none has offered a single chapter on urban-environmental questions, and only passing references to such topics as urban heat islands. In the journal, *Urban Geography*, which began publications in 1980, only two articles have been published that can explicitly be considered in the urban-environment context: Gary Talarchek (1990), "The Urban Forest of New Orleans: An Exploratory Analysis of Relationships," and Vibhooti Shukla and Kirit Parikh (1992), "The Environmental Consequences of Urban Growth: Cross-National Perspectives on Economic Development, Air Pollution, and City Size." In addition, Scott Carlin and Jody Emel (1992) published a Progress Report: "A Review of the Literature on the Urban Environment." They concluded (p. 482) that "geographical focus on this subject remains limited."

In addition to helping fill these gaps in the literature, the book impressively offers policy and planning insights and implications for using geospatial technologies to the study of environments, including such topics as green space, environmental justice, urban forests, and quality of life. Thus, the volume is attractive to a variety of readers. Students interested in urban applications of remote sensing and other geospatial methods will find much of significance in these chapters. Those readers concerned with the urban environment will also find much of value here, as will those attracted to policy and planning considerations. The book at once is alluring to academics and nonacademics, such as those employed in government agencies and public and private planning.

This book points urban geographers down a new and largely untrodden lane. Let us hope that many among us will tread the pioneer pathway into this mostly uncultivated place.

James O. Wheeler
University of Georgia
Athens, GA
January 31, 2004

Dedications

To my wife and children – RRJ

To my favorite editor, s., and our children, f. and m. –JDG

To my many students who challenged, nourished, and strengthened me as an educator – DDM

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About the Contributors

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1 Applying Geospatial Technologies in Urban Environments

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Cities have been around since the 3rd millennium B.C. and as long as they have existed, people have been drawn to them for what they offer. As recently as 1800, however, only 2 per cent of the world's population lived in urban areas. Today, with 6 billion people on earth, slightly less than one-half live in cities and towns; by 2007 one half of them will. In the century ahead, urban centres are expected to expand to sizes never before seen.

United Nations, Instanbul + 5, 2001, p. 1

1.1 About this book

As the epigraph suggest, cities are to become one of the chief policy concerns of the 21st century. Moreover, cities are unique policy realms in that urbanization is an issue and process that resides at the nexus of human and physical systems and unites the research and policy interests of natural and social scientists alike. This is true as urbanization as a process unites often-disparate social and physical systems to create entirely new policy challenges such as environmental degradation, the development and maintenance of physical and social infrastructures, the challenge of expanding economic opportunities, designing effective service delivery regimes that promote the overall sustainability of urban areas, and assessing the policy outcomes. Consequently, researchers and policy makers are concerned with identifying and overcoming the full range of challenges associated with urban systems. Unfortunately, the ability of researchers and planners to assess and investigate complex urban systems has been somewhat frustrated by a lack effective and accessible research and decision making tools. Over the past fifteen years, remote sensing and geographic information systems (GIS) have been shown to provide an excellent way to investigate urban areas. However, the availability, "usability", and range of potential applications of these technologies had until recently been limited to a community of specialists and scientistist. Today remote sensing and GIS technologies provide an accessible and increasingly user friendly suite of data and data analyses that facilitate the integrated investigation of spatial information. Further, the ability of GIS to integrate tabular data with spatial data allows for detailed investigations with socioeconomic data. .

The purpose of this book was to assemble a collection of studies that investigate and develop alternate methodological approaches to understanding the urban environment. In particular, it seeks to bring together studies that use remote sensing technologies and geographic information systems to explore issues often ignored by the mainstream community of geo-technical specialists, such as environmental justice, the meaning of data, and the everyday lives of urban residents. This book is meant to bridge the gap between the geography / planning / public administration communities and others that use geospatial technologies. Urban resource professionals need new management practices, skills, and tools to address the new and changing urban environment, and research is needed to place the best scientific data into the hands of decision makers (Hermansen and Macie, 2002).

This book seeks to expand the current frame of reference of remote sensing and geographic information specialists to include an array of socio-economic and related planning issues. Using remotely sensed data, the project explores the efficacy and policy implications of new approaches toward analyzing data (i.e., homogeneity indices), integrates approaches from human geography (i.e., Expansion Method), and explores the utility of employing geo-technologies to further the politics of local growth and smart growth coalitions (i.e., green space). Indeed, this book seeks to build upon Longley's (2002) call for better urban geography by integrating these technologies into the urban environment.

1.2 Chapters

There are many ways to classify the 12 main chapters of this book including the techniques used, the context of the analysis, the data sets used, the spatial resolution or scale of the data and so on. Because of this breadth, it made classifying the chapters into specific groups very difficult. This book not only gives many research examples of geospatial technologies in urban areas, but it also provides the basics of these technologies in several introductory chapters. These chapters are meant to provide a foundation of these technologies to readers that are not as familiar with them. For example, those readers lacking a basic understanding of the principles of urban remote sensing should read chapter 2. Those seeking to understand more of the Casetti expansion method and its role in this book and in spatial data processing should read chapter 5. Chapter 3 describes policy implications of remote sensing through a case study. Many chapters demonstrate the potential role of geospatial technologies in examining and solving urban problems. Specifically, two chapters examine urban quality of life and environmental justice (Chapters 7 & 8). Another chapter details how local community leaders perceive the costs and benefits of the urban forest to their community (Chapter 9) and how a healthy urban forest can actually spur economic development (Chapter 11), while another chapter details the economic impact of urban forestry on summertime electrical energy usage (Chapter 6). Chapter 10 reviews much of the remote sensing urban heat island literature and provides an urban heat island case study. Those readers seeking an example of how to provide spatial data to the public should read chapter 4. Chapter12 describes how remote sensing can be used to estimate urban sprawl, and chapter 13 details the links between satellite and census data.

Table 1. Summary of substantive chapters in this book

	Author(s)	**Subject**
2	J. Jensen et al.	Urban remote sensing
3	Lawrence et al.	Policy implications of remote sensing detection of an urban wetland
4	Morgan et al.	Making spatial and tabular data available to the public – the case of Internet tax mapping
5	Gatrell	Assessing socio-spatial interactions with the expansion method
6	R. Jensen et al.	Relationship between urban leaf area and energy consumption
7	R. Jensen et al.	Using remote sensing technologies to study urban environmental justice
8	R. Jensen and Gatrell	Using texture to assess urban quality of life
9	McLean et al.	Local government leaders perceptions of the urban forest
10	Weng and Larson	Remote sensing of urban heat islands
11	Gatrell and Jensen	Remote sensing and urban assessment – using remote sensing and urban forestry to compete for local investment
12	Hanham and Spiker	Urban sprawl detection using remote sensing
13	Muller and Gossette	The relationship between urban structural variables and socioeconomic conditions

The authors and editors hope that this book will be used by planners, landscape architects, urban foresters, GIS and remote sensing specialists, and many others to improve quality of life in the urban environment. People will continue to migrate to urban areas. Our ability to examine and mitigate the potential negative impacts of this migration is very important today and will be even more important tomorrow. As such, this book and the studies contained within it should be used as a point of reference of sorts for those who might imagine and re-imagine the range of potential geo-technical applications to assist urban decision making and promote the overall sustainability of social and physical systems.

References

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United Nations Centre for Human Settlements (HABITAT). 2001. BROCHURE: Istanbul + 5: The United Nations Special Session of the General Assembly for an Overall Review and Appraisal of the Implementation of the Habitat Agenda. New York: United Nations, Department of Public Information, 8 pages with figures.

2 Remote Sensing of Impervious Surfaces and Building Infrastructure

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2.1 Introduction

The rapidly expanding urban surfaces of today are generally impervious to water and are a key environmental indicator (Arnold and Gibbons 1996) that can be measured with remote sensing. Roads, sidewalks, parking lots, and rooftops are usually constructed of materials that repel almost all incident precipitation. In some cases, precipitation events can result in flash flooding that is similar to the flash floods occurring in rock canyons. The ability to detect, monitor, and analyze changes in the extent of impervious surfaces is important for many other aspects in the quality of environment, such as urban heat islands and pollution. This capability is in high demand for water quality engineering purposes (Zug et al. 1999) and for the assessment of stormwater taxes (Kienegger 1992).

There is also significant value in the ability to detect, monitor, and analyze changes in building infrastructure over large areas (hundreds to thousands of km^2). Individual dwelling units, for example, are an important surrogate for population estimates (Jensen 2000). Even though a census is routinely collected (e.g. every ten years in the United States), remote sensing of individual dwellings can provide annual (instead of just decennial) estimates of population status. The changing building landscape is important and relevant to the economy, the environment, and quality of life. Disorganized growth can lead to unintended consequences such as insufficient open space, traffic congestion, and overcrowded schools. Many public and private leaders are investigating new urban growth models that will mitigate these problems (O'Neill et al. 2000).

This chapter gives case studies of remote sensing of impervious surfaces and building infrastructure using a variety of remote sensor data sources, including aerial photography, digital aerial imagery, satellite imagery, and lidar.

2.2 Conventional Methods

In situ GPS surveying and digitization of hardcopy maps (e.g. engineering drawings) can provide urban infrastructural information suitable for analysis using GIS. These techniques can be expensive and difficult to implement on a systematic basis. Much effort has been expended to improve and simplify these methods. One popular technique for inventorying roads and paved surfaces is the use of GPS enabled vehicles, sometimes equipped with additional survey equipment. In another example, Great Britain is implementing methods for individual postal workers to identify commercial and dwelling locations nationwide (Ordnance Survey 2000). Digitization of hardcopy maps has progressed from the use of digitizing tablets to the use of a variety of scanners and feature extraction algorithms.

2.3 Remote Sensing Process

Remote sensing offers an alternative to *in situ* and/or hardcopy digitization methods which may or may not be sufficient (or efficient) for obtaining the desired urban information. However, remote sensing techniques also have their strengths and weaknesses that should be considered. Even if a remote sensing method is judged to be superior, it will likely require field verification. The scope and nature of the urban analysis problem must be carefully considered when deciding on a particular technique, or combination of techniques.

Remote sensing in the urban environment requires special considerations regarding data sources and utilization. Often these considerations are based on fundamental resolution requirements (i.e. suitable spatial, spectral, temporal, and radiometric resolutions). Many urban applications, including impervious surface and building infrastructure mapping, require a high to moderate temporal resolution of from 1 to 5 years. These types of applications also utilize high spatial resolution, often at or below 1×1 m, in order to capture the detail and complexity of the urban landscape (Jensen and Cowen 1999).

In traditional urban applications, which are primary based on manual image interpretation, most image analysts would agree that when extracting information from remotely sensed data it is more important to have high spatial resolution than to have high spectral or radiometric resolution (Jensen 2000). However, when using automated computer processing methods such as those presented in this chapter, subtle changes in spectral and radiometric response can prove to be of equal im-