REMOTE SENSING AND DIGITAL IMAGE PROCESSING

Tarek Rashed · Carsten Jürgens (Eds.)

Remote Sensing of Urban and Suburban Areas

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Remote Sensing of Urban and Suburban Areas

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We are convinced that with the publication of this book we are making an essential contribution to the knowledge about the different aspects of urban and suburban remote sensing.

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Chapter 1
Urban and Suburban Areas as a Research Topic for Remote Sensing

Maik Netzband and Carsten Jürgens

This chapter provides an introduction into the book's theme, its relevance for the scientific community as well as for instructors and practitioners. It tries to give an umbrella for the topics that have been chosen to bridge the gap between remote sensing and urban studies through a better understanding of the science that underlies both fields. In so doing, in the second half this first chapter introduces the following 16 chapters written by leading international experts in respected fields to provide a balanced coverage of fundamental issues in both remote sensing and urban studies.

Learning Objectives

Upon completion of this chapter, the student should gain an understanding of:

❶ Overview of urbanization research issues
❷ Introduction to recent developments in Urban Remote Sensing

1.1 Introduction

Starting the theme of research on urban and suburban areas, a recently taken aerial photograph in bird's eye perspective is illustrated. Figure 1.1 pictures a recent suburban development in the City of Rio Vista, California.

As a prosperous plan, 750 houses should be developed here once – most strikingly, these plans originate from a time, when still nobody suspected, what the term "largest economic crisis since 80 years" meant. And in such a way on 20 November 2008, thus few weeks after the collapse of the investment bank Lehman Brothers, the

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Fig. 1.1 Aerial photograph 'Rio Vista, California/USA' (Credits: Justin Sullivan/AFP)

house development project was already being adjusted in California's Rio Vista. Only the roads are still remaining – and a few sample houses. In the meantime the city in the north of the Sunshine state considers even to announce insolvency bankruptcy. Source: AFP

progress in information and communication technologies and the decentralization of economical activities are modifying the traditional patterns of urban agglomerations

It is a general argument, that every period of socioeconomic development is joined by different effects on population and landscape dynamics, e.g. the transition from agricultural-based economies to industrialization forced the urbanization process and the development of cities, predominantly accompanied by a monocentric urban growth pattern due to the concentration of industries, residences, and commerce in metropolitan areas (e.g., Mexico City, Beijing, London, New York) (Parés-Ramos et al. 2008; Anas et al. 1998). Today, one can observe in many countries a major transformation from an industrial-based economy to a knowledge-based economy (OECD 1996). As a result, innovations in information and communication technologies along with the decentralization of commercial, industrial, and financial activities are altering and diversifying the traditional patterns of urban agglomerations and driving new population and landscape dynamics (Munroe et al. 2005).

The consequences of these current socioeconomic trends comprise changes in the spatial structure of urban and rural areas, such as urban core population decline, the appearance of brownfields, suburban growth, and the urbanization of rural areas (Munroe et al. 2005). Decentralization tendencies are forcing urban sprawl and the conversion of agricultural lands and open spaces into urban land uses. Conversely, urban agglomerations with their manifold employment opportunities in manufacturing, trade, tourism, and other service sectors, attract more people, particularly the young and educated, to urban areas and supports the decline in agriculture jobs (Losada et al. 1998).

The cities today are spreading into their surrounding landscapes, sucking food, energy, water and resources from the natural environment, without taking into due account the social, economic and environmental consequences generated at all levels by their ‘urban footprints’. The urban environment itself is profoundly changing the entire global ecosystem. Environmental changes are also expressed in land-use changes. Social, economic or political trends are conveyed spatially. In recent decades, the strongest per capita growth shifted to the more rural areas of the urban fringe (Bugliarello 2003). Open spaces are increasingly included between cities, villages, and traffic axes. An urbanizing landscape, accompanying technical infrastructure, and uncontrolled dynamics of urban growth patterns are the results. The conversion from land cover to land being used progresses, i.e., predominantly agricultural surfaces are transformed into settlement and traffic surfaces, resulting in decreased settlement density, increased traffic, and costly infrastructure development. Especially the increase of imperviousness at the expense of the decrease of green and open spaces must be documented from local to global scale, and it is a ‘must’ that the knowledge is integrated into climate change investigations and further global change issues. Socio-spatial patterns are expressed in different building activities for single family houses of different strata, with different amounts of green spaces, shopping facilities and infrastructure have driven settlement areas to further expand. The settlement density and, correspondingly, the inner urban densification continue to decrease.

cities today are spawling into their surrounding landscapes, without taking into due account the social, economic and environmental consequences generated by their ‘urban footprints’

Merely characterizing and monitoring land-cover and land-use change is of limited use in understanding the development pathways of cities and their resilience to outside stressors (Longley 2002). Geological, ecological, climatic, social, and political data are also necessary to describe the developmental history of an urban center and understand its ecological functioning (Grimm et al. 2000). It is the process of urbanization that must be described, monitored, and even simulated on different scales. Dependent on the issue to be investigated upon, the relevant scale must be selected (see Fig 1.2). Local and regional environmental effects must be documented, analysed, evaluated, and, if possible, predicted. Without researchers and stakeholders exchanging and collaborating, the goal cannot be achieved.

In recent years ‘Urban Remote Sensing’ (URS) has proved to be a useful tool for cross-scale urban planning and urban ecological research. Remote sensing in urban areas is by nature defined as the measurement of surface radiance and properties connected to the land cover and land use in cities. Today, data from earth observation systems are available, geocoded, and present an opportunity to collect information relevant to urban and periurban environments at various spatial, temporal, and spectral scales.

The urban pattern causes deterioration in air quality, the urban ecosystem processes and biodiversity. In this context URS is a necessary prerequisite to examine how urban forms modify the landscape as a complex system. It can help to detect and evaluate the distribution of impervious or, likewise, sealed surfaces, a key parameter of urban ecology (surface and groundwater availability and runoff,

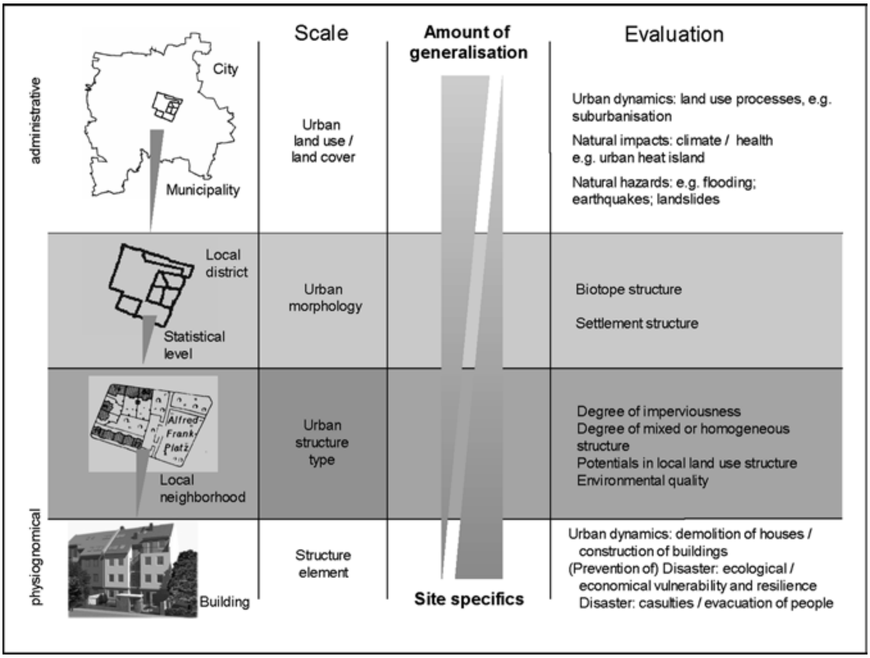

Fig. 1.2 Scale-dependent urban analysis (Banzhaf and Höfer 2008; modified after Wickop et al. 1998)

vegetation dynamics) and planning (storm water runoff, flooding hazards, landslides). Kühn (2003) explains the development of urban landscapes being shaped by the penetration of settlement and open-space structures. Remotely sensed data will be used to detect and evaluate the physical structure and composition of urban areas, such as the structure of residential, commercial or mixed neighborhoods, green spaces or other open spaces.

increase of geographical data availability has not been fully accompanied by an increase of knowledge to support spatial decisions, thus spatial analytical techniques are needed

The growth of 'Spatial Data Infrastructures', Geo-portals and private sector initiatives (e.g. Google Earth, Microsoft Virtual Earth, etc.) produced an increase of geographical data availability at any scale and worldwide. This growth has not been fully coupled by an increase of knowledge to support spatial decisions. Spatial analytical techniques and geographical analysis and modeling methods are therefore required in order to analyse data and to facilitate the decision process at all levels. As cities can be described as a concentration of people it is most striking to find coherence between urban land use and socio-demographic as well as socio-economic parameters. The statistical analysis of census data infers information on the human usage of the land, the human exposure to potential hazards in the city, and the configuration of each neighbourhood indicating the urban quality of life. For example, overlaying choropleth maps of socio-demographic features with land-use maps give information on gender and age distribution connected with proximity to urban green spaces, income and building density, or water consumption and level of provision of infrastructure. In this context URS aids at providing spatial information being linked to social indicators to explain the interrelations between ecological conditions and socio-spatial development (Banzhaf et al. 2009).

In this volume we try to cover most of but not all of the afore-mentioned topics and assembled widely known scholars of urban sciences specializing in the application of geospatial technologies or, vice versa, geo-information specialists with a distinct focus on urban and peri-urban developments to draw a widespread overview of the state-of-the-art knowledge in the growing field of urban remote sensing. "Remote Sensing of Urban and Suburban Areas" has been primarily assembled to introduce scientists and practitioners to this emerging field. Additionally it provides instructors with a text reference that has a logical and easy-to-follow flow of topics around which they can structure the syllabi of their urban remote sensing courses. The following six chapters of this book provide a comprehensive introduction in urban theories adapted to geospatial problems and solutions. In the second part of this book we present techniques and applications of various data sources and methodologies relevant for the analysis of urban status and dynamics.

Remote Sensing for Urban and Suburban Areas

Remote sensing in urban areas is by nature defined as the measurement of surface radiance and properties connected to the land cover and land use in cities. Today, data from earth observation systems are available, geocoded, and present an opportunity to collect information relevant to urban and peri-urban environments at various spatial, temporal, and spectral scales.

1.2 Introduction to the Chapters

Chapter 2 by Elena Besussi, Nancy Chin, Michael Batty and Paul Longley introduce the different *theoretical and methodological approaches* to understand and measure urban growth and urban patterns, their structure and form. The authors emphasize the idea that the contemporary city in both developed and developing worlds needs much more than just one theory or one method of analysis or one typology of data to be fully understood. It clearly appears to be a challenge to traditional analytical methods requiring interaction of social sciences and earth sciences, and urban economics using GIS techniques to understand patterns and trends of urbanization.

In Chapter 3 John R. Weeks reviews the vast literature on *dimensions of urbaneness*, but focuses especially on issues, such as classifying places as urban or rural by adequately capturing changes over time in the characteristics of a place. The urbaneness of a place as a continuum is determined based on a range of elements encompassing population size and density, social and economic organization, and the transformation of the natural and agricultural environments into a built environment. This chapter introduces you to one of such indices, i.e. an urban index that combines census and survey data (to capture aspects of the social environment) with data from remotely sensed imagery (to capture aspects of the built environment).

Martin Herold and Dar A. Roberts describe in Chapter 4 the *spectral properties of urban areas*, how different urban land-cover types are spectrally discriminated, and which sensor configurations are most useful to map urban areas. They also demonstrate potentials of new remote sensing technologies improving capabilities to map urban areas in high spatial and thematic detail. The authors stress the fact that urban areas with roofing materials, pavement types, soil and water surfaces, and vegetated areas represent a large variety of surface compositions. It is emphasized that most suitable wavelengths are characterized by specific spectral features to separate urban land cover.

The purpose of Chapter 5 authored by Richard Sliuzas, Monika Kuffer and Ian Masser is to examine the utility of remote sensing data on urban and suburban areas for *Urban Planning and Management* (UPM) from an *application perspective*. This chapter especially discusses the use of remote sensing at two different spatial scales, city-wide and neighborhood or site specific, the information needed with respect to monitoring planned and unplanned development, and the optimal spatial and temporal requirements for images used in this regard.

Rene M. Gluch and Meryll K. Ridd emphasize in Chapter 6 the *ecological nature of urban places* and introduce the *V-I-S (Vegetation-Impervious surface-Soil) model* to be used for remotely sensed data to characterize, map, and quantify the ecological composition of urban/peri-urban environments. The model serves not only as a basis for biophysical and human system analysis, it also serves as a basis to detect and measure morphological/environmental changes of urban places over time.

In Chapter 7 Debbie Fugate, Elena Tarnavsky, Douglas Stow review the *development of remote sensing systems and their contribution to the emergence of urban remote sensing*, especially how they promoted the pursuit of novel approaches to the study of urban environments. The chapter also covers data availability and requirements for a number of the most common earlier remote sensing applications such as land use and land cover classification, building and cadastral infrastructure mapping and planning, and utility and transportation system analysis. Additionally, the chapter highlights first attempts that have already been made to link the physical and social attributes of urban environments.

In Chapter 8, Victor Mesev explores *the role of ancillary data* (information from beyond remote sensing) *for improving the contextual interpretation of satellite sensor imagery* during spectral-based and spatial-based classification. Supplementary, explanations are given to the distinctions between urban land cover and urban land use, and how the inherent heterogeneous structure of urban morphologies is statistically represented between hard and soft classifications.

Basic knowledge about the differences between multispectral and hyperspectral data is provided by Patrick Hostert in Chapter 9, where the *potential of hyperspectral image analysis* is distinguished. He presents relevant pre-processing steps and different ways to analyze hyperspectral data. Moreover, relevant analysis approaches are explained including material detection techniques, spectral angle mapping, or spectral mixture analysis, to name some. The chapter closes with a short outlook on expected developments with relevance for urban applications.

Chapter 10, written by Elisabeth Schöpfer, Stefan Lang and Josef Strobl, focuses on *segmentation* of remotely sensed image data and *object-based image analysis* of urban areas. It also discusses the differences between the two different approaches 'pixel-based' and 'object-based' image analysis. They explain the main concepts of object-based image analysis: to work on homogeneous image objects rather than on single pixels and to use spectral and spatial information while merging pixels into homogeneous groups (image objects, segments). The chapter depicts very briefly urban applications by means of two case studies.

Thierry Ranchin's and Lucien Wald's Chapter 11 concentrates on techniques related to image and data from different sources with varying spatial and spectral resolutions. It presents and discusses some of the technical issues that influence *data fusion in the urban context*. Several fusion cases studies are discussed here to illustrate the potential of data fusion techniques. The authors emphasize on the importance of the diversity of data fusion. The few examples provided cannot fully describe its complexity and this field is still a strong and active research in urban remote sensing and the other civilian domains.

A case study from Phoenix, Arizona is depicted by William L. Stefanov and Maik Netzband in Chapter 12. They examine the *relationships between ecological variables and landscape structure* in cities. These relationships are assessed using ASTER and MODIS data; and through the techniques of expert system land cover classification and grid-based landscape metric analysis. The authors argue that this multi-scale approach is of great use to urban ecologists and spatial planners, as landscape structural analysis and measures of ecosystem function provide monitoring tools for regional habitat and climatic alteration associated with urbanization. Furthermore, the applied uniform spatial reference systems provided by remotely sensed data permit quantitative evaluation in comparative studies regarding the spatial configuration of existing developed and open spaces.

Chapter 13 by Mohamed Ait Belaid focuses on *remote sensing (RS) of desert cities*, within the context of developing countries. The characteristics of urban areas in the desert environment are described, and the potential of satellite imageries is discussed, how they are used to map and monitor changes in these areas over space and time. Urban and sub-urban landscapes of desert cities are shaped by various factors such as desertification, economic development, and wars and conflicts. In their chapter the authors include photo-interpretation techniques assisted by computer techniques to produce the classified imagery maps of land use categories and the comparison of the classified land use changes in urban areas.

In Chapter 14 Andy Kwarteng and Christopher Small give an overview over urbanization and the urban environment connected to urban vegetation, surface