

THE URBAN-ENVIRONMENT-SUSTAINABILITY-TECHNOLOGY NEXUS

# Urban Observation and Social Sensing



Edited by  
**Bin Chen** and **Fan Zhang**



**CRC Press**  
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# Urban Observation and Social Sensing

*Urban Observation and Social Sensing* helps readers see cities in a way they have seldom imagined before. Advanced technologies such as satellites in space, near surface drones, or even smartphones, can be used to explain how a city functions, or why certain areas are more populated than others. It examines the science of capturing city images and information gathered from above the ground combined with the information from social media and mobile data on the ground, and how to make sense of it all. From planning better neighborhoods to understanding how city life affects health, this book is a guide to the future of urban living and the technologies that help navigate it.

## Features

- Covers a broad spectrum of urban observation methods in one resource to ensure a thorough understanding of diverse data collection methods.
- Provides a unique emphasis on social sensing to enable a more holistic and human-centric view of urban landscapes.
- Includes practical applications to showcase how the data and methodologies can be used in real-world scenarios.
- Explains the current technologies and methodologies but also offers insights into the future trajectory of urban science.
- Integrates technological advances with informed urban planning and real-time insights to elucidate a holistic understanding of urban spaces.

This is an excellent, insightful resource for researchers, academics, students, and professionals in remote sensing, Geographic Information Systems, urban planning and design, data science, geography, earth science, and those interested in the future of urban living and planning.

## **The Urban-Environment-Sustainability-Technology Nexus**

*Series Editor: Qihao Weng, Chair Professor, Department of Land Surveying and Geoinformatics, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong*

This book series examines global urbanization's environmental impacts across different geographical settings and development stages. Rapid worldwide urbanization has dramatically altered ecosystems, biodiversity, climate, and water resources, creating complex challenges for assessment and monitoring. While urbanization generates local effects, evidence shows significant implications for regional environments and global climate change. The series addresses sustainable urban development strategies across continents, involving interdisciplinary research from environmental science, urban studies, data science, engineering, and social theories. Key topics include green cities, resilient cities, smart cities, urban computing, land use planning, climate, ecosystems, and geospatial AI.

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## *Preface*

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The idea for this book grew out of a growing discomfort shared by many in our field: while cities are transforming faster than at any point in human history, our tools for observing and understanding them have not kept pace with the complexity of the challenges they face. Urban heat crises, pandemics, aging infrastructure, biodiversity loss, energy stress, informal settlement growth, and widening socio-spatial inequities are no longer isolated phenomena—they are interlinked, accelerating, and deeply spatial. Yet much of urban research still relies on fragmented data, coarse generalizations, or disciplinary silos. Over years of working with satellite observations, AI, public health data, urban morphology, and social sensing, we realized that the most important stories about cities were falling through disciplinary gaps. We needed a new vocabulary and new methodological frameworks that integrate physical environments, human behaviors, and policy-relevant insights. That realization—and the urgency of climate change, demographic shifts, and digital disruptions—inspired this volume.

This book brings together the diverse strands of urban observations not as parallel developments, but as parts of a single evolving paradigm. The chapters reflect how the field has moved far beyond land cover detection and mapping. We now extract urban form from multispectral data, trace socioeconomic activity from nighttime lights, model material properties using microwave signals, reconstruct forests and building volumes with LiDAR, and monitor urban change in real time through nanosatellite constellations. At the same time, the boundary of “urban observation” itself has expanded. Street-view imagery, social media platforms, volunteered geographic information, and navigation patterns offer windows into how environments are perceived, used, and experienced. These emerging data sources force us to rethink what counts as urban observation and who participates in it.

What makes this book timely—and necessary—is that it does not treat these technologies as isolated tools but as interconnected instruments for reimagining urban research. From human thermal exposure in informal housing to AI-enabled facility planning, from spatial cognition and navigation to the geometry of living structures, each chapter addresses a dimension of urban life that traditional sensing could not reach. Taken together, they show how environmental sensing, behavioral insights, and spatial intelligence can converge to confront some of the most pressing urban challenges of this century. This volume is for researchers, educators, practitioners, and students who believe that cities must be understood as dynamic, data-rich, and human-centered systems. It is also a call for the next generation of scholars to

move beyond observational boundaries and disciplinary comfort zones. The future of urban science will not be built on better sensors alone, but on better questions, deeper integration, and a willingness to see cities as living, sensing, learning entities. We hope this book contributes to that shift—not only by synthesizing progress, but by challenging assumptions about what urban observation and sensing can be and whom it should serve.

**Bin Chen and Fan Zhang**

*20 October 2025*

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## About the Editors

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**Dr. Bin Chen** is an Associate Professor, Director of Future Urbanity & Sustainable Environment (FUSE) Lab at The University of Hong Kong. He obtained his BSc in Geographical Information Systems from Wuhan University, and his PhD in Global Environmental Change from Beijing Normal University. Before joining the University of Hong Kong in 2021, he worked as a post-doctoral researcher at the University of California, Davis.

Dr. Chen's research leverages geospatial big data, data-model fusion, and advanced interdisciplinary approaches to investigate the interaction loops between environmental change, human activities, and public health. Specifically, his major research includes the remote sensing of built and natural environmental changes; modelling of human-environment spatiotemporal interaction; and impact of environment and human activities on public health. He has published over 80 refereed publications in top academic journals. His achievements have received international recognition, including Geospatial World 50 Rising Stars (2024) and receiving the International Society of Digital Earth Young Scientist Award, American Association of Geographers Early Career Award in Remote Sensing, and HKU-100 Scholars Award and Outstanding Young Researcher Award.



**Dr. Fan Zhang** is an Assistant Professor at the Institute of Remote Sensing and GIS, Peking University. Prior to this, he was a Senior Research Fellow at MIT, where he led the Urban Visual AI group at the MIT Senseable City Lab. His research focuses on geographical artificial intelligence and data-driven urban studies, with particular emphasis on developing urban visual intelligence using street-level imagery. Dr. Zhang's work has been published in renowned academic journals, and he currently serves as an Associate Editor and Editorial Board

Member for various journals. He currently serves as an Associate Editor, an Editorial Board Member. His notable honors include the CPGIS Young Scholar Award (2024), the Geospatial World 50 Rising Stars Award (2022), and the Global Young Scientist Award in Frontier Science and Technology from WGDC (2020).



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# 1

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## *Multispectral Remote Sensing in Urban Environments*

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Ziming Li and Han Wang

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### 1.1 Overview

Remote sensing refers to remotely capture information via multiple sensors without any physical contact. This technology is widely used in the field of Earth observation. Typically using satellites or aircrafts, remote sensing can gather information about the Earth's surface by detecting and measuring emitted or reflected electromagnetic radiation from objects and areas on Earth. Remote sensing has numerous important applications, including environment, earth science, geography, and social science.

The fundamental principle of remote sensing is the interaction between electromagnetic radiation and the Earth's surface or atmosphere. Different objects and materials absorb, reflect, or emit electromagnetic radiation uniquely, producing distinct spectral signatures. The spectral signal intensity varies depending on the object's physical and chemical properties, allowing for differentiation and classification of diverse surface features.

From the perspective of spectral resolution, remote sensing can be classified into three categories: panchromatic, multispectral, and hyperspectral. Spectral resolution is a key factor in distinguishing between panchromatic, multispectral, and hyperspectral remote sensing. Panchromatic sensors have low spectral resolution as they capture data across a broad wavelength range, typically encompassing the entire visible spectrum (approximately 400–700 nm) or even extending into the near-infrared region. This results in a single-band grayscale image where each pixel represents the intensity of reflected light across the broad wavelength range, making it useful for detailed mapping and analysis of urban areas and infrastructure due to its high spatial resolution. On the other hand, multispectral sensors offer moderate spectral resolution by capturing data in several discrete spectral bands, typically ranging from 3 to 15 bands, covering specific portions of the electromagnetic spectrum including visible, near-infrared (NIR), and sometimes shortwave infrared (SWIR) regions (approximately 400–2500 nm). This results in a set of images, each corresponding to a specific spectral band,

which can be combined to form color composites like true color and false color images for various purposes. Multispectral imaging is widely used for vegetation analysis, land cover classification, water quality assessment, and environmental monitoring due to its ability to effectively discriminate broad categories of surface materials and conditions. In contrast, hyperspectral sensors provide high spectral resolution by capturing data in a large number of narrow and contiguous spectral bands, often exceeding 100 bands, spanning a wide range of the electromagnetic spectrum from the visible to NIR and SWIR. Some advanced systems can further extend into the mid-infrared (MIR) region (above 3000 nm). This results in a detailed spectral signature for each pixel, allowing for precise material identification and quantification. Hyperspectral imaging is used in applications that require detailed material identification and analysis, such as mineral exploration, precision agriculture, environmental monitoring, and medical diagnostics. The high spectral resolution enables the detection of subtle differences in spectral signatures, making it possible to identify specific materials and conditions that multispectral and panchromatic sensors cannot resolve. In summary, panchromatic sensors offer high spatial but low spectral resolution, making them suitable for detailed spatial analysis but limited in material discrimination. Multispectral sensors provide a balance between spatial and spectral resolution, allowing for effective broad-category discrimination and environmental monitoring. Hyperspectral sensors deliver high spectral resolution, enabling detailed material identification and analysis, though often with lower spatial resolution compared to panchromatic sensors. Spectral resolution thus serves as the defining characteristic that differentiates these three types of remote sensing, each with its specific strengths and applications.

In this chapter, we primarily focus on the multispectral remote sensing technique. Multispectral remote sensing is characterized as using sensors to capture information within several narrow bands of the electromagnetic spectrum, primarily including visible and NIR bands. Most multispectral images contain 3 to 15 bands ranging from around 400 nm to 2500 nm. The specific wavelengths of these bands can vary depending on the instruments being used. [Table 1.1](#) demonstrates common spectral bands and their typical applications.

To simulate human vision system and enhance imaging contrast and detail, it is a common practice to select three specific bands to form RGB composites, thereby supporting multispectral remote sensing analysis. This approach leverages the natural sensitivity of the human eye to red, green, and blue light, creating images that are both intuitive to interpret and rich in information. By combining these three bands, remote sensing imagery can effectively highlight various features and materials on the Earth's surface, making it easier to distinguish between different types of vegetation, water bodies, urban structures, and geological formations. [Table 1.2](#) shows typical three-band combinations and their applications.

**TABLE 1.1**

Classical Spectral Bands Used in Multispectral Remote Sensing

Spectral Band	Wavelength Range (nm)	Applications
Blue	450–515/520	Atmosphere and deep water imaging
Green	515/520–600	Vegetation and deep water structures
Red	600/630–690	Man-made objects, water bodies, soil, and vegetation
Near infrared (NIR)	750–1400	Vegetation imaging
Shortwave infrared (SWIR)	1400–3000	Moisture content of soil and vegetation, minerals, and rock types
Mid infrared (MIR)	3000–8000	Vegetation, soil moisture content, and some forest fires
Thermal infrared (TIR)	8000–15000	Imaging soil, moisture, geological features, silicates, clays, and fires
Far infrared (FIR)	15000–1000000	Atmospheric and astronomical research

**TABLE 1.2**

Common Composite of Multispectral Bands

Composite Type	Bands (Wavelength Range)	Applications
True color	Red Green Blue	Mimics natural human vision and is used for general landscape and urban area mapping.
False color	NIR Red Green	Vegetation appears in shades of red, making it easier to distinguish from other features; useful for assessing plant health and vegetation cover.
Agricultural	NIR Red Blue	Effective for monitoring crop health and vigor, as healthy vegetation reflects more NIR and less visible light.
Geological	SWIR 1 NIR Red	Used for identifying minerals and geological formations. SWIR bands are particularly useful for distinguishing soil and rock types.
Urban	SWIR 1 NIR Blue	Useful for urban studies, as it highlights built-up areas and infrastructure; helps in differentiating between vegetation, water, and urban features.
Water body analysis	SWIR Red Green	Ideal for mapping water bodies and assessing water quality; NIR and SWIR bands are sensitive to water content and can help in detecting moisture levels.

These classical three-band combinations are exemplary uses of multispectral remote sensing data for visual interpretation. By selecting appropriate bands, it is possible to enhance the visibility of specific features and gain valuable insights into various environmental and man-made phenomena.

Globally, numerous organizations are involved in the development and maintenance of various remote sensing platforms. Table 1.3 shows a range of widely used remote sensing sensors and platforms, operated by organizations such as NASA, the USGS, the European Space Agency (ESA), Maxar Technologies, and Planet Labs. These platforms offer various spatial resolutions and spectral bands, catering to diverse applications.

Multispectral remote sensing offers several advantages that make it a valuable tool for a wide range of applications. It provides broad geographic coverage, capturing data over large areas essential for regional and global studies. The use of multiple discrete spectral bands allows for the detailed

**TABLE 1.3**

Multispectral Remote Sensing Sensors and Platforms

Platform	Operator	Bands	Spatial Resolution	Applications
Landsat	NASA and USGS	11 bands (visible, near-infrared, shortwave infrared)	30 m	Land use and land cover mapping, agriculture, forestry, environmental monitoring, urban planning
Sentinel-2	European Space Agency (ESA)	13 bands (visible, near-infrared, shortwave infrared)	10 to 60 m	Agriculture, forestry, land use, water quality monitoring, disaster management
MODIS	NASA	36 bands	250 m 500 m 1 km	Large-scale environmental and climate monitoring, vegetation health, land surface temperature, ocean color
WorldView-3	Maxar Technologies	16 bands (visible, near-infrared, shortwave infrared)	Up to 1.24 m	Precision agriculture, urban planning, infrastructure monitoring, environmental assessment
PlanetScope	Planet Labs	4–8 bands (red, green, blue, NIR)	3–5 m	Agriculture, forestry, land use monitoring, disaster response

analysis of different surface materials and conditions, enabling the distinction between various types of vegetation, water bodies, soil, and urban features. Regular, repeatable observations from satellite-based multispectral sensors facilitate effective temporal monitoring, crucial for monitoring environmental changes such as seasonal vegetation growth, deforestation, urban expansion, and the impact of natural disasters. Additionally, multispectral remote sensing is generally more cost-effective than hyperspectral imaging, making it accessible for diverse applications and users. The data can be easily integrated with other geospatial information, enhancing comprehensive analysis and informed decision-making. Its versatility spans multiple fields, including agriculture, forestry, urban planning, environmental monitoring, and disaster management. The ability to create true color and false color composites enhances visual interpretation, aiding in the identification and analysis of specific features and conditions. Furthermore, capturing data in multiple spectral bands improves the accuracy of classification and analysis, allowing for precise differentiation of vegetation types and assessment of water quality parameters.

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## **1.2 Case Studies**

Using remote sensing technology to observe, monitor, and analyze urban environments is highly impactful. Remote sensing in an urban context involves leveraging spectral, texture, structural, and spatial features to identify and analyze urban environments; integrating image data with relational and statistical analysis to address socioeconomic phenomena; applying remote sensing techniques to urban-specific resource, ecological, and environmental challenges; providing essential information for urban planning, assessment, and predictive modeling; and enabling a comprehensive understanding of urban dynamics by combining remote sensing insights with other urban processes. Multispectral data with the advantages in the high accessibility, availability, and informativity, have facilitated a broad range of urban applications, which can be divided into two categories: urban object detection and environmental monitoring.

### **1.2.1 Urban Object Extraction and Classification**

Urban environments are inherently complex and heterogeneous, exhibiting significant challenges for accurate object detection and classification in urban areas. Unlike the rural or natural landscapes, where homogeneous land covers can be more easily classified, urban areas require improved approaches and techniques to effectively excavate and interpret the spatial patterns and spectral characteristics of the built environment. Traditional ground-based

survey methods, while accurate and detailed, are often impractical for large-scale urban analysis due to their labor-intensive nature and the rapidly changing dynamics of urban spaces. In contrast, multispectral remote sensing offers a comprehensive view and rich information, enabling the efficient monitoring of urban expansion, land use changes, and environmental impacts on a broader scale. Therefore, medium- to high-resolution remote sensing data has become indispensable for urban studies, particularly in the context of multispectral imaging. Medium- to high-resolution multispectral imagery is essential for capturing the fine-grained details needed to differentiate between complex urban features. In the following sections, we will delve into the methodologies used for extracting and classifying key urban objects: urban greenspaces (UGSs), water bodies, buildings, and roads, demonstrating how multispectral remote sensing data can be effectively used in these tasks.

### **1.2.1.1 Urban Greenspace**

UGSs, including parks, gardens, urban forests, residential greenery, and green roofs, are important components of the urban ecosystem. These spaces offer a range of essential ecosystem services, such as air purification, temperature regulation, and recreational areas for residents, all of which contribute to improving environmental quality and human well-being. Consequently, the accurate identification and classification of UGSs are critical for effective urban planning, environmental protection, and biodiversity conservation within urban areas.

The distinct spectral characteristics of UGSs are the foundation of designing feasible methodologies for classification with multispectral remote sensing data. The reflectance spectrum of vegetation is shaped by the physical and biochemical properties of the plant leaves and canopies, with spectral bands revealing various aspects of vegetation. In the visible spectrum (400–760 nm), the reflectance rate is mainly influenced by the chlorophyll in plant leaves, leading to a small reflectance peak around 550 nm (green), accompanied by absorption bands near 450 nm (blue) and 670 nm (red), which means chlorophyll absorbs blue and red light strongly while reflecting green light. In the NIR region (700–1100 nm), the reflectance of vegetation exhibits a substantial increase, which is known as the “red edge”. This feature is primarily due to the internal structure of plant leaf cells, which efficiently scatter NIR radiation, resulting in high reflectance. In the SWIR region (1300–2500 nm), reflectance is heavily influenced by the water content within. Here, the absorption increases, leading to lower reflectance, particularly at the water absorption bands centered around 1450 nm, 1950 nm, and 2700 nm. These spectral characteristics not only enable the differentiation of vegetated areas from non-vegetated surfaces in urban environments but also allow for the classification of different species and the assessment of vegetation health and environmental conditions.