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Remote Sensing of Impervious Surfaces in Tropical and Subtropical Areas



Hongsheng Zhang • Hui Lin
Yuanzhi Zhang • Qihao Weng



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Remote Sensing of Impervious Surfaces

in Tropical and Subtropical Areas

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Remote Sensing Applications

Series Editor

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Contents

List of Figures	ix
List of Tables	xiii
Preface.....	xvii
Acknowledgments	xxiii
List of Abbreviations	xxv
1. Introduction	1
1.1 Research Background.....	1
1.2 Significance of Impervious Surface	3
1.2.1 Environmental Significance	4
1.2.1.1 Hydrological Impacts	4
1.2.1.2 Urban Heat Islands	5
1.2.2 Socioeconomic Significance.....	6
1.3 Challenges of ISE	7
1.3.1 Land Cover Diversity and Spectral Confusion Issues.....	7
1.3.2 Scale Effects	7
1.3.3 Influence from Climatology and Phenology	9
1.3.3.1 Humid Subtropical Climate.....	9
1.3.3.2 Humid Subtropical Phenology.....	10
1.3.3.3 Seasonal Effects from Climatology and Phenology	10
1.3.4 Multisensor Fusion.....	11
1.4 Objectives and Significance	12
1.5 Organization of This Book	13
2. Impervious Surface Estimation Using Remote Sensing	15
2.1 Overview of the Methodology	15
2.2 ISE Using Single Data Source.....	16
2.2.1 Spectral Mixture Analysis.....	16
2.2.1.1 Endmember Selection.....	16
2.2.1.2 Linear Spectral Mixture Model and Fraction Images.....	17
2.2.1.3 Impervious Surface Estimation.....	18
2.2.2 Normalized Impervious Surface Indices	19
2.2.2.1 NDISL.....	19
2.2.2.2 BCI	20
2.2.3 Artificial Neural Network (Multilayer Perceptron and Self-Organizing Map).....	21
2.2.3.1 Multilayer Perceptron	21
2.2.3.2 SOM.....	23

- 2.2.4 Support Vector Machine 24
 - 2.2.5 Classification and Regression Tree..... 26
 - 2.2.6 Object-Oriented Analysis 27
 - 2.2.7 Multiprocess Classification Model 28
 - 2.3 ISE Using Multiple Data Sources 28
 - 2.3.1 Optical and Lidar Data 28
 - 2.3.2 Optical and SAR Data Using Random Forest..... 29
 - 2.4 Conclusion..... 31
- 3. Methodology of Combining Optical and SAR Data..... 33**
 - 3.1 Study Area 33
 - 3.1.1 Site A: Guangzhou 33
 - 3.1.2 Site B: Shenzhen 35
 - 3.1.3 Site C: Hong Kong..... 35
 - 3.1.4 Site D: Sao Paulo..... 36
 - 3.1.5 Site E: Mumbai..... 37
 - 3.1.6 Site F: Cape Town..... 38
 - 3.2 Satellite Data 38
 - 3.2.1 Landsat ETM+ 38
 - 3.2.2 SPOT-5 39
 - 3.2.3 ENVISAT ASAR 39
 - 3.2.4 TerraSAR-X..... 40
 - 3.3 Digital Orthophoto Data 40
 - 3.4 *In Situ* Data 40
 - 3.5 Framework of Methods 42
 - 3.5.1 Per-Pixel Modeling of Impervious Surfaces 42
 - 3.5.2 Investigation of Seasonal Effects 44
 - 3.5.3 Feature Extraction..... 45
 - 3.5.3.1 Conventional Feature Extraction 45
 - 3.5.3.2 SAN Feature Extraction..... 46
 - 3.5.4 Fusing the Optical and SAR Data..... 52
 - 3.5.5 Result Validation and Accuracy Assessment 53
 - 3.6 Conclusion..... 53
- 4. Impact of Climate Zone on Impervious Surface Estimation and Mapping 55**
 - 4.1 Introduction 55
 - 4.2 Datasets and Methodology..... 56
 - 4.3 Results and Discussion 58
 - 4.3.1 Guangzhou 58
 - 4.3.2 Mumbai 61
 - 4.3.3 Sao Paulo 65
 - 4.3.4 Cape Town 70
 - 4.4 Discussion..... 74
 - 4.5 Conclusion..... 77

- 5. Assessing the Urban Land Cover Complexity.....79
 - 5.1 Introduction79
 - 5.2 Datasets and Methodology.....79
 - 5.3 Results and Discussion80
 - 5.3.1 Guangzhou80
 - 5.3.2 Mumbai82
 - 5.3.3 Sao Paulo84
 - 5.3.4 Cape Town85
 - 5.4 Conclusion.....87

- 6. Comparative Studies with Different Image Data and Fusion Methods.....89
 - 6.1 Comparison of ISE with Single Optical and SAR Data89
 - 6.1.1 Parameter Configurations of ANN and SVM for Optical Data89
 - 6.1.2 Parameter Configurations of ANN and SVM for SAR Data90
 - 6.1.3 Comparative Results of ISE92
 - 6.1.3.1 Guangzhou92
 - 6.1.3.2 Mumbai.....94
 - 6.1.3.3 Sao Paulo.....96
 - 6.1.3.4 Cape Town.....99
 - 6.1.4 Discussion and Implications100
 - 6.2 Comparison of Different Levels of Fusion Strategies101
 - 6.2.1 Feature Extraction from Optical and SAR Data102
 - 6.2.2 Fusion Strategies at Different Levels.....102
 - 6.2.3 Fusion Results on Different Levels.....103
 - 6.2.3.1 Shenzhen103
 - 6.2.3.2 Mumbai.....105
 - 6.2.3.3 Sao Paulo.....106
 - 6.2.3.4 Cape Town.....107
 - 6.2.4 Comparisons of the Accuracy Assessment.....109
 - 6.2.5 Discussion and Implications111
 - 6.3 Comparison of Different Image Features.....112
 - 6.3.1 Experiment Design112
 - 6.3.2 Results of Feature Extractions.....113
 - 6.3.2.1 Features of Optical Images113
 - 6.3.2.2 Features of SAR Images.....119
 - 6.3.3 ISE and Comparisons122
 - 6.3.3.1 LULC Classification122
 - 6.3.3.2 ISE125
 - 6.3.4 Discussion and Implications129

- 7. In-Depth Study: ISE Using Optical and SAR Data 131
 - 7.1 Introduction 131
 - 7.2 Study Areas and Datasets..... 132
 - 7.2.1 Study Areas..... 132
 - 7.2.2 Satellite Data and Coregistration..... 133
 - 7.3 Feature Extraction of Optical and SAR Data 134
 - 7.4 Classification Strategy and Accuracy Assessment..... 135
 - 7.5 Optimization of RF 137
 - 7.5.1 Determining the Optimal Number of Features in Each Decision Tree 137
 - 7.5.2 Determining the Optimal Numbers of Decision Trees in the RF..... 139
 - 7.6 ISE with Optimized Models..... 141
 - 7.7 Discussion and Implications 146
- 8. Conclusions and Recommendations..... 149
 - 8.1 Conclusions..... 149
 - 8.1.1 Seasonal Effects of ISE in Tropical and Subtropical Areas 149
 - 8.1.2 Feature Extraction Methods 150
 - 8.1.3 Comparison between Optical and SAR Data 151
 - 8.1.4 Fusion Level and Fusion Methods 152
 - 8.2 Future Directions 152
 - 8.2.1 Feature Extraction..... 152
 - 8.2.2 Study Area Selection and Design..... 153
 - 8.2.3 Validation with *In Situ* Data 153
 - 8.2.4 Fusion Level and Strategy 153
 - 8.2.5 Fusion Methods..... 154
- Appendix 157
- Bibliography..... 159

List of Figures

Figure 1.1	Organization of this book.....	14
Figure 2.1	Structure of MLP.....	22
Figure 2.2	A node in the hidden layers	22
Figure 3.1	Locations of the six cities from four countries in this study.	34
Figure 3.2	(a) Landsat ETM+ (RGB: 5-4-3) and (b) ENVISAT ASAR images of the study site in Guangzhou.	34
Figure 3.3	(a) SPOT-5 (RGB: 4-1-2) and (b) ENVISAT ASAR images of the study site located in Shenzhen.	35
Figure 3.4	(a) SPOT-5 (RGB: 3-1-2) and (b) TerraSAR-X images of the study site in Hong Kong	36
Figure 3.5	(a) Landsat TM (RGB: 5-4-3) and (b) ENVISAT ASAR images of the study site in Sao Paulo	36
Figure 3.6	(a) Landsat TM (RGB: 5-4-3) and (b) ENVISAT ASAR images of the study site in Mumbai	37
Figure 3.7	(a) Landsat TM (RGB: 5-4-3) and (b) ENVISAT ASAR images of the study site in Cape Town.	38
Figure 3.8	Image from Google Earth showing the area where field data was collected	41
Figure 3.9	Devices employed for field data collection.....	41
Figure 3.10	Framework of the methodology of this research.	43
Figure 3.11	Illustration of a SAN of point A	46
Figure 3.12	Optical-SAR fusion for ISE	52
Figure 4.1	Estimation of impervious surfaces in Guangzhou using ANN.....	59
Figure 4.2	Estimation of impervious surfaces in Guangzhou using SVM.....	60
Figure 4.3	Estimation of impervious surfaces in Guangzhou using LSMA	62
Figure 4.4	Estimation of impervious surfaces in Mumbai using ANN.....	63

Figure 4.5	Estimation of impervious surfaces in Mumbai using SVM	64
Figure 4.6	Estimation of impervious surfaces in Mumbai using LSMA	66
Figure 4.7	Estimation of impervious surfaces in Sao Paulo using ANN	67
Figure 4.8	Estimation of impervious surfaces in Sao Paulo using SVM	68
Figure 4.9	Estimation of impervious surfaces in Sao Paulo using LSMA	69
Figure 4.10	Estimation of impervious surfaces in Cape Town using ANN	71
Figure 4.11	Estimation of impervious surfaces in Cape Town using SVM	72
Figure 4.12	Estimation of impervious surfaces in Cape Town using LSMA	73
Figure 4.13	Average digital numbers of different land use types in humid areas.	75
Figure 4.14	Effects of seasonal changes of typical targets	76
Figure 5.1	LULC classification in Guangzhou	80
Figure 5.2	LULC classification in Mumbai	82
Figure 5.3	LULC classification in Sao Paulo	84
Figure 5.4	LULC classification in Cape Town	86
Figure 6.1	Impacts of parameter configuration for Landsat imagery	90
Figure 6.2	Effects of parameter configuration for ASAR imagery	91
Figure 6.3	ANN training RMS with 4000 iterations	91
Figure 6.4	ISE using optical and SAR images alone in Guangzhou	93
Figure 6.5	ISE using optical and SAR images alone in Mumbai	95
Figure 6.6	ISE using optical and SAR images alone in Sao Paulo	97
Figure 6.7	ISE using optical and SAR images alone in Cape Town.	99
Figure 6.8	ISE with optical SAR fusion in Shenzhen	104
Figure 6.9	ISE with optical SAR fusion in Mumbai	105
Figure 6.10	ISE with optical SAR fusion in Sao Paulo	107

Figure 6.11	ISE with optical-SAR fusion in Cape Town	108
Figure 6.12	Spectral features of optical images in Hong Kong and Sao Paulo	114
Figure 6.13	GLCM-based textures of SPOT image in Hong Kong	115
Figure 6.14	GLCM-based textures of SPOT images in Sao Paulo.....	116
Figure 6.15	SAN-based textures and shape features in Hong Kong	117
Figure 6.16	SAN-based textures and shape features in Sao Paulo.....	118
Figure 6.17	GLCM-based textures of TerraSAR-X images in Hong Kong	120
Figure 6.18	GLCM-based textures of TerraSAR-X images in Sao Paulo.....	121
Figure 6.19	LULC classification results in Hong Kong	123
Figure 6.20	LULC classification results in Sao Paulo.	124
Figure 6.21	ISE by combining LULC subtypes in Hong Kong	126
Figure 6.22	ISE results in Sao Paulo.....	127
Figure 7.1	Impacts of different numbers of variables (or features) in each decision tree	138
Figure 7.2	Impacts of different numbers of trees in the RF.....	140



List of Tables

Table 3.1 Definition of the Land Covers Used in This Study 45

Table 4.1 Landsat Images for Four Study Sites..... 57

Table 4.2 Accuracy Assessment of the Classification Results by ANN 60

Table 4.3 Accuracy Assessment of the Classification Results by SVM..... 61

Table 4.4 Accuracy Assessment of the Classification Results by LSMA..... 62

Table 4.5 Accuracy Assessment of the Classification Results in
Mumbai by ANN..... 63

Table 4.6 Accuracy Assessment of the Classification Results in
Mumbai by SVM..... 65

Table 4.7 Accuracy Assessment of the Classification Results in
Mumbai by LSMA 66

Table 4.8 Accuracy Assessment of the Classification Results in Sao
Paulo by ANN 67

Table 4.9 Accuracy Assessment of the Classification Results in Sao
Paulo by SVM 69

Table 4.10 Accuracy Assessment of the Classification Results in Sao
Paulo by LSMA..... 70

Table 4.11 Accuracy Assessment of the Classification Results in
Cape Town by ANN 71

Table 4.12 Accuracy Assessment of the Classification Results in
Cape Town by ANN 72

Table 4.13 Accuracy Assessment of the Classification Results in
Cape Town by LSMA..... 74

Table 5.1 Confusion Matrix of ISE in Guangzhou Using ANN..... 81

Table 5.2 Confusion Matrix of ISE in Guangzhou Using SVM..... 81

Table 5.3 Confusion Matrix of ISE in Mumbai Using ANN 83

Table 5.4 Confusion Matrix of ISE in Mumbai Using SVM..... 83

Table 5.5 Confusion Matrix of ISE in Sao Paulo Using ANN 84

Table 5.6 Confusion Matrix of ISE in Sao Paulo Using SVM 85

Table 5.7	Confusion Matrix of ISE in Cape Town Using ANN.....	86
Table 5.8	Confusion Matrix of ISE in Cape Town Using SVM	87
Table 6.1	Datasets of Four Cities for Comparing Optical and SAR Images.....	90
Table 6.2	Impervious Surface Estimation in Guangzhou.....	94
Table 6.3	Accuracy Assessment of Impervious Surface Estimation in Mumbai.....	96
Table 6.4	Accuracy Assessment of Impervious Surface Estimation in Sao Paulo.....	98
Table 6.5	Accuracy Assessment of Impervious Surface Estimation in Cape Town.....	100
Table 6.6	Datasets of Four Cities for Comparing Different Fusion Levels	102
Table 6.7	Fusion Strategies of Three Different Levels	103
Table 6.8	Comparison of Accuracy Assessment in Shenzhen	109
Table 6.9	Comparison of Accuracy Assessment in Mumbai.....	109
Table 6.10	Comparison of Accuracy Assessment in Sao Paulo.....	109
Table 6.11	Comparison of Accuracy Assessment in Cape Town.....	110
Table 6.12	Datasets of Two Cities for Comparing Different Features	112
Table 6.13	Selection of Feature Measures of Optical and SAR Images	112
Table 6.14	Design of Combinational-Level Fusion	113
Table 6.15	Accuracy Assessment of Different Combinations of Datasets and Features	125
Table 6.16	Accuracy Assessment of Different Combinations of Dataset and Features.....	128
Table 7.1	Datasets of the First Group for Optimization Investigation of the RF Algorithm	133
Table 7.2	Datasets of the Second Group for ISE Using Optimized RF.....	133
Table 7.3	Coregistration Design between Optical and SAR Images	134
Table 7.4	Number of Bands and Features for the First Group of Datasets.....	135
Table 7.5	Number of Features for the Second Group of Datasets.....	135

Table 7.6 Parameter Settings for the Number of Features (m) and Decision Trees (T)..... 141

Table 7.7 Confusion Matrices for Urban Land Cover Classification (ASAR)..... 142

Table 7.8 Confusion Matrices for Urban Land Cover Classification (TSX)..... 143

Table 7.9 Confusion Matrices for Impervious Surface Mapping..... 145

Preface

Remote Sensing for Urbanization in Tropical and Subtropical Regions—Why and What Matters?

The twenty-first century is the first “urban century” according to the United Nations Development Program. Although urbanized land currently covers only approximately 2% of global land area, more than half of the world’s population live in the urban environment. By 2030, urbanized areas will expand to provide homes for 81% of the world’s population, with the majority of the population increase coming from developing countries. Thus, there is a rapidly growing need for technologies that will allow for the monitoring of the world’s urban assets and management of the exposure to natural and man-made risks. This need is further driven by increased concern over global climate change. Geographically, most developed countries are located in temperate regions, whereas developing countries are located in the tropical and subtropical regions. The continued urbanization in the tropical and subtropical regions has an important implication in biodiversity, the well-being of tropical rainforest ecosystem, and global climate change.

A characteristic change associated with urbanization is the expansion of impervious surface. Satellite remote sensing provides the only viable option to detect and monitor impervious surface from space in an efficient, affordable, and timely manner. Numerous previous studies have utilized satellite imagery of different spatial resolutions to estimate and map impervious surface (Weng 2012). The nightlight derived from the DMSP OLS and MODIS land cover products was used to produce the global urban dataset at 1 km resolution (Elvidge et al. 1997; Imhoff et al. 1997; Friedl et al. 2002; Schneider et al. 2003; Zhou et al. 2014). Global urban maps at coarse resolution can cover large areas and also be updated frequently. However, due to the complexity of urban landscapes and inherent resolution of human activities, coarse-resolution global urban maps are difficult to use for many applications at local to regional scales (Small 2003). Medium-resolution satellite imagery possesses unique advantages in mapping urban areas more accurately. Sensors on board the Landsat series of satellites have been providing Earth observation data continuously since the early 1970s (Townshend et al. 1991; Loveland and Shaw 1996), which have been applied in numerous urbanization studies at the local, regional, and continental scales (Seto et al. 2002; Jantz et al. 2005; Schneider et al. 2005). As part of the National Land Cover

Dataset, impervious surface maps were produced for the United States from Landsat data for 2006 and 2011 (Xian et al. 2011). However, the majority of previous urban land cover and land use studies tended to focus on a single image at one time (Schneider et al. 2003). Applications using Landsat data are surging due to the availability of free Landsat data from the US Geological Survey since 2008 (Woodcock et al. 2008). New methods and techniques are being developed to utilize abundant medium-resolution images and produce consistent maps for monitoring urban expansion (Sexton et al. 2013; Zhu and Woodcock 2014). The Landsat time-series data will also allow for more detailed studies to determine the impacts of urbanization on energy, water, carbon cycles, vegetation phenology, and surface climate (Weng and Fu 2014).

Continuity of medium-resolution data is critical for monitoring land use and land cover changes worldwide. However, the failure of the Scan-Line Corrector on board the Landsat 7 satellite in 2003 caused a loss of 25% of the data toward the edges of each image; Landsat 5 suspended operations in November 2011. Although Landsat-8 OLI data was available after 2013, maintaining the continuity of Landsat-like data is precarious. This situation highlights the need to combine the capabilities of existing and future international sensors to provide a more robust observational record (Weng et al. 2014). When considering international satellite missions such as Sentinel, CBERS-2, and IRS, the rich source of medium-resolution remotely sensed data suggests that we may now move urban mapping from the local and regional, to the global scale. Despite the great potential for the combined use of existing and future medium-resolution imagery, many issues deserve to be studied further, including cross-sensor comparison and normalization (Schroeder et al. 2006; Wulder et al. 2008), multisensor fusion (Gao et al. 2006; Weng et al. 2014), and utilization of full suite of Landsat-like data for any location and date (Powell et al. 2007; Gao et al. 2012). Significant challenges remain for mapping urbanization over large areas, in terms of validation and systematically processing data from multiple times, various sources/instruments, and different seasons (Gao et al. 2012).

In the tropical and subtropical regions, remote sensing of urban environment faces more challenges than in the temperate zones due to all-year-round cloudy and rainy climate conditions, complex hydrological systems that often display a strong seasonal change in water surface area, and vegetation phenology and morphological and species complexity. Optical data frequently show their weakness in remote sensing in the tropical and subtropical regions, which prompts researchers to use different sources of imagery from microwave remote sensing. Synthetic aperture radar (SAR), for instance, was widely employed previously to provide complementary information to optical imagery because it works on all-weather conditions, free from the influence of clouds and rains. Previous studies show that SAR is very sensitive to ground surface roughness, shape, structure, and dielectric properties of illuminated ground targets (Henderson and Xia 1997).