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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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Contents

List of Figures

List of Tables

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).