Remote Sensing of Environment xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Detecting change in urban areas at continental scales with MODIS data

C.M. Mertes [a,b,*], A. Schneider [a,b], D. Sulla-Menashe [c], A.J. Tatem [d,e], B. Tan [f]

[a] Center for Sustainability and the Global Environment, Nelson Institute for Environmental Studies, Madison, WI, USA
[b] Department of Geography, University of Wisconsin–Madison, Madison, WI 53726, USA
[c] Department of Earth and Environment, Boston University, 685 Massachusetts Avenue, Boston, MA 02215, USA
[d] Department of Geography and Environment, University of Southampton, Highfield, Southampton SO17 1BJ, UK
[e] Fogarty International Center, National Institutes of Health, Bethesda, MD 20892, USA
[f] NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

ARTICLE INFO

Article history:
Received 24 May 2014
Received in revised form 29 August 2014
Accepted 8 September 2014
Available online xxxx

Keywords:
Urban areas
Urbanization
Cities
Land cover
Change detection
Classification
Machine learning
Decision trees
Data fusion
Decision fusion

ABSTRACT

Urbanization is one of the most important components of global environmental change, yet most of what we know about urban areas is at the local scale. Remote sensing of urban expansion across large areas provides information on the spatial and temporal patterns of growth that are essential for understanding differences in socioeconomic and political factors that spur different forms of development, as well the social, environmental, and climatic impacts that result. However, mapping urban expansion globally is challenging: urban areas have a small footprint compared to other land cover types, their features are small, they are heterogeneous in both material composition and configuration, and the form and rates of new development are often highly variable across locations. Here we demonstrate a methodology for monitoring urban land expansion at continental to global scales using Moderate Resolution Imaging Spectroradiometer (MODIS) data. The new method focuses on resolving the spectral and temporal ambiguities between urban/non-urban land and stable/changed areas by: (1) spatially constraining the study extent to known locations of urban land; (2) integrating multi-temporal data from multiple satellite data sources to classify c. 2010 urban extent; and (3) mapping newly built areas (2000–2010) within the 2010 urban land extent using a multi-temporal composite change detection approach based on MODIS 250 m annual maximum enhanced vegetation index (EVI). We test the method in 15 countries in East–Southeast Asia experiencing different rates and manifestations of urban expansion. A two-tiered accuracy assessment shows that the approach characterizes urban change across a variety of socioeconomic/political and ecological/climatic conditions with good accuracy (70–91% overall accuracy by country, 69–89% by biome). The 250 m EVI data not only improve the classification results, but are capable of distinguishing between change and no-change areas in urban areas. Over 80% of the error in the change detection can be related to definitional issues or error propagation, rather than algorithm error. As such, these methods hold great potential for routine monitoring of urban change, as well as for providing a consistent and up-to-date dataset on urban extent and expansion for a rapidly evolving region.

1. Introduction

The demographic transformation toward an urban world has pushed urbanization – population growth as well as the expansion of built-up areas – to the forefront of environmental and development agendas. The consequences of urbanization are largely contingent on the size, location, and configuration of development (Weng, 2001; Zhou et al., 2004), with many environmental impacts exacerbated when new growth is expansive and/or fragmented in form (Alberti, 2005). A meta-analysis of urban expansion indicates that local- to regional-scale studies are geographically biased, leaving even many large cities unstudied (Seto, Fragkias, Güneralp, & Reilly, 2011). Detailed maps on regional- to global-scale changes in urban land do not exist. Previous efforts have been sample-based (Angel et al., 2005; Schneider & Woodcock, 2008; Taubenböck, Esch, Felbier, Wiesner, & Roth, 2012), have focused on one country (Homer, Huang, Yang, Wylie, & Coan, 2004; Wang et al., 2012), or have drawn conclusions from datasets with substantial temporal and spatial mismatch or variability in how cities are defined (Seto, Sanchez-Rodriguez, & Fragkias, 2010). Routine monitoring of urban expansion across large areas could therefore provide the spatial information on patterns of urban growth that are essential for understanding differences in socio-economic and political factors that spur different forms of development, as well the social and environmental impacts that result (World Bank, 2014).

Several global maps of c. 2000 urban areas have been produced in the past decade (Bhaduri, Bright, Coleman, & Dobson, 2002; CIESIN,

* Corresponding author.
E-mail address: cmertes@wisc.edu (C.M. Mertes).

http://dx.doi.org/10.1016/j.rse.2014.09.023
0034-4257/

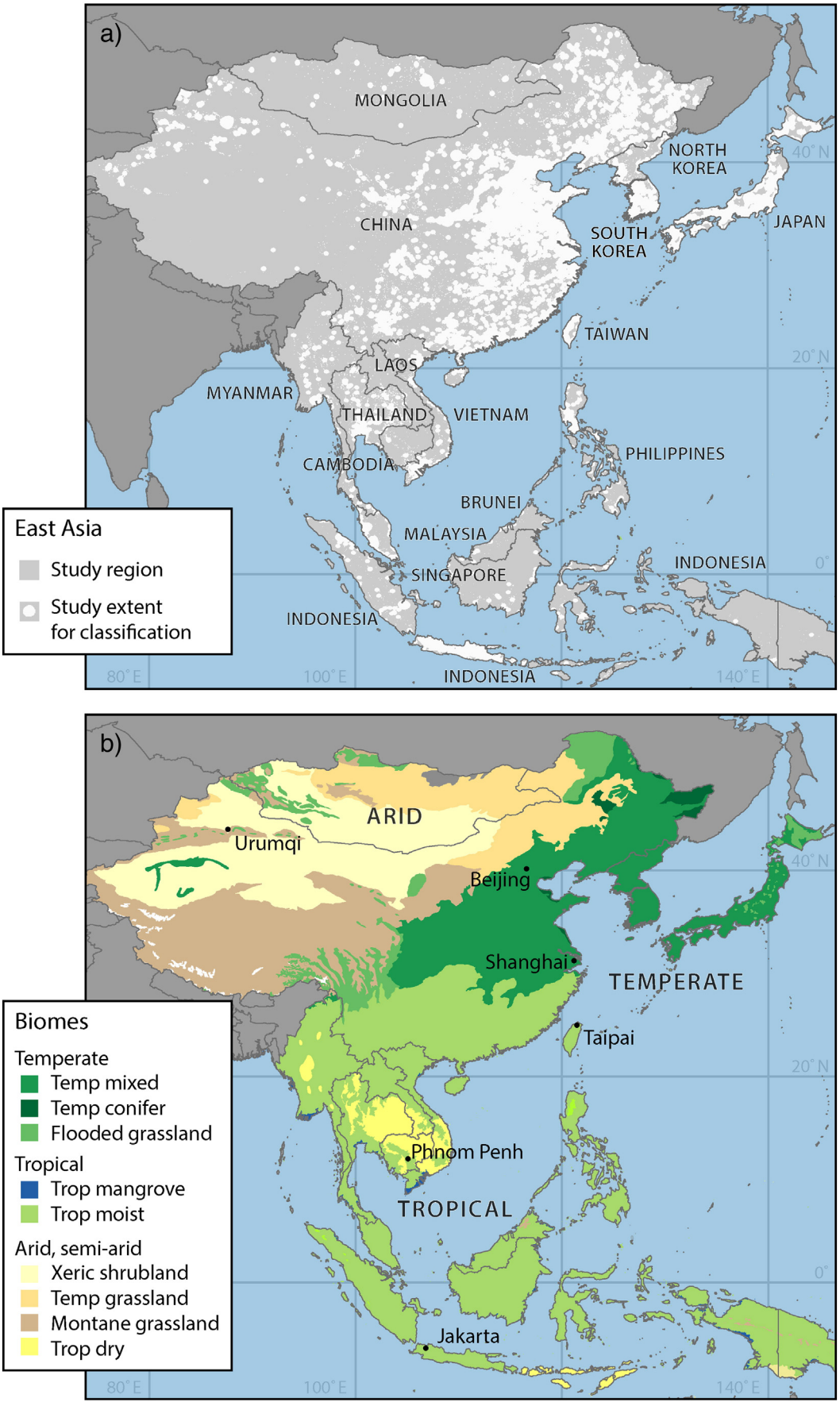

Fig. 1. Maps of the East Asia region illustrating (a) the study area extent defined by known locations of urban land, and (b) Olson's biome designation, used to delineate areas of similar ecoclimatic characteristics for data processing.

Please cite this article as: Mertes, C.M., et al., Detecting change in urban areas at continental scales with MODIS data, *Remote Sensing of Environment* (2014), http://dx.doi.org/10.1016/j.rse.2014.09.023