PROGRESS REPORT

SYNTHESIS OF LCLUC STUDIES ON URBANIZATION: STATE OF THE ART, GAPS IN KNOWLEDGE, AND NEW DIRECTIONS FOR REMOTE SENSING

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1. Introduction

The overarching objective of this project is to assess the patterns, drivers, and outcomes of global urban LCLUC by synthesizing existing remote sensing research on urban LCLUC. The project has five primary components:

1) To identify the existing and available remotely sensed datasets and analyses on urban LCLUC;
2) To identify the available change detection algorithms to characterize urban LCLUC and to assess if a best practices guide for which change detection algorithms to apply across different geographies, conditions, and applications is possible;
3) To identify the spatial patterns of urban LCLUC and to explain how they vary across place, time, and economic development levels;
4) To determine the socioeconomic and policy drivers of urban LCLUC across different world regions, stages of economic development, and land use trajectories;
5) To examine and explain the effects of urban LCLUC on other land uses and land covers.

During the 12-month period covered in this progress report, we have made considerable process on objectives 1, 2 and 3 of the project. Our primary research activities for each of these components during this period are described below.

2. Research Activities

2.1. Identifying the existing and available remotely sensed datasets and analyses on urban LCLUC

Task 1 of the project entails conducting a detailed literature review on urban LCLUC studies that use remotely sensed imagery, extracting the relevant information from the papers identified during the literature review, and organization of this information - including developing the GIS dataset for urban land change analysis.

Since the start of the project, we have developed a Zotero (bibliographic) database of 181 published peer-reviewed research articles on urban land use change, together with their associated pdf files.

In addition, we are continuing with the literature search, reading and evaluating the identified research articles, extracting key information from these papers, entering the information into Excel files, and organizing them in Endnote and Zotero databases.

The literature review of the following regions have been completed: India, Southwest Asia, Northern Africa, Central Africa, Southern Africa, North America, Central America, and South America. We have so far identified 27 papers from India, 17 from Southwest

Asia (excluding Turkey), 30 from Africa, and 23 from America. The literature review of China is ongoing. These regions broadly follow the UN geographical sub-region definitions.

Most of our efforts in this area has been focused on identifying the relevant research articles out of a large number of papers returned by the literature searches. Extracting the relevant information from each paper and entering this data into the excel sheet are the most time-intensive components. We also quality check all the records that have been created.

2.2. Identifying the available change detection algorithms to characterize urban LCLUC and to assess if a best practices guide to determine which change detection algorithms to apply across different geographies, conditions, and applications is possible

This task is divided into 2 parts:
1) Identifying the available change detection algorithms to characterize urban LCLUC
2) Assessing if a best practices guide for which change detection algorithms to apply across different geographies, conditions, and applications is possible.

Part 1 of Task 2 also involves conducting a detailed literature review on urban remote sensing change detection studies, extracting relevant information from the papers identified during the literature review, and organizing and synthesizing this information. We have made considerable progress on this aspect of the project.

Current Database Summary Statistics
Final database results continue being refined. To date, 163 peer-reviewed journal articles have been identified and being reviewed for their inclusion in the final database, representing 67 unique journals, conference papers, and book chapters, spanning the years 1981 to 2016. *Remote Sensing of Environment, Photogrammetric Engineering and Remote Sensing, and International Journal of Remote Sensing* are most heavily represented journals in the database, providing 17, 16, and 14 papers, respectively.

Urban expansion and binary urban change/no change are the most frequently measured types of change in the database, followed by building height, urban vegetation, building materials, road networks/connectivity, and changes in urban morphology/spatial patterns. Final types of land change categories are being refined. Studies reporting "from-to" change classes are being compiled, as are papers which explicitly compare multiple methods of change detection and report resulting accuracy information.

Figure 1 depicts the geographical distribution of study sites, while **Figure 2** highlights the frequencies of study sites per country. Forty-two unique countries are represented in the database with China and the USA as the most often studied locations. Twenty-five countries report only one study each.

Figure 1: Spatial distribution of study locations. Multiple studies occur at some city locations.
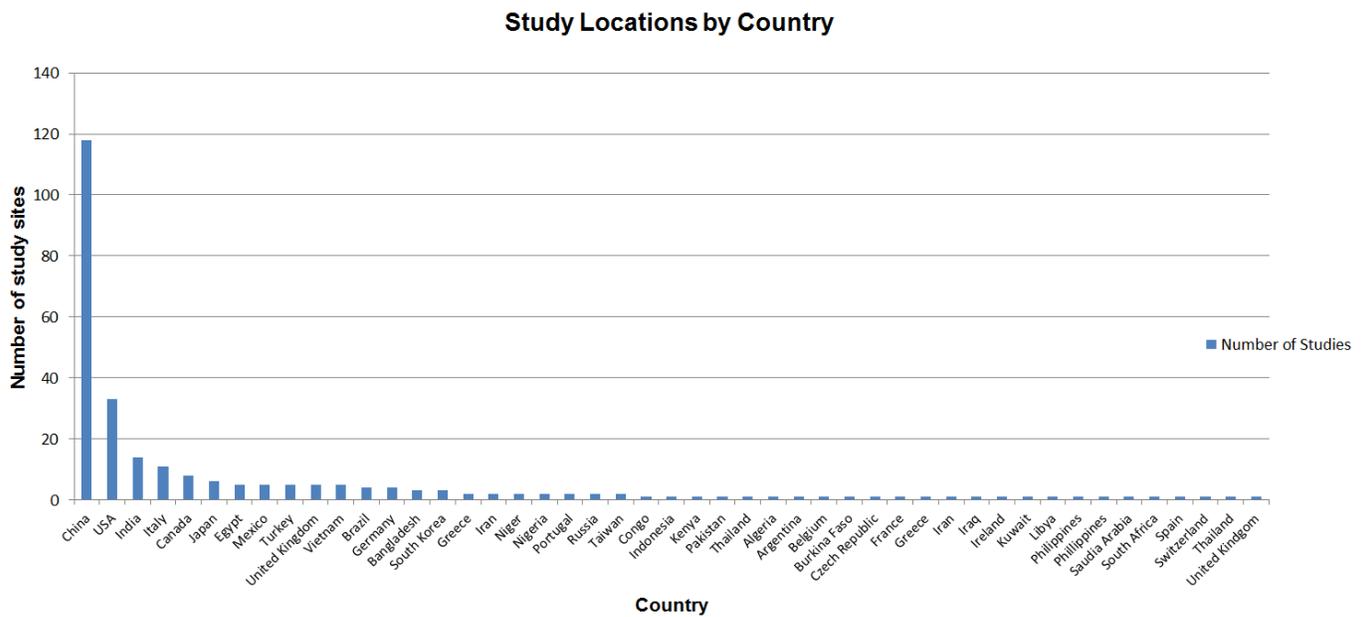

Figure 2: Frequencies of study site locations by country.

Imagery used to measure urban change in the database studies spans a wide range of resolutions from global studies using MODIS imagery to VHR SAR (Very High Resolution, Synthetic Aperture Radar) imagery, with the 114 studies using Landsat imagery of some form.

The results of Task 2, Part 2 will become a stand-alone manuscript that will be submitted for publication in a peer review journal. Part 2 of Task 2 involves synthesizing the results of Part 1 to determine if a best practices guide is possible. We have begun this synthesis process to determine which algorithms detect, monitor, and characterize urban change. Our aim is to provide a 'roadmap' for which algorithms to use where and under what conditions. We are currently working to summarize the advances in urban algorithm development and categorizing the methods based on:

a) geography
b) types of urban change (expansion, building height, binary change, etc.)
c) degrees of success

Current questions we are considering when synthesizing the results of Part 2, Task 2 include:
1. Are there simple, easy to use algorithms which seem to work in many different environments and geographies?
2. What algorithms work in only some geographies or landscapes?
3. Are there some urban changes that are important for policy and science that are not being monitored by remote sensing algorithms, offering new research opportunities?
4. What is the most common type of urban change being detected?
5. Can we develop a table of geographies and LCLUC and the types of algorithms being used?
6. Is there a significant difference in the accuracies of these algorithms?
7. Do some work better than others, or is there no systematic comparison of algorithms?
8. Where in the world are these algorithms being applied?

2.3 Identifying the spatial patterns of urban LCLUC and to explain how they vary across place, time, and economic development levels
Literature Review Synthesis

The literature review synthesis is being compiled to become a stand-alone manuscript that will be submitted for publication in a peer review journal. The focus is on synthesizing research related to land use and land cover pattern and pattern analysis of areal features. The primary objective is to identify which techniques (or lack of them) are researchers using to analyze the pattern (and change) of land cover pattern. The second focus is on broadening the search beyond landuse/cover to evaluate whether other pattern methods exist.

To date, 32 journal articles have been reviewed for their inclusion in the final review with an additional 13 anticipated for inclusion but not yet reviewed. Reviewed articles

represent 25 different journals, and 89 unique authors, while non-peer reviewed articles add six journals and 30 more authors. Search terms included "land use pattern", "land cover pattern", "area pattern analysis", "urban land pattern", and "urban land change". Future literature searches will focus on area pattern outside of landscape contexts and consideration of the citation index for the articles herein.

The anticipated outline for the literature review is as follows:
1. Introduction
    a. Importance of examining LULC pattern and change
    b. Problems/barriers in urban LULC pattern/change detection
2. Background
    a. Typical data types/sets
    b. Broad pattern categories
        i. Patch, Class, Landscape level landscape metrics
            1. Shape metrics
            2. Size functions
            3. Density
            4. Spatial heterogeneity (fragmentation, complexity)
            5. Fractal geometry/dimension
        ii. Spatial Autocorrelation indices
            1. Moran's I
            2. Getis
            3. LISA
    c. Broad change approaches
        i. Post-classification comparison
            1. Mapping spectral change
            2. Markov change
            3. Dynamic degree models
        ii. Regression
3. Factors to consider in developing/selecting urban modeling approaches
    a. Spatial scale and multiscale dependence in data and analysis
    b. Temporal scale, effects, and lag
    c. Neighborhood effects (growth)
    d. Quantifiable results
    e. Location and time placed results
4. Conclusions

3. Planned conferences supported by this project

ASU Workshop Planning

The first of the two multi-day workshops will be held in late September or early October 2016, at Arizona State University in Tempe Arizona. The focus of the workshop will be

one of the five research questions of this project, the focus of the workshop will be finalized this month. The location of the workshop meetings and hotel rooms is also being finalized, the workshop will be held on campus, the attendees will stay at a hotel adjacent to campus. A webpage for the workshop is being created and will be posted via a link on the Arizona State University School of Geographical Sciences and Urban Planning website. An itinerary for the workshop will be finalized in March. Invitations will be sent out to the 12-15 desired participants in February, the invitees will be researchers and scientists who use NASA data products and whose work focuses on the drivers of urban LCLUC.