

# The Urban Transition in Ghana and Its Relation to Land Cover and Land Use Change Through Analysis of Multi-scale and Multi-temporal Satellite Image Data Year 2 Progress Report

Principal Investigator: Douglas A. Stow

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Recipient's Institution: San Diego State University, 5500 Campanile Drive, San Diego, CA 92182-4493

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## Introduction

The objectives of this project are: (1) to identify, map, and quantify land cover and land use change (LCLUC) within an extensive study area of Ghana over 25 years (1986 through 2010), (2) to understand the relationship between rural-to-urban migration as an outcome of LCLUC and concomitant drivers for the 2000 through 2010 period, and (3) to assess LCLUC and its effect on demographic and quality of life factors for four major Ghanaian urban centers during this time period. To meet the project objectives, we are mapping and quantifying LCLUC at two spatial scales: (1) inter-regional scale for the Greater Accra, Central, Ashanti and Eastern (recently added) regions of southern and central Ghana, and (2) intra-urban scale for Accra, Kumasi, Cape Coast and Obuasi, the four major cities within the study area. LCLUC and its impacts on demographic and socio-economic dimensions of the target populations are being analyzed across four regions (states) in Ghana. Quantitative spatial analysis techniques are being utilized to examine relationships between LCLUC and magnitudes and changes of demographic, socioeconomic, and health variables. In addition, we are examining the effects of LCLUC on quality of life indicators such as child mortality, migration, slum indices, and food security, within four of the major cities of Ghana. Here we report progress over the past 12 months, which primarily pertains to the generation of LCLU maps at the two spatial scales of analysis.

## Inter-regional Mapping of LCLUC

For the majority of inter-regional mapping of LCLUC between 2000-2010 the team is exploiting high temporal resolution Landsat 7 ETM+ imagery that has been converted to spectral reflectance values using the LEDAPS process. High temporal resolution has been critical due to the high percentage of cloud cover that regularly blankets the southern Ghana study area. We are creating multitemporal composite images (such as maximum NDVI and maximum local spatial texture) to create c. 2000 and c.2010 LCLU products (urban, agriculture, forest and other natural land cover classes). Composites are created using approximately 20-30 images with relatively low cloud cover (e.g., 33%). The “fmask” product that is provided with the LEDAPS imagery is being utilized to mask cloud, cloud shadow, and water prior to compositing. Urban extents derived from ERS-2 radar imagery are also being incorporated into the mapping. Example land cover/land use products are shown in Figure 1 for Greater Accra and surrounding areas. Several innovative processing techniques were developed and employed for handling significant data gaps associated with cloud, cloud shadow, and SLC-off conditions. In addition, products characterizing within-image spectral variability are used to enhance Ghanaian agriculture fields that are present in the imagery but not easily identified using visual or traditional computer-assisted techniques. Inter-regional LCLUC mapping will be completed this summer. Proportions of these LCLU classes and their changes between 2000 and 2010 are summarized at the region, district and neighborhood levels for substantial statistical analyses with demographic and health variables.

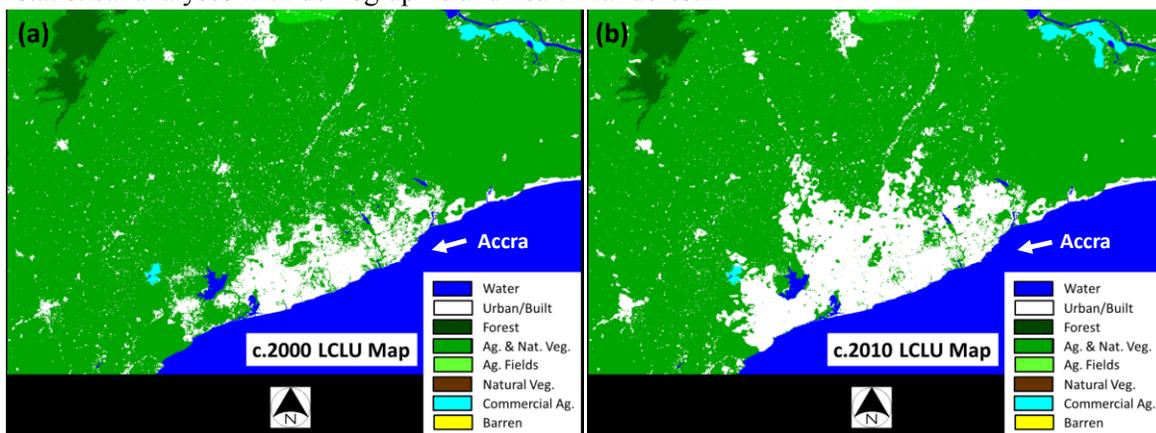


Figure 1. Land cover and land use (LCLU) maps for Greater Accra region for c.2000 (a) and c.2010 (b).

Our team is testing a pixel-based, discrete data post-classification comparison approach for identifying with greater temporal precision when LCLUC occurs, when utilizing a noisy time stack of Landsat TM/ETM+/OLI data. Because the study area is prone to cloud cover (with associated shadows when cloud cover is patchy), smoke, haze and dust transported by Harmattan winds, along with Landsat 7 ETM+ scan line corrector off (SLC-off) effects since May 2003, a noisy and patchy image time sequence results. Our hypothesis is that a post-classification comparison approach is more effective at capturing LCLUC associated primarily with urbanization and with greater temporal precision, than a simultaneous classification of a continuous data time sequence. An approach based on supervised classification using stable training features, with subsequent spatial and temporal filtering and post-classification comparison has been tested. We are evaluating the reliability and temporal precision in identifying LCLUC based on known LCLUC areas.

### Intra-urban Mapping of LCLUC

High spatial resolution (Hres) commercial satellite imagery for most of Ghana was acquired through the NGA Commercial Archive Data access portal, as part of the NextView licensing agreement. In addition, we purchased several image sets for Accra, Kumasi, Obuasi, and Cape Coast from commercial sources. Team members at George Washington University (GWU) have pre-processed the large number of Hres images sets obtained to date. Team members from San Diego State University (SDSU) and GWU are analyzing the Hres images sets and mapping LCLUC for the four cities and surrounding areas. SDSU is using object-based image analysis to map LCLUC for c.2000 and c.2010 periods with QuickBird and IKONOS imagery, and Landsat when no Hres imagery is available for the c.2000 period. LCLU classes include: urban residential, urban non-residential, undeveloped vegetated, undeveloped non-vegetated, and urban agriculture. SDSU researchers are also exploring the utility of relatively dense stacks of high spatial resolution commercial satellite data in support of LCLUC mapping within Ghanaian cities. A LCLUC map based on post-classification comparison approaches using a bi-temporal (2002-2010) QuickBird multispectral data set was compared to a LCLUC map derived with a multi-temporal QuickBird set that also included three additional images from 2007-2009. These additional images, made available through the NASA-NGA NextView program, proved to be useful in minimizing false change identifications associated with phenological differences in the 2002 and 2010 images. More extensive validation analyses have been initiated and a journal manuscript is under development.

GWU team members are examining if pervious and built surfaces derived from Hres imagery are spatially associated with quality of life indicators within Ghanaian cities. Quickbird-2 imagery from 2002 and 2010 has been analyzed with decision tree methodology. Over 200 combinations of spectral band inputs, image derived variables (spectral vegetation indices, texture measures etc.) and spatial resolutions were examined. The highest overall accuracies were found with images spatially aggregated to 5 m and when using 12 input bands. Outputs from the image analysis are highly correlated with housing density, population density, cooking fuel type, no sewage, and informal sector workers. Example products are provided in Figure 2. A journal manuscript is under development.

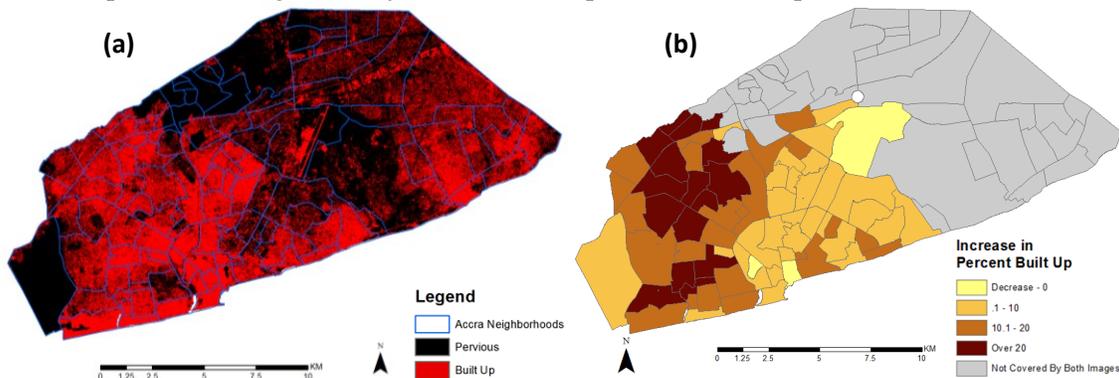


Figure 2. Analysis of Intra-urban LCLUC for the Accra Metropolitan Area (AMA). An example c.2010 map of pervious vs. built up land cover is provided (a), as well as a change map created by comparing c.2000 and c.2010 built up (b).

### Reference and GIS Data Generation

University of Ghana collaborators facilitated acquisition of ground-level, geo-tagged digital photography in support of calibration and validation of satellite-image classification and change analyses. An emphasis was placed on recent or under construction built land use in urban and peri-urban areas of the cities of Accra, Cape Coast, Kumasi and Obusai. Natural vegetation and agricultural areas were also photographed. While photographing in the savanna portions of the Eastern region, commercial agricultural owners and agronomist were interviewed to assist in our studies of conversion

from subsistence to commercial agriculture. The University of Ghana collaborators also have provided important GIS data layers and Foster Mensah (Director of Center for Remote Sensing and GIS) visited SDSU to aid in development of classification schemes and training data sites, and was trained in the use of advanced image classification software.

**Analysis of Drivers of and Impacts on LCLUC in Relation to Demography and Health**

Our team’s analysis of migration between districts based on the 2000 census shows that the highest rates of out-migration are from areas with the highest levels of natural vegetation and agriculture. Some of this is due to the higher rate of natural population increase in rural areas, and some is almost certainly due to the increasing mechanization of agriculture, which changes how the land is used. We are currently analyzing the image-derived LCLU data in combination with 2010 census data and the Ghana Living Standards Survey to decompose the migration patterns into their likely environmental determinants. Migration data also tell us that migrants out of rural areas are moving disproportionately to peri-urban areas of the largest cities, especially Accra and Kumasi. The data thus far suggest a non-linear process in which migrants to these areas alter the land cover by converting natural vegetation into a built environment, and the resulting LCLUC is then associated with subsequent in-migration, continuing the interaction between LCLUC and population change.

Magdalena Benza completed her doctoral dissertation that supports this project. She utilized Landsat spectral imagery and ERS-2 radar imagery to classify vegetation and built land cover classes. From those products, measures of landscape fragmentation were combined to create an urban context definition using a gradient approach (Figure 3). Census data were used to estimate fertility levels and household structure, and the association between urban context, household composition and fertility levels was modeled through OLS regression, spatial autoregressive models and geographically weighted regression. Results indicate that there are significant differences in fertility levels between different urban contexts, with below average fertility levels found in the most urbanized end of the urban context definition and above average fertility levels found on the opposite end. Additional findings indicate further important relationships between land cover patterns and characteristics of family organization and reproduction decisions.

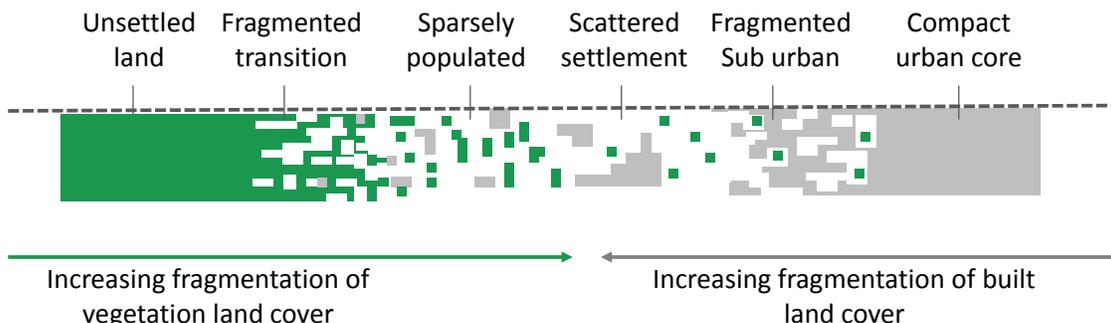


Figure 3: Pattern based urban context definition

**Outcomes and Next Steps**

LCLUC mapping and change analyses will conclude by the end of Fall 2014 and the project is entering a phase that will be focused on analysis of migration-related drivers on LCLUC and the impacts of LCLUC on demography and health in Ghanaian cities. Changes in health and demographic variables at the district level from the Ghana Census, WHS and DHS data sets are underway, with more detailed demographic analyses within cities being conducted as soon as 2010 Ghana census data at the enumeration area level are released to our team. Literature reviews on land consolidation and conversion from subsistence to commercial agriculture will be completed in summer 2014, with survey research and image-based analyses on amount of commercial agricultural expansion to commence shortly after.

A list of manuscripts that have been accepted (one) or are in advanced stages of preparation (eight) is included in the supplementary materials section that follows. Also included is a list of completed (one) and in-progress (two) doctoral dissertations, and master’s theses completed (one) and in-progress (two). In total one post-doctoral fellow, four doctoral, five master’s and one undergraduate student have contributed to this project.

The project continues to maintain a project web page ([http://geography.sdsu.edu/NASA\\_IDS/research/ids.html](http://geography.sdsu.edu/NASA_IDS/research/ids.html)) as well as imagery and GIS databases for ongoing analyses. Our team will soon be contributing completed, non-proprietary land cover, value-added imagery, and terrain data sets to the NASA Earth Exchange (NEX).

## SUPPLEMENTARY MATERIALS:

### **Doctoral Dissertations, Master's Theses, Papers and Students Associated with NASA IDS Project**

#### Doctoral Dissertations

- Benza-Fiocco, Magdalena (SDSU/UCSB) Degree of Urbanization and Population Dynamics: A Case Study in Sub-Saharan Africa Utilizing Remotely Sensed Imagery, John Weeks, Adviser, completed February 2014.
- Mensah, Foster (U. Ghana) Detailed Land Cover and Land Use Change Assessment of Accra, Ghana, 2000 – 2010, in progress.
- Toure, Sory (SDSU/UCSB) Urban Land Use and Land Cover Change in Ghana: Connections to Demography, Health and Wealth, Doug Stow, Adviser, in progress.

#### Master's Theses

- Sandborn, Avery (GWU), Quantifying Spatial Features of Built-Up Areas and Their Relationship to Quality of Life Indicators in Accra, Ghana, in progress.
- Shih, Hsiao-Chien (SDSU), Identification of land cover and land use change based on discrete analyses of dense Landsat time series and spatial and temporal filtering, in progress.
- Vejraska, Milo (SDSU) Image Metrics As Indicators of Socioeconomic and Demographic Characteristics in Slum Neighborhood of Accra, Ghana, John Weeks advisor, completed June 2013.

#### Manuscripts in Preparation

- Benza, M., Weeks, J., Stow, D., López-Carr, D. and Clarke, K. A, in preparation. Pattern based definition of the urban context using remote sensing and GIS: A case study in West Africa, *Remote Sensing of Environment*. In preparation.
- Benza, M., Weeks, J., Stow, D., López-Carr, D. and Clarke, K. In preparation. Comparing a GIS based urban gradient to the census definition of urban spaces in Ghana, *Population, Space and Place*.
- Coulter, L., D. Stow, and N. Ibanez, in preparation. Detection and classification of built land cover in Ghana using Landsat time series image sets, *International Journal of Remote Sensing*.
- Coulter, L., D. Stow, and N. Ibanez, in preparation. Enhancement and classification of agricultural fields within mixed vegetation cover in Ghana, *International Journal of Remote Sensing*.
- Engstrom, R. and A. Sandborn, in preparation. Mapping spatial variability in Health and Wealth Indicators in Accra, Ghana using High Resolution Satellite Imagery. *International Journal of Remote Sensing*.
- Stow, D. H-C, Shih and L. Coulter, in preparation. Discrete Classification Approach to Land Cover and Land Use Change Identification Based on Landsat Image Time Series: Initial Results for a Ghanaian Study Area, *Remote Sensing Letters*.
- Toure, S. and D. Stow, in preparation. Land Cover and Land Use Change Analysis Using Multi-Spatial Resolution Data and Object-Based Image Analysis, *Remote Sensing Letters*.
- Taniguchi, K., D. Stow and S. Toure, in preparation. Potential of high spatial and temporal frequency satellite imagery for refining land cover and land use identifications of urban areas in Ghana, *Remote Sensing Letters*.
- Vejraska, M., J. Weeks and D. Stow, in preparation. Satellite image metrics as indicators of socioeconomic and demographic characteristics in slum neighborhoods of Accra, Ghana, *Photogrammetric Engineering and Remote Sensing*.

#### Conference Papers Presented

- Stow, D., L. Coulter, J. Weeks, M. Benza-Fiocco, S. Toure, and N. Ibanez. The Urban Transition in Ghana and Its Relation to Land Cover and Land Use Change Through Analysis of Multi-scale and Multi-temporal Satellite Image Data, Annual Meeting of the American Society of Photogrammetry and Remote Sensing, Louisville, March, 2014.
- Weeks, J., D.A. Stow, D. Lopez-Carr, R. Engstrom, L. Coulter, S. Toure, N. Ibanez, F. Mensah, and S. Taugher, Environmental Drivers of Internal Migration in Ghana, Annual Meeting of the Association of American Geographers, Miami, April 2014.

Participating Students

*SDSU Doctoral (w/UCSB):*

Magdalena Benza-Fiocco  
Stephen Crook  
Sory Toure  
Cindy Tsai

*SDSU Master's:*

Hsaio-Chien (Ace) Shih  
Sean Taugher  
Milo Vejraska

*SDSU Undergraduate:*

Nicholas Ibanez

*GWU Post-doc:*

Qin Yu

*GWU Master's:*

Avery Sandborn

*U. Ghana Legon Doctoral:*

Foster Mensah