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 1 Progress Report

Principal Investigator: Douglas A. Stow
Period Covered by Report: August 1, 2012 – May 31, 2013
Recipient's Institution: San Diego State University, 5500 Campanile Drive, San Diego, CA 92182-4493
Grant Number#: G00009708, NASA Award Number: NNX12AM87G

Introduction

The official start date was August 1, 2012 and project activities commenced in fall 2012 with many Year 1 activities to be occurring in summer 2013. Much progress has been achieved and the project is on schedule. The objectives of this proposed 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 LCULC 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 working to map and quantifying LCLUC at two spatial scales: (1) inter-regional scale for the Greater Accra, Central, and Ashanti 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. Quantitative analysis tools include generalized linear and multi-level regression models, multinomial logit models, regression tree analysis, and agent-based models.

Inter-regional Mapping of LCLUC

The team conducted detailed searches of Landsat ETM+, ASTER, and SPOT archives to select available imagery for mapping inter-regional LCLUC between circa 2000 and circa 2010. The team has downloaded the best available Landsat ETM+ imagery for four path/row combinations covering the study region. Most of the study region has cloud free imagery available, so the team is currently preprocessing the Landsat imagery in preparation for inter-regional mapping of LCLUC. We performed a preliminary analysis of LCLUC for Kumasi, Ghana using Landsat ETM+ imagery for the period 2001 to 2007. Large areas of vegetation (11% of vegetation mapped in 2001) were replaced by bare ground or built up areas (Figure 1). High spatial resolution imagery is currently being used to better understand the LCLUC changes detected using Landsat ETM+ imagery, and to refine the automated classification of LCLU transitions.

A proposal requesting radar imagery has been submitted to the European Space agency (ESA), so that radar imagery may be used to analyze inter-regional urban growth. Fourteen ERS-2 SAR precision images for circa 2000 and twelve ENVISAT-ASAR precision images for circa 2010 were requested. Preliminary testing of the radar imagery has been conducted with a portion of the study area covering the Greater Accra Region. Three SAR scenes from the year 2000 covering the Greater Accra region were ordered from ESA and evaluated. The pre-processing of the ground range images included removing the antenna pattern, applying a terrain correction using ASTER GDEM and applying radiometric normalization in NEST (ESA) software. A refined Lee filter was selected to reduce coherence speckle while preserving the sharpness and detail of edges. Given the heterogeneity of the built environment measures of spatial variability in backscatter are good indicators for human settlements. Radar texture for detection of built areas has been implemented for the three available scenes using a 9 by 9 moving window and has yielded promising results.

Intra-urban Mapping of LCLUC

High spatial resolution imagery for most of Ghana was acquired through the NGA Commercial Archive Data access portal, as part of the NextView licensing agreement for government owned commercial satellite imagery. Our project was registered with the image acquisition group and we provided them with a shapefile containing our area of interest and the date range for which we needed imagery. We submitted the order in December of 2012 and received all of the hard drives with the imagery in February of 2013. These images were then catalogued to determine the footprint and image dates for each of image. From this we have made an initial determination as to our data gaps and the exact images we will process. We found additional high spatial resolution imagery that was not available from the government archive, and are currently in the process of requesting these image scenes from the commercial archive.

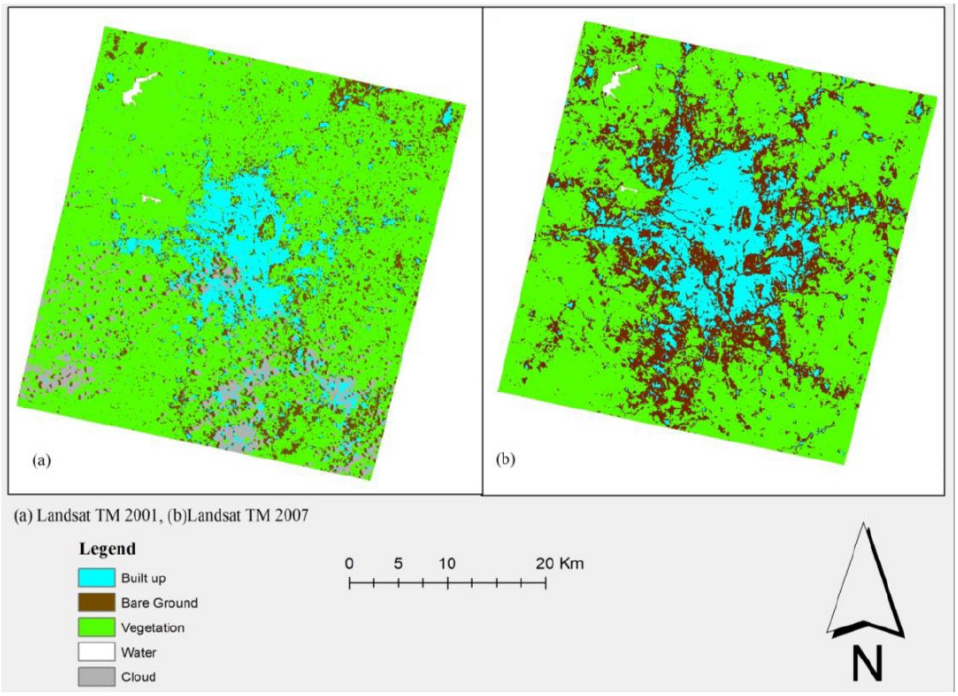

Figure 1. Kumasi, Ghana land cover and land use classifications for (a) 2001 and (b) 2007.

Demographic, Socio-economic and Health Data

With the assistance of researchers at the University of Ghana, Legon, we have acquired and prepared several datasets that include demographic, socioeconomic and health data for all or parts of the study region. We have complete coverage for all enumeration areas (EAs) within the study area of the 2000 Census of Population and Housing, georeferenced to the EA centroid. We also have georeferenced data from the Ghana Demographic and Health Surveys for the years 1993, 1998, 2003, and 2008. Respondents were sampled from EAs for which we have the EA centroid. We have the 2007 World Health Organization's Study on Global Ageing and Adult Health (SAGE) for Ghana. Like the DHS data, these sample data are georeferenced to the EA centroid of the primary sampling units and we have coverage for EAs in the entire study area. We also have data from the 2003 World Health Survey for Ghana. For respondents in this national survey (thus covering the entire study area), we have exact longitude and latitude coordinates for all respondents. For District 1 (Accra Metropolitan Assembly) of the Greater Accra Region, we have data from the 2003 Women's Health Study of Accra linked with the same respondents in the 2008 Women's Health Study of Accra. Respondents are georeferenced to the exact coordinates of their residence. Within Accra we have the 2003 UN Habitat Slum Survey in 37 EAs, for which we have comparable data gathered in 2009 in the Health and Welfare Study of Accra. Data are georeferenced to the EA centroids. Team members from George Washington University have been assisting Ghana Statistical Services with implementing GIS procedures for the geocoding of 2010 Ghana census data, which has been behind schedule for release.

Analysis of Regional-scale Impacts of LCLUC on Migration, Demography, and Health

In Sub-Saharan Africa rapid urban growth combined with rising poverty is creating diverse urban environments inhabited by people with a wide variety of lifestyles. To understand the factors that drive differences in women's reproductive behavior in urban places, we studied how the characteristics of urban landscapes correlate with diverse family settings that drive fertility decline in southern Ghana. The physical characteristics of the urban context were examined through remote sensing techniques and landscape metrics to generate a land cover based definition of an urban gradient. Landsat imagery from 2000 was classified using spectral mixture analysis into built and vegetation patches. Land cover fragmentation was estimated for 10 km by 10 km uniform grid cells, assessing the number of patches per land cover, average patch area, fractal dimension index (a measure of complexity of shape) and largest patch index (a measure of dominance of patches). The resulting 14 measures of fragmentation were combined through principal components analysis into five factors that describe how compact or fragmented the land cover is in the study area (Figure 2). Additional information about the built environment was extracted from radar imagery through the analysis of ERS-2 SAR precision images.

Individual level data from the 2000 census was used to extract variables describing fertility levels and the characteristics of the household and then aggregated to the cell level. Fertility was modeled through ordinary least square

regression and spatial error models using urban context and household composition as explanatory variables of interest while controlling for age, education and parity. Results from independent clusters show that polygamist households have consistently higher fertility throughout the urban gradient whereas households where grand-children of the head reside have higher fertilities in the sub urban fringe and for scattered settlements. Results from combining all clusters show that fertility is significantly lower in the urban core and fragmented urban areas with the lowest reproductive levels found in the most urbanized core urban areas. Results from the spatial autoregressive error model show that there is spatial dependence in the association between fertility, household composition and urban context. A poster summarizing this work was recognized as being one of the top five presented at the Population Association of America 2013 meeting.

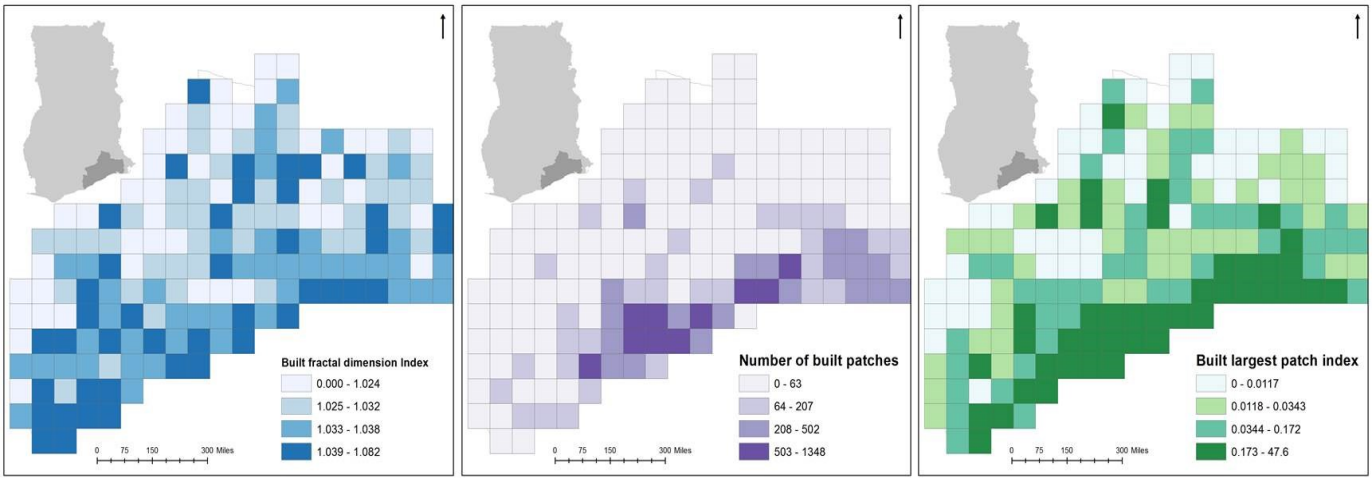

Figure 2. Measuring land cover fragmentation at the 10 km cell level.

Analysis of LCLUC Impacts within Urban Areas

Our team utilized data collected in the 2003 UN-Habitat Accra Slum Survey (Accra SS), a supplement to the 2003 Ghana Demographic and Health Survey (DHS), and the 2009-2010 Housing and Well-being Survey (HAWS) to examine the degree of co-variability between changes in household level survey variables and changes in metrics derived from high spatial resolution satellite imagery through multivariate regression analyses. The main objective was to derive proxy variables of changes in housing and welfare attributes from satellite, census, and health survey data for Accra, Ghana. Fourteen of 19 regression models based on change in census/health and change in satellite-derived variables exhibit power to explain greater than 20% of the variance in the changes in survey variables for the years between 2003-2010. Eleven of 19 multivariate models accounted for > 30% of the variance alone. For example, changes in image metrics were moderately correlated with changes in sewerage variables – more specifically, the proportion of households that primarily utilize Kumasi ventilated pit latrines (KVIPs) and the proportion of households whose disposal of sewerage is through neither a flushing toilet nor a KVIP (informal facilities).

Data Management and Analysis

We have established a geospatial database (geodatabase) to store a large volume of imagery and health datasets so that they are geography organized and topologically consistent. We have compiled numerous datasets, dealing with topological inconsistencies in the best cases and erroneous data in the worst. The central piece to this data collection is the topologically corrected EA boundaries for the city of Accra from the 2000 Census conducted by the Ghana Statistical Service. It features 1723 polygons which have all been rectified to a georeferenced, orthogonally corrected, panchromatic Landsat image. In anticipation of 2010 census data availability, 2010 district boundaries for the Greater Accra Region have also been digitized and included in the geodatabase.

Next Steps

The project team will complete preprocessing of moderate spatial resolution imagery and ordering of high resolution imagery during summer 2013; pre-processing of the latter image data set will commence fall 2013. We expect that our proposal for ERS-2 imagery will be accepted and that imagery will be obtained and preprocessed similarly during summer 2013. Change identification processing and mapping of LCLUC based on moderate spatial resolution will continue throughout most of Year 2, with similar processing and mapping of high resolution image sets commencing in fall 2013. Changes in health and demographic variables from the WHS and DHS data sets will be analyzed during summer 2013, with more extensive demographic analyses being conducted as soon as 2010 Ghana census data are released to our team.