Land cover/land use change analysis using multi-spatial resolution data and object-based image analysis

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Abstract

The purpose of this paper is to develop and test land use and land cover change techniques when only Landsat imagery is available for the first date and high spatial resolution imagery is available for the second. The study site is the city of Accra, the capital and largest city in Ghana, located in Western Africa and characterized by rapid urbanization and land change in recent years. The paper probes two important questions regarding remote sensing derived land cover change analyses in urban environments in the developing world. First, given the classes of interest (residential, non-residential, and undeveloped) in the context of analyzing LCLUC in major urban areas of Ghana, how accurately and reliably can LCLU be identified based on Landsat ETM+ moderate spatial resolution satellite imagery? Secondly, what is the utility of a post-classification change identification approach that is based on an initial object-based classification of a high spatial resolution time 2 image, which is used to constrain the segmentation and subsequent classification of a time 1 moderate spatial

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resolution image? Land use change (LCLUC) analysis with remote sensing requires image datasets of the different periods to be as similar as possible, which includes near anniversary date of capture, similar spatial, spectral, and radiometric resolutions and coverage. However, this is not always feasible due to several factors, including unavailability of high spatial resolution imagery for historical dates and frequent cloud cover. While it is preferable to use high spatial resolution imagery to perform detailed urban land use and land cover change, such imagery for much of the tropics is not readily available for the early 2000s. Results suggest the suitability of using Landsat imagery combined with more contemporary high resolution imagery.

Keywords

Urbanization, Remote sensing, Multi-spatial resolution.

Introduction

Traditionally, performing land cover and land use change (LCLUC) analysis with remote sensing requires image datasets of the different periods to be as similar as possible, which includes near anniversary date of capture, similar spatial, spectral, and radiometric resolutions and coverage. However, this is not always feasible for several reasons. One reason is the unavailability of newer generation, high spatial resolution imagery for historical dates. Moreover, tropical and high latitude regions of the world are affected with frequent cloud cover throughout most of the year, which makes it difficult to capture cloud-free and high quality satellite imagery. Finally, commercial satellite coverage is partially driven by market potential; developing countries may not have been considered a high value market and tasking and capturing imagery for such countries occurred less frequently at the start of the commercial satellite era (c. 2000).

Landsat imagery covering the whole world since the mid-1970s has been freely available for the past decade. However, Landsat imagery has moderate spatial resolution (nominal ground sampling distance of 30 m). While it is preferable to use high spatial resolution imagery to perform detailed urban land use and land cover change, such imagery for much of the tropics is not readily available for the early 2000s. Thus, it is necessary to select alternative imagery types to perform change analysis. The purpose of this paper is to develop and test land use and land cover change techniques when only Landsat imagery is available for the first date and high spatial resolution imagery is available for the second. The study site is the city of Accra, the capital and largest city in Ghana, located in Western Africa and characterized by rapid urbanization and land change in recent years. Following are our research questions.

a) Given the classes of interest (residential, non-residential, and undeveloped) in the context of analyzing LCLUC in major urban areas of Ghana, how accurately and reliably can LCLU be identified based on Landsat ETM+ moderate spatial resolution satellite imagery?

The objective associated with this first research question is to evaluate the potential for accurately classifying residential and non-residential LCLU from Landsat imagery. LCLU classification studies involving the use of satellite images with moderate spatial resolution appropriately focus on general land cover classes such as built or impervious. On the other hand, studies that use high spatial resolution

(HRES) imagery data can be very detailed in their classification system. We investigate how well image classification schemes derived from HRES imagery can be derived from moderate resolution imagery and at what level of accuracy. We also investigate how the LCLU maps derived from Landsat imagery compare with those derived from high spatial resolution QuickBird imagery.

Although residential areas can be classified with high spatial resolution imagery to identify subclasses of residential such as single family residential (SFR), multiple family residential (MFR), low or high socio-economic status (SES), We retain the classification scheme general at the residential level. Similarly, non-residential class can cover a great variety of land uses, from school to factories or offices. Therefore, we limit the definition of non-residential to any building or complex with an area of 700 m^2 or greater. Based on a preliminary assessment of the study area, living houses in Ghana very rarely exceed this size.

b) What is the utility of a post-classification change identification approach that is based on an initial object-based classification of a high spatial resolution time 2 image, which is used to constrain the segmentation and subsequent classification of a time 1 moderate spatial resolution image.

Post-classification change detection is conducted by classifying the image data of two or more different dates separately and independently, and then comparing the results to identify LCLUC. The accuracy of the resulting change map is normally the product of the accuracies of the individual LCLU maps. OBIA approaches have been used for the classification of HRES images of urban areas. The approach consists of first segmenting the image into objects of interests and then classifying them. We test a novel approach where a time-2 HRES imagery is classified using an OBIA approach and then the classification results will be used to guide the classification of the MRES imagery from time 1. Specifically, we use the segments and class attributes derived form time 2 segmentation to constrain and control the segmentation results of time 1.

Study site and data

Study site

The study area is located in the Accra Metropolitan Area and has an area of 192 km^2 as shown in Figure 1. The capital city of Ghana, Accra has experienced massive population growth and built area expansion since the country independence in 1957. It has a population of 2.24 million (CIA 2015). The city is defined as the continuously built-up area of the Accra Metropolitan Assembly (AMA). Accra is the central city of a much wider area referred to as the Greater Accra Metropolitan Area comprising AMA, the Ga District Assembly and the Tema Municipal Assembly. The total urban area of Accra and its surrounding suburbs, regardless of the administrative boundaries, has more than doubled in recent decades; the area covered 216 km^2 in 1985, 276 km^2 in 1991, and 555 km^2 in 2002 (Moller-Jensen *et al.*, 2005). Today, Accra's urban growth has expanded beyond the boundary of AMA and spilled over mostly into the Ga District in the north, but also into the Tema District in the east. The Pambros Salt Ponds on the western edge of Accra serve as a natural barrier to growth, although residential areas are building up to the north and east of them as well (Yeboah, 2003). At a general level, the major LCLU types in the study area include residential, non-residential, and undeveloped categories.

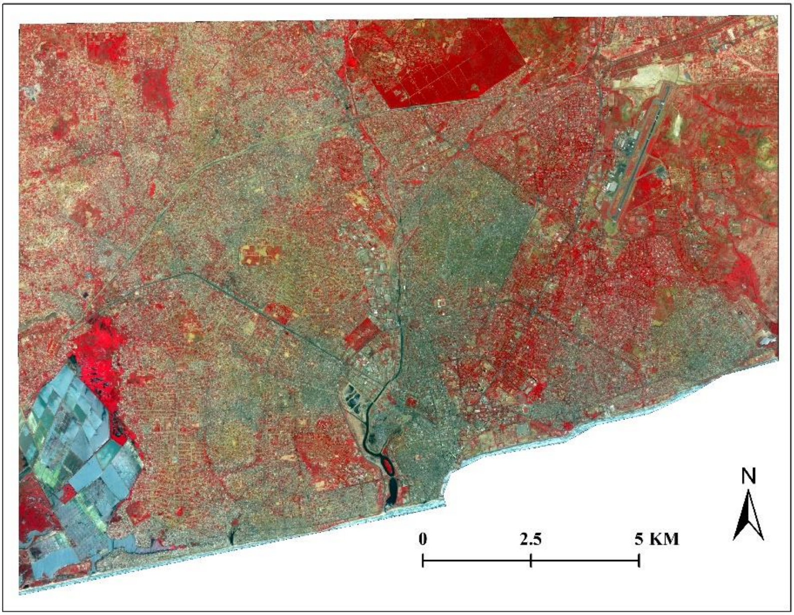

Figure 1 - Study area. April 14 2002 QuickBird multispectral image displayed in false color visual near infrared format.

Data

A Landsat 7 ETM+ satellite image acquired on December 26, 2002 will be used for the time 1 period. It has a spatial resolution of 30 m and was obtained already terrain-corrected at Level 1T from the Land Processed Data Active Archive Center. It has seven multispectral bands and one panchromatic band of 15 m. Reference data for training and evaluating LCLU classes will be generated from a georeferenced QuickBird multi-spectral data acquired on 14 April 2002. It has three visible (V) and one near infrared (NIR) multi-spectral bands with a spatial resolution of 2.4 m. Time 2 has two sets of high spatial resolution imagery: QuickBird and GeoEye. The QuickBird images also have four V/NIR multi-spectral bands, 2.4 m spatial resolution, and were acquired on January 11 and February 10, 2010. The GeoEye image was acquired on April 13, 2010. It has four VNIR multi-spectral bands and a spatial resolution of 1.65 m. All three images were georeferenced. It is necessary to use three images for the time 2 period for spatial completeness and to substitute areas with high cloud cover.

Methods

Figure 2 presents the general classification strategy of the study. Two LCLU maps will be generated for time 1 with a Landsat ETM+ and a QuickBird image. The GeoEye-1 and QuickBird 2 of 2010 will be combined to create a LCLU map for time 2. Two change maps will be generated through post-classification comparison, one representing the change between two HRES images and the other representing the changes between the ETM+ and HRES images. There will be a total of five LCLUC maps.

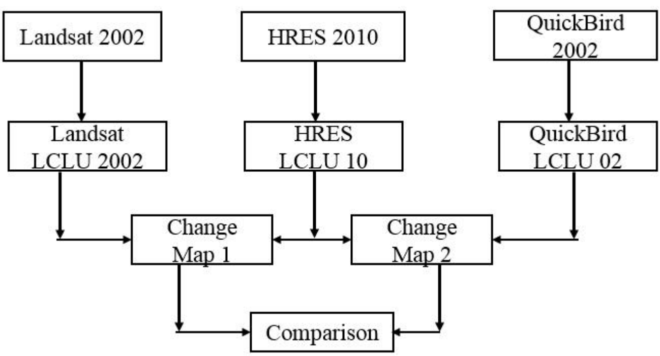

Figure 2 - General Classification Strategy. HRES: High Resolution.

Conclusion and future work

In this paper, we presented the challenges associated with performing urban land cover and land use change using remote sensing data and methods. There are spatial and temporal issues associated with the collection of high spatial resolution imagery. Moreover, there are methodological difficulties encountered when performing change analysis with satellite dataset that have very different spatial resolutions. We proposed a general framework that consisted of first simplifying the definition of the classes of interests and then extracting them from a moderate Landsat ETM+ image.

The next steps will consist of presenting the details of the processing flow for the multi-resolution LCLUC mapping procedures. The process will entail classifying the time 2 imagery first, and then using the segments obtained to help in classifying the time 1 data. We will adopt an object-based image analysis (OBIA) approach to classify all commercial high spatial resolution imagery using eCognition OBIA image processing software. We will generate two maps for every image: a vegetation-impervious-soil (VIS) land cover map and a residential, non-residential built and non-built land use map. Lastly, we will use the image object hierarchy in eCognition to generate the two maps such that the VIS image objects will be sub-objects of the land use objects. The information provided in the VIS sub-objects will inform the classification of the land use objects.

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