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Change Detection Process and Techniques

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Abstract
Land use / land cover changes studies have become very interesting over the past decades through using remote sensing because of the availability of a suite of sensors operating at various imaging scales and scope of using various techniques as well as considered the good ways for effective monitoring and accurate land use /land cover changes. This paper looks into the following aspects related to the remote sensing technology, change detection process and techniques for land cover changes, and factor affecting change detection techniques and considerations.
Keywords: Remote Sensing, Land Use / Land Cover, Change Detection

1. Introduction

The earth's surface is changing as a result of natural phenomena or human activity, for example, wildfires, lightning strikes, storms, pests, agro-forestry, agricultural expansion, social, economic, technological, historical factors and urban growth and the like (Borak, Lambin & Strahler 2000). Generally, the earth's surface changes are divided into two categories: land use and land cover (Barnsley, Moller-Jensen & Barr 2001). Land cover initially describes the physical state of the land surface, which includes cropland, forests, and wetlands, but it has broadened in subsequent usage to contain human structures such as buildings, pavements and other aspects of the natural environment, including soil type, biodiversity, surface water and groundwater (Cheng et al. 2008, Jaiswal, Saxena & Mukherjee 1999) In contrast, land use refers to the way in which human beings exploit the land and its resources including agriculture, urban development, grazing, logging and mining. However, land cover and land use are often used interchangeably because the two terms are interdependent and closely related (Verburg, De Groot & Veldkamp 2003, Verburg et al. 2009). Regardless of that, land use/land cover change (LULCC) is defined as the transformation of the land or replacement of one land-cover type on the earth's surface (Meyer, Turner 1992).

LULCC is the impact of several related processes operating over a wide range of scales in space and time (Foody 2002b) . Lambin, and Ehrlich 1997, suggest that there are three major causes of land use/land cover changes that happen, with differing rates and on different scales: biophysical factors, technological and economic considerations, and institutional and political arrangements. Besides these, the changes are resulting from military conflicts. In order to be able to plan and implement meaningful policies and effective schemes to sustain regional development, there is a crucial need to know the land use/land cover patterns in a particular region (Lillesand, Keifer 1994, Lillesand, Kiefer & Chipman 2004, Lu et al. 2004) . Fortunately, there is now available documentation of the spatiotemporal pattern of land use/cover using satellite imagery, which allows scientists the ability to determine the causes and results of change in relation to human activity patterns (Cardille, Foley 2003), therefore, studying changes in land use/land cover has become an important research theme in the remote sensing spatial analysis Since the 1970s (Lo, Shipman 1990).

For extracting LULC change information, traditional methods and remote sensing technology may be used. Traditional methods such as field surveys, map interpretation, collateral and ancillary data analysis are not effective to acquire LULC changes because they are time consuming, date-lagged and often too expensive, whereas the remote sensing technology method includes using aerial photographs, satellite images, spatial data set and other data (Paradzayi et al. 2008) , and is a much more cost-effective and time-efficient means to study LULC changes, especially over regional or national areas in comparison with the traditional methods (Nordberg, Evertson 2003).

2. Remote Sensing Technology

The term "remote sensing," first used in the United States in the 1950s by Ms. Evelyn Pruitt of the U.S. Office of Naval Research. Remote Sensing (RS) is now commonly used to describe the science and art of obtaining information about an object, area, or phenomenon under investigation by a device that records the spectral properties of surface materials on the earth from a distance (Singh 1989a, Rogan, Chen 2004). Basically, there are two types of remote sensing instruments; passive and active. Passive instruments detect the natural energy that is reflected or emitted from the observed scene whereas active instruments provide their own energy (electromagnetic radiation) to illuminate the object or scene they observe.

Remote sensing from airborne and space borne platforms provide a huge amount of valuable data about our earth's surface including aerial photographs, satellite images, spatial data set and other data (Paradzayi et al. 2008). The increased availability of mid- to fine-resolution satellite imageries since the early 1990s, offers repetitive data variance among themselves in terms of spatial, radiometric, spectral, temporal resolution and its synoptic view (Stoney 2006), also the digital format makes them suitable for many computer image processing softwares. All these have made remotely sense data the main source for various remote sensing applications (Lu et al. 2004, Kennedy et al. 2009, Lu et al. 2010b, Lu et al. 2010a). Remote sensing satellite imagery has given scientists a remarkable way to determine the reasons for land use/land cover changes and the resultant consequences due to human activity (Cardille, Foley 2003).

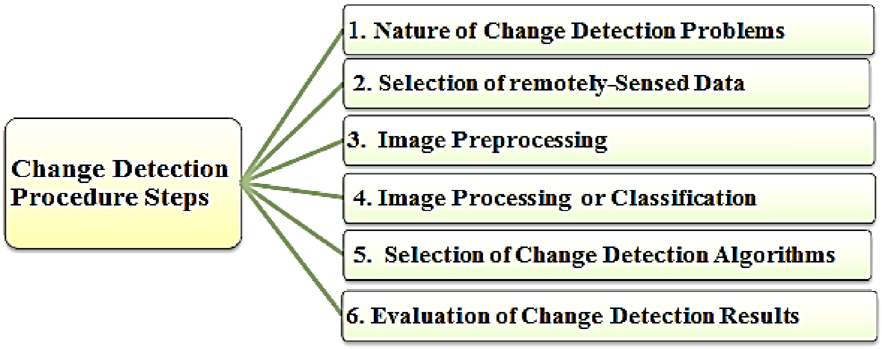
The latest remote sensing and spatial analysis technology has become available to researchers such a powerful equipment used to map and identify land use/land cover changes, especially in the crop rotation of agriculture (Macleod, Congalton 1998), in deforestation assessment (Binh et al. 2005) , in yield assessment, and yield estimation (Rao, Rao & Venkataratnam 2002), in coastal zone changes(Hongquan Xie, Yanyan Zhang & Xia Lu 2011; Kesgin, Nurlu 2009), in land degradation detection (Fadhil 2009), vegetation mapping(Müllerová 2005), in wetland landscape changes (Wang Huiliang et al. 2009) , in urban change detection (Martínez et al. 2007) , and other applications.

RS presents a useful tool for understanding and managing earth resources and LULC change detection (Matinfar et al. 2007) . Enormous efforts have been made to delineate LULC on a local scale as well as global scale by applying different multi-temporal and multi-source remotely sensed data from both airborne and space borne sensors. Medium resolution satellite imagery such as Landsat satellite data, are the most widely used data types of monitoring and mapping land cover changes(Williams, Goward & Arvidson 2006) . They have been successfully utilized for monitoring LULC changes especially in the land that has been affected by human activity to various degrees, for example, Lu Junfeng et al. (2011) used Landsat Multi-Spectral System (MSS), Landsat TM and ETM+ remote-sensing data for land cover changes. Fan, Weng and Wang (2007), used TM and ETM+ images for detecting and predicting land use and land cover in the Core corridor of Pearl River Delta (China). Zaki, Abotalib (2011) applied Landsat images (TM) for detecting land cover changes in Northeast Cairo, Egypt. Not only Landsat data have shown the ability to detect LULC changes but data from other sensors are equally useful in monitoring LULC changes, for instance, Chavula, and Bauer (2011) showed the radar and Advanced Very High Resolution Radiometer (AVHRR) and Moderate-resolution Imaging Spectro-radiometer (MODIS) sensor data is able to detect LULC in the Lake Malawi Drainage Basin, while, Zhang and Zhu (2011) employed Quick Bird remote sensing data for land cover changes. A study by Perea, and Aguilera (2009) utilized the digital aerial images to produce thematic maps for detecting changes. Huiran and Wenjie (2008), showed in their study that bi-temporal hyper spectral of Compact High Resolution Imaging Spectrometer (CHRIS/PRBOA) satellite images are good for identifying LULC changes.

Moreover, several researchers worked with combining different sensor data in monitoring LULC changes, among them, Wen (2011), who used Landsat Multi-Spectral System (MSS) and Quick Bird data to derive land cover information and changes in Guam, USA, while Geymen and Baz (2008) used Landsat TM and Landsat Geo-Cover LC satellite images for detecting land cover changes on the Istanbul metropolitan area. Zoran and Anderson (2006) used multi-temporal and multi-spectral satellite data Landsat MSS, TM, ETM, SAR ERS, ASTER, and MODIS for change detection analysis of the Romanian Black Sea. However, some of these studies show the ability of multi-temporal and multi-source data from sensors with different spatial, temporal and spectral resolutions that can be used for global LULC changes while others cannot provide regional land cover maps because of their spatial resolution. Still, medium resolution satellite imagery such as Landsat is ideal for monitoring regional land cover changes (Franklin, Wulder 2002).

3. Change Detection

Detecting and analyzing LULCC over large geographic areas as well as over regional areas have been highlighted both in a manner of discrete long-time span and in sequential time series with high temporal resolution remote sensing satellites through a process commonly called 'change detection' (Coppin, Bauer 1996). Change detection has been defined as a "process of identifying differences in the state of an object or phenomenon by observing it in different times" (Singh 1989b). This is considered an important process in monitoring LULCC because it provides quantitative analysis of the spatial distribution of the population of interest and this makes LULC study a topic of interest in remote sensing applications (Song et al. 2001, Gallego 2004). Using remotely-sensed data to detect LULC changes, six main steps are important as mentioned by Jensen in 2005 (see figure 1).



Figur1. Major Change Detection Procedure Steps

4. Change Detection Techniques

Since launching the first of the Landsat satellite system in 1972, a wide range of data have been provided (Williams, Goward & Arvidson 2006). The availability of a large archive of data leads to the development and evaluation of many digital change detection techniques and methods for analyzing and detecting LULC changes (Dewidar 2004). Various methods have been extensively reviewed and provided with excellent descriptions and comprehensive summaries (Singh 1989a, Xiubin 1996, Lu et al. 2004, Corresponding et al. 2004). Basically, there are two categories of change detection methods: pre-classification and post- classification change detection techniques (Lu et al. 2004).

4.1 Pre-classification Techniques

The pre-classification techniques, also known as binary change or non-change information detecting techniques, include various techniques that directly use the multiple dates of satellite imagery to generate “change” vs. “no-change” maps(see table 1). Many pre-classification techniques have been used and compared to assess and identify LULCC changes such as, Image Differencing (ID) (Hayes, Sader 2001), Improved Change-Vector Analysis (Green, Kempka & Lackey 1994), Band Image Differencing (Chavez, MacKinnon 1994), RGB-NDVI Change Detection Method(Wen, Yang 2009, Geun-Won Yoon, Young Bo Yun & Jong-Hyun Park 2003, Johnson, Kasischke 1998), Spectral Change Vector Analysis (Wen, Yang 2009), Principal Component Differencing (PCD), Change Vector Analysis (CVA)(Chen et al. 2003) and others.

Table1. Summary of Different Pre-Classification Change Detection Methods

Method	Code	Definition
Image Differencing ID	ID	Image differencing is the subtraction of two spatially registered imageries, pixel by pixel. The pixels of changed area are expected to be distributed in the two tails of the histogram of the resultant image, and the unchanged area is grouped around zero. This simple method easily interprets the resultant image; however, it is crucial to properly define the thresholds to detect the change from non-change areas.
Modified Image Differencing	MID	Different image bands have their own reflectance characteristics of each land-cover type. The image differencing results between images bands of two dates have varying capabilities in identifying land cover changes. Thus, the majority rule is used in this paper. First, the image differencing was done for each band, i.e. ID (TMi) = TMi (t1)–TMi (t2). Thresholds were determined to identify the land cover change and to provide a binary image for each band, 1 as change and 0 as non-change. Then, the binary images were developed to provide a new summarized image. For a TM image (six bands), if the value of a pixel is greater than or equal to 4, then the pixel belongs to change class; otherwise, it belongs to unchanged class based on the majority rule
Principal Component Differencing	PCD	PCA is often as accepted as an effective transforms to derive information and compress dimensions. Most of the information is focused on the first two components. Particularly, the first component has the most information. The difference of the first PCA component of two dates has the potential to improve the change detection results, i.e. PCD= PC1 (t1)–PC1 (t2). The change detection is implemented based on thresholds.
Multi-temporal PCA	MPCA	Two dates of image data are superimposed and treated as a single dataset. PCA is implemented on the stacked dataset. The main component images often contain the overall radiation difference that reflects different land cover types. The minor component images contain land cover changes between the different dates. Normally, the third and fourth components are employed to analyze the land cover change. However, it is often not easy to determine the change areas in the absence of a careful and complete examination of the resultant image and field data or in combination with visual interpretation of the multi-date composite image.
The combination of ID and PCA	IDPCA	Similar to the multi-temporal PCA. The only difference between them is to change the single image to resultant image from image differencing. The difficulty is to determine which component images indicate the main land cover changes. It is necessary to examine thoroughly the components and multi-date composite image to determine which component can give the best change information
Image Ratioing	IR	Ratioing is also a simple and rapid means to identify changed areas. It implies calculation of the ratio of two registered images from different dates, on a band-by-band basis. In the changed areas, the ratio values will be significantly greater than 1 or less than 1 depending on the nature of the changes between two dates of the images. Ratioing has received criticism due to the non-normal histogram distribution of the resultant image.
Modified Image Ratioing	MIR	Similar method as modified image differencing. The only difference between them is the replacement of the differencing images with ratioed images.
The combination of IR and PCA	IRPCA	Same method as the IDPCA. The only difference between them is replacement the differencing images with ratioed images before implementation of PCA.
Change Vector Analysis	CVA	CVA generates two outputs: a change vector image and a magnitude image. The spectral change vector explains the direction and magnitude of change from the first to the second date. The total change extent per pixel is calculated by determining the Euclidean distance between end points through dimensional change space of CVA is its ability to process any number of spectral bands required and to obtain detailed information on any detected change,

Source: Lu et al. (2005)

The basic premise in these techniques is measuring the nature of changes, which means changes in the features of interest that will result changes in radiance or reflectance values (Lu et al. 2004). Most of the pre-classification techniques are identified as the most accurate change detection techniques because, they are straight forward, effective for identifying and locating change and are easy to implement (Sunar 1998). However, three aspects are critical for pre-classification techniques: selecting suitable thresholds or vegetation index to identify the changed areas, being sensitive to mis-registration of pixels and they cannot provide details of the nature of change or provide a matrix of change information (Lu et al. 2004).

4.2 Post-Classification Comparison Technique

The post-classification comparison has been proven to be the most popular approach in change detection analysis (Foody 2002b). This approach is based on rectification of more than one classified image; where it involves the classification of each of the images independently, then the thematic maps are generated, followed by a comparison of the corresponding labels or themes to identify areas where change has occurred (see figure 2). There are several advantages to this technique: it minimizes sensor, atmospheric, and environmental differences because data from two dates are separately classified, thereby minimizing the problem of normalizing for atmospheric and sensor differences between two dates and it provides a complete matrix of land cover change when using multiple images (Lu et al. 2004, Jensen 2005, Naumann, Siegmund 2004, Teng et al. 2008). A series of "from-to" matrixes can be built by comparing on a pixel by pixel basis, and these matrices include pixel conversion matrix, percentages conversion matrix, and area conversion matrix. However, results derived from this method are only as accurate as the individual classification images themselves (Jensen 2005, Corresponding et al. 2004, Civco et al. 2002). Furthermore, this method could lead to wrong results especially when using multi-date or multi-sensor images due to the differences in the radiometric characteristics of the images from which thematic maps were obtained (Foody 2002b, Foody 2002a)

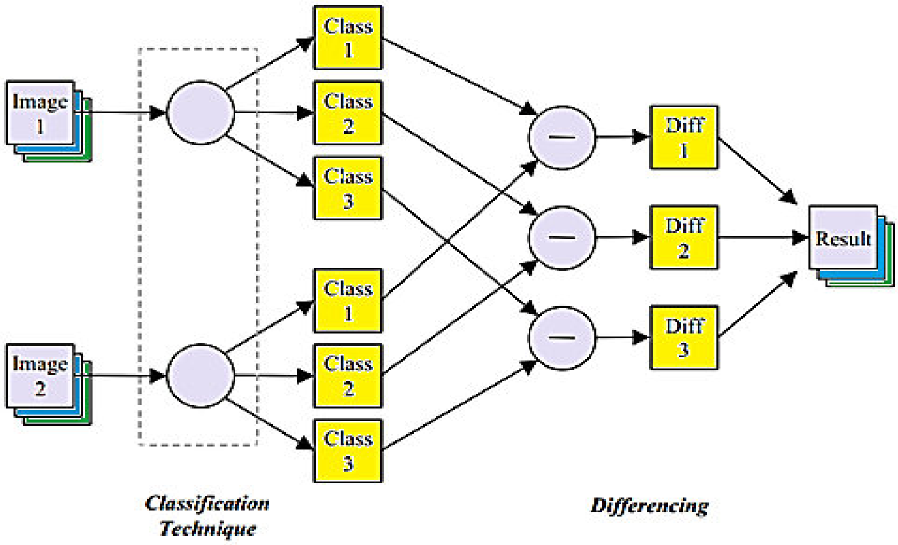


Figure2. Diagram of Post-classification Comparison Change Detection

The post-classification comparison approach used by many researchers such as (Diallo, Hu & Wen 2009, Bayarsaikhan et al. 2009 ,Shalaby, Tateishi 2007, Muttitanon, Tripathi 2005 Torahi, Rai 2011) employed post-classification change detection techniques based on Maximum Likelihood Supervised Classification to detect land use/land cover change detection and concluded that it has achieved high overall accuracy for a variety of data. Dewidar, (2004) applied Maximum Likelihood Supervised Classification and Post-classification Change Detection Techniques to Landsat images for mapping and monitoring land cover and land use changes in the North-western coastal zone of Egypt. Sun, Ma and Wang (2009) utilized the post-classification comparison approach method base on maximum likelihood algorithm to determine land use changes in Datong basin, China using multi-temporal Landsat data. Similarly, Fan, Weng and Wang(2007)Maximum Likelihood (ML) procedure and combined post-classification images of Landsat TM and ETM+ classification and socioeconomic data used in an effective way to research land use land cover change dynamically.Recently, post-classification has been employed in different areas around the world based on the use of the new classification algorithms for different purposes so as to quantify land cover change, improve spectral classification, reduce the classification error propagation and improve the land use and land cover change classification accuracy.

5. Factor Effecting Change Detection Techniques and Considerations

It is not an easy to determine the most appropriate method of detecting changes in a particular area under study.

This is because of the varying nature of the physical characteristics of the features of interest, problems with image registration, cloud/haze detection, sensor anisotropy or hysteresis, advantages and disadvantages of change detection methods themselves and lack of knowledge about approach (Macleod, Congalton 1998, Nielsen, Conradsen & Simpson 1998). Generally speaking, to select a suitable method of detecting change is very significant because there is no single method that is can be efficiently applied to all study areas. Selection of an appropriate change-detection technique, in practice, often depends on the nature of the change detection problem under investigation, which considers a critical step in change detection studies, the requirement of information, application , the data sets availability and quality, time and cost constraints of the data sets, analysis skill and experience, and registration of multiple image data sets (Macleod, Congalton 1998, Johnson, Kasischke 1998, Nielsen, Conradsen & Simpson 1998, Cracknell 1998, Dai, Khorram 1998)

Regardless of the technique used, the success of change detection from imagery can be affected by many factors: the quality of image registration between multi-temporal images, the atmospheric conditions, acquisition times, illumination, viewing angles, soil moisture, noise , shadow present in the images (Singh 1989a), vegetation phenological variability or differences (Lu et al. 2002, Rogan, Franklin & Roberts 2002); sensor calibration (Lillesand, Keifer 1994) in addition to the landscape and topography characteristics of the study areas, analyst's skill and experience, selection of the change detection technique, besides, the different steps during the implementation of change detection procedure that can produce problems and errors and affect the success of change detection, for example, image pre-processing (Lu et al. 2004, Jensen 2005).

6. Conclusion

One of the most important uses of remote sensing is the production of Land Use and Land Cover maps. Land Use: refers to the purpose the land surveys, for example, recreation, wildlife habitat, or agriculture, urban development, and most areas impacted by human activity. Knowledge of land use helps us to develop strategies to balance conservation, conflicting uses, and developmental pressures. Some of the issues which are of concern include the removal or disturbance of productive land, urban encroachment, and depletion of forests. Land Cover: refers to the surface cover whether vegetation, water, bare soil, urban development or other. Identifying, delineating and mapping land cover are important for global monitoring studies, resource management, and planning activities

Detecting and analyzing LULC changes by using remote sensing satellites can be done through a process commonly called 'change detection'. Since launching the first of the Landsat satellite system in 1972, a wide range of data has been provided thus lead to the development and evaluation of many digital change detection techniques for analyzing and detecting LULC changes and can be divided basically into two categories: pre-classification and post- classification change detection techniques. Most of the pre-classification techniques are identified as the most accurate change detection techniques because, they are straight forward, effective for identifying and locating change and are easy to implement. While the post-classification comparison technique has been proven to be the most popular approach in change detection analysis because of there are several advantages to this technique: it minimizes sensor, atmospheric, and environmental differences and it provides a complete matrix of land cover change when using multiple images. For many researchers in the field of remote sensing is not an easy to determine the most appropriate method of detecting LULC changes in a particular area under study because of the varying nature of the physical characteristics of the features of interest, problems with image registration, cloud/haze detection, sensor anisotropy or hysteresis, advantages and disadvantages of change detection methods themselves and lack of knowledge about approach.

In summary there are many considerations that considered very important for most of researcher in the remote sensing field which are considerations about remote sensing systems and environmental characteristics must be satisfied. These include geometric and registration of multi-temporal images, radiometric and atmospheric calibration or normalization between multi-temporal images, and similar phonological states between multi-temporal images. There is also the need to consider the selection of the same spatial and spectral resolution images if possible as well as understanding the major steps of image processing in order to reduce errors or uncertainties in each step.

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