Land Use Change Detection Using Satellite Images for Najran City, Kingdom of Saudi Arabia (KSA)

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SUMMARY

Determination of land use changing is an important component of regional planning for applications ranging from urban fringe change detection to monitoring change detection of land use. These data are very useful for natural resources management. On the other hand, the technologies and methods of change detection also have evolved dramatically during the past 20 years. So it has been well recognized that the change detection had become the best method for researching dynamic change of land use by multi-temporal remotely-sensed data. The objective of this paper is to assess, evaluate and monitor land use change surrounding the area of Najran city, Kingdom of Saudi Arabia (KSA) using Landsat images (June 23, 2009) and ETM+ image (June. 21, 2014). The post classification change detection technique was applied. At last, two-time subset images of Najran city are compared on a pixel-by-pixel basis using the post classification comparison method and the from-to change matrix is produced, the land use change information obtained. Three classes were obtained, urban, bare land and agricultural land from unsupervised classification method by using Erdas Imagine and ArcGIS software. Accuracy assessment of classification has been performed before calculating change detection for study area. The obtained accuracy was found between 61% to 87% percent for all the classes. Change detection analysis showed that rapid growth in urban area has been increased by 73.2%, agricultural area has been decreased by 10.5 % and barren area reduced by 7% between 2009 and 2014. The quantitative study indicated that the area of urban class has unchanged by 58.2 km^2, gained 70.3 $km^2$and lost 16 km^2. For bare land class 586.4km^2 has unchanged, 53.2km^2 has gained and 101.5km^2 has lost. While agriculture area class, 20.2km^2 has unchanged, 31.2km^2 has gained and 37.2km^2 has lost.

1. INTRODUTION

Najran city is located to the south west of the Kingdom of Saudi Arabia (KSA), has been considered as one of the new industrial communities growing rapidly with a planned urban community. The city has witnessed remarkable expansion, growth and developmental activities such as building, road construction and many other activities just like many other cities in KSA.

Knowledge of the present distribution and area of such agricultural, bare, and urban lands, as well as information on their changing proportions, is needed by legislators, planners, and State and local governmental officials. If public agencies and private organizations are to know what is happening, and are to make sound plans for their own future action, then reliable information is critical (2). There are many useful purposes for change detection information:

- to determine better land use policy.
- to project transportation and utility demand.
- to identify future development pressure points and areas to implement effective plans.
- to manage regional development.

Land use information are not only useful to improve the natural resources but also play a vital role in probable natural hazards like flash floods. Observations of the earth (Satellite Images) from space by remote sensing technique provide objective information of human activities and utilization of the landscape. The classified images provide all the information to understand the land use of any study area. There are several methods for mapping land cover changes using remotely sensed data (21) (14) and (16). Many researcher have used remote sensing data for determining change detection, satellite imagery and Markov and cellular automata models were used to predict land cover in 2030 in Al Ain, a city in the Emirate (21). Countries which are suffering from the rapid growth of population, land use is very important be to expected and planned (7).

The objective of this research is to identify the nature and extent of land-cover changes of Najran area through the period from 2009 to 2014. Four of the most commonly used change detection techniques were discussed to detect the nature and extent of the land-cover changes in Najran area using Landsat images. These techniques are;

1. post-classification,
2. image differencing,
3. image rationing, and
4. principal component analysis.

In this study, the post classification method is used. Finally, quantitative evaluations for the results of these techniques were performed to determine the most appropriate change detection technique which will provide the highest accuracy for identifying the nature and extent of land-cover changes in Najran city. In this study several image processing steps were conducted by the aid of Erdas imagine version 2011 (6) and ArcGIS version 10.1 software (8). The obtained results should be examined and checked from errors, therefore, accuracy assessment step should be proceed. Classification accuracy assessment generally include three basic components: sampling design, response design, and estimation and analysis procedures (18). Accuracy assessment allows users to evaluate the utility of a thematic map for their intended applications. The most widely used method for accuracy assessment may be derived from a confusion or error matrix (17), (5) and (4).

The confusion matrix is a simple cross tabulation of the mapped class label against the observed in the ground or reference data for a sample set. Two important information can be derived from the error matrix: errors of omission, or producer's accuracy, and commission, or user's accuracy (19). The user's accuracy of a specific class is the ratio of the correctly classified samples to the total number of samples selected in that class. A Kappa coefficient is commonly used as a measure of the map accuracy (5) and (10).

2. STUDY AREA AND DATA SET

2.1 Study Area

The study area (figure 1), is bounded by coordinates of (219205.660E, 3633792.740N) and (223405.060E, 3637277.540N), an area of approximately 800 square kilometers. It includes various land use activities: urban, desert and road networks.

Fig. 1 Study area location map.

Two epochs (2009 and 2014) were used for land-cover classification. A total of two scenes of Landsat -7 ETM + images were used. In 2009 epoch; scene of Jun 23, 2009. For 2014 epoch, Jun 21, 2014 were available. The data scene numbers are Path 166 Row 048. Table 1, figure 2 and 3 show the used data sets.

Table 1 Used data sets

Image	Image Type	Image Source
Landsat -7 ETM + 2009	Ortho-Products level 1-G	USGS website
Landsat -7 ETM +2014	Ortho-Products level 1-G	USGS website
District's boundary map	shape file	Najran municipality
Google Earth images	Satellite images	Google Earth website

The used Landsat satellite imagery for the study area is downloaded from the USGS Earth Explorer (http://earthexplorer.usgs.gov/). The images of the two epochs were selected within the dry season of the area, normally between May to October months of a year because generally it is clear sky in the city. In order to remove seasonal sun angle and plant phonological differences images with similar anniversary date were recommended (11).

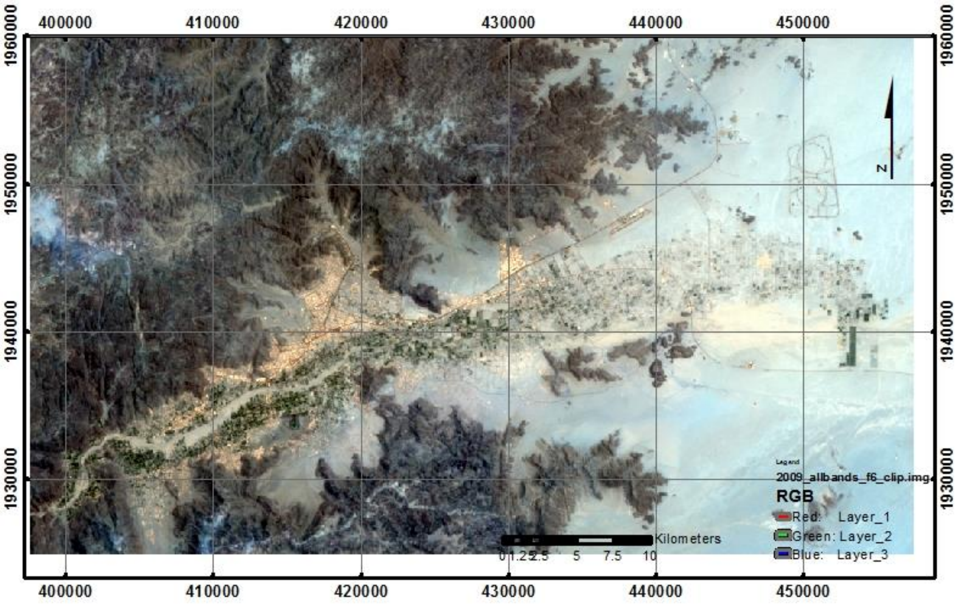

Fig. 2 Land sat 7 image 2009

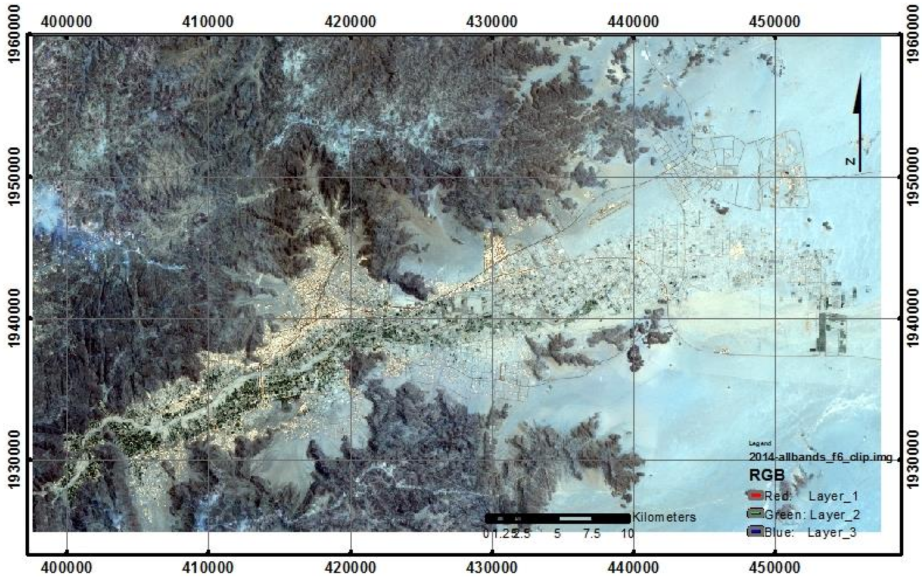

Fig. 3 Land sat 7 image 2014

By using Google Earth (www.GoogleEarth.com) two images for study area are downloaded to be used as reference data for classification accuracy assessment.

Google Earth has time slider that allows user to get the historical image records for any study area. Several reasons to use Landsat satellite images in our work. All Landsat data in the U.S. Geological Survey (USGS) archive are now free and have good spectral (seven bands from visible to the infrared spectrum) and spatial characteristics (30 m resolution). ETM+ data are obtained in eight spectral bands simultaneously. Band 6 corresponds to thermal (heat) infrared radiation. ETM+ scene has a spatial resolution of 30 meters for bands 1-5 and 7 while band 6 has a 60-meter spatial resolution and the panchromatic band has a 15-meter spatial resolution.

3 METHODOLOGY

3.1 Review of Change Detection Methods

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Change detection is the act of comparing two or more satellite images acquired at different times (multi temporal) for the purpose of detecting spectral reflectance differences between the images (15). Over the past years, researchers have used large numbers of change detection techniques of remote sensing image and summarized or classified them from different viewpoints (3) and (13). It has been generally agreed that change detection is a complicated and integrated process. Change detection methods could be listed as following:

- Change detection using write function memory insertion.
- Image algebra change detection.
- Post-classification comparison change detection.
- Multi-date change detection using a binary mask applied to date 2.
- Multi-date change detection using ancillary data source as date 1.
- Manual on-screen digitization of change.
- Spectral change vector analysis.

3.2 Used Methodology

Four of the most commonly used change detection methods were used (13). The most common change detection methods are:

- post-classification
- image differencing
- image rationing, and
- principal components analysis (PCA).

The post classification comparison method is the most preferable by many researchers. In this work, the post classification method is used. The magnitude and location of change were determined for the hole study area. Different software packages were used because each one has strength in certain operations needed for this study. Due to the gaps in the recent Landsat images in and after 2003, focal analysis function in ERDAS Imagine 2011 was used to fill the gaps. ArcGIS version 10.1 was used to produce suitability maps and final maps because of its strength in raster analysis and capabilities in maps production. ERDAS Imagine 2011 was used for classification step. The sequences of operations is schematically shown in figures 4.

4 Post Classification Method

Landsat 7 image includes 7 bands, thermal and panchromatic were excluded for their coarser and finer spatial resolution. Only bands of the same spatial resolution were used in this study. Used two images have the same acquisition date, therefor no need for atmospheric correction. The study area was clipped from two images by clip tool in ArcGIS 10.1 with district boundaries layer.

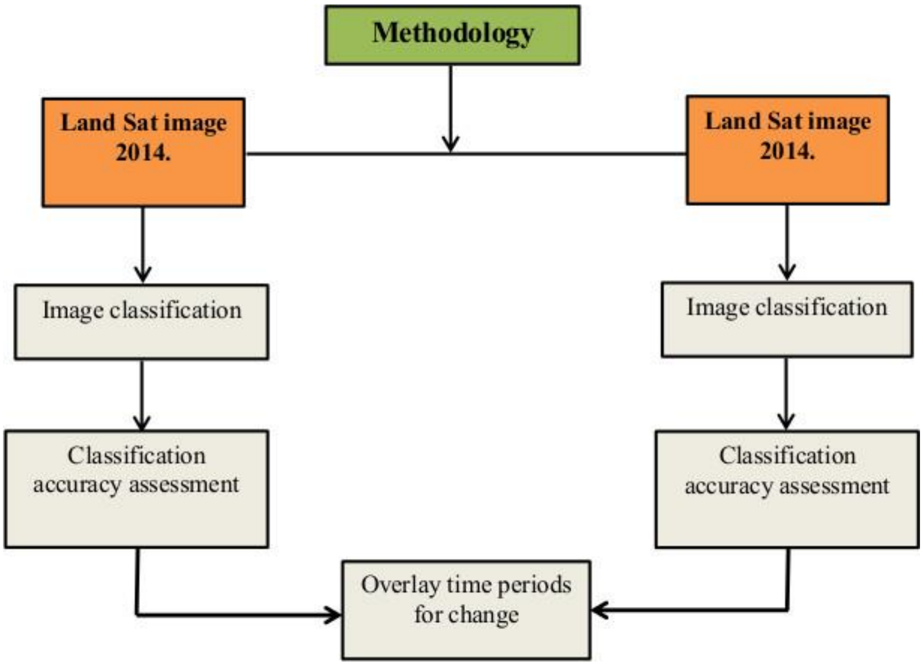

Fig. 4 Used methodology.

The main purpose of satellite image classification is the recognition of objects on the earth surface and their presentation in the form of thematic maps. The famous type of classification technique is the unsupervised classification which doesn't need a prior knowledge of the area and the supervised classification which needs prior knowledge of the area (12). It seems evident that when one knows what classes are desired and where they occur (at least as a sample), supervised classification strategies are preferable. However, over large areas the distribution of classes is not known a priori. This is compounded by the spatial trends in spectral signatures, resulting in the well-known signature extension problem. These complexities render sample selection very difficult and often arbitrary. Thus, where spatial distribution information is not available, e.g. when mapping a large area previously not well known, unsupervised classification is arguably the better strategy (1), although a supervised method has also been used in such case (9).

The post- classification transformation of the classified raster into shape three vectors has been done using ArcGIS 10.1. The obtained shape was converted into a geodata base in order to introduce the change detection analysis.

Before this step, it is necessary to make sure that the classification used for the change detection procedure is matching fact in the field using the accuracy assessment technique. By using Erdas imagine software version 2011, unsupervised classification method is used to classify the images 2009 and 2014. At the beginning, fifty classes are chosen with 50 iteration number and 0.975 conversion threshold value. Finally by using Reclassify function, three classes were obtained urban, bare and agricultural land. The land cover classification maps for both dates are shown in figures 5 and 6. Post-classification refinement was done to improve the accuracy of the classification. The mis-classifications have been mostly corrected manually. The magenta color represents the urban are area, green color shows the agricultural area and yellow color shows the barren land.

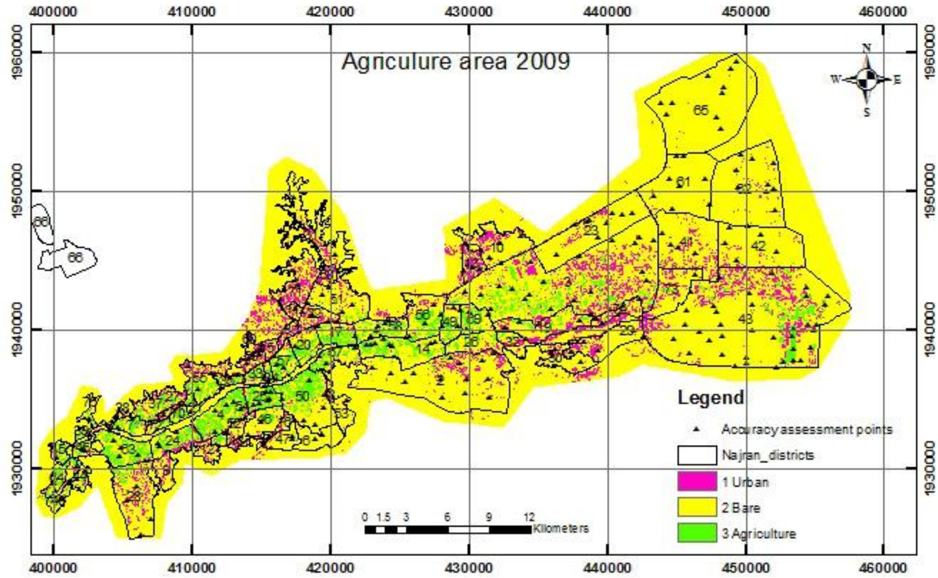

Fig. 5 Land use classified image of 2009.

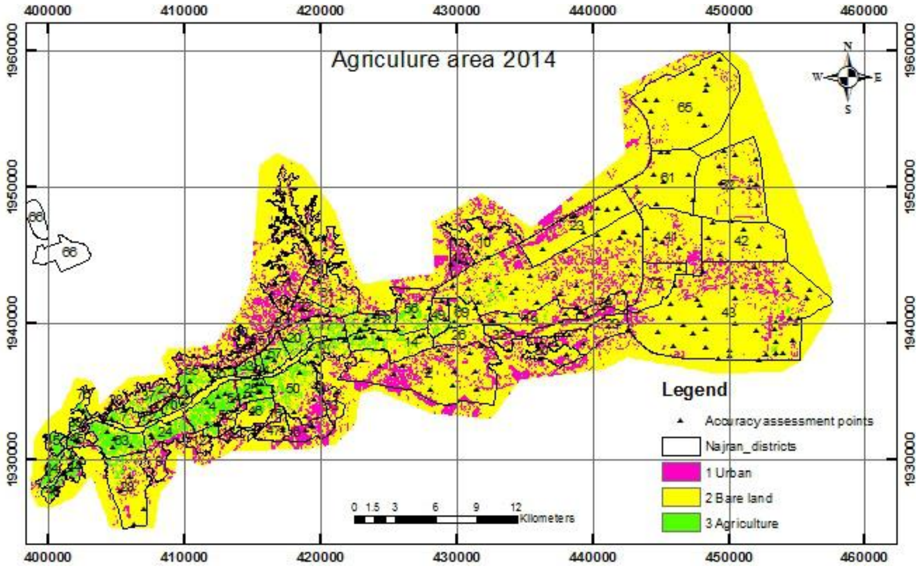

Fig. 6 Land use classified image of 2014.

5 ACCURACY ASSESSMENT AND ANALYSIS OF THE RESULTS

Evaluation of the classification's accuracy is calculated by comparing some specific pixels of the classified image and their corresponding reference pixels, which belong to a known class, succeeds the evaluation of the classification. The results of this comparison are the error matrix, the accuracy totals and the kappa statistics. By using data management tools in ArcGIS, 263 random points are created for classification accuracy assessment. The reference data were collected from Google Earth. Table 2 and 3 present design matrix, overall accuracy and Kappa coefficient for used two Landsat images.

Table 2 Design matrix, overall accuracy and Kappa coefficient for Landsat image 2009.

	Urban	Bare	Agriculture	Row total	User's Accuracy
Urban	27	11	1	39	69.23%
Bare	15	135	22	172	78.49%
Agriculture	3	9	40	52	76.92%
Column total	45	155	63	263	
Producer's accuracy	60.00%	87.10%	63.49%		
Total Accuracy		76.8%			
Kappa		0.76			

Table 3 Design matrix, overall accuracy and Kappa coefficient for Landsat image 2009.

	Urban	Bare	Agriculture	Row total	User's Accuracy
Urban	30	15	4	49	61.22%
Bare	18	130	20	168	77.38%
Agriculture	1	5	40	46	86.96%
Column total	49	150	64	263	
Producer's accuracy	61.22%	86.67%	62.50%		
Total Accuracy		76.0%			
Kappa		0.76			

Accuracy results for image 2009 show that, the urban class 60%, bare land is 87%, while agriculture area is 63.49%. Overall Accuracy is 76.8% and Kappa coefficient of agreement is 0.77. For image 2014, urban is 61.22%, bare soil is 86.7% and agriculture area is 62.5%. Overall Accuracy is 76% and Kappa coefficient is 0.76. Accuracy results are weak for urban class while, resolution is 30 meter and most of building dimensions less than 30 meter by 30 meter, road width also less than 30 m. Table 4 shows the observed major land cover changes and the area of each land cover class has been given in km^2. The urban area has increased from 74.2 to 128.5 km^2, the bare land area decreased from 687.8 to 639.6 km^2 and agriculture has decreased from 57.5 to 51.4 km^2.

Table 4 The lands cover changes in (km^2) in 2009 and 2014.

Class name	2009 km^2	2014 km^2	Total km^2	change
Urban	74.2	128.5	54.3	73.2%
Bare	687.8	639.6	-48.2	-7%
Agriculture	57.4	51.4	-6	-10.5%
Total km^2	819.4	819.4		

The area extent of the three main classes namely were determined from the classified images of 2009 and 2014. Then, the areas of the "from to" classes were also determined but from the classified change image. These areas of the from-to classes represent the nature and extent of the changes for each of the three main classes. To determine the area of any class whether it is a main class or a from-to class, a bit map was created to code and separate this class from the others. The raster values 1,2 and 3 has given to urban, bare and agriculture classes respectively.

By using raster calculator, the classified image of the year 2009 is multiplied by 10 and then subtract the classified image of the year 2014. The unchanged area of urban class will take raster value 9, unchanged area of bare land will take 18 as a raster value while the unchanged area of agriculture class will take the number 27 as raster value. The lost urban area will take the number 8, while gained area will take the number 19 as shown in figure 7.

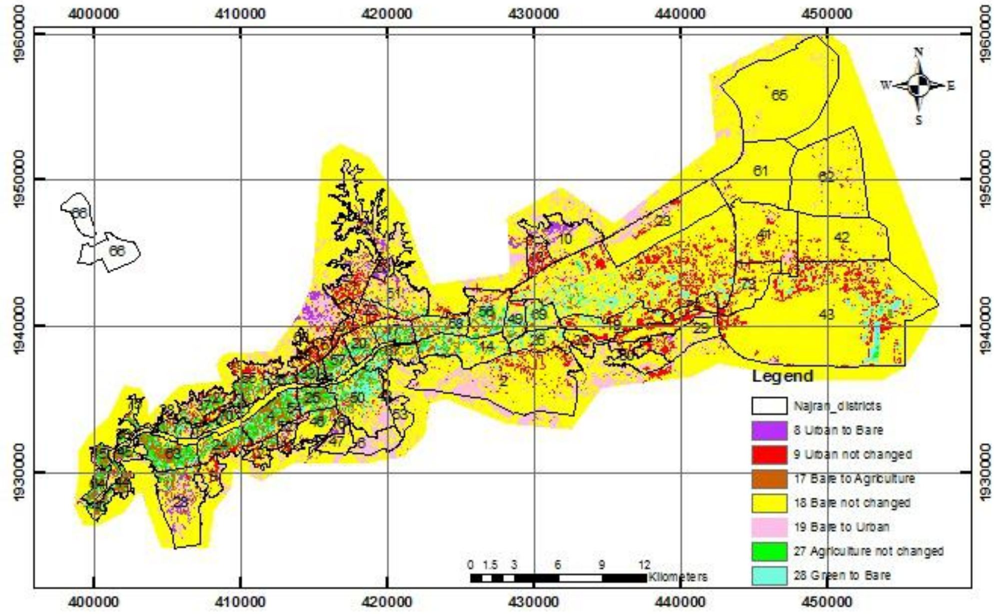

Fig. 7 The changes of land-cover classes between 2009 and 2014 for Najran city KSA.

Table 5 summarizes the area extent of the three main classes in 2009 and 2014 in addition to the types and extent of changes (unchanged, lost, and gained) for each class during the study period.

Table 5 Changes of land-cover classes from 2009 to 2014.

	Urban		Bare		Agriculture	
	km^2	%	km^2	%	km^2	%
2009	74.2	9.1	687.8	83.9	57.4	7
2014	128.5	15.7	639.6	78.1	51.4	6.3
Unchanged	58.2	78.4	586.4	85.3	20.2	35.2
Gained	70.3	94.7	53.2	7.7	31.2	54.4
Lost	16	21.6	101.5	14.8	37.2	64.8

6 CONCLUSIONS

The Landsat imagery used in this study proved to be appropriate for distinguishing approximately ten to twenty land cover categories with a spatial resolution of 30 m. After image preprocessing, unsupervised image classification has been performed to classify the images in to different land use categories. Three land use classes have been identified as urban, barren land and agricultural. Classification accuracy is also estimated using the field knowledge obtained from Google earth images. The obtained accuracy is between 61% to 87% percent for all the classes. Change detection analysis showed that Built-up area has been increased by 73.2%, agricultural area has been decreased by 10.5 % and barren area reduced by 7% during time from 2009 to 2014. The quantitative study indicated that the area of urban class has unchanged by 58.2km^2, gained 70.3 $km^2$and lost 16 km^2. For bare land class 586.4km^2 has unchanged, 53.2km^2 has gained and 101.5km^2 has lost. While agriculture area class, 20.2km^2 has unchanged, 31.2km^2 has gained and 37.2km^2 has lost.

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http://glcf.umd.edu/data/landsat/ and or http://glovis.usgs.gov/(LANDSAT sources)

BIOGRAPHICAL NOTES

Ismail Elkhrachy born in 1968, Egypt, holds a PhD in Surveying Engineering in 2008 (Institute for Geodesy and Photogrammetry, Technical university Braunschweig, Germany), a M.Sc. in Surveying Engineering in1999 (Al Azhar University, faculty of engineering, civil engineering department, Cairo, Egypt) and a B.Sc. in Civil Engineering in 1992 (Al Azhar University, faculty of engineering, civil engineering department, Cairo, Egypt). He has many years of practical and academic experience in the field of surveying engineering, Terrestrial Laser scanner, remote sensing. Several published papers. Currently, working as assistance professor, Najran University, college of Engineering, civil engineering department, Kingdome of Saudi Arabia.