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Digital Change Detection and Map Analysis for Urban Expansion and Land Cover Changes in Karbala City

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K E Y W O R D S

Change detection, Land cover, Urban expansion

A B S T R A C T

Urban growth driven by uncontrolled expansion is one of the greatest problems that reduces the fertile lands in Karbala Governorate, Iraq. This phenomenon is the cause for variety of urban environmental problems such as an increase in local temperature, cost of land, and loss of agricultural produce. Multiple images of different time periods were used, passing them through a series of image processing steps according to the methodology of work to achieve the aims of the paper by calculating land cover changes for Karbala City from 1992 to 2013. The aim of this research is to take the temporal and subtle changes in urbanization and land cover primarily to take into account a superior perception of the connection and activities between urban growth and urban environmental problems. To take action and greater control of land surface features, the data from Landsat 4 (MSS) 1992, Landsat 7 Thematic Mapper (ETM) 2003, and Landsat 8 Operational Land Imager (OLI) 2013 were used to deliver the research's aim.

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1. Introduction

Urban growth in developing countries such as Iraq is a great problem, where most of the municipality's expansion occurs without planning or let's say that the procedures of municipalities in the preparation of designs and schemes are often lagging behind the growth and urbanization practiced by the population, and therefore the urbanization is not studied in detail.

The population growth, migration, movement of residential, and commercial areas are expanded over agricultural areas. The population expansion in Iraq is joined with uncontrolled and unplanned developmental activities which leads to loss of agricultural lands and lack of infrastructure facilities. Ministry of Agriculture should take the responsibility to estimate the loss of agricultural lands during any time period. Population growth may be the main factor in the expansion of the urban areas. It should be noted that Karbala City is not subject to the standard factors of exponential growth, where it has the elements of population and migration attractions. This is due to its religious specificity and the availability of employment compared to the surrounding cities. Table 1 below shows the increase in population of Karbala province where it can be noticed that the population of the city is found to almost double during the period between 1997 and 2012[central Statistical Organization]. The process of identifying differences in the state of a phenomena or object by remotely observing at different periods of time is known as change detection [1]. The target of change detection is to compare the criterion of two points in time by controlling all discrepancies of interest [2]. Identifying changes between two or more dates is the fundamental assumption in using remote sensing data for change detection [3]. Remote sensing data is very useful for change detection application because of its general observation, unvarying coverage, and real time acquiring data [1]. The digital data from satellite imageries, such as thematic mapper (™), observation dela terra (SPOT), radar advanced very high resolution radiometer (AVHRR), in addition to Arial photographs are essential data source for various change detection implementations.

These applications include: environmental change, urban change, landscape change, wetland change, deforestation, forest mortality, vegetation change, road segmentation, and damage assessment [4]. However, three main steps must be implemented in any change detection project that include: image pre-processing, selection of suitable techniques, and accuracy assessment for attainment of good change detection results [4]

Image preprocessing involves geometrical rectification and image registration, radiometric and atmospheric correction [5]. The success of any remote sensing change detection projects affected by temporal , spectral spatial, and radiometric resolution of remotely sensed data, while miss registration led to specious results [6,7]. It is crucial to use the similar sensor, similar radiometric and spatial resolution data, to minimize the impact of external sources such as sun angle, seasonal and phonological differences [8].

In order to select an appropriate change detection technique; the selection depends on change detection direction. Normally, change detection techniques can be classed into two categories; those detecting binary change /no-change, and those detecting detailed from to change [9]. Detecting binary change / no-change techniques such as image differentiation, image ratio, and vegetation index differencing have limitation in the accuracy because the accuracy depends on the selection of the threshold which cannot supply detail from to change information [11]. From to change techniques such as unsupervised change detection, hybrid change detection, and post classification comparison provides a complex matrix of change directions, so the primal is to create a precise thematic classification images [10]. The essential steps to perform change detection include: designing the accuracy assessment sample, collecting data for each sample, and analyzing the results [10], [11]. The overall accuracy, producer's accuracy, user's accuracy, and Kappa coefficient are the extremely ordinary accurate assessment evaluation factors [12]. Since collecting true temporal field-based datasets is a problem; therefore accuracy assessment for change detection is difficult, because of Error Matrix-Based Accuracy Assessment Method's ability to describe individual accuracies of each map category with both inclusion (commission) errors and exclusion (omission) errors those present in the map; it is considered one of the valuable methods for evaluation change detection results [10, 11].

Based on remote sensing data (Landsat4, Landsat7 ETM and Landsat8 (OLI) in years (1992, 2003, and 2013), Karbala City within Karbala Governorate has experienced a rapid growth in urban population during recent decades; therefore in this research it was selected as a case study.

Detecting Karbala City's urban expansion and land cover change, producing thematic maps of study area in interested years is the main aim of this research in order to investigate and assess urban sprawl impact on agricultural land from 1992 to 2013 by means of remote sensing images.

2. Study Area and Data Used

I. Study Area

The study area is the center of Karbala district. It is one of the most typical extension cities, laying about 110 km south-west to the capital of Baghdad, on the edge of the desert in the western Euphrates, between UL 398041 E, 3615679 N and LR 417406E, 3602069 N, as shown in Figure 1. Table 1 bellow illustrates the population estimation of Karbala City for the period from 1997 to 2012. It shows the actual numbers through the last Iraqi census until 2012, where all these numbers obtained from the official estimations of the Ministry of Planning.

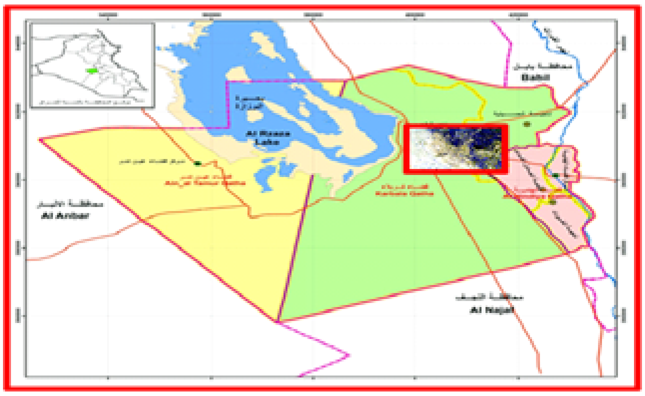


Figure 1: Map of Karbala Governorate (By Authors)

Table 1: The population estimation for Karbala governorate [central Statistical Organization]

Population	Year
594235	1997
618395	1998
643640	1999
670013	2000
697503	2001
726155	2002
755994	2003
787072	2004
819376	2005
852963	2006
887858	2007
924085	2008
961638	2009
1000546	2010
1040842	2011
1082615	2012

II. Data Used

The main spatial data used in this paper are three satellite images; Landsat 4(MSS) 1992, Landsat 7 Thematic Mapper (ETM) 2003, and Landsat 8 Operational Land Imager (OLI) 2013. These data were downloaded from the United States Geological Survey USGS Earth Explorer. Table 2 illustrates the properties of the used images to assess the changes of agricultural lands and urban encroachments in Karbala City.

Table2: Characteristics of used images [USGS web]

Space craft ID	Landsat 4	Landsat 7	Landsat 8
Sensor ID	MSS	ETM	OLI
WRS path	167-168	167-168	167-168
WRS row	38	38	38
Nadir-off nadir	Nadir	Nadir	Nadir
Output format	GEOTIFF	GEOTIFF	GEOTIFF
Geodetic	World Geodetic System (WGS84)	World Geodetic System (WGS84)	World Geodetic System (WGS84)
Referencing units	Meter	Meter	Meter
Bits per sample	8	8	16

Projection	UTM-38	UTM-38	UTM-38
Sample format	8 bit US	8 bit US	8 bit US

3. Methodology

I. Data pre-processing

Data preprocessing consist of many steps which include the following:

1) Radiometric correction

Radiometric correction is applied on satellite images from 1992, 2003, and 2013 (raw data). The conversion from digital numbers (DN'S) to radiance which is based on lowest and highest spectral radiation values (minimum and maximum); is the top of atmosphere (TOA) process. These values are extracted from the metadata file of satellite sensor type by using equation (1) [13] then converting radiation values to TOA reflectance using reflecting coefficients provided in metadata file(MTL file) by using equation (2) [14]. It is an essential process to make comparisons among images from different dates.

$L_\lambda=(M_{L*}Q_{cal})+AL$ ……….. (1)

$L\lambda$=top of atmosphere spectral radiance Watts/ (m2*srad *µm)

ML =Band –specific multiplicative rescalling factor from the metadata (RADIANCE-MULT-BAND- X, where x is the Band number)

AL = Band –specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_ X, where x is the Band number).

Qcal = Quantized and calibrated standard product pixel values (DN)

$p\lambda' = MpQcal+Ap$ …….. (2)

$p\lambda'$ = TOApalanetary reflectance, without correction for solar angle. Note that $p\lambda'$ does not contain a correction for the sum angle

Mp =Band –specific multiplicative rescalling factor from the metadata (RADIANCE-MULT-BAND- X, where x is the Band number)

Ap = Band –specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_ X, where x is the Band number).

Qcal = Quantized and calibrated standard product pixel values (DN)

2) Resampling

Eight spectral bands with a spatial resolution of 30 meter in bands one-fifth and seventh, while its eighth band (panchromatic) has a spatial resolution of 15 meter; were used as data from the Landsat7 (ETM). Nine spectral bands with a spatial resolution of 30 meter in bands one- seventh and ninth, while its eighth bands (panchromatic) has a spatial resolution of 15 meter; were used as data from the Landsat8 (OLI) While the spatial resolution of Landsat MSS, which has four spectral bands, is 60 meter so the data was re-sampled to 30 meter to fit pixel size of MSS with that of other sensors (Landsat7 and 8) to achieve the conditions of change detection. Figure 2 shows the satellite images of study area before and after resampling. The resampling results show that pixel size reduced from 60 to 30m and file size increased about 3 times from 14.3MB to 41.9MB mentioning to the increasing of pixels.

3) layer stack

The process of combining multiple images (bands) into a single image is called layer stacking. By layer stacking, we acquired multi band image built for special analysis.

We are studying environmental parameters (agriculture, settlement, and barren land), and we know that each parameter has specific response to limit wavelength. Therefore, we are merging these bands in a multi band image to support our analysis or parameters recognition required. These images should have the same extend (no. of rows and columns), which means resampling other bands which have different spatial resolution to the target resolution before this step. Layer Stack was made for the selected bands required to achieve the aims of this paper as shown in Figure 3. USGS assigned the band combination for each application as in Table 3.

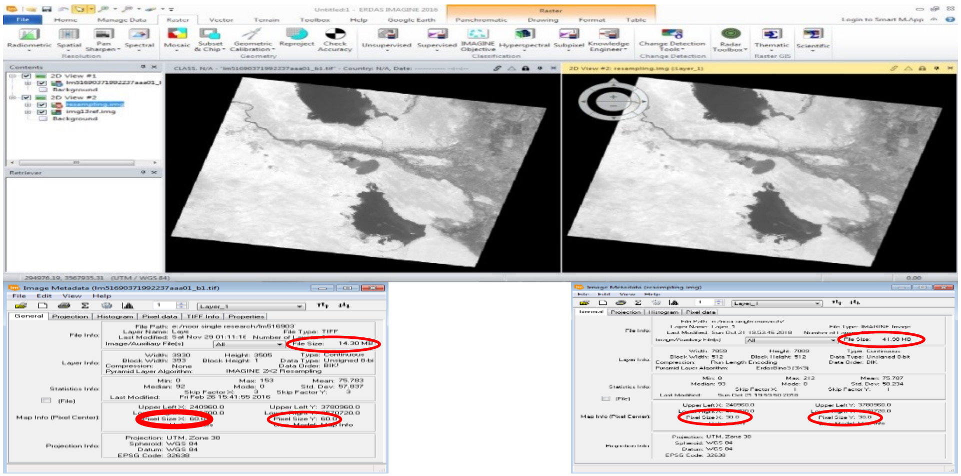


Figure 2: Resampling of Landsat 4 (MSS) images.

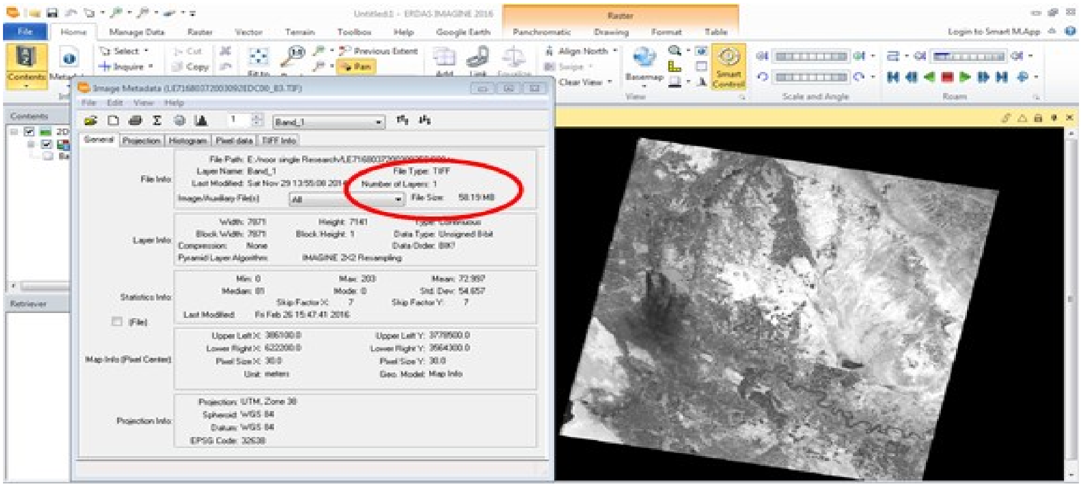
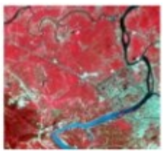
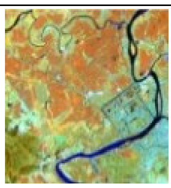


Figure 3: Layer stick, merging bands of Landsat images.

Table 3: Band Combination for Landsat [USGS]

Photo	Bands	Details
	1,2,3	This color composite is as close to true color that we obtain with a Landsat ETM image. In addition, it is convenient for studying aquatic habitats. The drawback of this set of bands that they be likely to yield a fogy image.
	2,3,4	Since this contains the near infrared channel (band 4) land water boundaries are clear and different types of vegetation are more obvious, but it has related classification to the image bands 3, 2, 1. Since Landsat MSS data did not have a mid-infrared band this was a popular band combination.
	3,5,4	Since the two shortest wavelength bands (band 1 and 2) are not contained; this is crisper than the prior two images because. unique vegetation types can be more distinctly determined and the land /water interface is very obvious. Distinction in moisture content is noticeable with this set of bands. This is no doubt the most common band combination for Landsat imagery.

	7,4,2	The biggest difference to the 3,4,5 band combination the vegetation is green, but it has similar properties to them NASA selected this band combination for the global Landsat mosaic.

4. Subset

The downloaded Landsat scene covers an area of about 190 km by 185 km comparing with the area of interest which is about 19.25 km by 13.5 km. It makes sense to cut out a subset of this larger image to simplify our analysis and focus on the area of interest mentioned in Figure 4.

5. Geometric Correction

To avoid geometric disfigurement from the disfigurement image; geometric correction is assured. This achievement was done by generating a connection between the geographic coordinate system, and the image coordinate system using calibration data from the sensor, measured data of the same position and attitude, ground control points, atmospheric condition, etc. There are many ways of geometric correction that can be classified regarding to the type processing or data sources. Image to image geometric correction was applied by returning the low resolution image (as source) to the high resolution image which assumed as the base (target). Figure 5 shows the result after drawing polygons around the Holy Shrines in the base and make the comparison with Landsat image to find high accuracy in this process.

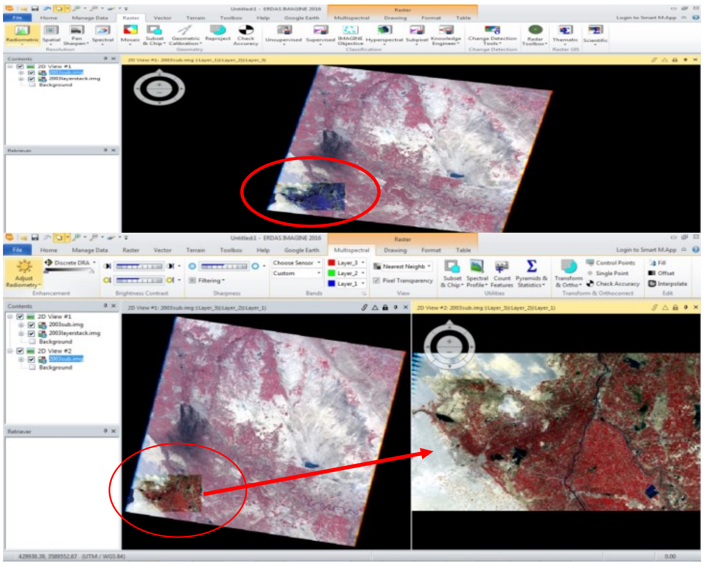


Figure 4: Area of interest; Full scene and Subset scene.

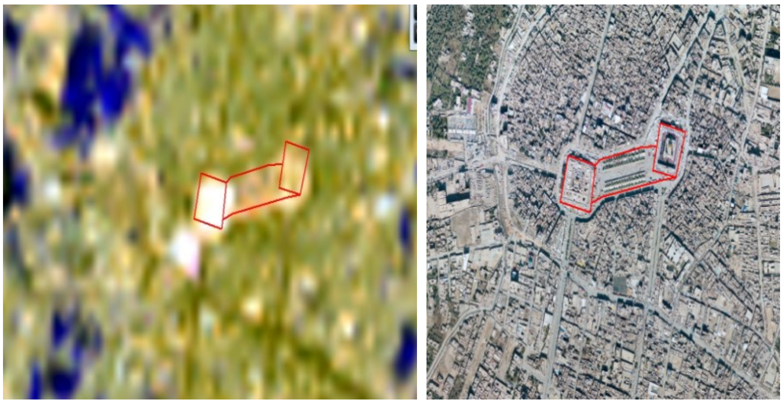


Figure 5: Geometric Correction

I. Change detection technique used

In order to determine the changes that took place during the two periods: 1992-2003 and 2003-2013, change detection used to give us indicators about the amount of change. ERDAS Imagine Software used to check the change detection. In the beginning we tried 10% changes and found that most of area of interest was changed more than 10%, then 25% was tried to get that the main locations were changed to focus our study on these areas that changed more than 25% between the start and the end of the period. The results are shown in Figure 6 below which helps to reach to the ground truth.

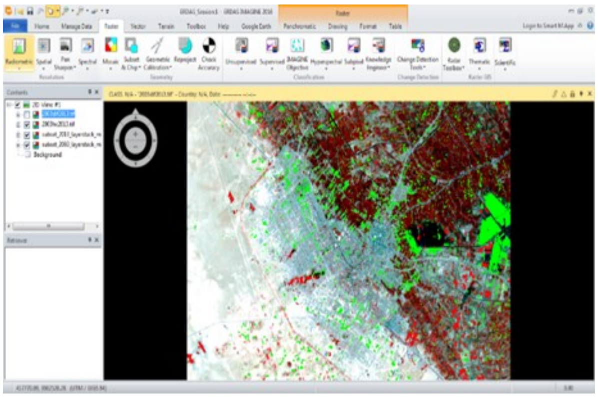


Figure 6a: change detection took place during required period 10%;

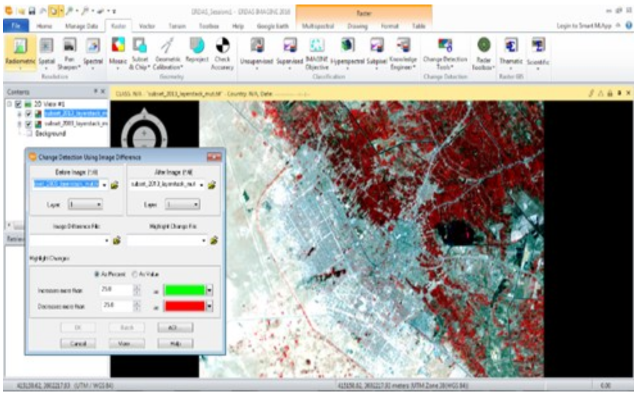


Figure 6b: change detection took place during required period 25%;

II.Supervised Classification

The supervised classification was used in this research to classify the three images, produce thematic maps, and analyze the land cover change. Performing post classification comparisons of the produced thematic maps to assess the various types of change was applied by using Erdas Imagine V 16 Software. In supervised classification, the computer computes the spectral signatures of each class after the operator determines the areas where a distinct particular class of land cover is presented. Supervised classification for Landsat Multispectral Scanner (MSS) dated 10 April 1992, Landsat Thematic Mapper (ETM) dated April 11, 2003 and Landsat 8 (Operational Land Image, OLI) dated April 21, 2013 were used. Maximum likelihood algorithm was applied, using samples of known identity (training data) to classify the unknown identity. In order to choose what types of pixels for a specific land cover; the training data was given by the operator to guide the software. More than 50 training areas as polygon of known land cover classes were chosen. The selection of training samples is the most important step in supervised classification, and these training samples include at least 10 samples of each representative feature type within land cover classes. Three classes of land cover were specified. Each class was selected based on information of prior knowledge of study area that obtained from topographic map and very high resolution satellite image (World View 03, 30 cm resolution) which was used as a reference source. Thus, very high resolution satellite images used as a reference data instead of ground truth points. Then, each pixel classified based upon which of the training sites that is matched most closely. Land cover maps are the result of classification shown in Figure 7. Each of the produced maps includes three classes (agriculture, settlement, and barren).

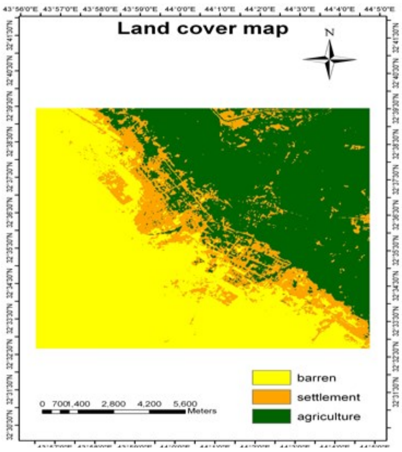


Fig 7 a, Thematic map of supervised classification 1992

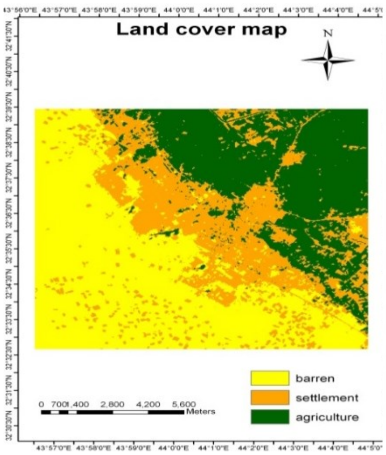


Fig 7 a, Thematic map of supervised classification 2003

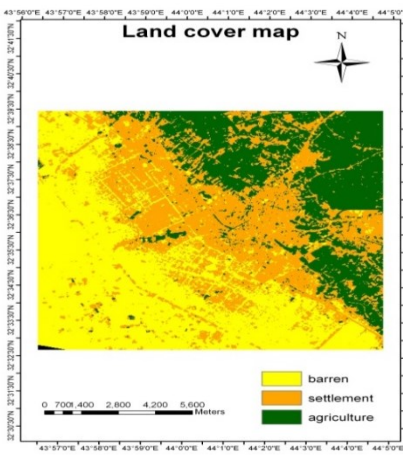


Fig 7 a, Thematic map of supervised classification 2013

6. Results

The main factor that dominates land degradation in our case study is urban expansion which causes loss of agricultural land. Therefore, it was assessed by showing the changes that occurred during the period of 1992 to 2013 using multi dates satellite images. Table 4 illustrates the total inspected area which was decided by 16,402.32 hectare and area of each class. Table 5 illustrates urban growth rate for the two periods (1992-2003) and (2003-2013) in study area. Figure 8 shows the changes in area of each class for the two periods (1992-2003) and (2003-2013).

Table4: The supervised classification result of each image.

area	1992 Hectare	%	2003 Hectare	%	2013 Hectare	%
Agricultural land	6278.85	38.280	4717.17	Agricultural land	6278.85	38.280
Settlement	2421.90	14.766	4428.09	Settlement	2421.90	14.766
Barren land	7701.57	46.954	7257.06	Barren land	7701.57	46.954
total	16402.32	100	16402.32	total	16402.32	100

Table 5: Urban growth rate

class	Change area 1992 /2003 Hectare %		Change area 2003/2013 Hectare %	
Agricultural land	-1561.68	-9.702	Agricultural land	-1561.68
Settlement	+ 2006.19	+12.215	Settlement	+ 2006.19
Barren land	-444.51	-2.513	Barren land	-444.51
class	Change area 1992/2003 Hectare %	Change area 2003/2013 Hectare %	class	Change area 1992/2003 Hectare %

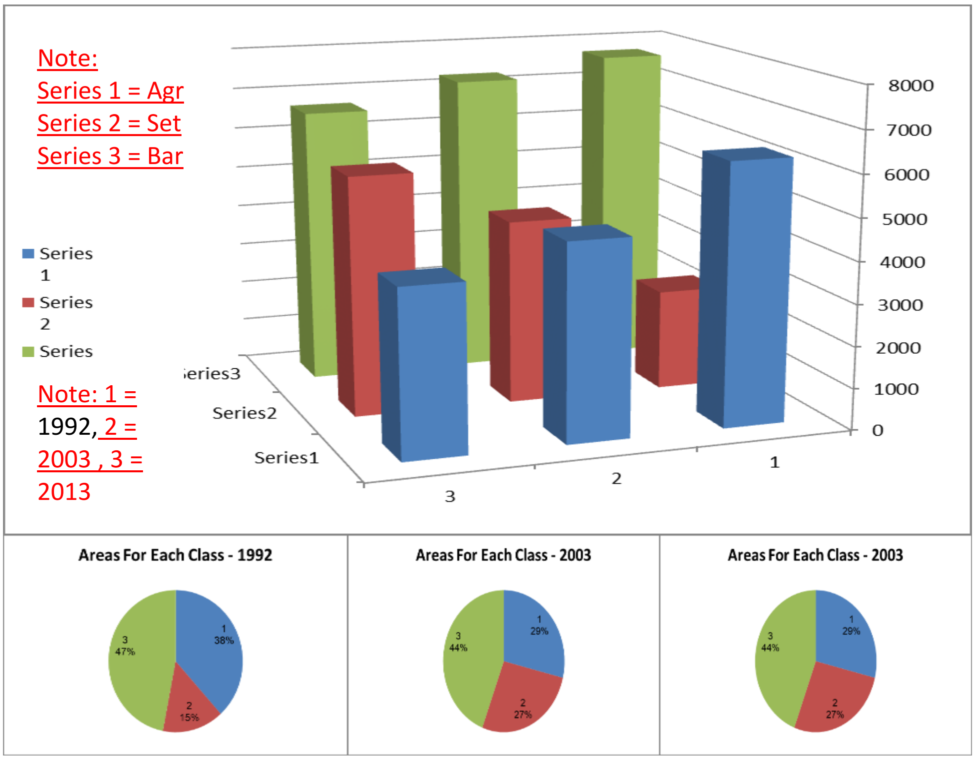


Figure 8: Charts explaining areas of each class of land use in 3 periods

7. Discussion

The discussion is based on Post classification matrix and Classification accuracy assessment.

I. Post classification matrix

Post classification is used to find quantities of conversion from a specific land cover to another land cover category at a later date. The obtained change matrices were based on post classification comparison as illustrate in Tables 6 and 7. The changes of different land classes into another land class for the period (1992-2003) and (2003-2013) were presented.

Settlement covered 2421.90 hectare in 1992 and 4428.09 hectare in 2003, 4717.17 hectare of agriculture land which was vegetation in 1992 was still vegetation cover in 2003 but 1561.68 hectare has been converted to settlement, 7257.06 hectare of barren land in 1992 was still barren land in 2003 but 444.51 hectare has been converted to settlement in 2003 .

Settlement covered 4428.09 hectare in 2003 and 5750.654 hectare in 2013, 3989.209 hectare of agriculture land which was vegetation in 2003 was still vegetation cover in 2013 but 727.962 hectare has been converted to settlement, 6662.458 hectare of barren land in 2003 was still barren land in 2013 but 594.602 hectare has been converted to settlement in 2013.

Table 6: Post classification matrix of study area from 1992 to 2003.

Class	Agriculture land 1992	Settlement 1992	Barren land 1992	Total 1992
Agricultural land 2003	4717.17	0	0	4717.17
Settlement 2003	1561.68	2421.90	444.51	4428.09
Barren land 2003	0	0	7257.06	7257.06
Total 2003	6278.85	2421.90	7701.57	16402.32

Table 7: Post classification matrix of study area from 2003 to 2013.

Class	Agriculture land 2003	Settlement 2003	Barren land 2003	Total 2003
Agricultural land 2013	3989.208	0	0	3989.208
Settlement 2013	727.962	4428.09	594.602	5750.654
Barren land 2013	0	0	6662.458	6662.458
Total 2013	4717.17	4428.09	7257.06	16402.32

II. Classification accuracy assessment

Accuracy assessment of derived land cover maps is very important. Information concerning the distribution of earth's resources is provided by maps. Maps are helpful tool for measuring the extent and distribution of resources, analyzing interactions of resource, and identifying suitable locations for particular actions. The accuracy of the derived land cover map must be known because the decisions are based on results that extracted from these maps. The accuracy of any map may be tested by comparing the positions of points whose locations or with corresponding positions as determined by traditional ground surveying with high accuracy. In this study, the accuracy of the classified maps was evaluated by making comparison with reference date that is obtained from selecting random sample points. The Reference data were collected by satellite imagery IKONOS and field survey work was carried in 2013. During this field surveying, a large amount of different field data was collected from different sites by using portable GPS device (TOPCON GMS2) to allow for further integration with the spatial data in image classification system. It was found that overall accuracy assessment is 86.54%. Table 8 illustrates accuracy assessment by checking classification results with ground truth and Table 9 illustrates accuracy assessment percentage.

Table 8: Accuracy assessment by checking classification results with ground truth

Point	Vector Class	Raster Class	Identical
1	Green Area	Green Area	TRUE
2	Green Area	Green Area	TRUE

5	Green Area	Green Area	TRUE
6	Green Area	Green Area	TRUE
7	Green Area	Green Area	TRUE
8	Green Area	Green Area	TRUE
9	Green Area	Green Area	TRUE
10	Green Area	Settlement	FALSE
11	Green Area	Green Area	TRUE
12	Green Area	Green Area	TRUE
13	Green Area	Green Area	TRUE
14	Green Area	Settlement	FALSE
15	Green Area	Settlement	FALSE
16	Green Area	Green Area	TRUE
17	Green Area	Green Area	TRUE
18	Green Area	Green Area	TRUE
19	Green Area	Settlement	FALSE
21	Settlement	Settlement	TRUE
22	Settlement	Settlement	TRUE
23	Settlement	Settlement	TRUE
24	Settlement	Settlement	TRUE
25	Settlement	Settlement	TRUE
26	Settlement	Green Area	FALSE
27	Settlement	Settlement	TRUE
28	Settlement	Settlement	TRUE
29	Settlement	Green Area	FALSE
30	Settlement	Settlement	TRUE
31	Settlement	Settlement	TRUE
32	Settlement	Settlement	TRUE
33	Settlement	Settlement	TRUE
34	Settlement	Settlement	TRUE
35	Settlement	Settlement	TRUE
36	Settlement	Settlement	TRUE
37	Settlement	Settlement	TRUE
38	Settlement	Settlement	TRUE
39	Settlement	Settlement	TRUE
40	Settlement	Settlement	TRUE
41	Settlement	Settlement	TRUE
42	Settlement	Settlement	TRUE
43	Settlement	Settlement	TRUE
44	Settlement	Settlement	TRUE
45	Settlement	Barren area	FALSE
46	Barren area	Barren area	TRUE
47	Barren area	Barren Area	TRUE
48	Barren area	Barren area	TRUE
49	Barren area	Barren area	TRUE
50	Barren area	Barren area	TRUE
51	Barren area	Barren area	TRUE
52	Barren area	Barren area	TRUE
53	Barren area	Barren area	TRUE
54	Barren area	Barren area	TRUE
55	Barren area	Barren area	TRUE

Table 9: Accuracy assessment percentage

	Green Area	Settlement	Barren area	SUM	Percentage
Green Area	13	4	0	17	76.47%
Settlement	2	22	1	25	88.88%
Barren area	0	0	10	10	100%
SUM	15	26	11	52	
	86.66%	84.61%	90.90%		**86.54%**

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