

Urban Expansion Classification using the Change Detection of High-Resolution Images, for Jeddah Province



A. M. Abdel-Wahab, Ahmed K. Abdel-Gawad, Alaa Al Din I. Awad

Abstract: The Kingdom of Saudi Arabia is heading to catch up with civilization, to be one of the major international country in the first world. One of the important things is to identify the urban changes taking place in the city growth. Also, high resolution satellite images of Jeddah are available from various sources such as GeoEye (2010) and WorldView-3 (2015). Jeddah has different satellite images from different sources with different accuracy and therefore the spectral, spatial resolution and coverage area are different. So, the aim of this research work is to assess, compare, and describe the some ways of dealing with image of the GeoEye (2010) and image of the WorldView-3 (2015). To reach the desired uses of these methodologies and to achieve a degree of accuracy appropriate to the required results, formulating this comparison within the boundaries of the Jeddah Governorate to define the scope of the study and dealing with different geographical factors that characterize the province of Jeddah. In this context, in the current research work, the sample representing the urban area was chosen from 2010 and 2015. The quality control process was done on the product using different methods to detect automatic changes of the Study areas, like (area - geometric shape - number of changes). For Geometric shape of the image in 2015, it is noted that the best result was the ratio ranges between 50-60% in the following methods (IHS to RGB - Image Segmentation - Unsupervised (ISODATA) - Supervised (min)). As for the rest of the results, it ranges between 30% - 40%. As for the number of Vertex of the geometric shape of the image 2015, it is noted that the lowest number of points that make up the buildings is from the Image Segmentation method and the largest number of points that make up the buildings is from the Unsupervised (K-means) method. In the area of the building in 2015, is noted that the best result, where the ratio ranges between 65%-70% in the following methods (IHS to RGB - Image Segmentation - Unsupervised (ISODATA) and Supervised (Maximum)). On the contrary, the lowest result was the ratio reaches 59% in Supervised (Minimum) method. For the number of buildings in 2015, is noted that all the results of the supervised classification and the unsupervised classification are close to what was achieved by digitizing.

Keywords: Change detection, Classification, High Resolution Satellite Imagery, Image Segmentation.

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* Correspondence Author

A. M. Abdel-Wahab*, Civil Engineering Department, National Research Centre, Egypt(NRC). Email:abdwhab@gmail.com

Ahmed K. Abdel-Gawad, Professor, Department of Civil Engineering, National Research Centre, Egypt.

ALAA AL DIN I. AWAD, Assistant Professor of Surveying, Public Works Department, Faculty of Engineering, Ain Shams University, Egypt.

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I. INTRODUCTION

Nowadays, many developing countries, like Jeddah city in KSA have many challenges and complications in planning municipal services and managing available resources. So, it was important to make a comparative study and monitor the rapid expansion of the city and the impact of this expansion of services and the environment.

Recently, more and more space images are available. These images are very cost effective in mapping large regions, which is typically needed for rapid expansion detection. So, producing and updating maps are very important, especially with the rapid and dynamic changes in land use and development. Nevertheless, one of the problems that could hinder the use of such imagery is the classification of images. Hence, the current paper is devoted to assess, compare, and describes the some ways of dealing with images. Change detection is the method of recognizing differences in the case of a place / phenomenon by determining it at different times period [4]. Therefore, the classification process and change detection are computer algorithms for information extraction. On the other hand, image classification is a form of pattern recognition, or identification of the pattern associated with each pixel position in an image in terms of geographic locale [17]. Also, the change detection is a process used to identify changes with time [16]. On account of the advantages of available satellite imagery data, such as GEOEYE, WORLD VIEW3 which have an advanced of Very High Resolution for change detection and classification applications [9]. The essential technology for detecting change -depends on remotely sensed data- is based on the examination of two digital images of the same area obtained on two different dates GeoEye (2010) and WorldView-3 (2015) [5], [8]. The subtraction or overlap between the two images indicates areas undergoing change. The obtained results can be evaluated using supportive sources such as fieldwork or ancillary data as mentioned before. Several algorithms were used to extract the change using remote sensing data [7], [13]. In this context, Change Detection - Zonal Change (Images Difference), Classification (Supervised - unsupervised - image classification) will be done in this research work.

II. DATA USED, DATA PREPARATION, AND STUDY AREAS

In this research the sample is chosen for residential area, and it is located in regular zone represent a certain district in Jeddah as shown in figure (1).



In addition, the two different dates one in 2010 for GEOEYE satellite image as shown in figure (2) and the other in 2015 for the world view 3 satellite image for the regular area as shown in figure (3).

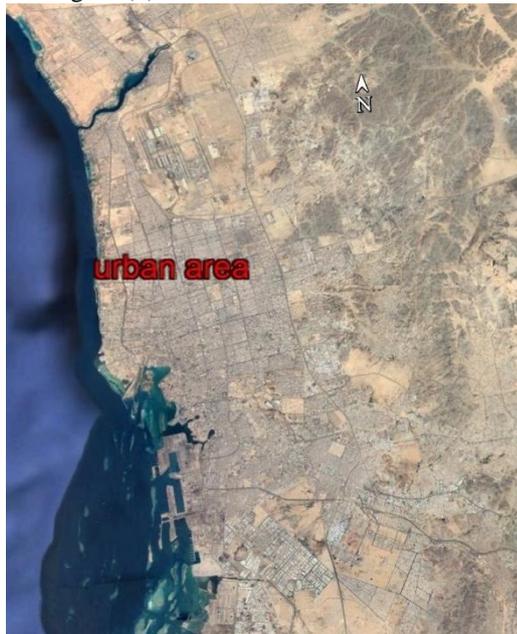


Fig.1. Jeddah city and the location of Sample area.

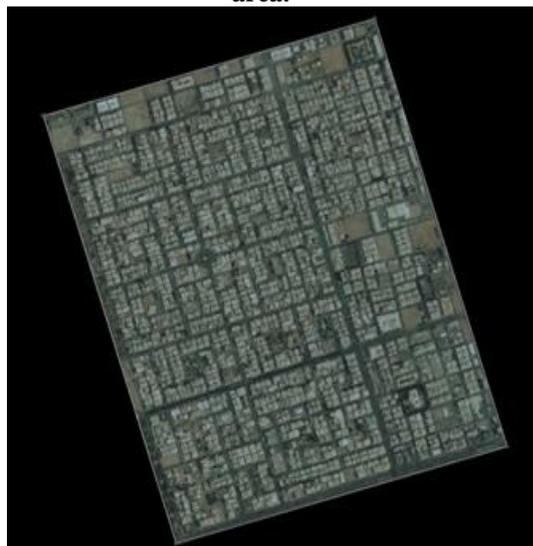


Fig.2. The regular area for GeoEye 2010.

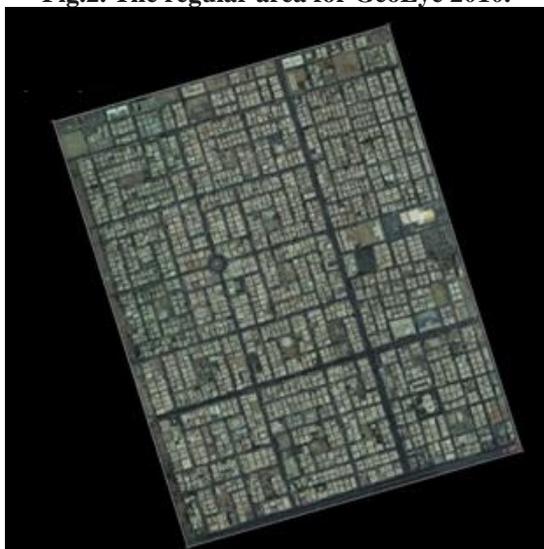


Fig.3. The regular area for worldView-3 2015.

Table (I) represents the most specifications of the images which were used in this research.

Table I: Image Specifications (Data used) [5], [8]

Platform	Sensor and Spatial resolution		Swath width At nadir	Revisit Time
	PAN	Multi-spectral		
GeoEye-1	0.41 m	1.65 m	15.2 km	2.8 days
World view 3	0.31 m	1.24 m	13.1 km	<1days

III. METHODOLOGY

There are many changes in both of regular and slum areas, which are located in the east of Jeddah city, near the mountainous areas. So, the study area was determined, and this was done by extracting samples from Jeddah city represent a certain district of organized urban areas. The change in buildings was manually drawn between 2010 and 2015 from the available visualizations and a strict quality control process by field check which carried out on the product, so that the producing layer is a standard measure to determine the accuracy of the results of methods to detect automatic changes in terms of (area - geometric shape - number of changes). The digital image processing used to extract meaningful information from remote sensing data consists of four main areas of computer operation: image processing (recovery), image improvement, image classification, and discovery of change [3], [9]. The digital image processing is the important steps before extracting the information from remote sensing data. In other words, there are two main branches of image processing (geometric correction and radiometric correction) [1]. Also, the classification process and change detection are made using computer algorithms for information extraction. On the other hand, image classification is a form of pattern recognition, or identification of the pattern associated with each pixel position in the image in terms of geographic locale [17]. Change detection is a process used to identify changes with time [16]. The basic technology for detecting change based on remotely sensed data is based on the examination of two digital images of the same area obtained on two different dates GeoEye (2010) and WorldView-3 (2015) [5], [8]. The subtraction or overlap between the two images indicates areas undergoing change. The obtained results can be evaluated using supportive sources such as fieldwork or ancillary data as mentioned before. Several algorithms were used to extract the change using remote sensor data. In this context, Change Detection - Zonal Change (Images Difference), Classification (Supervised - unsupervised - image classification) will be used in this research work.

In this research, an investigation and analysis were carried out using high resolution satellite image data and supplementary information to come up with, hopefully, good change detection results. Image processing with GIS were performed using ERDAS Imagine and ARCMAP software Building on experience gained elsewhere, the following change detection and image classification were used as shown in figure (4):

- Image processing (visual evaluation) and extraction of the area of interest.

- Geometric and radiometric correction and image enhancement of the test data.
- Change detection methods (Zonal change - Delta cue).
- Classification techniques (supervised - unsupervised- image segmentation).

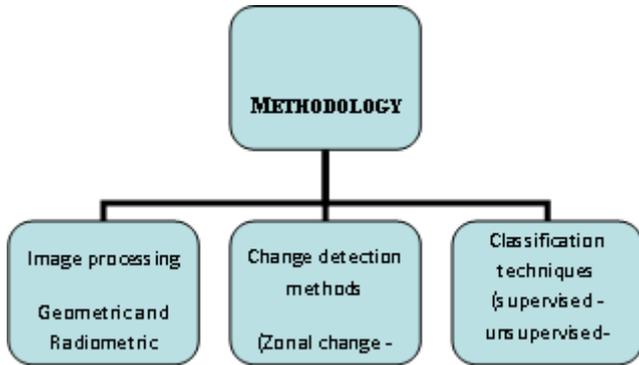


Fig.4. Research Methodology

IV. IMAGE PROCESSING

(GEOMETRIC AND RADIOMETRIC CORRECTION)

To achieve the aim of the current research which is to get a change detection and image classification; the following steps can be done. The data used in this research have different geometric properties and need to be co-registered. So, the geometric distortions in satellite images are usually handled through a Geo-referencing step [1]. Geo-referencing is the procedure of returning ground coordinates to image coordinates which might have already projected onto a plane surface. In this research, the different data used are registered to each other rather than Geo-referencing each image separately, knowing that the reference image is already Geo-referenced to ground coordinate system. This process was done using the affine transformation technique [1] as mention in equations (1 and 2) by using ERDAS Imagine software) and as shown in figure (5). Also, Co- registration with Auto Sync and the radiometric correction are done by using Histogram Matching as shown in figures (6 and 7).

$$x = a + b i + c j \tag{1}$$

$$y = d + e i + f j \tag{2}$$

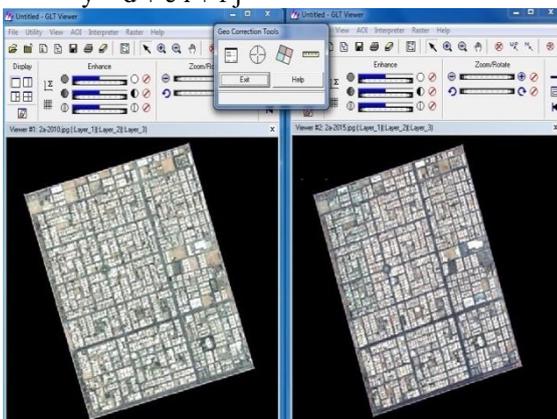


Fig.5. Image to image registration.



Fig.6. Radiometric correction of images (2010 and 2015) together, using Histogram Matching.



Fig.7. Orthorectification process for adjusting the roofs of buildings, with some images between 2010 and 2015 using the Auto Sync method.

V. CHANGE DETECTION

A. Images Difference

Change detection using an image difference method to determine the difference of every pixel in each image (after geometric and radiometric process) as show in figures (8,9 and10). Equation (3) represents the image difference [10].

$$I_d(x,y) = I_1(x,y) - I_2(x,y) \tag{3}$$

Where:

- I_1 and I_2 indicate the two images with two different dates
- (x, y) : represent the coordinates of each pixel
- I_d is the difference between two images.



Fig.8. Image difference between the 2010 and 2015 using the Images Difference method.

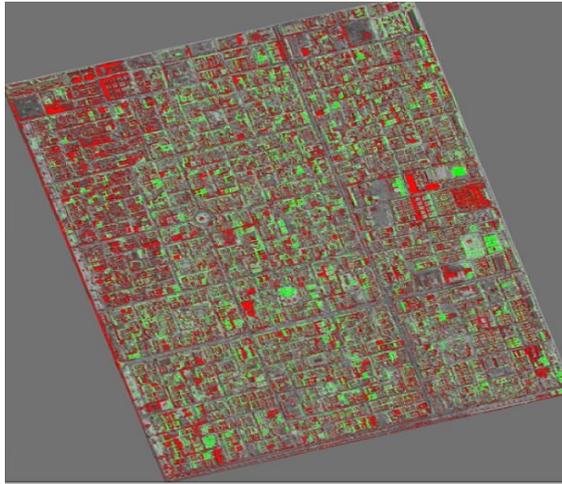


Fig.9. The change between the image in 2010 and the image in 2015 for the changed areas. (A red color indicates an increasing area and a green color indicate a reducing by using the Images Difference method).

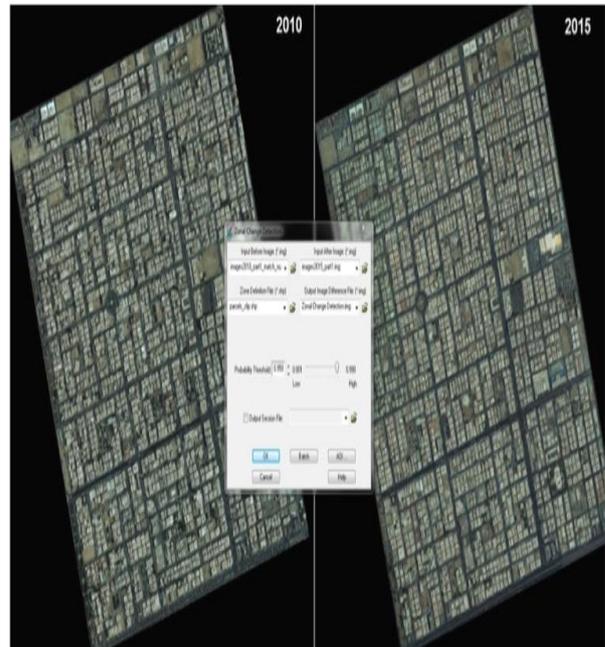


Fig.11. The change between 2010-2015 using Zonal change.

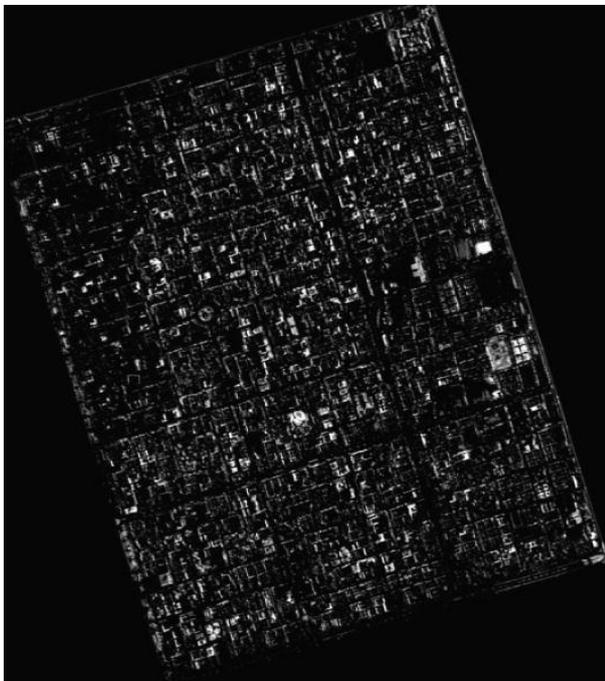


Fig.10. The change between the image in 2010 and the image in 2015 for the areas have the change by white color using the Images Difference method).

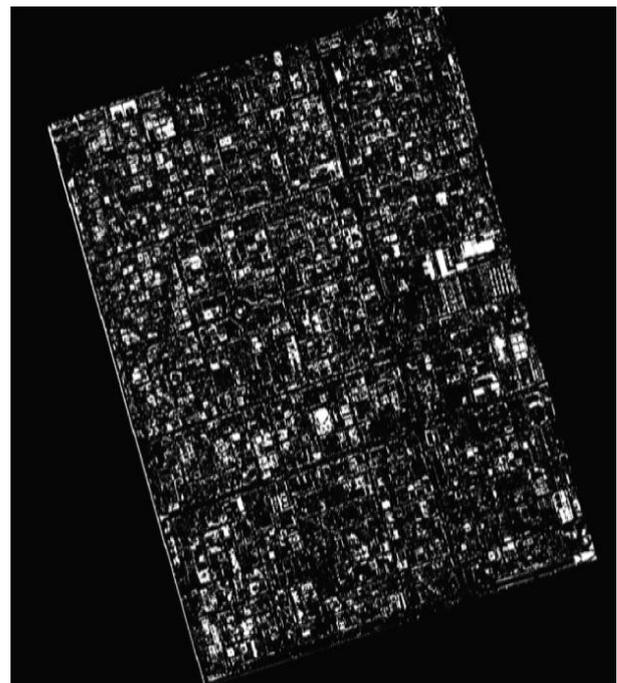


Fig.12. The change between images 2010 and 2015 where the change appears in white color using the Zonal Change method.

B. Zonal Change

This method is based on calculating the variation range for two images which was saved in the database in the Shape file for the two fields (change area - percentage of change) [13], [4] and [7]. In this context, the differences within a zone between 2010 and 2015 images, prioritizing the likelihood of change, and completing the result. Change detection by using the zonal change is used to identify significant differences in imagery acquired in the same area, at date 2010 and 2015. Also, the GIS features provide the capability to update data based on two different two imagery to obtain this information as show in figures (11,12 and 13).



Fig.13. The change between images in 2010 and 2015 using the Zonal Change method.

C. Discriminat Function

Discriminat function Used to compute the likelihood of change for each pixel of two different images of different dates [15]. Else, Discriminat function is a method to obtain which weightings of quantitative variables / predictors the best discriminate between two different images or more as seen in equation 4 and figures (14 and15).

$$Z_{jk} = a + w_1X_{1K} + w_2X_{2K} + \dots + w_nX_{nK} \quad (4)$$

Where:

- Z_{jk} = Discriminat Z score of discriminant function j for object k.
- a = Intercept.
- w_i = Discriminat coefficient for the Independent variable i.
- X_j = Independent variable i for object k.

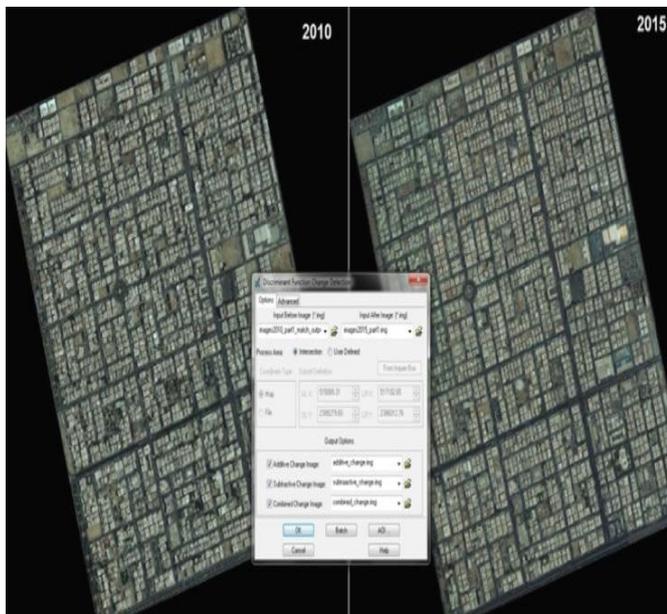


Fig.14. The change between 2010 and 2015 images using the Discriminat Function method.

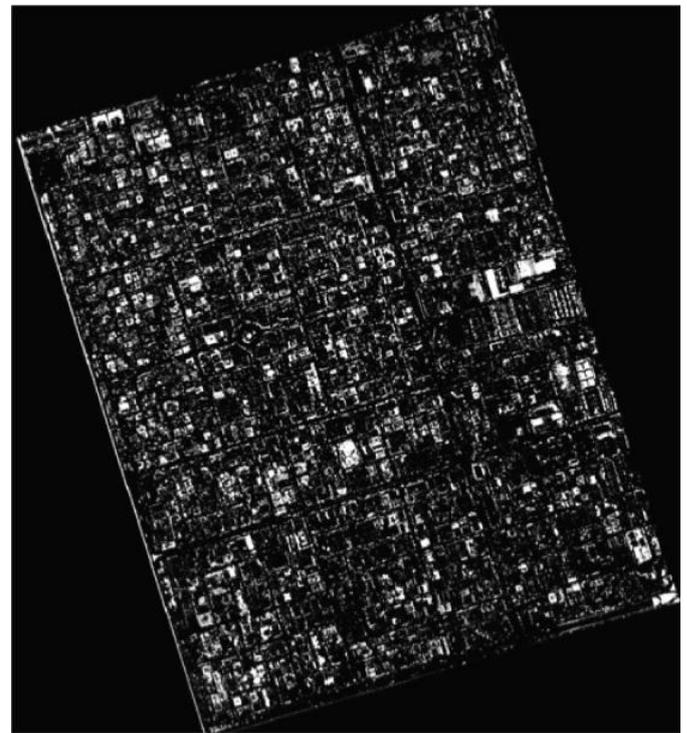


Fig.15. The change between images 2010 and 2015 where the change appears in white color by using Discriminat Function method.

D. Delta Cue (Site Monitoring)

Delta Cue is considered one of change detection techniques and used to help in identifying the changes which happened on two images with two different dates [6] as show in figures (16,17 and18).

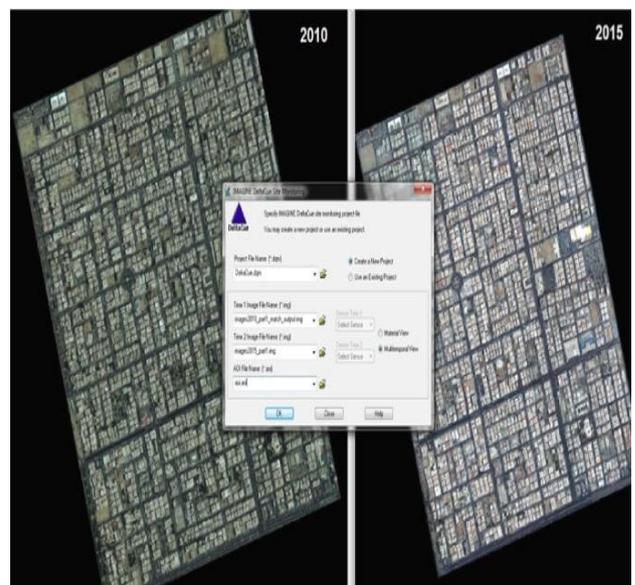


Fig.16. The change between 2010 and 2015 images using Delta Cue Site Monitoring method.



Fig.17. The change between images 2010 and 2015 where the change appears in different color by using Delta Cue Site Monitoring method.

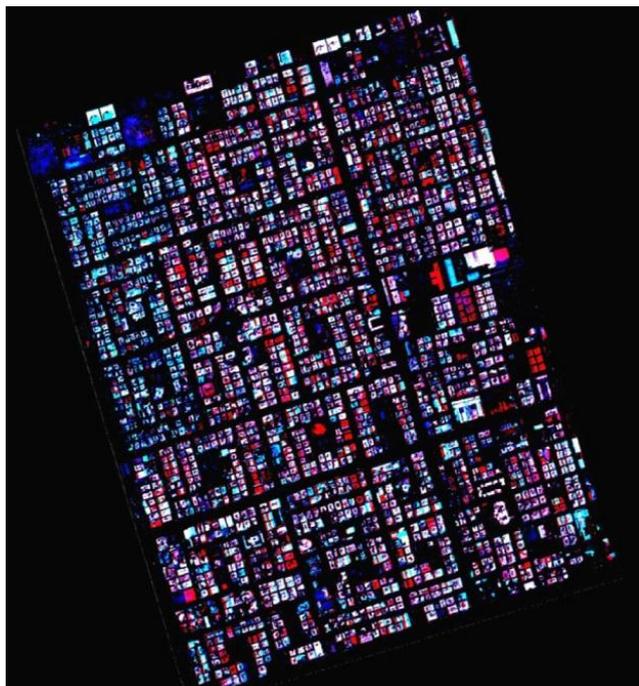


Fig.18. The change between images 2010 and 2015 where the change appears in color red with a choice of the bands are displayed 4,3 and 2 by using Delta Cue method.

VI. CLASSIFICATION

Classification is the procedure of classifying satellite imagery into layers or groups of data according to pixel values according to the spectral signature for each group that have the same pixel values. There are two types of classification (Supervised classification -Unsupervised classification). In the current research the following

techniques will be applied: Supervised classification (Maximum Likelihood (ML) -Minimum Distance-Mahalanobis Distance), Unsupervised classification (K-Means - Isodata), image segmentation, IHS to RGB, and Raster to Vector(digitizing).

A. Supervised classification

▪ (Maximum Likelihood (ML))

In this method (ML) is used to rule according to the likelihood (BAYES theorem) that a pixel pertinent to a class [2]. The equation calculates the statistical probability of a pixel belonging to a specific signature, which expressed by the a posteriori distribution $P(i|\omega)$, i.e., as seen in equation (5) and figures (19 a and b).

$$P(i|\omega) = \frac{P(i|\omega)P(\omega)}{P(\omega)} \quad (5)$$

where: -

$P(\omega|i)$ = likelihood function,

$P(i)$ = The a priori information, and

$P(\omega)$ = The probability that ω is observed,

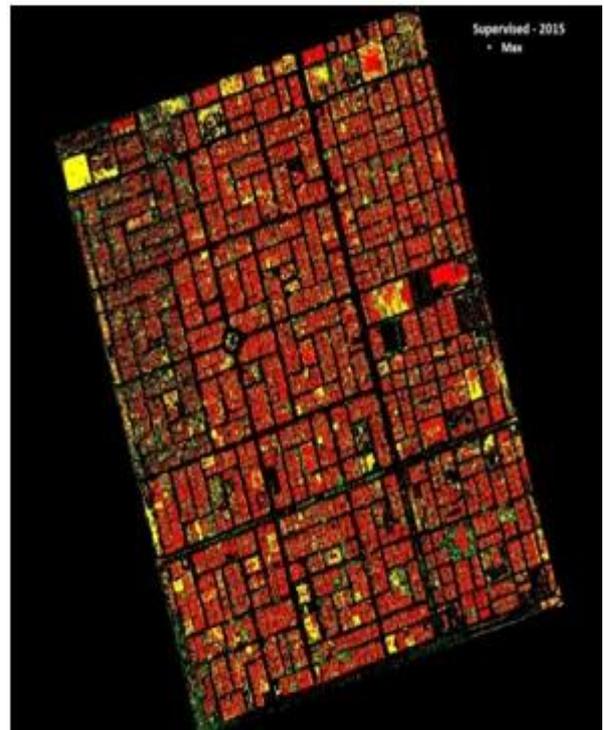


Fig.19 (a) 2015.



Fig.19 (b). 2010.

Fig.19(a and b). The supervised classification for two images (2010 and 2015) using Maximum Likelihood method.

▪ **Minimum Distance**

The current method (Minimum Distance) calculates the distance in multispectral space of each pixel from the mean of each signature [13]. A pixel can be classified according to the mean to which it is closest, as shown in figures (20 a and b).

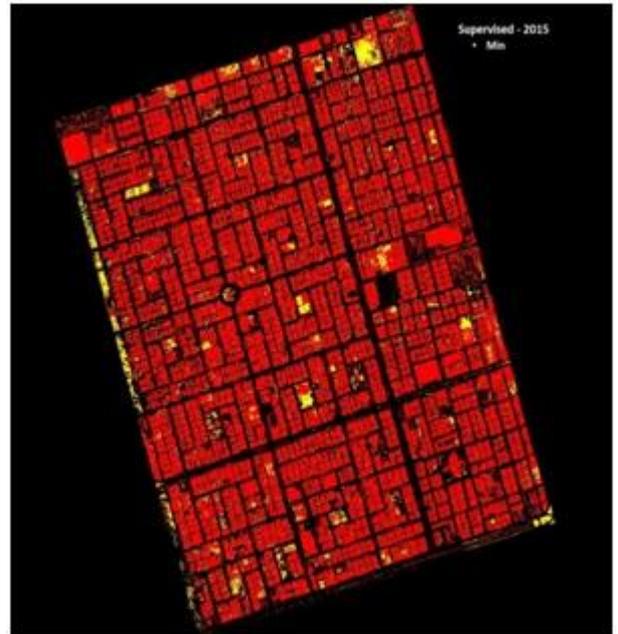


Fig.20 (b). 2010.

Fig.20 (a and b). The supervised classification for two images (2010 and 2015) using Minimum Distance method.

▪ **Mahalanobis Distance**

The Mahalanobis equation is a parametric classification algorithm. It relies on a normal distribution of data in each band for each class [13]. Usually, it gives more discriminate results than the minimum distance option because it also considers the difference of the data, as shown in figures (21 a and b).

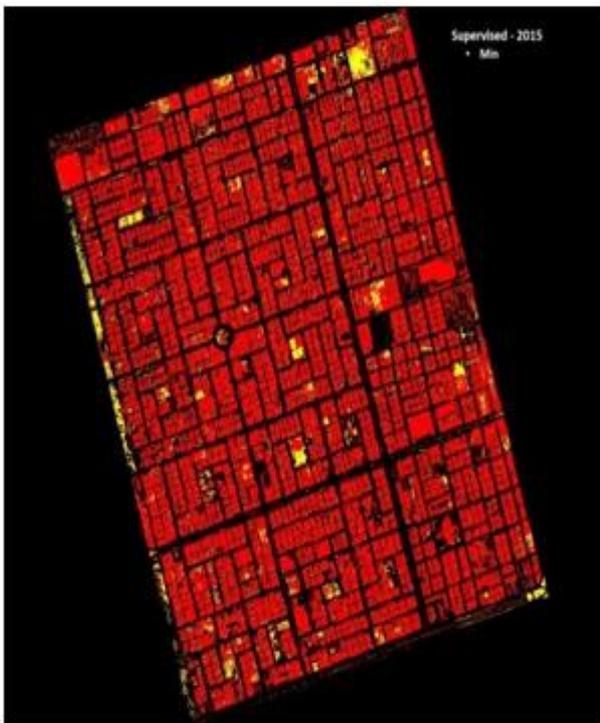


Fig.20 (a). 2015.

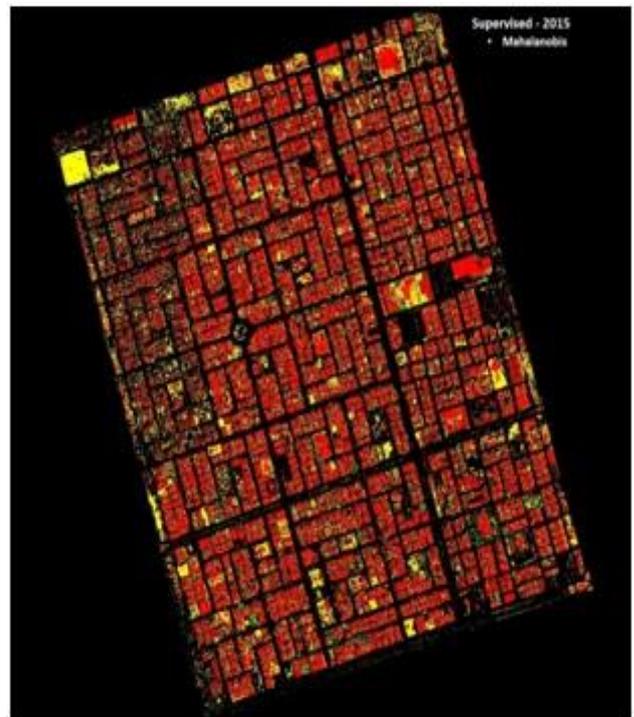


Fig.21 (a). 2015.



Fig.21 (b). 2010.

Fig.21(a and b). The supervised classification for two images (2010 and 2015) using Mahalanobis Distance method.

B. Unsupervised Classification

▪ K Means

This method requires one to enter a predetermined number of output clusters [12]. Pixels are iteratively classified into this number of clusters without any deleting, splitting, or merging during the process as shown in figures (22 a, b and 23 c, d).

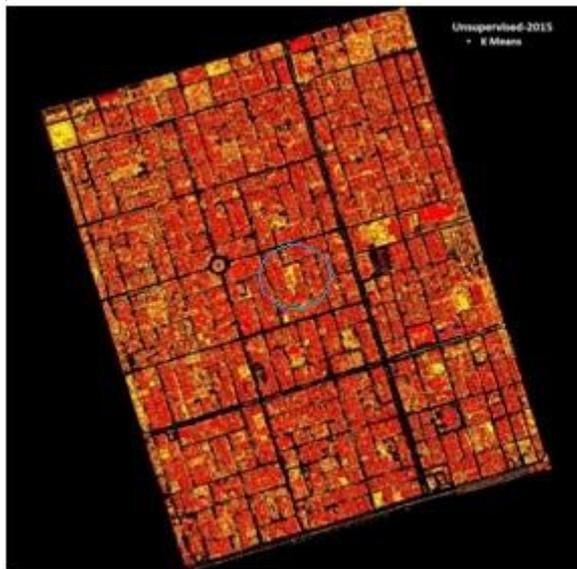


Fig.22 (a). 2015.

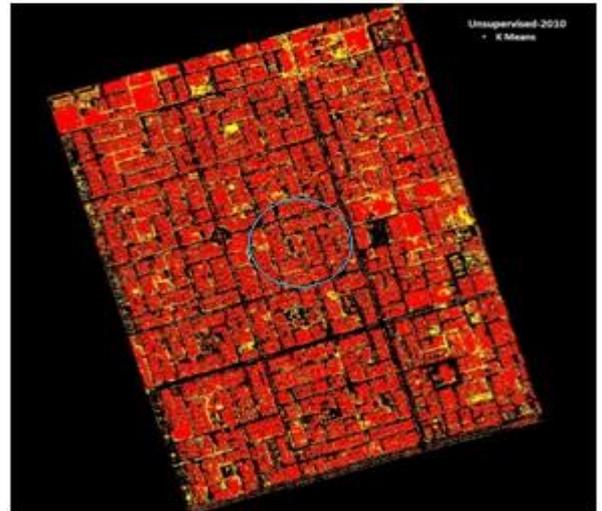


Fig.22 (b). 2010.

Fig.22(a and b). The unsupervised classification for two images (2010 and 2015) using K-means method.

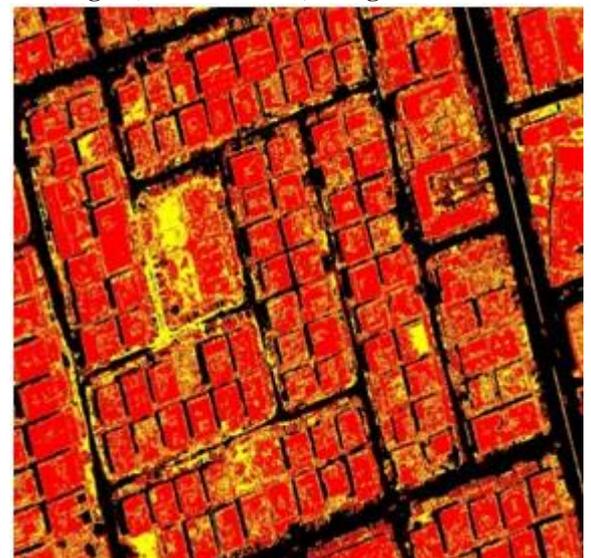


Fig.23 (c). 2015

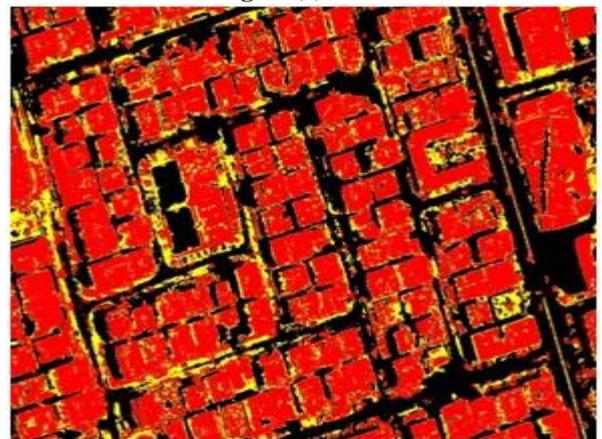


Fig.23 (d). 2010.

Fig.23 (c and d). The unsupervised classification for same part (zooming) of the two images (2010 and 2015) using K-means method.

▪ Isodata

This method The ISODATA method recurs the clustering of the image into an unavoidable choice between two alternatives [11]. a max No of iterations has been carried out

or a max percentage of not changed pixels have been come to between two iterations as shown in figures (24 a, b and 25 c, d).

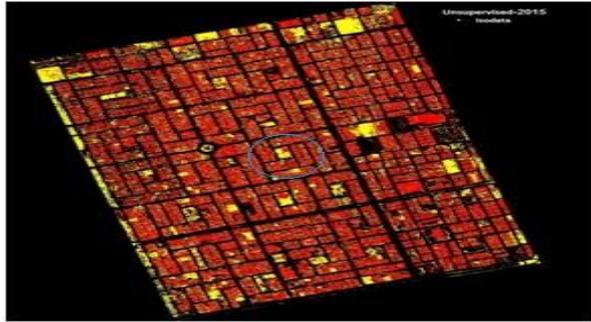


Fig.24 (a). 2015.



Fig.24 (b). 2010.

Fig.24 (a and b). The unsupervised classification for two images (2010 and 2015) using Isodata method.

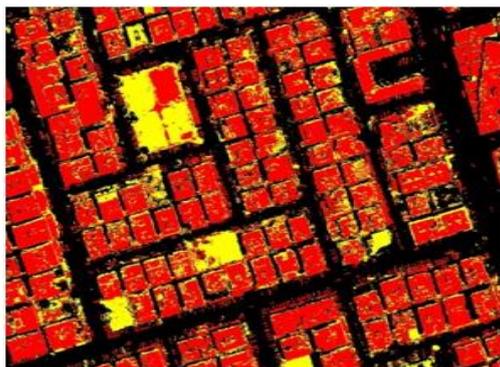


Fig.25 (c). 2015.

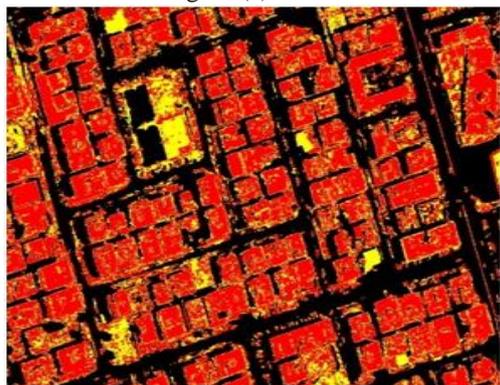


Fig.25 (d). 2010.

Fig.25 (c and d). The unsupervised classification for same part (zooming) of the two images (2010 and 2015) using Isodata method.

C. Image Segmentation

Segmentation is a method of dividing raster images into parts related to the value of each pixel and its locations [13]. All similar and spatially connected pixels have much the same value are grouped into one segment as shown in figures (26 a, b and 27 c, d).

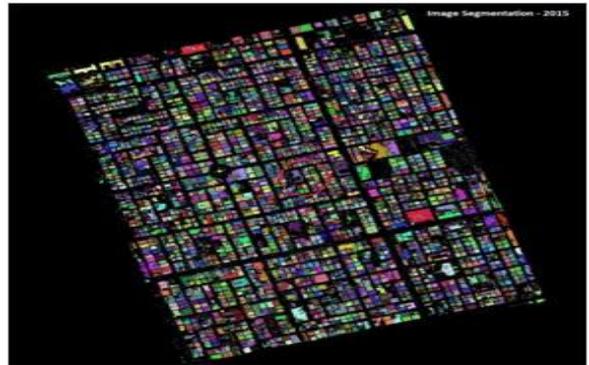


Fig.26 (a). 2015.

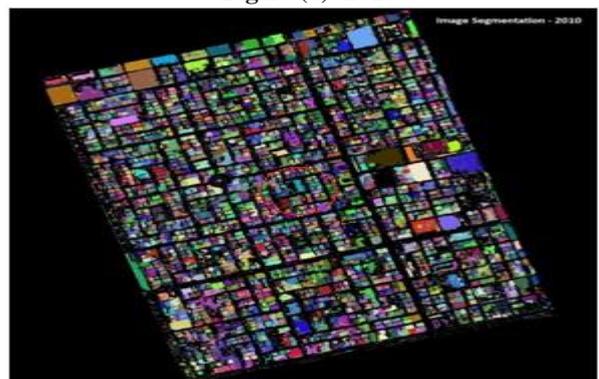


Fig.26 (b). 2010.

Fig.26(a and b). The two images (2010 and 2015) using image Segmentation method.



Fig.27 (c). 2015.



Fig.27 (d). 2010.

Fig.27 (c and d). The same part (zooming) of the two images (2010 and 2015) using image Segmentation method.

D. IHS to RGB

This method depends on transforming (IHS) color space values to (RGB) color space values [1], as shown in figures (28 a, b and 29 c, d).



Fig.28 (a). 2015.

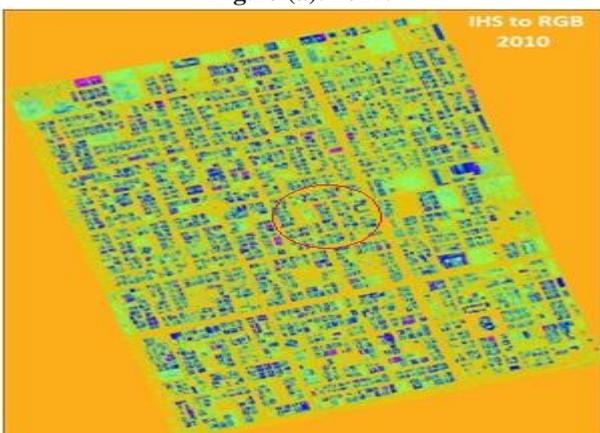


Fig.26 (b)2010

Fig.28 (a and b). The two images (2010 and 2015) using

IHS to RGB.

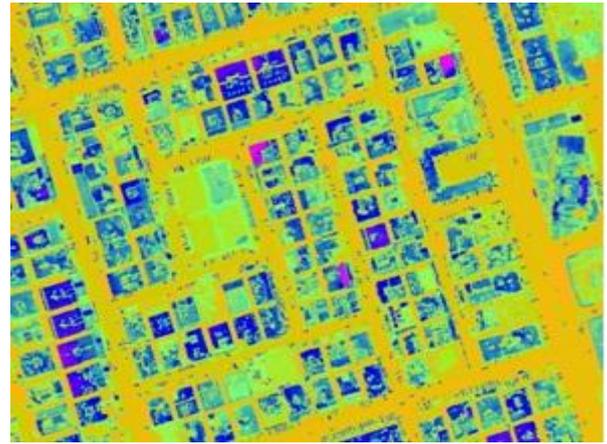


Fig.29 (c). 2015.

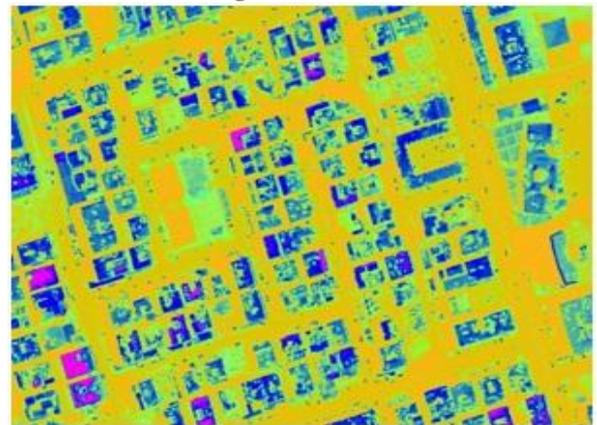


Fig.29(d)2010

Fig.29 (c and d). The same part (zooming) of the two images (2010 and 2015) using IHS to RGB.

E. Raster to Vector

The final application of this research used for obtaining a vector map for raster image [14], to determine results used for the purpose of comparison with other methods as shown in figures (30 a and b).



Fig. 30 (a).

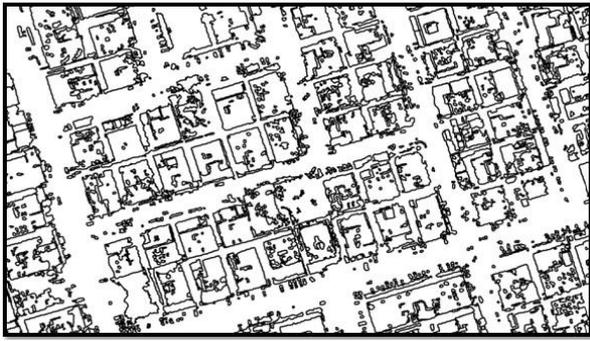


Fig. 30 (b).

Fig. 30 (a and b). The Raster to Vector with some errors. Referring to figure 30 b the result contains three problems (Small area – Gaps - Geometric shape) that need to be resolved as the following steps:

- Calculate Area of every shape and delete small area as shown in figure (31).
- For Gaps, insert area by face and merge this area as shown in figure (32).
- Draw Geometric shape as shown in figure (33).

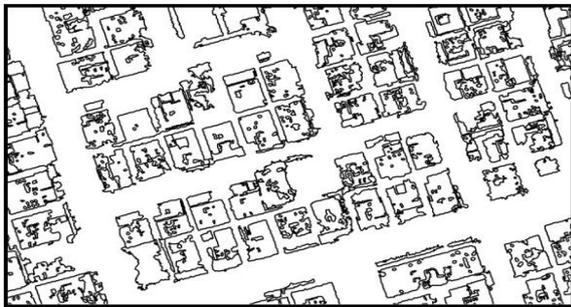


Fig. 31. Calculating Area of every shape and Delete small areas.

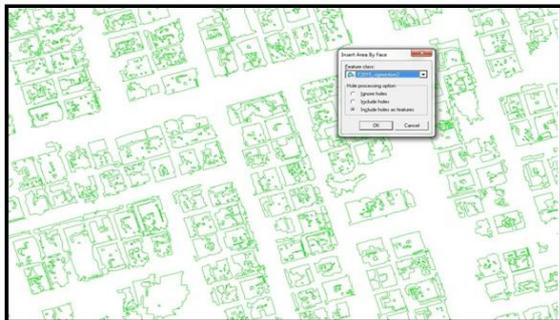


Fig. 32. Merging the area.



Fig. 33. The Geometric shape.

VII. RESULTS

After reviewing all results of different methods of the Change Detection techniques, and, the classification different method of the satellite image by using several

different techniques and methods, finally, the most important results of this research will be illustrated.

First:

Table (II) summarizes the most important results that have been reached in this research for the different methods of change detection techniques for the satellite images as well as figure (34).

Table (II). The results of different change detection techniques for the two images 2010 and 2015.

#	Method	Geometry (%)	Count
1	Images Difference	30	40
2	Zonal Change	40	66
3	Discriminant Function	40	56
4	Delta Cue (Site Monitoring)	50	153
5	Digitizing	100	190

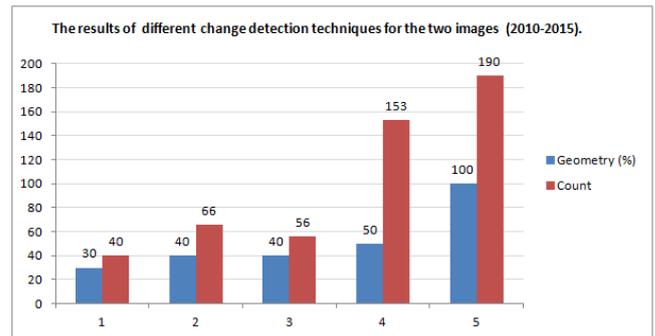


Fig. 34. The results of different change detection techniques for the two images (2010 and 2015).

After comparing the results with the aforementioned methods with what has been accomplished by digitizing, the following was found:

- 1) Most results converge for all methods as internal consistency in terms of number of buildings and the geometric shape, but it has a bias w.r.t the digitizing method.
- 2) The percentage of most of the results are less than 50%, and it is only suitable for knowing where the change occurred, especially method No. 4 (Delta Cue).

Second:

Table (III) summarizes the most important results that have been reached in this research for the different methods of classification methods for the satellite images. Also, figures (35, 36 and 37) show these results.

Table (III). The results of different of classification methods for the image 2015.

#	Method	Geometry (%)	Area (%)	Count
1	Supervised (Mahalanobis)	40	69	2227
	Supervised (min. distance)	50	59	1779
	Supervised (mix. Likelihood)	40	67.6	2333
2	Unsupervised (Isodata)	50	68.9	2053
	Unsupervised (k-means)	30	61.6	1924

3	Image Segmentation	50	72	2252
4	IHS to RGB	60	72	2348
5	Digitizing	100	100	2947

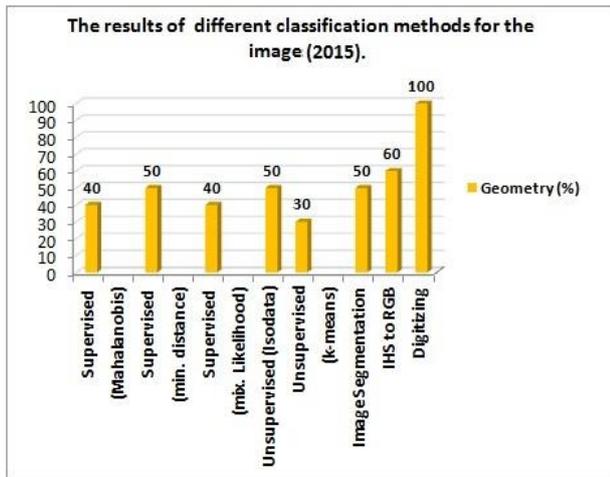


Fig.35. The results of Geometry (%) for different classification methods for the image 2015.

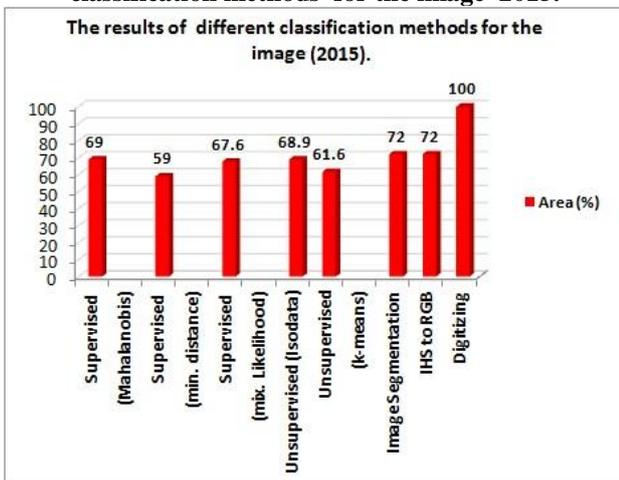


Fig.36. The results of Area (%) for different classification methods for the image (2015).

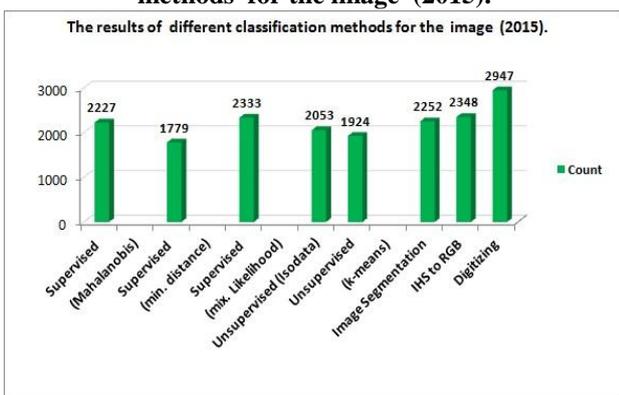


Fig. 37. The results of Count. for different classification methods for the image (2015).

VIII. CONCLUSION

After comparing the results with the previous mentioned methods and with what has been accomplished by digitizing, the following can be concluded:

- 1) Most results converge for all methods as internal consistency in terms of number of buildings and the

geometric shape, but it has a bias w.r.t the digitizing method.

- 2) The percentages of most of the results are less than 50%, and only suitable for knowing where the change occurred, especially method No. 4 (Delta Cue).
- 3) With reference to the geometric shape for the image 2015, it is clear that the best result was the ratio ranges between 50-60% in the following methods (IHS to RGB - Image Segmentation - Unsupervised (Isodata) - Supervised (min. distance)). As for the remaining results of the results, it ranges between 30% - 40%.
- 4) According to the building area for the image 2015, it is noted that the best result was the ratio ranges between 65% -70% in the following methods (IHS to RGB - Image Segmentation - Unsupervised (Isodata) - Supervised (mix. Likelihood)), on the contrary, the lowest result, where the ratio reaches 59% In Supervised (min. Distance method).
- 5) For the number of buildings in the image 2015, it is obviously that, all the results of the supervised classification and the unsupervised classification are close to what was accomplished by digitization.

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AUTHOR PROFILES



A. M. Abdel-Wahab, Assistant Professor Civil Engineering Department, National Research Centre, Egypt (NRC). Assistant Professor (Researcher) Civil Engineering Department, Engineering Research Division, National Research Center 2006 – Present. Geodesy and Remote sensing and Photogrammetry Consultant, - GIS Jeddah Municipality from May 2007 - January 2010. GIS Jeddah Municipality from May 2009 - January 2010. Geodesy and Remote sensing and Photogrammetry Consultant, - GIS Jeddah Municipality from May 2007 - January 2010. General Manager of GIS Jeddah Municipality from 2010 - 2014. Consultant for Vice Mayor Jeddah Municipality of construction 2014-2018. Member of Civil Engineering Unit of Engineering Research Division, National Research Center 2004 – present. Member of Ain Shams University Faculty of Engineering Surveying unit 1994– 2007.

Email: abdwhab@gmail.com.



Ahmed K. Abdel-Gawad, Professor of Civil Engineering, Civil Engineering Department, National Research Centre, Egypt. Head of Civil Engineering Department, National Research Centre. Head of Civil and Architecture Engineering Consulting Unit of National Research Centre. Research Activity includes: Engineering Surveying, GIS, Photogrammetry.

Email: ahmed_khedre@yahoo.com.



Alaa Al Din I. Awad, Assistant Professor of Surveying, Public Works Department, Faculty of Engineering, Ain Shams University, Egypt. Research Activity includes: Engineering Surveying, Geodetic and Satellite Surveying, Photogrammetry.

Email: alaa.ibrahim@eng.asu.edu.eg