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Determining and Estimating the Creep of Tigris Riverbanks at the Baghdad University Camp Using GIS Analytical Symmetrical Difference Method

Ala S. Mahdi[1], Mahdi Mustafa Ali[*2]

[1] Department of Remote Sensing, College of Science, University of Baghdad, Baghdad. Iraq.

[2] Department of Surveying, Institute of Technology, Middle Technical University, Baghdad. Iraq.

Abstract

The Tigris River in Iraq is of highly meandering in several of its parts. So, the largest meandering inside Baghdad City, is in Al-Jadriyah. During its course, the Tigris Riverbanks are facing erosion frequently due to alteration in the geomorphological and hydrological characteristics affecting the river channel. The entire length of Tigris River from the northern entrance of Baghdad to the convergence with Diyala River at southern of Baghdad is about 49 km length. The Tigris River is suffering from the erosion, deposition, and migration conditions. The river migration was found as maximum in the left bank at the side of the University, and lesser in the right bank in the opposite side, Dora. The aim of this study is to measure the magnitude of changes happened to the Tigris Riverbanks adjacent to the Baghdad University Camp in Al-Jadriyah for a period of last fifty years extended between 1962 and 2013, using Remote Sensing (RS) and Geographic Information System (GIS) techniques. Symmetrical Difference Analytical method was used to obtain changes for Tigris Riverbanks in the study area. The obtained results in this study demonstrate that Remote Sensing and Aerial Photography are important sources of data in monitoring and detecting the movement of Tigris riverbanks. Accordingly, the measured areas of deposition and erosion are (657 073 m^2) and (173 087 m^2) respectively, and the ratio between them was 3.83 to 1.

Keywords: RS, Worldview-1 Pan Satellite Image-2013, Mosaic Aerial Photo-1962, Tigris Riverbanks Change Detection, GIS, Symmetrical Difference Analytical method, Al-Jadriyah, Baghdad-Iraq.

تحديد وتقدير إزاحة ضفاف نهر دجلة في مجمع جامعة بغداد باستخدام طريقة فرق التحليل المتماثل في نظم المعلومات الجغرافية

علاء سعود مهدي[1]، مهدي مصطفى علي[*2]

[1] وحدة الإستشعار عن بعد ، كلية العلوم، جامعة بغداد، بغداد، العراق.

[2] قسم المساحة، معهد التكنولوجيا، بغداد، الجامعة التقنية الوسطى، بغداد، العراق.

الخلاصة

نهر دجلة في العراق هو كثير التعرج في العديد من أجزائه. لذلك، فإن أكبر تعرج داخل مدينة بغداد هو في الجادرية. أثناء مسار نهر دجلة، تواجه ضفافه التعرية في كثير من الأحيان بسبب التغيرات في الخصائص الجيومورفولوجية والهيدرولوجية التي تؤثر على قناة النهر. ويبلغ طول نهر دجلة من المدخل

*Email: mahdimustafa55@yahoo.com

الشمالي لبغداد إلى التقائه مع نهر ديالى في جنوب بغداد حوالي 49 كم. ويعاني نهر دجلة، شأنه في ذلك شأن الأنهار الأخرى، من حالات التعرية والترسيب والزحف. وجد زحف النهر كحد أقصى هو في الضفة اليسرى في جانب الجامعة، وأقل في الضفة اليمنى في جانب الدورة. والهدف من هذه الدراسة هو قياس مقدار التغيرات التي حدثت على ضفاف نهر دجلة المتاخمة لمجمع جامعة بغداد في الجادرية لمدة الخمسين سنة الأخيرة الممتدة بين عامي 1962 و2013 باستخدام تقنيات التحسس النائي ونظم المعلمات الجغرافية (جي.آي.أس). تم استخدام الطريقة التحليلية للاختلاف المتماثل للحصول على تغييرات ضفاف نهر دجلة في منطقة الدراسة. النتائج التي تم الحصول عليها في هذه الدراسة تبين أن الاستشعار عن بعد والتصوير الجوي هما مصدران مهمان للبيانات في رصد وكشف حركة ضفاف نهر دجلة. وطبقا لذلك، فقد بلغ قياس مساحتي منطقة الترسيب ومنطقة النحت (073 657 م^2) و(087 173 م^2) على التوالي، وأن النسبة بينهما كنسبة 3.8 الى 1.

1. Introduction

The Earth surface features usually subject to daily, monthly, or annual changes according to the characteristics of that features and the substances that are consist of. Some of changes are possible to be sensed visually, and the others are impossible to be sensed unless using suitable software such as ERDAS Imagine and/or ArcGIS. One of the most changeable targets on the earth surface is the river. The longitudinal targets, such as a river, are subject to continuous changes in their riverbanks especially in the meandering part. More details about rivers are illustrated in section three. Referring to the Paper Organization, the rest of the paper is organized as follows: The next section, refer to the location and the extent of the study area. Section Three, gives a Scientific Overview which includes some basic information about rivers as well as basic ideas of change detection. Section Four**,** this section deals with the materials and the method that used to carry out change detection. Results and Discussion are given in Section Five.

2. Area of Study

It is necessary to know the city that include the study and its location. So, the following Figure -1 (a, b, & c), shows the map of Iraq including both, the location of Baghdad City (the Capital of Iraq) and the location of the study area. The study area lies between lat. (33˚ 17′ 3.79″-33˚ 15′ 27.16″) N, long. (44˚ 21′ 20.27″- 44˚ 24′3.73″) E. The Baghdad University camp is situated in the central part of Baghdad City. From the geomorphologic perspective, Baghdad ground surface is mostly homogeneous and it is specified as a plain. The study area is almost flat, and has elevations reach to (36) meters above Mean Sea Level (MSL). The predominant land uses is residential. The study area locates between Al-Jadriyah Bridge and the two-storey Bridge. A part of this region started from nearby of Al-Jadriyah Bridge about 60m and continued to a distance of 5.250 Km which represents the end of the university camp as shown in Section Four. This region was selected to identify the changes in the riverbanks adjacent to the Baghdad University Camp using Remote Sensing (RS) and Geographical Information System (GIS).

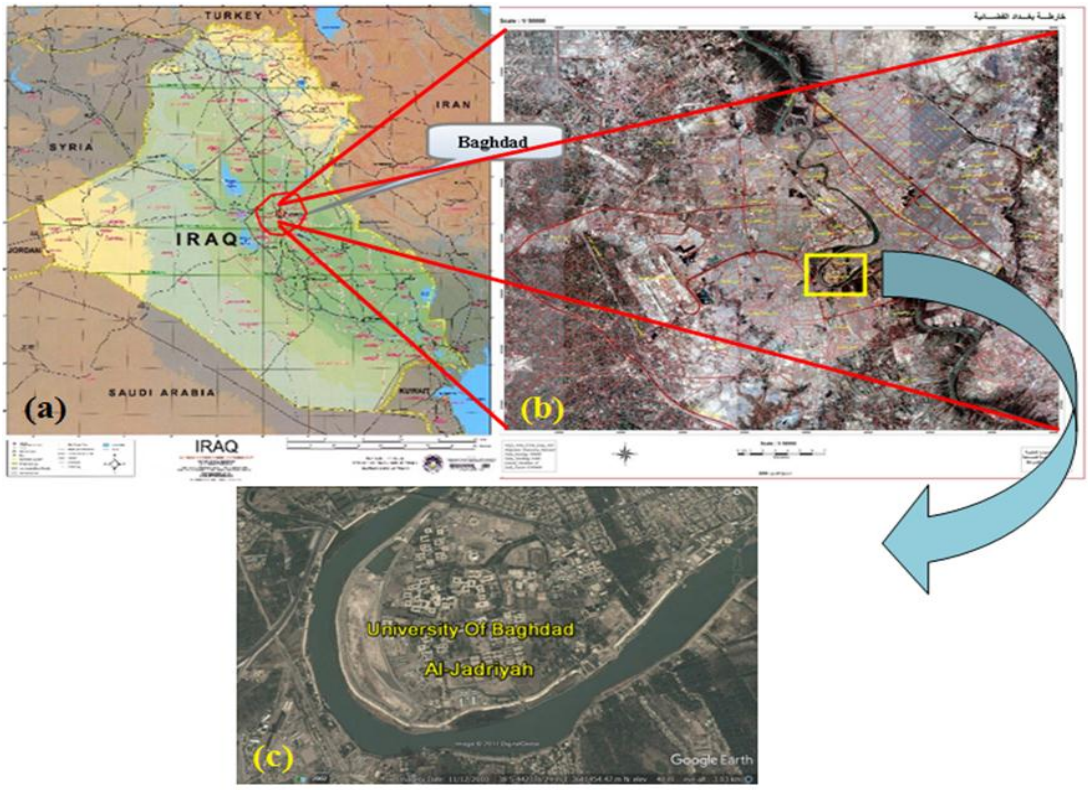


Figure 1(a, b, and c) - Represents the Location of the study area.

The study area is a region that has the dimensions, 4.21 km length and 3 km width, and has an area of 12.63 km^2. It represents the Baghdad University Camp and its adjacent area. University Camp has a riverbank perimeter of 4.655 km. Finally, the Dora side in the opposite riverbank, is mostly consists of residential and agricultural areas.

3. Scientific Overview

3.1 The River

It seems that there is no official definition for the generic term "river" because many definitions are found in the Encyclopedia of Hydrology. But generally, Rivers are part of the hydrological cycle and considered as natural flowing watercourse laying between the upstream (Source) and downstream (mouth), usually freshwater, flowing towards lake, sea, ocean, or another river. Small rivers have different names such as stream, creek, brook, rivulet, and rill. Water generally collected in a river from precipitation through a drainage basin from surface runoff and other sources such as groundwater recharge, springs, and the release of stored water in natural ice and snow. Potamology is the scientific study of rivers while limnology is the study of inland waters in general. River's characteristics vary between its upper and lower course, so there are high relationships between the channel slope, depth, and its width. These three characteristics are function of discharge in the river system. Generally, rivers are characterized in three main types according to the Davis's river “ages” criteria, namely: [1]

1) Youthful River: A river with a steep gradient that has very few tributaries and flows quickly. Its channels erode deeper rather than wider.

2) Mature River: A river with a gradient that is less steep than those of youthful rivers and flows more slowly. A mature river is fed by many tributaries and has more discharge than a youthful river. Its channels erode wider rather than deeper.

3) Old River: A river with a low gradient and low erosive energy. Old rivers are characterized by flood plains. Examples are the Tigris, Euphrates and others.

3.2 Change Detection Process

Change detection refers to the process of identifying differences (changes) in the state of Earth’s surface features by observing them at different times. Usually the changes can be determine from images exposer at different times for the same area. There are variety of change detection techniques that have been developed. But it seems that there is no universally optimal change detection technique. The choice of any change detection technique is dependent upon the application, the type of dataset used, and the efficiency of the operator as well as the objective of change detection process. Despite many factors affecting the selection of suitable change detection methods, image differencing, Principle Component Analysis (PCA), and post-classification are, in practice, the most commonly used. Image differencing produces one of the highest change detection accuracies. For image differencing, if the imagery was matched well enough, the raster can use subtraction to detect differences (raster functions in ERDAS). In recent years, GIS has become one of the important techniques to improve change detection accuracy. The following are some specific recommendations: [2]

(1) For a rapid qualitative change detection analysis, visual interpretation of multi-temporal image color composite is still a common and valuable method.

(2) For digital change detection, single band image differencing and PCA are recommended.

(3) When multi-source data are used for change detection, GIS techniques are helpful.

(4) A combination of different change detection methods can be useful to produce higher quality change detection results.

3.3 Symmetrical difference

In GIS, symmetrical difference is an analytical process in which two layers are used to create one new layer with the overlapped areas of the original layers. Simply, this analysis process creates a new layer with the features of either one of the original layers, but the new layer does not include the areas where both of the layers existed. The symmetrical difference operation must use two polygon features in its analysis. As shown in Figure-2, this tool creates a feature class from those features or portions of features that are not common to any of the other inputs, [3].

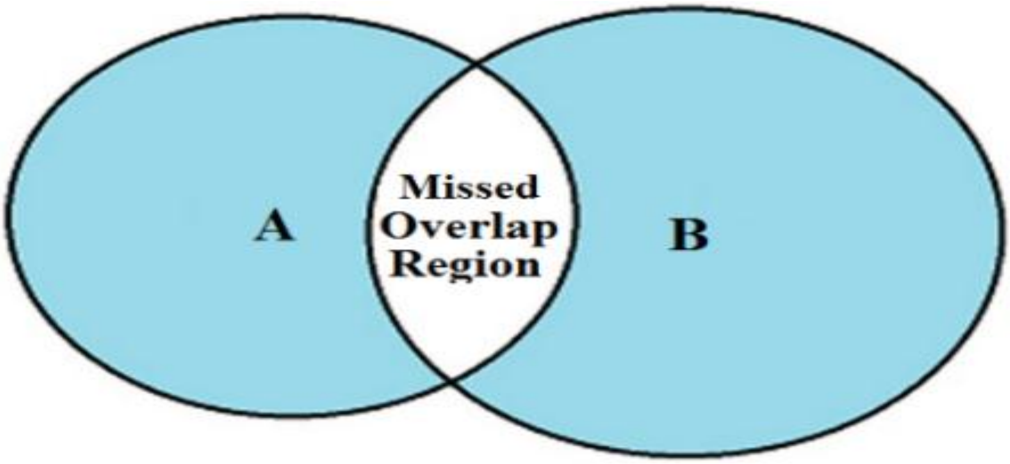


Figure 2- Symmetrical difference of A and B, (Modified) [3].

4. Materials and Methodology

4.1 Materials: Materials have two basic components, datasets and software, as described below:

4.1.1 Datasets: **1)** A rare original controlled Mosaic Aerial Photograph (MAP) dated 1962 was obtained. The source of this mosaic is the State Organization on Survey (SOS) - Baghdad, Iraq. The lack of space data before the last 50 years led to select the appropriate alternative by reference to the old aerial photographs. So, the accuracy of the aerial photograph (spatial resolution) is still higher than the current very high resolution satellite images. Knowing that the oldest satellite image that could be obtained is Landsat MSS (MSS data are available after 1972), which has low resolution (90 meters) and is not suitable for good change detection. Table-1 shows the Coordinates (X&Y) of the Upper Left and the Lower Right Corners, (UL X&Y) and (LR X&Y) in pixels, and other details of the controlled MAP/1962, while Figure-3 shows the photograph itself.

Table 1- the information of controlled Mosaic Aerial Photograph/1962

Mosaic Ariel Photograph 1962 / Coordinates Extent (pixel)				Raster Information			Spatial Reference/ Scan Resolution
				Columns / Rows	Pixel Size/ Format	Raster Size / Pixel Depth / Pyramid	
ULX	-0.50	ULY	0.50	1568/ 2272	1x1 / PNG Image	10.19 MB / 8Bit / Nearest Neighbor	Undefind / H: 600 dpi, V: 600 dpi
LRX	1567.50	LRY	-2271.50				

The following Figure shows the rare Original Controlled Mosaic Aerial Photograph. This photograph had been captured in April, 1962. As Seemed, the University Camp was still not built.

Figure 3- shows the Original Controlled Mosaic Aerial Photograph/ 1962. (Source, SOS).

2) WorldView-1 (WV_1) is one of the very high resolution satellite images. This satellite has only panchromatic (pan) sensor with a maximum spatial resolution of 0.5m. WorldView-1 pan satellite image 2013 is obtained from SOS. Table-2 shows the Image Extent [UTM Coordinates (X&Y) of the Upper Left and the Lower Right Corners, (UL X&Y) and (LR X&Y) in pixels] and other details, while Figure-4 shows the WorldView-1 pan satellite image 2013 itself.

Table 2- The extent of the WorldView-1 Pan very high resolution satellite images/2013

WorldView-1 Pan Sat. Image 2013/ UTM Coordinates Extent (m)				Raster Information			Spatial Reference/ False E./ False N./ Central Meridian/ S.F.
				Columns / Rows	Pixel Size/ Format	Raster Size / Pixel Depth / Resampling	
ULX	432770	ULY	3687017	37786 / 35840	0.5m / TIFF	1.26 GB / 8Bit / Nearest Neighbor	WGS_1984_UTM_Zone38N / 500000 m / 0 m/ 45°E / 0.9996
LRX	451683	LRY	3669078				

4.1.2 Software

Many software packages such as ERDAS v. 8.4, ArcGIS v. 10.4.1 are used to construct and process the basic database. These software are very useful for changes detection.

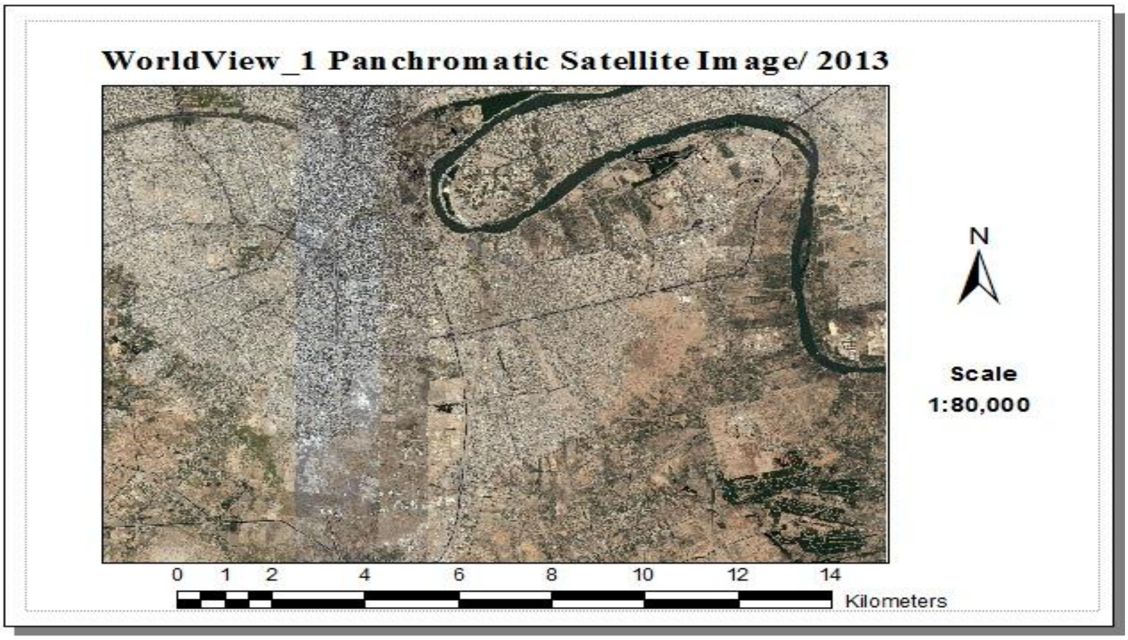


Figure 4- shows the WorldView-1 pan satellite image_2013. (Source, SOS).

4.2 Methodology

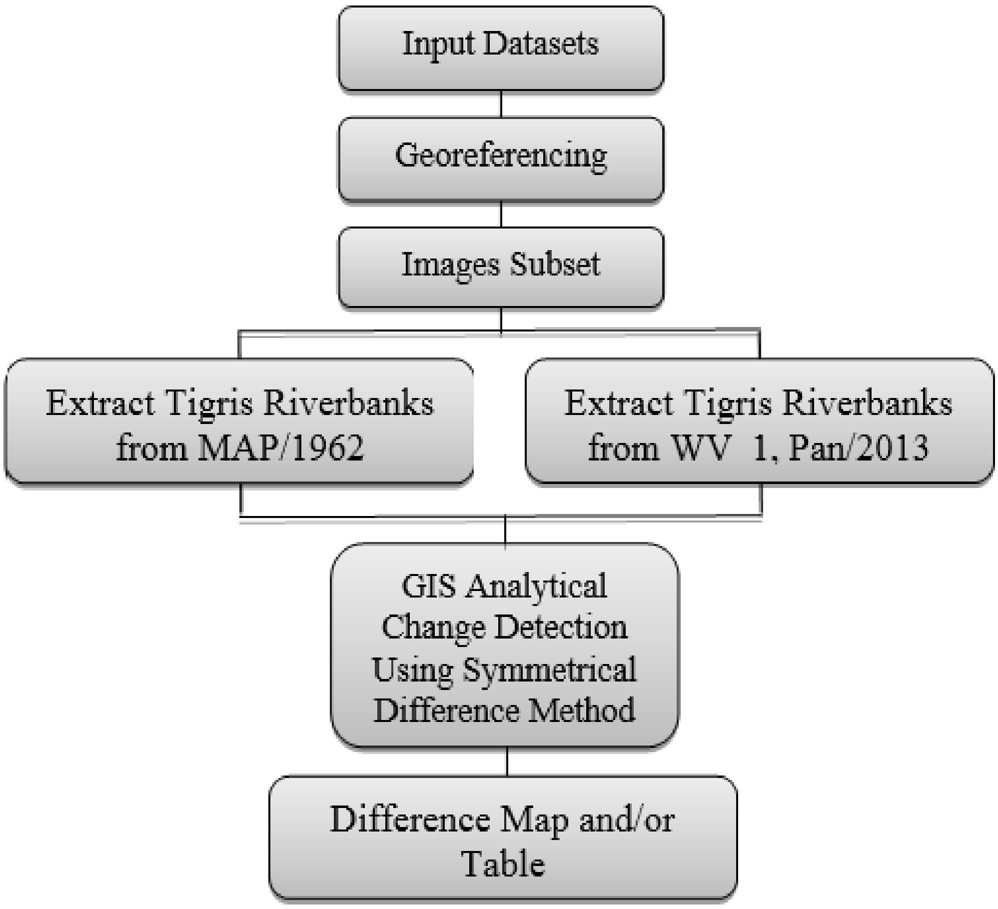


Figure 5- Diagram showing the procedure that employed for change detection. (Designed)

Symmetrical Difference Analytical method is carried out to obtain the best results of change detection that happened to the Tigris Riverbanks. Below is the Diagram, Figure-5, which includes the main steps to perform this process.

4.2.1 Georeferencing

The Mosaic Aerial Photograph/ 1962 is georeferenced onto the WorldView_1 Panchromatic/ 2013 (WV_1, Pan) satellite image using image-to-image 1st order polynomial (Affine) georeferencing method. Four points selected in the Mosaic Aerial Photograph considered as reference points appear in the satellite image were used for georeferencing. Nearest neighbor resampling method and a pixel size of 0.5mx0.5m are used. Root Mean Square Error (RMSE) of the georeferencing process was **7** pixels due to the difficulty of selecting sharp features in the mosaic aerial photograph. Table-3 shows the results of the georeferencing process, whilst Figure-6 shows the Georeferenced Mosaic Aerial Photograph /1962. In the other hand, Table-4 shows the Information of the Georeferenced Mosaic Aerial Photograph/1962.

Table 3-The results of the georeferencing process

Total RMS Error: Forward:7.63317

	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
☑	3	13980.513502	-50880.160...	440892.376...	3679826.85...	-6.42469	6.68161	9.26933
☑	4	4973.715270	-22402.956...	439985.960...	3682749.59...	4.07134	-4.23415	5.87399

☑ Auto Adjust Transformation: 1st Order Polynomial (Affine)

☐ Degrees Minutes Seconds Forward Residual Unit : Unknown

Figure 6- The Mosaic Aerial Photograph/1962: The original (left) and the Georeferenced (right).

Table 4- Shows the Information of the Georeferenced Mosaic Aerial Photograph/1962

Mosaic Ariel Photograph 1962 / UTM Coordinates Extent (m)				Raster Information			Spatial Reference/ False E./ False N./ Central Meridian/ S.F.
				Columns / Rows	Pixel Size/ Format	Raster Size / Pixel Depth / Resampling	
ULX	439516.00	ULY	3684959.00	9489 / 11109	0.5m / IMG Image	301.59 MB / 8Bit / Nearest Neighbor	WGS_1984_UTM_Zone38N / 500000 m / 0 m/ 45°E / 0.9996
LRX	444260.00	LRY	3679405.00				

4.2.2. Image Subset

Both, Georeferenced Mosaic Aerial Photograph/ 1962 and WorldView_1 Pan Image/ 2013, were subset with a suitable extent as specified in the Table-5. Figures- (7, 8) show the subset of the previous datasets.

Table 5- The UTM Coordinates of Subset Extent (m).

UTM Coordinates of Subset Extent (m)			
ULX	440000.00	ULY	3683000.00
LRX	444210.00	LRY	3680000.00

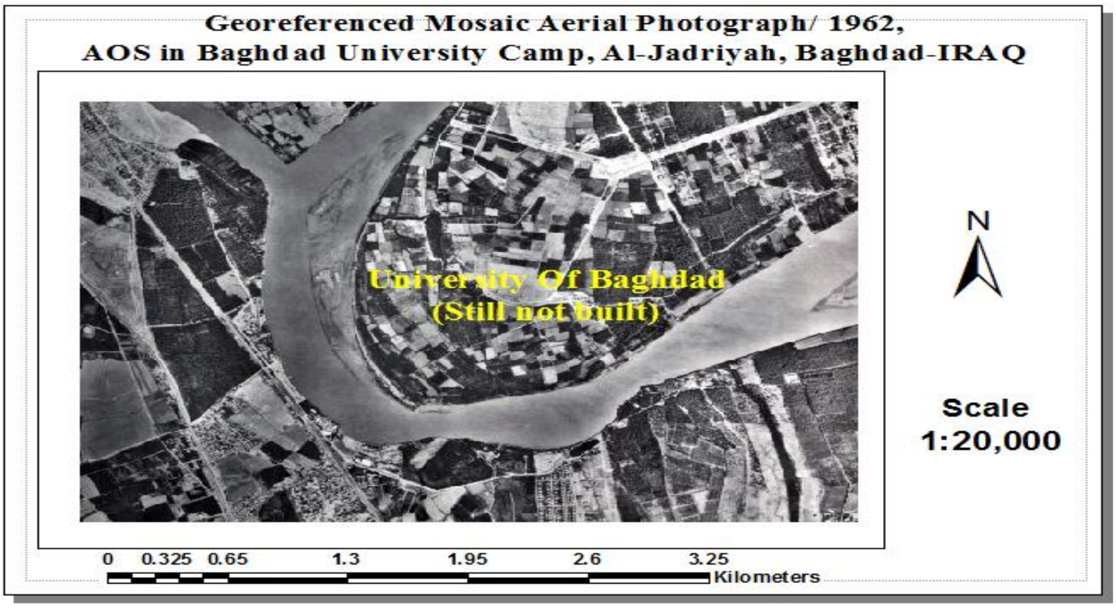


Figure 7- The subset Georeferenced Mosaic Aerial Photograph/ 1962.

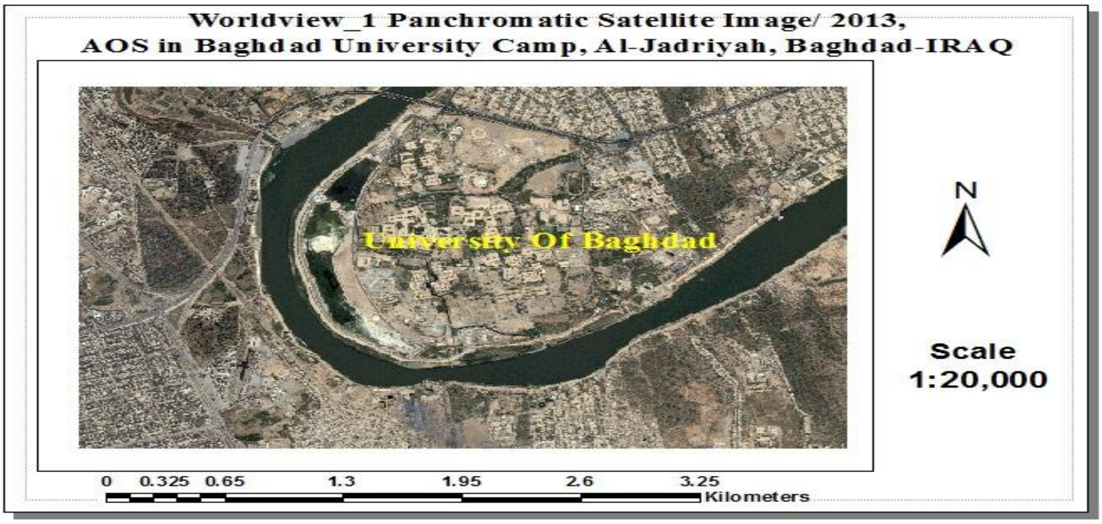


Figure 8- The subset WorldView-1 pan satellite image/ 2013.

4.2.3 Procedure Change Detection Using Symmetrical Difference Analytical Method

Analytical Symmetrical Difference method is used to obtain Change Detection for Tigris Riverbanks in the study area. This procedure is discussed in detail as follows:

This method is summarized in constructing two layers each represents the edges of the Tigris riverbanks in the study area. The first layer refers to the Georeferenced Mosaic Aerial Photograph/ 1962, while the second layer refers to the WorldView_1 Panchromatic satellite image acquired in 2013. These two layers are prepared by polygon option in GIS as shown in Figures- (9, 10) and Figures-(11, 12) below.

This method was carried out on both, the Mosaic Aerial Photograph/1962 and the Worldview_1 Panchromatic Image/ 2013, as input data. The following steps are implemented:

1) A polygon was drown representing the Tigris Riverbanks on the Mosaic Aerial Photo/ 1962 as shown in the Figures-(9, 10).

2) A polygon was drown representing the Tigris Riverbanks on the WV_1 Pan Image/ 2013 as shown in the Figures-(11, 12).

3) Apply Symmetrical Difference Analytical Method to detect changes in the Tigris Riverbanks as shown in the Figure- 13.

To carry out Symmetrical Difference Analytical Method, follow the path below:

(Arc Toolbox/ Analysis Tools/ Overlay/ Symmetrical Difference).

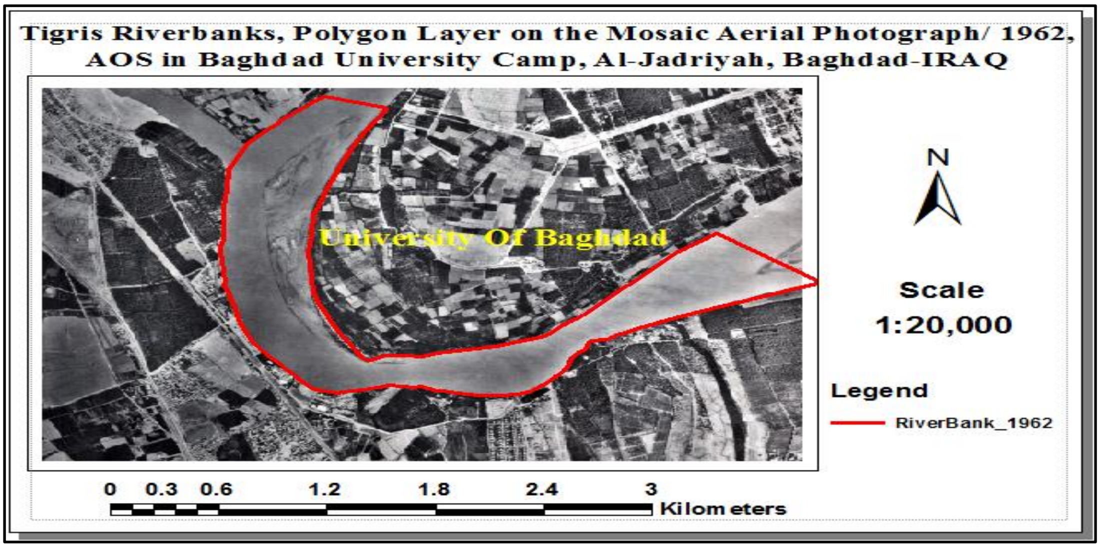


Figure 9- Tigris Riverbanks on the Mosaic Aerial Photograph/1962.

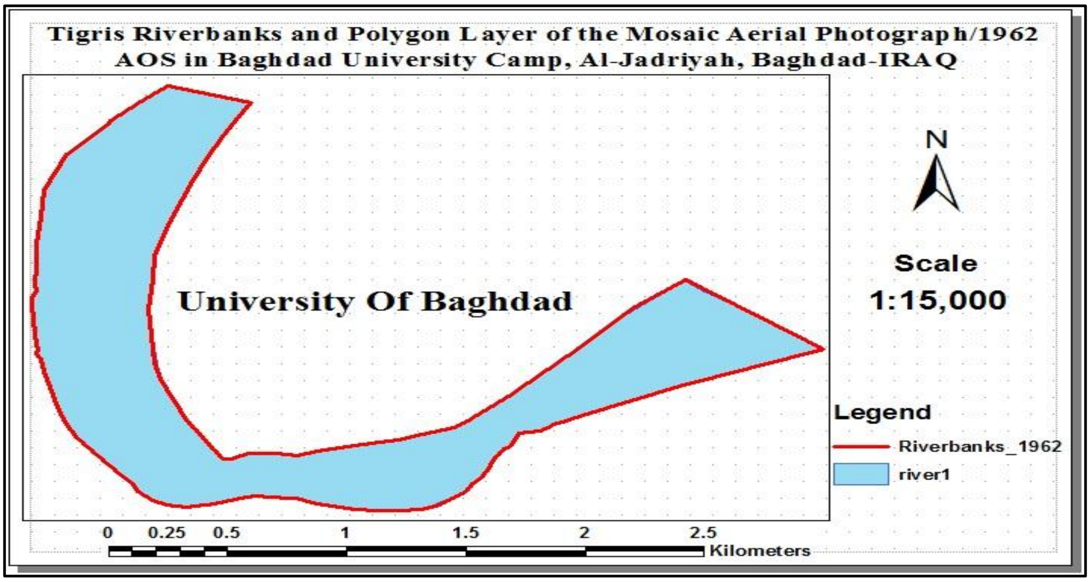


Figure 10- Tigris Riverbanks and Polygon Layer of the Mosaic Aerial Photo/1962.

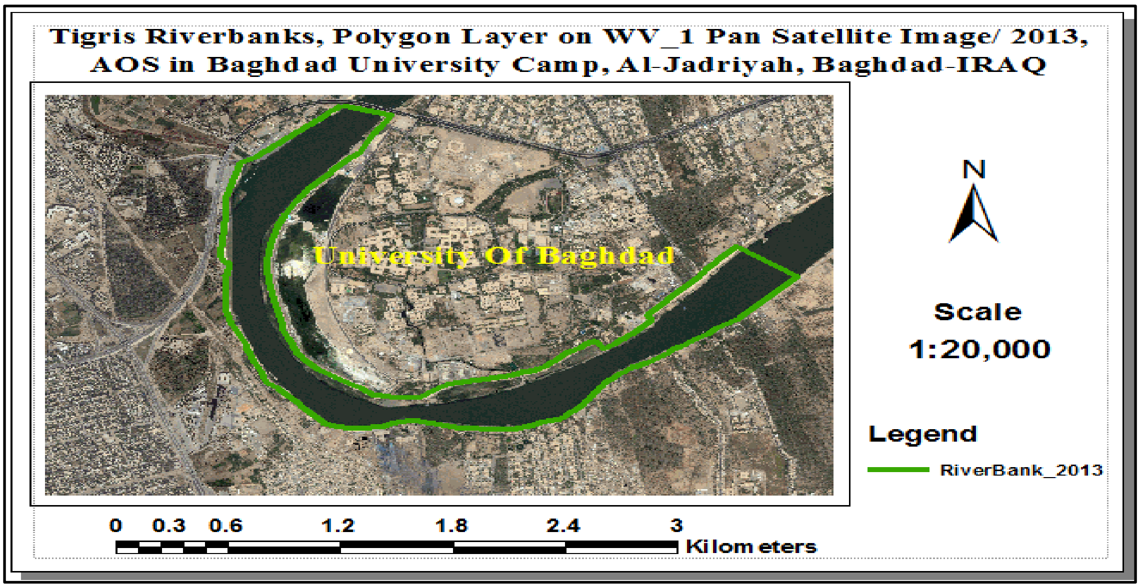
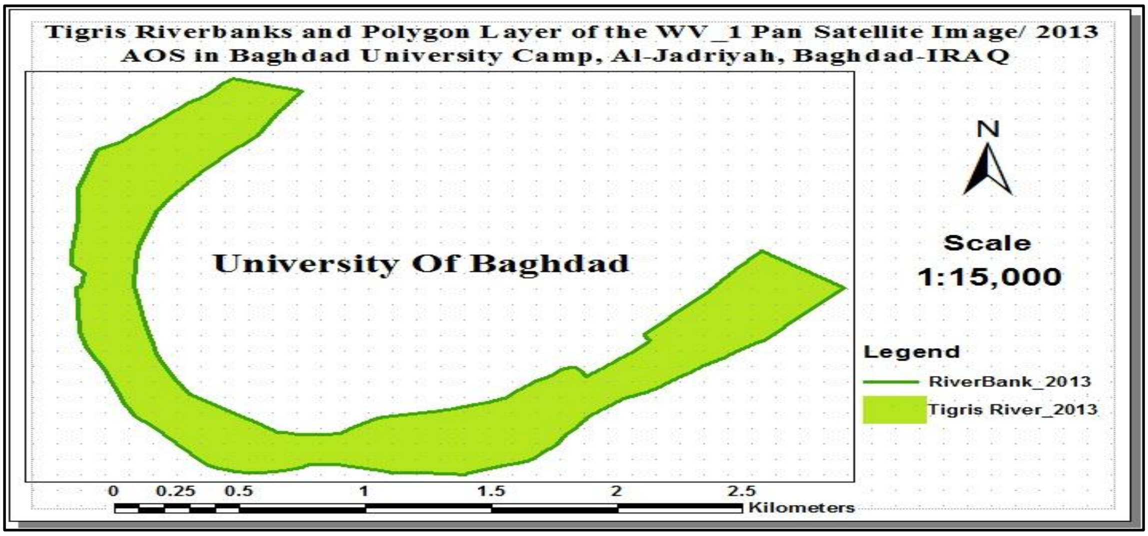


Figure 11- Tigris Riverbank on the WorldView_1 Pan Satellite Image/ 2013.



Figures 12- Tigris Riverbanks and Polygon Layer of the WorldView_1 Pan Satellite Image/ 2013

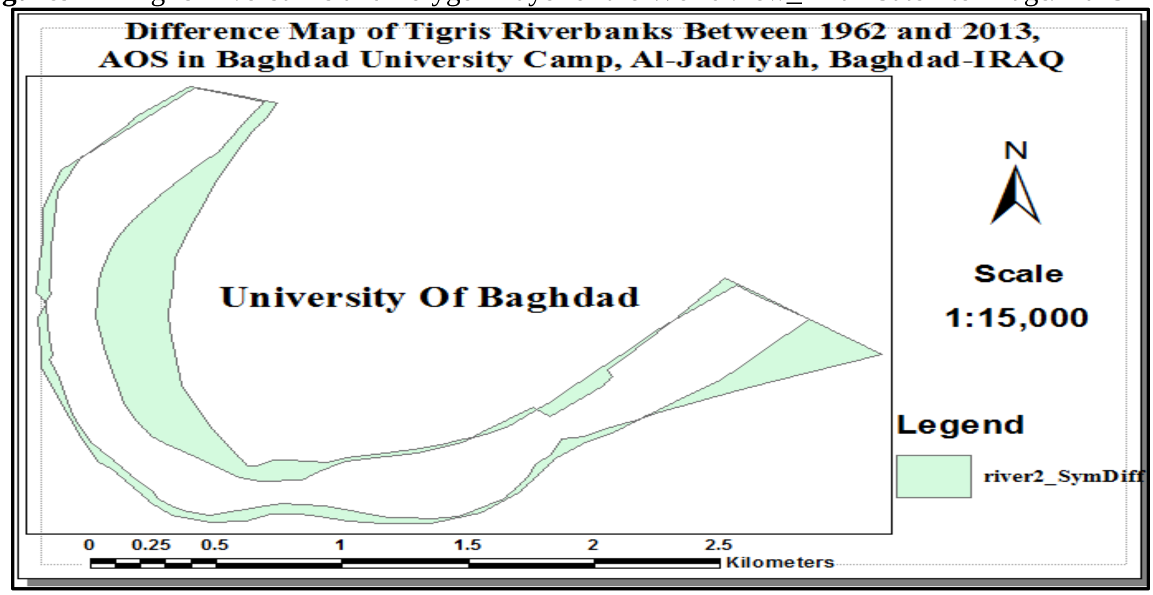


Figure 13- The Tigris Riverbanks Difference Map between 1962 and 2013.

To apply Features Category in the legend of the difference map, follow the path below:
(Right click on the Selected Layer/ Select properties/ Select Symbology/Categories/ From Value Field (select Area m^2)/ Apply/ Ok.)

The Figure-14 shows the difference map and its Categories, The deposition area and the erosion area. The white area between the two categories represents the overlapped area between the two input datasets. Visually, the area of deposition is larger than the area of erosion more than three times.

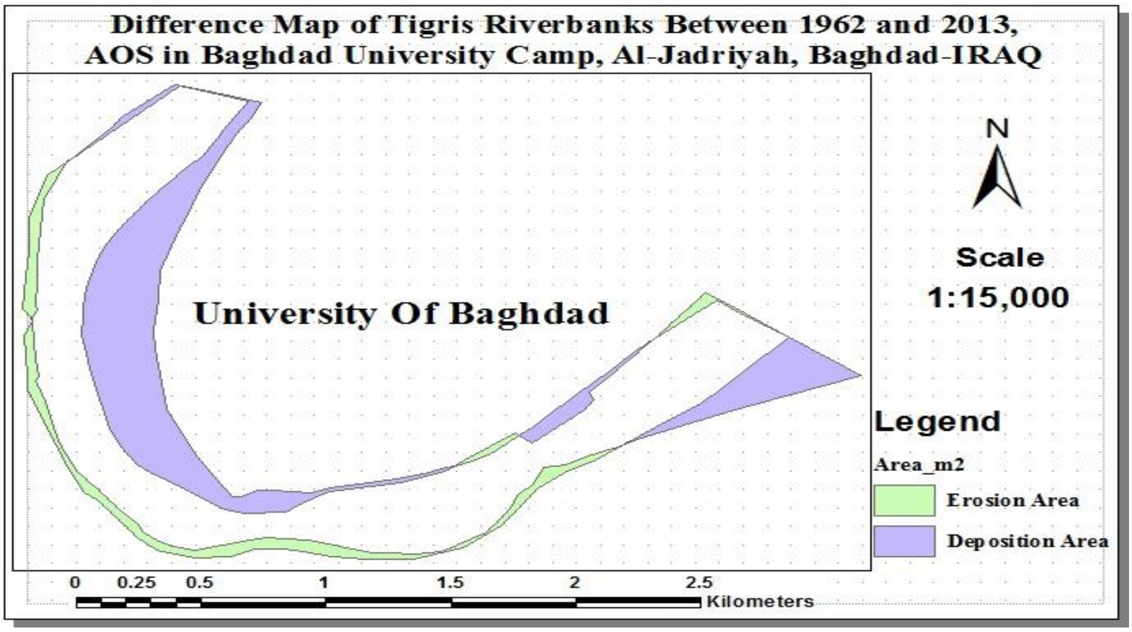


Figure 14- The Tigris Riverbanks Difference Map between 1962 and 2013.

The Figure-15 shows the movement of the Riverbanks, erosion and deposition areas, and the migration of Tigris River as mentioned in the legend.

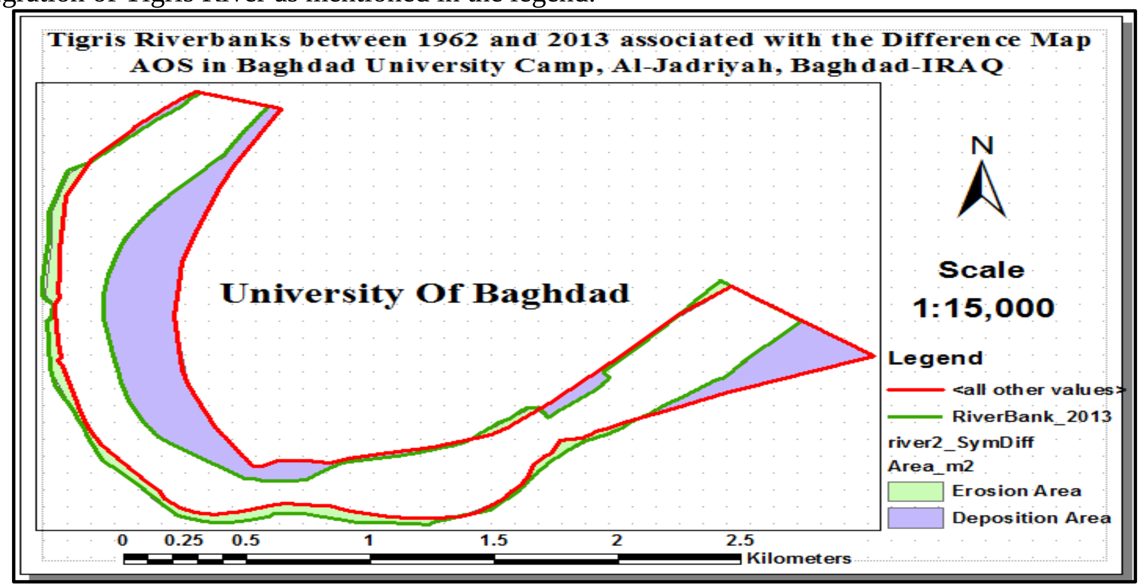


Figure 15- The final Difference Map.

5. Results and **Discussion**

5.1 Results

5.1.1 Area Measurement

To compute the areas of both deposition and erosion follow the path below:

(Right click on the Selected Layer / Select attribute / Right click on the column of table / calculate geometry / compute area/ Apply / Ok).
So, Table-6 shows the magnitudes of each of the deposition area and erosion area caused by the movement of the Tigris Riverbanks adjacent to the Baghdad University Camp in Al-Jadriyah between 1962 and 2013.

Table 6- The deposition area and the erosion area

Table

river2_SymDiff

OBJECTID *	SHAPE *	FID_river2	Area_m2	n	FID_river1	Area_m2	n	SHAPE_Length	SHAPE_Area	Type_Area_12
1	Polygon	2	<Null>	<Null>	-1	0	0	12 260	657 073	Deposition
2	Polygon	-1	0	0	3	<Null>	<Null>	10 584	173 087	Erosion

5.2 Discussion

In this study, Results depends on two elements. The first element depends on the personal experience to prepare the required layers and how to use it to visually detect changes. The second element depends on the selection of a suitable change detection method to obtain reliable results.

1) As a result of this process, areas of both the deposition and erosion are digitally computed. A difference map indicates that the area of Deposition is larger than the area of Erosion as below.

2) From Table- 6: Deposition Area (A_D) = 657 073 m^2, Erosion Area (A_E) = 173 087 m^2

Diff. in Area= A_D - A_E =483 986 m^2 ➞ Rate of Change=A_D/A_E=657 073 /173 087=3.8/1=380%

3) To calculate the polygon area, follow the path below:

From the table of content, check the polygon box, making R.C on it, and then choose (selection)/ Select all/ R.C on the polygon on the viewer /Select (Identify), Identify window will open with the required Area.

Therefore, the difference in Area between a part of the River1/1962 and a part of the River2/2013:
Area of River1/ 1962 (A1) = 2 061 566 m^2, Area of River2/ 2013 (A2) = 1 577 580 m^2
Δ Area (Diff. in Area) =A1-A2= 2 061 566 - 1 577 580 = 483 986 m^2 =193.5944 Donem, refer to Table-7.

Table 7- The Difference in Area between a part of the River1/1962 and a part of the River2/2013.

Donem	**Olk**	**m^2**
193	14	86

Overlapped Area between River1& River2 = A_1 - A_D = 2 061 566 – 657 073 = 1 404 493 m^2
Overlapped Area between River1& River2 = A_2 - A_E = 1 577 580 – 173 087 = 1 404 493 m^2 (Check)
In general, erosion was occurred on the western Tigris Riverbank in the Karkh side of the study area. This erosion occurred in different amounts, concentrated in the southern part of the study area on the Dora side due to the meandering of the Tigris River there. Certainly the area of the erosion is about quarter of the area of the deposition region. The risk is always comes from the occurrence of the erosion, especially when there is a narrow strip of land near the riverbank, such as the western riverbank of Al- Saiedyah side of the study area. It is necessary to monitor the occurrence of erosion during periods of time proportional with the nature of the land through which the river passes.

6. Conclusions

The erosion area obtained during the period from 1962 to 2013 was 173,087 square meters (refer to Table-6). The main conclusion of this study is that the yearly average area of erosion happened to the western Riverbank in Al-Karkh side was about 3462 m^2 per year. The average length of the erosion zone is 4566 meters as measured from the satellite image, and the average width of that zone is about 0.76 meters. More precisely, some parts of the western Tigris riverbank (especially in Dora side) have the largest amount of erosion in the last 50 years. The maximum erosion is up to 73 meters as measured from the satellite image. Therefore, the amount of the annual erosion is equal to 1.46 meters, and has an average of about 0.73 m per year. The amount of erosion is so small that it is not dangerous when structures are constructed across the river or on both sides of the riverbanks, since hydrologic control projects in the upstream direction were increased significantly during the last period. In addition, the Tigris Riverbanks were covered by stones that eliminating the erosion process to the lowest limit in the study area. Finally, depending upon these results, it is concluded that it is possible to say that the Tigris River has entered the old stage in the study area. Therefore, it is advised that for the change detection applications (such as riverbanks movement) needing good results to use the Analytical Symmetrical Difference method.

7. Acknowledgements

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8. References

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