# *DETECTING MORPHOLOGICAL CHANGES IN THE NILE RIVER: CASE STUDY- THE THIRD REACH*

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## ABSTRACT

The Nile River is the longest river in the world with 6670 km long and 3.20 million km$^2$ catchment area. The morphological and hydrological characteristics of Nile are affected by environmental changes, like erosion and sedimentation. The present study aims to detect the temporal changes in surface water areas of the third reach of the Nile River during the period of 1987-2010 using Remote sensing and GIS technologies utilizing Landsat images. Various satellite-derived indices including NDWI, WRI and AWEI were examined for the extraction and detecting changes of surface water from Landsat data. The results indicated high performance of NDWI in extracting the surface water area and detecting the surface water changes in the third reach of Nile River. The results Showed insignificant change in surface water areas of the third reach of the Nile river during the period 1987-2010. Overall, the Nile River in the considered reach lost about 1.8% of its surface area in the period 1987-2010.

**Keywords:** Remote Sensing, GIS, Nile River, Morphology, Change Detection, Third reach

## 1 INTRODUCTION

Morphological analysis of river streams is needed for many reasons such as navigation safety, allocation of intake structures and scour calculations at bridges. It also plays an important role in the planning of the area on the river sides for sustainable development, Moussa& ElMoustafa (2010).

The Nile River has experienced major morphological changes during the past decades. The changes of flow discharges (for both cases; high and low flows ), suspended sediment concentration changes, human interventions and the effect of new projects have a major contribution for these changes, Dalia Mostafa(2012).

Monitoring the temporal morphological changes is very difficult with the conventional methods. Using remote sensing data and GIS, solutions to potential morphological and environmental problems can be found on time. Furthermore, accurate, fast and low coast data / information can be obtained to determine the potentials in morphological and environmental changes and updating relevant information, Seker & Goksel et al. (2003) .

Although many water bodies change detection studies have been carried out on rivers and lakes all over the world ( e.g. Mohammadi et al. (2008), El Gammal(2010), Cruzio (2013), Moghaddas (2013) and Rokni et al. (2014)). Concerning the assessment of morphological changes of Nile River several studies were conducted including ( Dalia Mostafa(2012), Moussa& ElMoustafa (2010), Suzan Ahmed(2014) and Negm et al. (2016)).

The objective of this research is to study the morphological changes for the third reach of The Nile River using Geographic Information Systems (GIS) and Remote Sensing technique.

The main objective is divided into two sub- objectives:

1-Evalute the performance of different spectral water indices in extracting and detecting surface morphological changes.

2-Analyze the morphological changes and estimate scour and deposition areas for the study reach during the period from 1987 to 2010.

## 2 STUDY AREA

The third reach of the Nile River which links between the DS of New Naga Hammady Barrages and US of Assiut Barrages was selected as the study area. It is located between latitudes 26° 8\ 12\\ N and 27° 12\ 10\\ N downstream of Aswan High Dam with a total length of 185 km .


**Figure 1. Location map of the study area**

## 3 DATA COLLECTION

### 3.1 Data Set

In this paper, eight satellite images are downloaded freely from the US Geological Survey (USGS) http://earthexplorer.usgs.gov/ with (Path/Row = 176/041, 175/042) to cover the period between years 1987 and 2010 to enable the monitoring and detection of morphological changes in the study area. The first two images are Landsat TM data acquired on 1987. Meanwhile, the remaining six images are Landsat ETM+ data acquired in years 1999, 2005, and 2010 respectively (two images per each). The used Landsat images were georeferenced using the world reference system (WGS-84 datum) to Universal Transverse Mercator system (UTM) zone, 36 North projection. Also, these images are free of radiometric, noise, and geometric errors7. All images were obtained for the same season almost (summer) to avoid the seasonal water level change. Table 1 shows the specifications of Landsat images.

**Table 1. The specifications of Landsat TM and ETM+ Images**

| Satellite | Sensor | Path/Row | Year | Spatial Resolution |
|---|---|---|---|---|
| Landsat-5 | TM | 176/041<br>175/042 | 1987 | 30 m |
| Landsat-7 | ETM+ | 176/041<br>175/042 | 1999<br>2005<br>2010 | 30 m |

The Thematic Mapper (TM) and the Enhanced Thematic Mapper (ETM+) images contains seven bands in Blue, Green, Red, Near Infrared(NIR), Mid-Infrared (MIR) and Shortwave Infrared (SWIR)= band7 with spatial resolution of 30m, expect for the Thermal band= band6, where it has a spatial resolution of 120m for TM images and 60m for ETM+ images, Rokni et al (2014).

## 4 METHODOLOGY

To achieve the objective of the present study, the methodology presented as shown is applied:

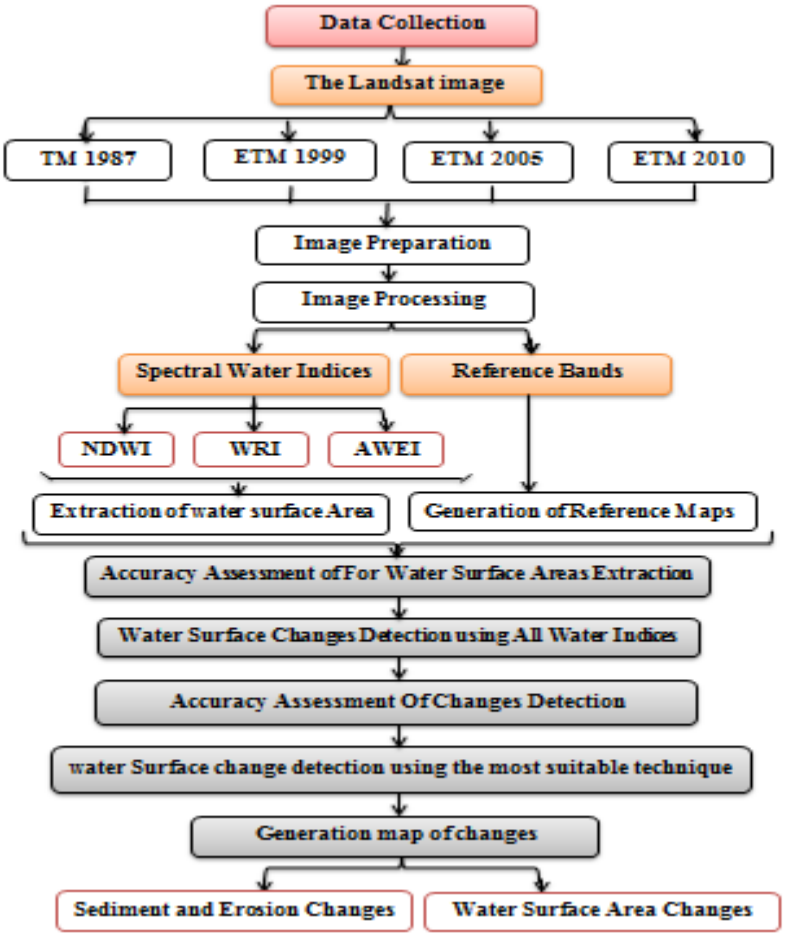



**Figure 2, Flowchart showing methodology adopted in this research**

## 4.1 Image Preparation

To prepare the Landsat images for the water surface change detection, a clip and mosaic tool in Arc GIS 9.3 was used. This step was performed as the study area covered by two Landsat images.

## 4.2 Computation of Spectral Water Indices

This step aims to detect the water surface area of the study reach for years 1987, 1999, 2005 and 2010 separately. In doing so, the performance of different spectral water indices including NDWI, WRI, and AWEI was tested for extracting of water surface area from Landsat data. Therefore (land-water) map is generated for each index using raster calculation tool in ArcGIS software. In this respect, the NDWI, WRI and AWEI indices were calculated from Landsat TM image to evaluate their performances for the extraction of water surface area. The equations of the spectral water indices and their ranges for water bodies are indicated as below:

- Automated Water Extraction Index (AWEI)

$$AWEI = 4 \times (Green\text{-}MIR) - (0.25 \times NIR + 2.75 \times SWIR) \quad (1)$$

where water bodies have positive values.

- Normalized Difference Water Index (NDWI)

$$NDWI = (Green - NIR)/ (Green + NIR) \quad (2)$$

where water bodies have positive values.

- Water Ratio Index (WRI)

WRI = (Green + Red)/ (NIR + MIR) (3)

where the water body value is greater than 1, Elsahabi & Negm (2016)

### Extraction of Water Surface Areas

Through ArcGIS software, water surface areas can be extracted from (land-water) maps by separated the water area from land area.

### 4.3 Reference Maps

In this study, the Near-Infrared (NIR) is selected as a reference map, due to its higher ability to differentiate the water area from land. The "NIR is strongly absorbed by water and is strongly reflected by the terrestrial vegetation and dry soil", Rokni et al. (2014). The reference maps are generated using on- screen digitizing.

### 4.4 Accuracy Assessment For Water Surface Areas Extraction

The overall accuracy and absolute error were calculated by overlaying the reference maps with the water surface areas which extraction from (land-water) maps to evaluate the performance of each index.

### 4.5 Water Surface Changes Detection Using Water Feature Extraction Techniques

This step aims to detect the change maps of water surface area by comparing and overlaying the extracted water surface area of the year 1987 with that of the year 2010 for each index. The main reason for choosing this period is observing a big and realizable change in the water area which helps in the accuracy assessment of water surface change detection.

### 4.6 Accuracy Assessment Of Changes Detection

The performance of different indices to detect water surface area changes between 1987-2010 was evaluated firstly, through calculation the absolute error, which is the difference between the changed map detected using the applied index and that which detected using the reference maps . Finally, the overall accuracy of each derived change map was computed.

### 4.7 Water Surface change detection using the most suitable technique

To achieve this task, we applied the most suitable technique (has the highest overall accuracy) for extracting and detecting the temporal changes in water surface of the study reach during periods (1987-1999), (1999-2005) and (2005-2010) respectively.

## 5 RESULTS AND DISCUSSION

One scene from Landsat TM data was acquired in 1987, and three scenes from Landsat ETM+ data were acquired in 1999, 2005 and 2010 for the study reach to detect the multi-temporal morphological changes. Three water indices including NDWI, WRI, and AWEI were applied to extract water features and to detect water surface changes from remote sensing images.

### 5.1 Water Surface Extraction of the total reach Using Different Indices

The extracted water surface maps of the year 2010 are shown in Figure 3 as sample results.

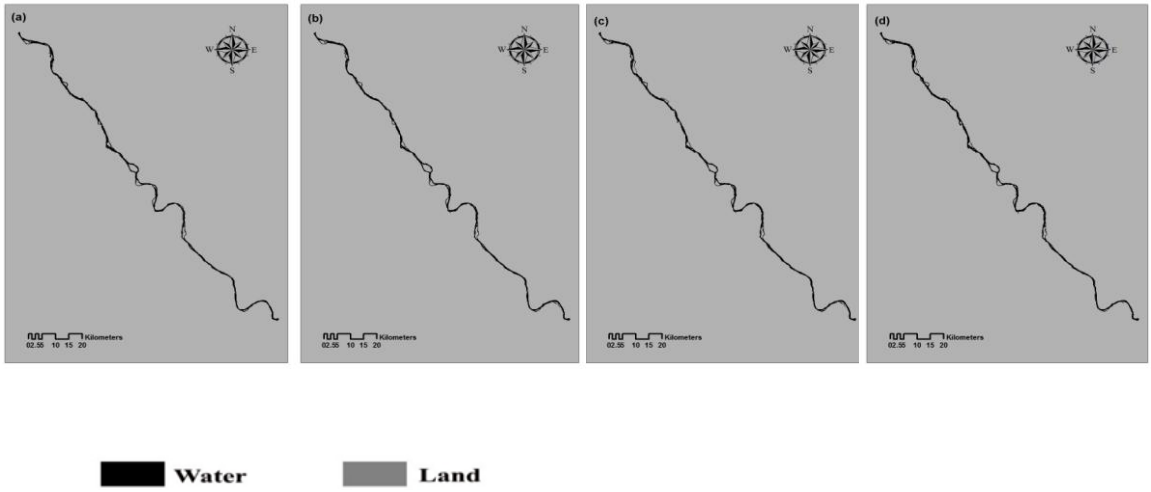
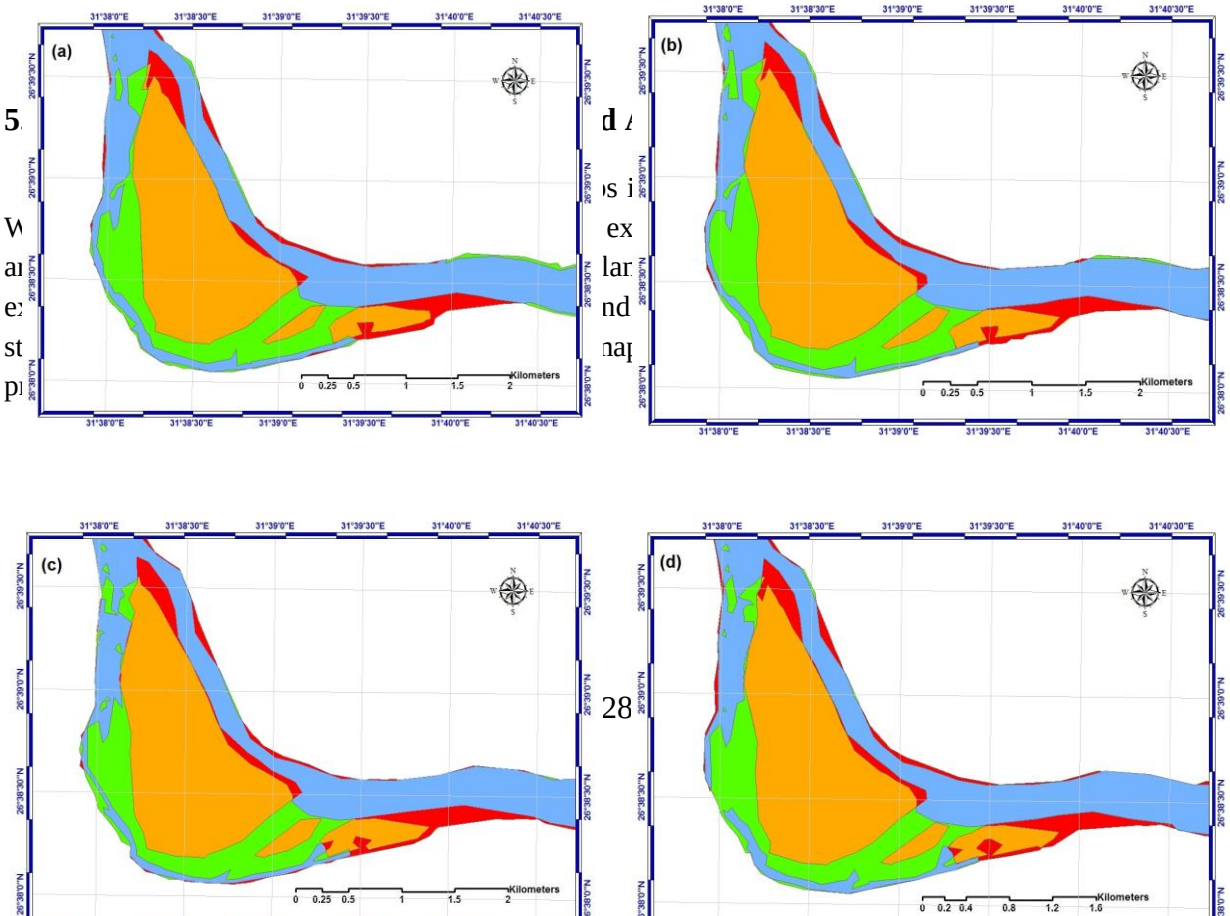



**Figure 3. the extracted water surface maps from Landsat 5 TM image (2010).(a) Reference map; (b) NDWI map; (c) AWEI map; (d) WRI map.**

The accuracy assessment of the extracted water surface maps shown in Figure 1 is analyzed and illustrated in Table 2. The results show superiority and higher performance of the NDWI method for water surface

**Table 2 Accuracy assessment analysis of water surface extraction**

| Index | Water area in 2010(km2) | Absolute Error (km2) | Overall Accuracy(%) |
|---|---|---|---|
| Reference | 91.28 | 0 | 100 |
| NDWI | 90.87 | 0.41 | 98.62 |
| AWEI | 91.88 | 0.6 | 97.26 |
| WRI | 96.30 | 5.02 | 90.20 |



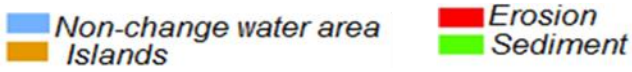



**Figure 4. The Change Detection Maps Of Water Surface In 1984 And 2010 Using Different Water Indices (a) Reference Map, (b) NDWI, (c)AWEI (d) WRI for island ALBujah and its surrounding**

**Table 3. Accuracy assessment analysis of water surface area changes**

| Index | Changed area | Absolute Error | Overall |
|---|---|---|---|
| Reference | -1.73 | 0 | 100 |
| NDWI | -1.67 | 0.06 | 99.13 |
| AWEI | +7.5 | 5.77 | 87.33 |
| WRI | -5.7 | 3.97 | 92.72 |

It is observed from Table 2 that the NDWI method for water change detection provides the highest performance compared to other methods with an absolute error of 0.08 $km^2$ and an overall accuracy of 99.23%. Accordingly, the NDWI is used to model the temporal changes of the study reach in the period 1987-2010. For this purpose, the NDWI is calculated from Landsat images of years 1987, 1999, 2005, and 2010 .

## 5.3 Generation of water surface maps Using NDWI

Figure 5 indicates the reach surface area in years 1987,1999,2005 and 2010 respectively.

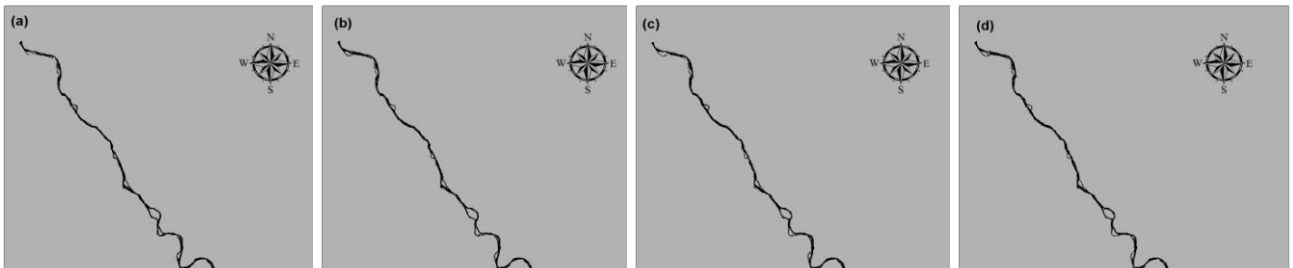



**Figure 5. Time series NDWI (land- water) maps, (a) map of 1987, (b) map of 1999, (c) map of 2005 and (d) map of 2010.**

## 5.4 Quantitative analysis of change detection results

Table 4 shows the water surface areas changes that occurred in the study reach during the study periods.

**Table 4 Statistics of water surface area change**

| Year | Surface Area (km2) | Surface Area change |
|---|---|---|
| 1987 | 92.54 | |
| | | -3.74 |
| 1999 | 88.8 | |
| | | +2.42 |
| 2005 | 91.22 | |
| | | -0.35 |
| 2010 | 90.87 | |

According to Figure 5, it is obvious that from the year 1987 to the year 1999 and from 1999 to the year 2005 a significant change has been observed. While no significant change has occurred in the water surface of the study reach during the period from the year 2005 to the year 2010. Overall the results show that the total surface area changes of the study reach between the year 1987 and year 2010 were decreased by about 1.8km$^2$. The decrease in the study water surface was may be attributed to the increase of the area of Nile river islands in the same period. A morphodynamic investigation is needed to understand the mechanism of such increase.

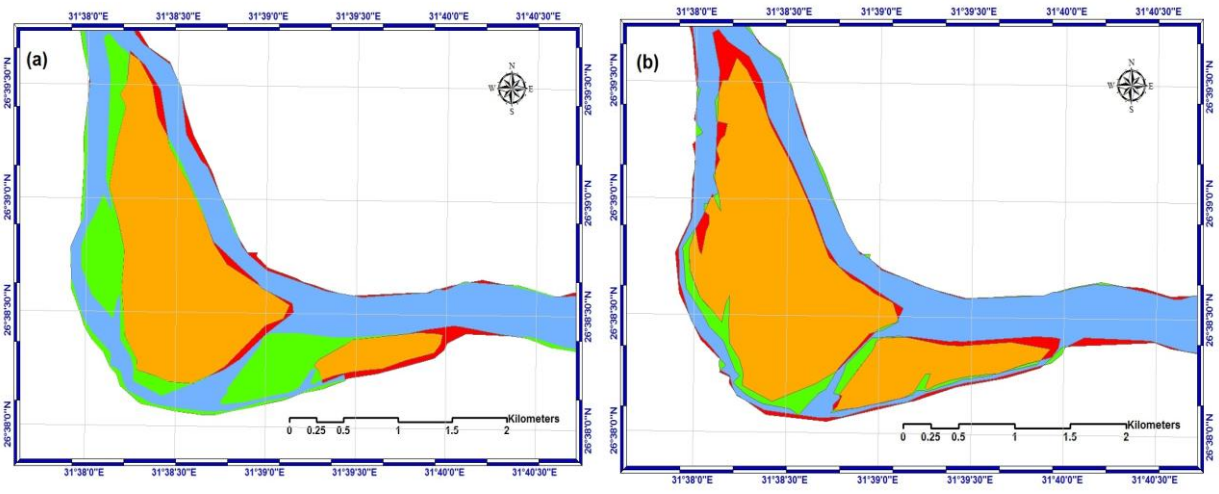


**Figure 6. Time series change maps (a) 1987 to 1999, (b) 1999 to 2005and (c) 2005 to 2010 for island AL Bujah and its surrounding**

Figures6 (a, b and c) show the time series change detection maps obtained by applying the NDWI method over the period (1987-2010) for AL Bujah island as sample results. The maximal changes are observed around the islands. The loss in water areas can explained through a morphodynamic investigation to understand the mechanism of the sedimentation process and the increasing of islands area. Overall, the reach lost about1.8% of its surface area in the period 1987-2010

## 6. CONCLUSIONS

This research presents and discusses the results of detecting the morphological changes in water surface areas of the third reach of the Nile River from Naga Hammady Barrages to Assuit Barrages (inside Egypt) using RS/GIS technologies based on Landsat images. The results indicated the NDWI method provided the highest performance for water surface extraction and change detection compared with other methods. The NDWI gave an overall accuracy of 99.23%. Moreover, the results showed that the total surface area changes of the study reach over the period between 1987 and 2010 were decreased by about 2 $km^2$ (1.8% of total area). It is observed in this reach that the maximal changes are located around the reach islands.

To improve the navigation path through this reach, the mechanism of the sedimentation process through the river banks and islands fringes should be understood. Therefore, it is highly recommended to conduct a comprehensive morphodynamic studied to the study reach.

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## REFERENCES

Ahmed, S.A.M. (2014) *Morphological and Environmental of The Nile River (Case Study Reach Four)*, Master of Environmental Science Thesis, Environmental Engineering Science Department, B.Sc. of (Civil), Faculty of Engineering , Cairo University, 1997.

Curzio, S.L.; Russo, F. & Caporaso, M. (2013) *Application of Remote Sensing and GIS Analysis to Detect Morphological Changes in An artificial Lake*, International Journal of Remote Sensing & Geoscience (IJRSG) 2(4), 2319-3484.

El Gammal, E.A.; Salem, S.M. & El Gammal, A.A.(2010) *Change detection studies on the world's biggest artificial lake (Lake Nasser, Egypt*, The Egyptian Journal of Remote Sensing and Space Sciences. 13,89–99.

Elsahabi, M.; Negm A.M, & Ali, K. (2016) *Performances Evaluation of Water Body Extraction Techniques Using Landsat ETM+ Data: Case-Study of Lake Nubia, Sudan*, The Egyptian International Journal of Engineering Sciences & Technology. 19(2), 275-81.

Moussa, A.M.A. & El Moustafa, A.M.(2010) *Morphological Changes Analysis for Nile Bed at Aswan Bridge Area Using GIS*, Ain Shams Journal of Civil Engineering (ASJCE), Vol. 1. March, 2010, pp. 599-610

Mostafa, D.A. (2012) *Morphological Study of The Nile River Fourth Reach*, Master of Science Thesis, Irrigation Department, Faculty of Engineering, Cairo University.

Mohammadi, A., and Alaghmand S. & Mosaedi, A.(2008) *Study and Determination of Morphological Changes of Dough River in North of Iran Using GIS*, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 3, 1217-1220. http://www.isprs.org/proceedings/XXXVII/congress/8_pdf/12_WG-VIII-12/06.pdf

Moghaddas, N.H.; Jalilvand, R. & Soloki, H.R.(2013) *The investigation of the Sistan River morphology using Rosgen classification*, Indian Journal of Science and Technology. 6(2), ISSN:0974-6846.

Negm, A.M.; Elsahabi, M.; El-Sayed, R,; Abd El-Basset, N.; Ghaly,S.& Ali, K. (2016) *Morphological Variation of the Nile River First and Second Reaches Using RS/GIS Techniques*, The Nile River,Hdb Env Chem, DOI 10.1007/698_2016_126, © Springer International Publishing AG 2016.

Rokni, K.;Ahmad, A.; Selamat, A. & Hazini, S.(2014) *Water feature extraction and change detection using multitemporal landsat imagery*, Remote Sens. 6, 4173–4189.

Seker, D.Z.; Goksel,C.; Kabdasli,S; Mosaoqlu,N; Kaya, S (2003) *Investigation of Coastal Morphological Changes due to Rriver Basin Characteristics by Means of Remote Sensing and GIS Techniques*, Water Sci Technol. 2003;48(10):135-42.