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CASE STUDY

Study of morphologic changes in Karun River using linear directional mean, remote sensing and geographic information system

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ABSTRACT: The study region is a section of the Karun River located in Khuzestan Province that stretches from Gotvand to Tange Aghili in Shushtar. This article intended, to study morphological changes in the Karun River using the "linear directional mean" and "mean center methods", based on four series of satellite (Landsat TM and Landsat – ETM) images. The linear directional mean and the mean center methods were employed in a GIS environment to analyze the degree of changes in the river. Based on the linear directional mean method, the length of the river increased from "1958 to 1989 "but declined from" 1989 to 2010". Results obtained from the mean center method, indicate that the extent of displacement in the studied interval did not follow a regular pattern. Finally, Results indicate that Karun River has undergone considerable changes and displacements in the different study periods in the study region.

KEYWORDS: Linear Directional Mean; Mean Center Method; Karun River; Morphological Change; Remote Sensing.

INTRODUCTION

Rivers and channels are totally dynamic systems and their morphological features continuously change due to their dynamic properties (Farrokhi, *et al*., 2005). Hydrological changes in nature gradually change the position and morphology (size, shape, and configuration) of rivers. These changes are caused either by long-term changes in the environment, by seasonal fluctuations (wet and dry), and/or by changes caused in the hydrology regime through human activities (Al-Yasin, 2007). Moreover, a set of factors such as channel slope, flow rate, characteristics of bed materials, frequency and intensity of floods, etc., cause temporal and spatial changes in river morphology (Arshad, *et al.,* 2007). In this relation, (leopold and wolman, 1965). divided rivers morphologically, as influenced by these same factors, into the three classes of straight, meandering and braided rivers, among which the meandering pattern attracts the greatest interest because it is the most frequently found one in nature, Morid, (2004) examined four series of Landsat and IRS satellite images and found that meanders in Karoun River have changed and moved downstream. Yang, (1999) studied six series of MSS and TM satellite images and reported that the Yellow River in China was transformed from the direct current state into the poor meander state during the study period. Cencetti, *et al.,* (2004) investigated the evolution of Jacqueline River alluvial plain in the center of Italy in the past 200 years through surveys of 14 sections of the river bed. Their results revealed an increasing decrease in bed width from 206.7 m in 1821 to 53.9 m in 1999. The river bed moved 121 m from 1821 to 1977 and its depth increased. Gharibreza, (2006) reported that two cut offs occurred in Zohreh River

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during 1967, which not only increased the bed meander angle from 43 to 48 degrees, but also put this river into the group of highly-developed meanders. Farrokhi, (2005) studied the plan of Dez River and reported that this river mostly displays a meander-like pattern and its banks demonstrate extensive displacements. McCusker, (2006)conducted a GIS-based historical analysis on Pamprogue River in west Connecticut (United States) and reported that in the past 70 days in addition to the increased bed changes, bed sinusoidal degree decreased. Mossa and Coley, (2005) believed the changes in Pascagoula River bed (in the southeast of Mississippi) were the result of mining operations and stated that bed width increased by 400 to 500% in some regions. Michael and Tamara, (2004)studied the morphology of Rigorand Silver bed and reported that the main river bed deepened significantly and the average conduit width decreased from 275-520 m in 1918 to 70-14- m in 1972. According to Simon, *et al*., (1999), the rate of destruction of river banks in the United States changes from 1.5 m to over 100 m in some watercourses of Totel River.

Thorne, (2002); Chris Parker, (2008); Gabrielle ,(2009); Petts, G.E. ,(1986) who studied river morphology based on geometrical specifications, number of inter-conduit dams, flow discharge rate, river morphology, sediment input, etc.

Abdolrassoul Talouri (1994) studied a segment of the Karun River (from the Ahvaz Hydrometry Station) in his M.Sc. thesis. Results he obtained indicated the meandering patterns of the Shatit and Karun Rivers (at least after the construction of the Dez and Karun Dams) have remained unchanged due to the regulation of flow and of sediment characteristics in these rivers, but riverbank erosion could be observed in the meanders (Talouri, 2004).

Globevnik, (1998) studied environmental changes and changes in the morphology of a 92-kilometer segment of the Dragonja River Basin in Slovenia during the past two decades. He used three series of satellite images at a scale of 1:10,000 and employed GIS analysis to investigate morphological changes that took place in the river during two decades. He intended to study the current water regime of the river, and offered a suitable environmental management method for the river water (Globevnik, 1998).

Orfeo and Stevaux, (2002) conducted a study to evaluate the spatial dimension (the effects of land use on river basins) and the temporal dimension (the years from 1979 to1998) of morphological changes that have taken place in a river in Oregon (in the United States). They intended to investigate the possibility of relating these changes to management parameters, topography, and other factors in the study region using aerial photographs together with the GIS, RS, and GPS techniques (Orfeo and Stevaux, 2002).

(Miller and Sias) studied the need to investigate the morphological behavior of large rivers and introduced a study framework to carry out this investigation using modern methods. It is very difficult to regularly monitor channel patterns and to analyze temporal changes in geometric parameters. In recent years, the remote sensing (RS) technique with its special features has made it possible to obtain images and has made it possible, by using a geographical information system (GIS), to process the images faster and more easily (Miller and Sias, 1998).

Davarpanah, Gholamreza, (2002) studied morphological changes downstream Zanjanroud and the factors that influenced them in a 35-year period. He examined topography maps, aerial pictures taken in 1950 and 1962, and images taken by the Cosmos Satellite. Based on his analyses, the main factors that created the morphological changes in downstream of Zanjanroud were natural ones and those resulting from human activities, with factors related to human activities being more important and more severe compared to other factors (Davarpanah, 2012).

Hajiabadi, (2004) studied changes in the Ghezel Ozan River between the Shampata and Achachi villages. Results showed aerial pictures and satellite images indicated the trend and type of changes could vary at different periods. Finally, considering the possibility of studying land use, vegetative cover, types of the formations in the region, geological conditions, etc., and using the mentioned pictures and images, he related changes in the morphology of the river to the factors mentioned above (Hajiabadi, 2004).

Arshad, S.; Morid, S.; and Mirabolghasemi, (2007) used remote sensing to study the trend of morphological changes in the Karun River from Gotvand to Farsiat. They used four series of satellite (Landsat TM, IRS-LISS-III) images and found these images had suitable capability in studying morphological changes in rivers with dimensions of the Karun River. Of course, TM images were sometimes more capable than those of IRS because of their spectral resolution (greater number of bands).

IRS images have their own special capabilities because they enjoy better spatial resolution. Results indicated that the characteristics of the bends were changing, and bends with high sinuosity had migrated to downstream (Arshad, *et al*., 2007).

Seyed Nezam Alavinezhad, (2004) dealt with changes in Moosa Creek using the fuzzy logic method and developing its main components, and obtained the extent and intensity of the changes. He concluded that factors such as land use changes and low and high tides caused riverbank changes (Alavinezhad, and Ghanavati, 2004).

Mahrokh Sardashti, (2004) studied the morphodynamics of the Taleghan Watershed situated in the Central Alborz Heights, and predicted developments in this watershed by identifying accurately morphodynamics processes, measuring their performance and their thresholds and, based on this prediction, dealt with management and planning for the watershed (Sardashti, 2004).

In his doctoral thesis, Javaheri Nasrollah, (2005) studied prediction of morphological changes in meandering rivers by using hydroinformatic methods. He intended to determine mechanisms of morphological changes in rivers and predict how these change would happen in the following five years. To predict morphological changes in the Karun River during a 50-year period, he employed aerial pictures, topography maps, and satellite images from the year 1955 to 2002. Moreover, he proposed a model for harmonic-periodic waves for the river plan using the models introduced by Leopold and Longbin (Javaheri, 2006).

In his doctoral thesis, Jafar Morshedi, (2009) "Detection and Determination of Changes in the Course of the Karun River using Satellite Data, Fuzzy Logic, and GIS",studied changes in the morphology of the Karun River from Tange Aghili in Shushtar to its entry into the Arvand Rud during a 52-year period (1955-2007) with the use of Satellite (Landsat TM) images. He intended to detect and determine changes in the Karun River and to analyze factors influencing them. Results related to the geometrical features of the river showed there were three patterns in this section of the river: the straight, the arterial, and the meandering patterns. Moreover, the overall results of this study showed that the type and intensity of changes were directly related to the channel pattern and slope, tectonic changes, and degree of channel sinuosity (Morshedi, 2004).

The Karun River is one of the most effluent rivers in Iran. Geomorphologic ally speaking, the Karun is an alluvial river with a bed consisting of fine particles including silt and clay. Under the influence of the special hydrological and topographical conditions, the morphology of the materials forming the riverbed and banks, and for many other unknown reasons, the Karun is a meandering river. The specific morphological form of the Karun River causes the annual migration of its meandering loops and its bank erosion (Javaheri, 2006). This research intended to detect changes in the course of the Karun River from the Gotvand Dam to Tange Aghili in Shushtar during 1958-2009 using GIS and remote sensing, and to estimate the extent of changes. Obviously, using results of this research will make it possible to develop a dynamic monitoring system that will be a suitable tool for designing, planning, executing, utilizing, and managing the Karun River.

This study has been carried out in Karun River of Khuzistan Province of Iran during 2015- 2016.

MATERIALS AND METHODS

The study region

The Karun River, one of largest and longest rivers in Iran, is located in the Persian Gulf Basin (the high-salinity water of which flows into the Sea of Oman). The Karun Watershed, which is situated in southwestern Iran in Khuzestan, Chahar Mahal and Bakhtiari, and Kohkiloyeh and Boyer Ahmad Provinces. It consists of five main branches called Khersan, Ab Vanak, Ab Kiar, Bazoft, and Dez. This watershed is geomorphologically divided into two main parts: the mountainous part which extends from creeks consisting of 291 small and large rivers to Shushtar, and the middle plain part flows from Shushtar to Arvand Rud. Zardkooh Bakhtiari with about 4549meters is the highest point in this basin and the Arvand Rud estuary with less than one meter is the lowest. Many dams have been constructed on this river, the oldest of which are the Shahid Abbaspour Dam and the Gotvand Diversion Dam constructed in 1976 and 1977, respectively (Al-Yasin, 2007).

The study region is the plain section of the Karun River that extends from the Gotvand Dam to Tange Aghili in Shushtar, and covers an area of 29936.24 square kilometers. Fig. 1 shows the location of the study region.

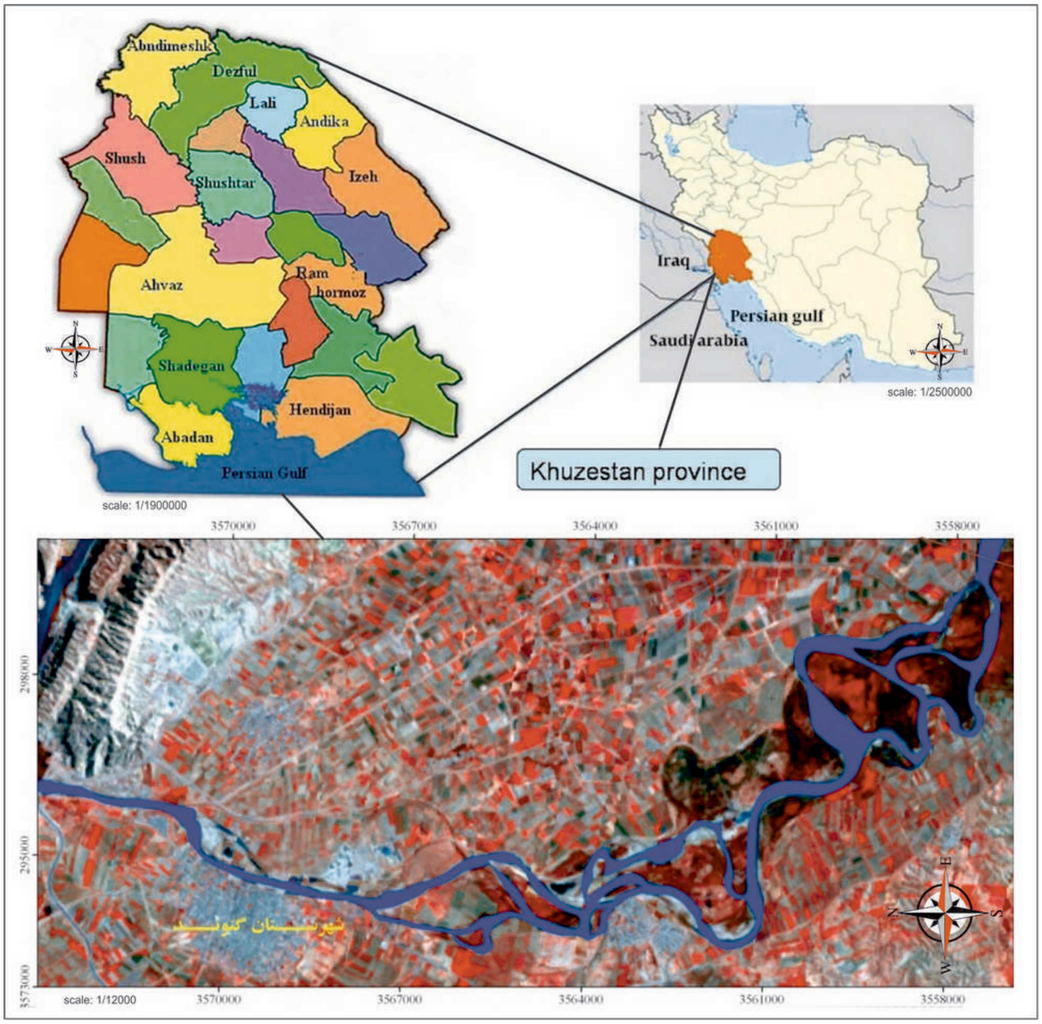

Fig. 1: The location of the study region

RESULTS AND DISCUSSION

Accurate study of satellite images taken in various years is required to investigate the trend of changes in the Karun River. The available satellite images for this study were those taken by the Landsat TM and Landsat ETM^{+} satellites. The cells in these images were 28.5 and 30 meters. The study period was 52 years (from 1958 to 2010). Topography maps of 1958, Landsat TM images of 1989, and Landsat ETM images of 2002, 2005, and 2010 (seen in 1958- 1986) were employed to study the section of the Karun River from Gotvand Dam to Tange Aghili in Shushtar.

The topographic map of 1858 in two sheets of 5754 II Shushtar and 5754I Gotvand at the scale of 1:250,000 was scanned, georeferenced in a GIS environment, turned into a mosaic format, and finally digitized. Since the value of the RMS(Root Mean Square) index used for dereferencing in this research was that listed in Table 1, the transformation was very accurate and the changes were measured with suitable accuracy. Finally, the transformed topographic map was used to study morphological changes in the river.

Table 1: The value of the RMS index

Year	RMS
1958	0/72
1989	510/
2002	430/
2005	210/
2010	200/

Since raw satellite images do not have coordinates, it is impossible to measure changes. Therefore, the first step in analyzing satellite images was their geometrical correction and dereferencing based on 1: 50,000 scaled maps and on about 30 ground control points. The geometrical correction was made using the nearest neighbor algorithm and all of the mentioned maps were adjusted to the UTM coordinate system and zone number 39.

The river course was digitized in a GIS environment using the 1958 topographic maps of the Army Geography Organization, Landsat Tm images of 1989, and Landsat ETM images of 2002, 2005, and 2010 in order to study changes in the Karun River during the study periods. The necessary corrections were made and the river course was digitized as a polygon. The centerline of the river at each of the mentioned periods was then extracted, and changes in the Karun River were studied based on the river pattern and the trend of its movement and on the general course of the river at each of the periods in relation to the geographical north. Following that, the geographical information system tools, the linear directional mean method, and the mean center of each year were used to analyze the extent of change in each of the study periods. Fig. 2 shows the linear directional mean at each study period.

The linear directional mean method is used for linear courses and, hence, a map of the centerline of the river in the various years is needed in order to use it. Therefore, a map of the centerline of the river was extracted for the years 1958, 1989, 2002, 2005, and 2010 using the ARC GIS software.

The trend of changes in the river course at each period was determined by calculating the average angle of each line. This statistical method for calculating the trend of the lines is called directional mean. Each line has a beginning and an ending point, and each line shows a course along which movement takes place such as that of water along a river course and of wind and atmospheric systems. In a GIS system, each line is specified by a beginning and an ending point and is directional. Therefore, obtaining the direction of movement by a digitizer or digitizing software is very important because directions and orientations may be calculated inversely if only the orientation option is used and the direction option is ignored (Alijaniand and Gol Parnian, 2004).

CONCLUSION

An overall look at the river course in this research from the beginning (the Gotvand Dam) to the end (the Tange Aghili) of the study area at the vari-

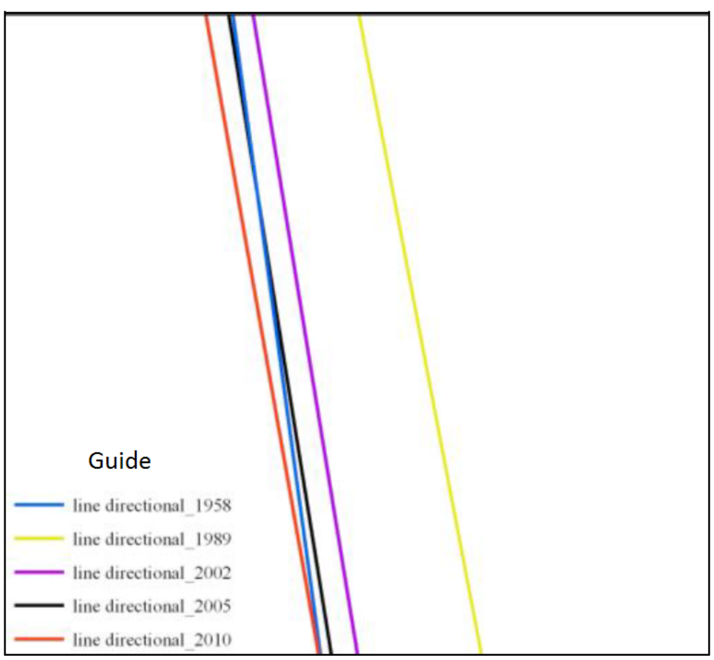

Fig. 2: Linear directional mean

ous mentioned periods indicates the course of the river was 2971.72, 32756.63, 31528.35, 31412.28, and 29936.24 meters long in 1958, 1989, 2002, 2005, and 2010, respectively. Table 2 shows that the lengths of the river course were at its minimum in 1958 and at its maximum from1989 onwards, but had a declining trend from 1989 to 2010.

Table 2: Changes in the length of the Karun River from 1958 to 2010

Changes in the length of the river	Year
2971/72	1958
32756/63	1989
31528/35	2002
31412/28	2005
29936/24	2010

Moreover, study of the centerline of the river at the five study periods indicates that it was displaced by 670.31meters from 1958 to 1989, by 338.31 meters from 1989 to 2002, by 26.64 meters from 2002 to 2005, and by 320.93 meters from 2005 to 2010. Table 3 show displacement of the Karun River in the study periods and the changes in the displacement, respectively. The minimum displacement of the centerline of the river in the study periods (26.64 meters) happened between 2002 and 2010 and the maximum (670.31 meters) between 1958 and 1989.

The maximum changes in the directional mean of the Karun River (9730.57 meters) was that of the period between 1989 and 2002 and the minimum changes (18.28 meters) was that of the period from 2002 to 2005. Table 4 show the maximum changes in directional means. Moreover, the measured changes in the beginning and ending point of each line of directional mean in different periods are shown in Table 5.

Table 3: Extent of displacement of the Karun River from 1958 to 2010

Year	Displacement
1958-1989	670/31
1989-2002	338/31
2002-2005	26/64
2005-2010	320/93

Table 4: Maximum changes in directional mean from 1958 to 2010

Year	Maximum changes in direction
1958-1989	261/65
1989-2002	9730/57
2002-2005	18/28
2005-2010	82/76

Table 5: Maximum changes in directional mean at the beginning and ending point of each line

year	changes in directional mean at the begin	changes in directional mean at the End
1958-1089	246/53	276/76
1989-2002	98/85	196/17
2002-2005	6/85	29/72
2005-2010	126/07	39/45

SUGGESTION

Results indicate that Karun River has undergone considerable changes and displacements in the different study periods in the study region. Therefore, it is suggested that:

1. Other methods of processing satellite images such as the method of land use changes and the Principal Components Analysis (PCI) should be used in estimating changes in rivers.
2. It is possible to use remote sensing techniques such as the Normalized Difference Vegetation Index (NDVI) and Water Index (WI) for specifying the boundary between water and soil.
3. Considering the importance of the changes that have taken place, study of the trend of these changes, especially in residential areas and agricultural lands is very important.
4. Since considering these changes can be very influential in location and construction of water facilities, river improvement projects, and flood control, it is recommended that such studies be carried out before undertaking these activities.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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