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Assessing landscape change of Minab delta morphs before and after dam construction

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Abstract
As special depositional environments which are adjacent to the seas, deltas have provided a field for human habitat establishment. Geomorphic features of deltas are in constant transformation due to their dynamic features. Constructing dams on rivers can intensify these changes and cause either negative or positive consequences. Minab delta in Hormozgan Province of Iran is a round or crescent-shaped delta which has Esteghlal Dam constructed on its creating river. Minab Dam is constructed upstream of Minab Delta in Hormozgan Province. The research aimed to derive landscape metrics of delta and assess their changes before and after the construction of dams. Landsat Satellite images of 1983 and 2013 provided the four classes as abandoned delta, active delta, subaqueous deltaic plain and aquatic environment, using maximum likelihood method, with a Kappa Coefficient accuracy of 86.55 and 88.42 for revealing changes quantitatively. To quantify landscape metrics, percentage of landscape (PLAND), Number of Patch (NP) and Mean Patch Size (MPS) metrics were computed. As indicated by the results, the NP metric increased in all the classes except active delta, and all classes showed a reduction in MPS metric. The amount of NP, Mean Nearest Neighbor (MNN) and Largest Patch Index (LPI) increased to the 22, 19 m and 1.43 percent, respectively, which clearly reveals landscape fragmentation, along with growing NP metric and a reduction in MPS.

Keywords
dam, delta, landscape, minab, morphology.

1. Introduction
Timely and accurate change detection of Earth surface features provides a foundation for greater understanding of the relationships and interactions between human and natural phenomena (Berberoglu and Akin, 2009). Many protected ecosystems are difficult to monitor because of their locations in remote or poorly accessible areas of the world (Nagler et al., 2009). Satellite images are especially valuable for the study and frequent updating of maps in areas that are poorly accessible or contain rapidly changing landforms (Blodget et al., 1991).

The concept of delta is dated back to 2500 years ago when Herodotus mentioned its usage by the Grecian people and the fertile alluvial deposits used in outfall of River Nile. A delta is formed when the aggregation of alluvial sediments is more than erosion. Most deltas are constituted in places where the river runs into the seas with weak or no tide. The shape of a delta is prone to changes because each of the branches of the river raises their beds and creates dams

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on each side. In some cases, water dominates all the borders. However, river flooding results in formation of cracks in the walls of delta which causes a new water current in those cracks. Delta areas are one of such environments which are affected by hydrogeomorphical processes in shorter intervals (AzmoodehArdalan and Mosayebzadeh, 2003). Deltas are formed and transformed by three main factors which include river, waves and tide. The Deltas of Iran are also affected by this rule; the northern coastal deltas are often influenced by river or waves factors resulting from the absence of tide in Caspian Sea (Farajzadeh, 2011).

Regarding the complicated process of sedimentation and erosion in river and enormous importance of Morphic changes in organized plans, flood control within deltas, and a recognition of deltas morphic changes is essential. The establishment and evolution of Delta is not restricted to weather zones, geography formation and special weather regimes (Kaltat, 2003). New deltas have various shapes across the world and are created in several types of geotechnical, geomorphological, oceanic and climatic environments (Coleman et al., 1986a). Natural and human factors affect the phenomena and ground effects in different ways in accordance with the surrounding conditions and situation. Some applications of deltas morphology maps include: identifying coastal vulnerabilities, infrastructure for ideal development of agriculture, locating tourism areas in coastal areas, useful in identifying flooding zones in deltaic areas, useful in identifying areas with potential for rivers material removal, useful in identifying areas with potential mineral resources and identifying and zoning areas with mineral reserves. Although delta areas comprise only 5% of the global land area, it is inhabited by over 500 million people, and Yangtze, Ganges, and Nile Delta alone comprised a population which exceeded 230 million people in the year 2000 (Overeem and Syvitski, 2009).

A review of primary observations and assessment of prior researches, and comparing with other areas in some countries, the ranges of delta changes of the south varied more and were broader. Geomorphological studies were conducted on the general identification of shape, expansion process and process changes process for analyzing the stability and phenomena of deltas. Several researches were carried out in the field of morphologic changes of rivers, and most of them were related to river engineering. However, the geomorphological studies of deltas are underestimated. To assess Dez River plan changes, using remote sensing and GIS, Farokhi et al. (2006) deduced that most rivers were influenced by meanderic pattern and their shores encountered great movements.

Chow et al. (2006) conducted similar studies using remote sensing on Yellow Delta of China. From the evaluation of the increase of pattern changes of the present Yellow River (Howang Hu) in 1976-2000, the results indicated that the extent of erosion occurred on Diyaoko Head and continued about 4.5 to 7 meters to the shoreline. Arshad et al. (2007) investigated the morphological changes process of Karoon River from Getond to Farsi using remote sensing.

The study concentrated on the morphological changes process based on four series of satellite images of Landsat-TM and IRS-LISS-III in 1990- 2003 interval, with a conclusion that curves features changes along river, while the density and size of curvature of curves moved downstream. In some places, the amount of wide movement of curves was 1950 meters during the 13 years.

Rangzan et al. (2008) studied the downstream of Karkheh River before and after constructing a dam, using multitemporal images of Landsat Satellite. Land cover changes were examined by engaging different techniques of image processing like classification and it was discovered that the river exhibited a meanderic pattern as its main pattern, and the path experienced a wide movement. In addition, the growth in vegetation increased by 13%. A review of the present sources revealed that extensive studies in the field of coastal morphology, especially deltas, using remote sensing thus far, is lacking. Remote sensing images can be an appropriate tool for eliciting information about hydrological effects and assessing their changes. Minab River Delta is located in the Eastern part of Hormozgan Province, it is a round or crescent-shaped delta formed by the combined processes of rivers and waves. Esteghlal dam was constructed on Minab River in 1984. Dam construction has brought about some changes in Minab River, as seen in the amount of its sediment and changes in delta morphs. Landscape structure and composition may change dramatically over time in a variety of landscapes. So far, morphic changes of deltas, using landscape metrics have not been studied. The purpose of this study therefore is to research on changes of landscape of delta morphs before and after constructing a dam.

2. Study Area

Minab Delta is located at coastal plain on the north of Hormozgan Straight, with geographical coordinates of 26º 52´ and 27 º 18´ of northern latitude and 55 º 41´ and 57 º 5 ´minutes of the eastern longitude (Fig. 1). This delta, with 40 km length and maximum and minimum of 14 and 3 km width, an average height of six meters and an average slope of less than one degree, is one of the round or crescent shaped deltas, which is developed as a result of the combined processes of the Minab River and sea waves (Farajzadeh, 2011). It experiences an average annual precipitation of 192 mm. Minab Delta is located in the arid climate. The regional climate is hot and dry like much of other south and southeast of the country, and has a Mediterranean regime. The rainfall in the study area is mostly originated from humid Mediterranean and Sudan fronts which enters the country from West and Southwest, and affects the whole South and Southwest, including the Minab's Esteghlal dam catchment. The study area is a part of the construction zone of the folded Zagros and its structural morphology is the result of the last tectonic activities of Alpine in the Polio-Pleistocene which is yet to be concluded according to the geodynamic data (Nohegar and Hosinzade, 2003). A study of satellite images and land capability maps, and comparing them with field work suggest that the area is poor in vegetation due to geological status, human activities and climatic conditions (Farajzadeh, 2011).

Minab Delta consists of fine particles as sedimentology and is developed on alluvium of Minab River as geology (Farajzadeh, 2011). The area is dependent on hydrological and hydro dynamical characteristics of Minab River (Nohegar and Hosinzade, 2003). This river consists of two important branches of Jaghin and Roudan. Rivers, after leaving the Esteghlal reservoir dam, following a quite meanderic path, shows their seasonal and corrosive properties. The length of the river from the dam construction site to the area of the river reaching the open waters is about 30 km. However, the Minab Delta was created in the study area adjacent to the sea, as a result of sedimentation during Quaternary, and this this delta caused the extent of coastal plain

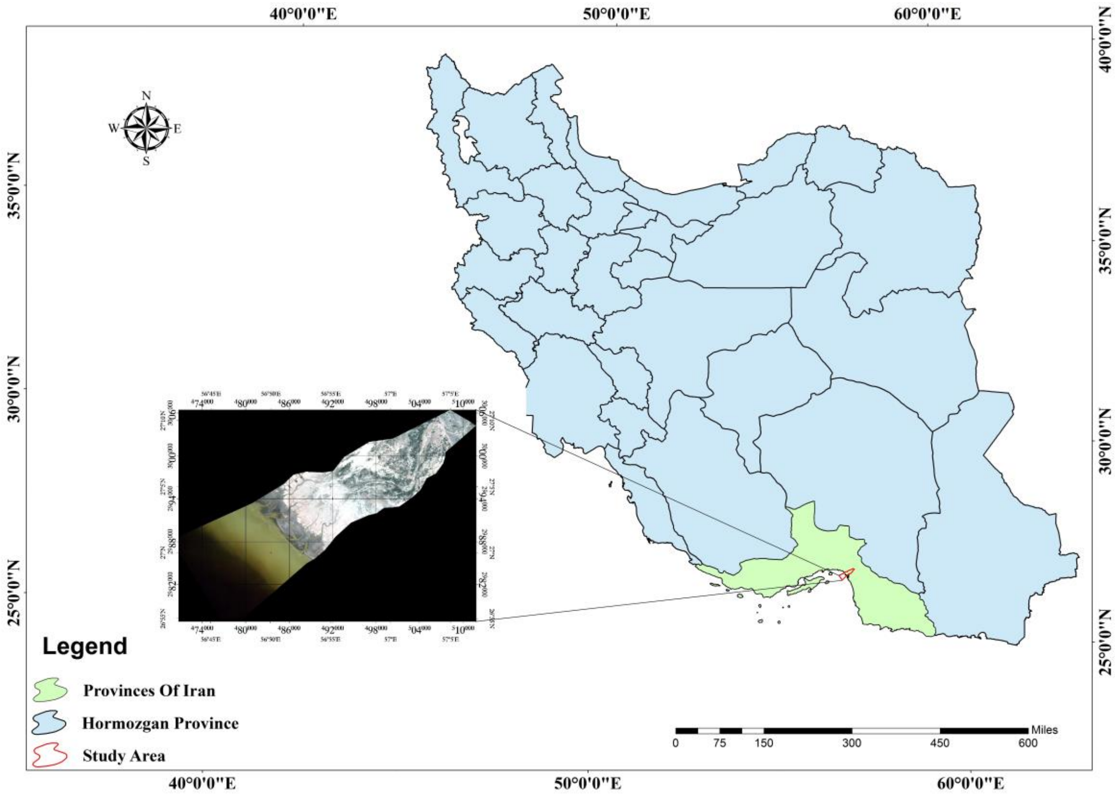

Fig. 1. The studied area's position in Iran and in the Hormozgan Province

(Farajzadeh, 2011). A review of the aerial photographs and satellite images showed that the delta base projected considerably along the coastline where Minab River flowed into the sea. Delta are characterized by gentle slope, thus main bed of a river divides on it and this creates a divergent drainage network.

3. Materials and Methods

The study utilized the Landsat TM Sensor with path of 159 and row 49 images, which was taken from the period before the construction of the dam on the Minab River, in 1983. Also, the image of the Landsat 8 OLI Sensor in 2013, relating to about twenty years after the dam construction, was utilized. The topographic maps, with a scale of 1:50,000 and sheet numbers (7344 and 7433) of Iran geography organization were used to georeference images and also to locate the delta. Multitemporal data analysis was derived from an accurate geometric co-registration because the absence of this factor in images could result in a reduction in the restoration of the accuracy of digital changes. Selection of the appropriate Ground Control Points (GCP_s) was done by employing ENV14.8 software. For georefrencing images of area study, the first step involved geometrical rectification of 2013 images by applying topographical map with 26 control points in combination with images equal to 0.48 pixel. Control points were selected on road intersections, streams and field nets with suitable spread, and were employed in images by applying first class Polynomial equations and Nearest Neighbor Interpolation method for re-sampling degrees of pixels light in image.

Co-registration of images of 1983 and 2013 was carried out by choosing control points. The need for high quality of images distinction, in order to carry out this operation, was vital. Thus, before selection of the control points, Linear Contrast Enhancement and Noise Removing methods were used to increase the transparency and quality of images. Following this, a geometrical rectification was implemented on TM 1983 images, utilizing 24 control points with proper distribution for more accurate co-registration, with appropriate distribution by applying first class multisentences equations in proportion to image of 2013. The given area was differentiated from the rectifying co-registration images derived from TM1983 and OLI2013, using delta border, and was applied to the study. The amount of error for co-registration of the two images was 0.39 pixel. Classification of images was done after they were prepared.

As one of the main issues of remote sensing, classification was derived from pattern discernment science, and was useful in decision making regarding which satellite image pixel belonged to which ground effect, based on its features. After preparing images for deriving, classified maps made with maximum likelihood method were used determine how morphs changed and which one of classes expanded or reduced in area. Parametric method of maximum likelihood classification was based on Bayes Law. Due to the incorporation of most of the statistical parameters, such a Basic probability, Variance, Covariance and Mean of Classes, this method stand out as the the best of all statistical algorithms of basic pixel classification by comparison.

The method was based on the probability that pixels belonging to each set of m class were checked and assigned to the class where there was maximum probability. In mathematical terms, this logic can be written as follows:

$$x \in w_i \quad \text{if} \quad p(x|w_i) > p(x|w_j) \quad \text{for all} \quad j \neq i \tag{1}$$

From the equation, a pixel with spectral vector, x, belonged to the spectral class of w_i, if the probability of a pixel belonging to this class, $p(x|w_i)$, was larger than the probability of belonging to other classes. The first step was to calculate the probability of $p(x|w_i)$. Since the image data were prepared for classification in several bands, therefore, the equation for each spectral vector X for each class in the training data is as follows:

$$p(X|w_i) = \frac{1}{(2\pi)^{\frac{f}{2}}|\Sigma_i|^{1/2}} \exp\left[-\frac{1}{2}(X - M_i)^T \Sigma_i^{-1} (X - M_i)\right] \tag{2}$$

where x represents the value of one pixel, M_i is the mean value for all training pixels of the class.

Metrics which characterize and quantify the shape, geometric features and nature of spreading and distribution of fundamental components of landscape, are appropriate tools for approximating ecological bases to land use programs and their use in these planes (12). Regarding class level, in this study, three metrics, PLAND (Percentage of Landscape), NP (Number of patch) and MPS (Mean Patch Size) were selected. PLAND computed the area percentage proportion of each class. NP quantified the number of patches in class or landscape levels and revealed that a large number of patches denoted a greatly broken class or patch type. LPI showed that the percentage of landscape included the biggest patch. Mean distance between two patches was calculated by MNN metric.

4. Results and Discussion

The different delta morph features or the classes considered in this study included:

a) Abandoned deltas were active deltas in the past, but currently, transportation and sedimentation activities were not observed. Based on transportation and sedimentation processes, two main types of deltas, known as constructive and destructive were detected.
b) Active deltas were the deltas with existing transportation and sedimentation activities.
c) Subaqueous deltaic plain: It is the part influenced by fluvial and marine interactions,with the area on the land side limited to the tidal effect.
d) Aquatic environments: It is a part of delta below the tide minimum level which had finer particles on the sea side. The area comprised the finest size (clay particles) called the delta front.

Introducing the training samples taken from ground surveys, images of the years 1983 and 2013 were classified using maximum likelihood method (Figs. 2 & 3).

According to experimental samples extracted from 2013, a classification of the images of study area and its control by documents, maps, Ariel images and field observation, yielded a valid classification accuracy of 95.39 and Kappa Coefficient of 88.42. PLAND metric measured the proportion of each class percentage. Temporal changes of PLAND could be used in providing a general mentality for landscape change in the study area study. Class percentage of abandoned delta and aquatic environment increased by 1.18 and 1.16, in interval between 1983 to 2013, respectively. The class percentage of subaqueous deltaic plain experienced no changes in this time range. However, there was a decrease in the active delta class percentage from 6.7 in 1983 to 3.97 in 2013. NP and MPS metrics for pointed interval are illustrated in following figures. NP metric experienced an increased in all of the classes, except the active delta (Fig. 4). There was considerable increase in all classes in MPS. Augmentation and reduction of NP metric indicated a destruction and fragmentation of abandoned and subaqueous deltaic plain.

According to Table 2, amount of NP, MNN and LPI increased by 22, 19 (m) and 1.43% in landscape area.

Table 1. Area of delta morph

Class	**Abandoned deltas**	**Active delta**	**Subaqueous deltaic plain**	**Aquatic environments**
Area in square kilometers (1983)	203.64	28.35	82.56	108.19
Area in square kilometers (2013)	208.58	17.19	83.95	113.2

Table 2. Computation of metrics in landscape area

Metric year	NP	MNN (m)	LPI (%)
1983	389	126.1	47.67
2013	408	145.1	49.1

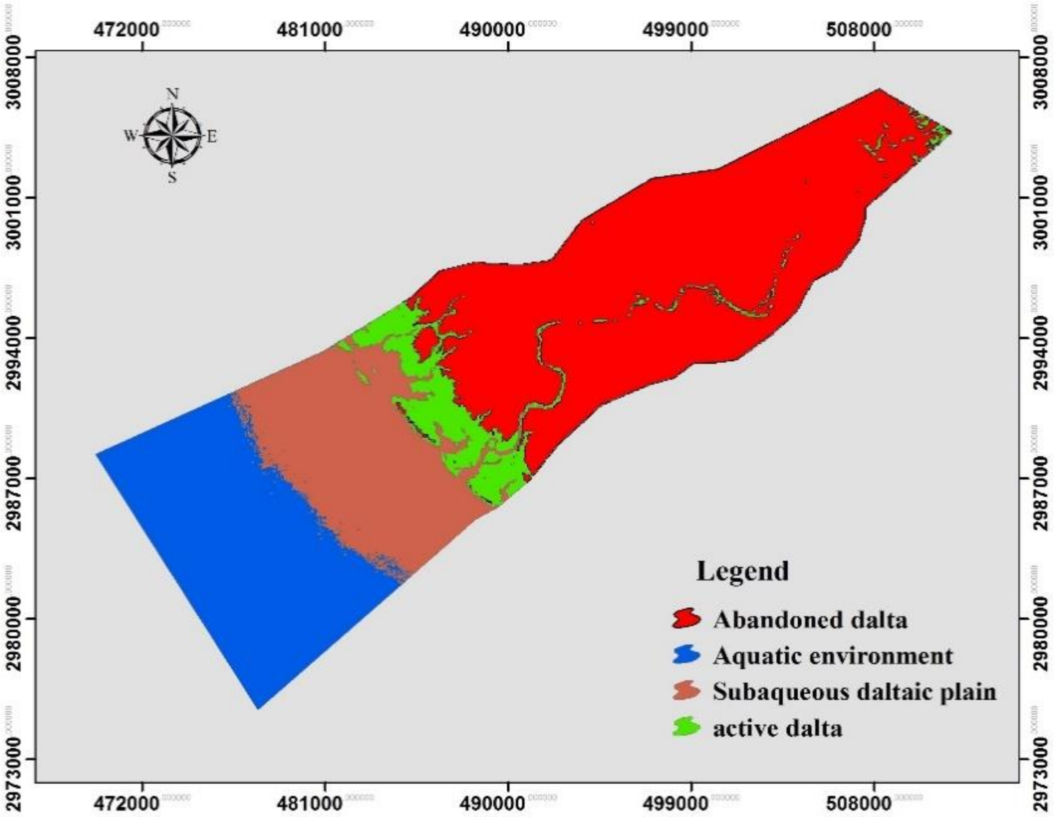

Fig. 2. Classified image of Minab delta of 1983

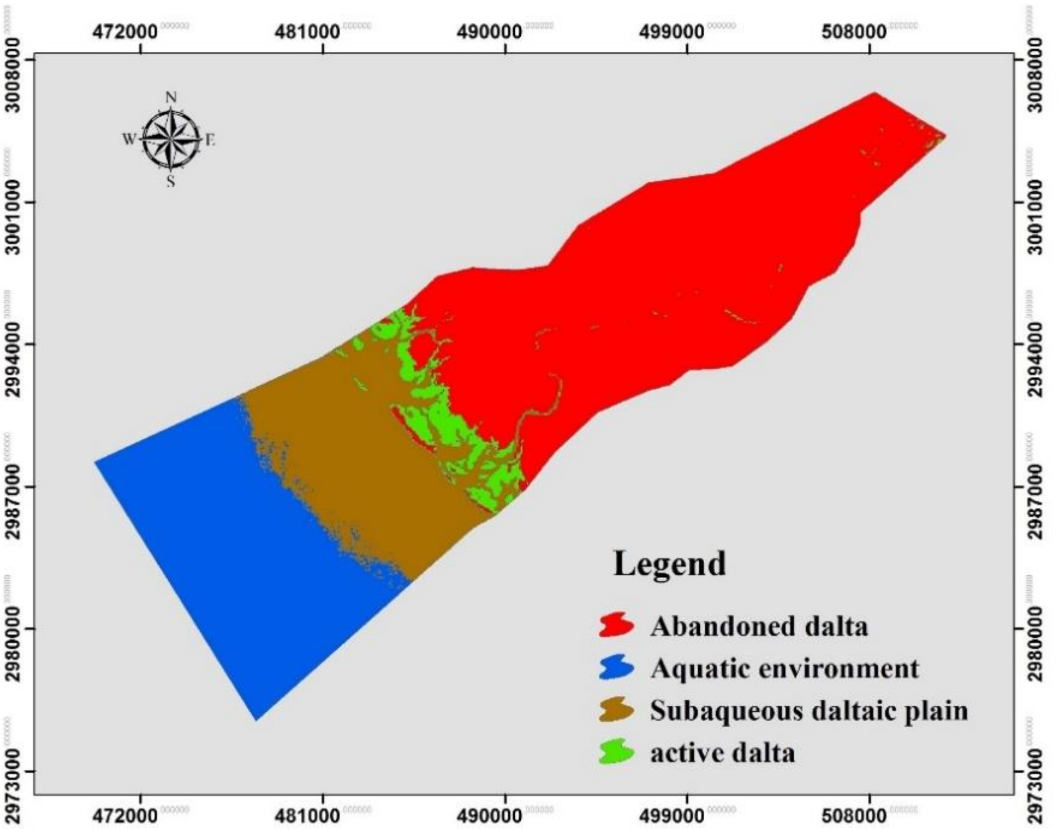

Fig. 3. Classified image of Minab delta of 2013

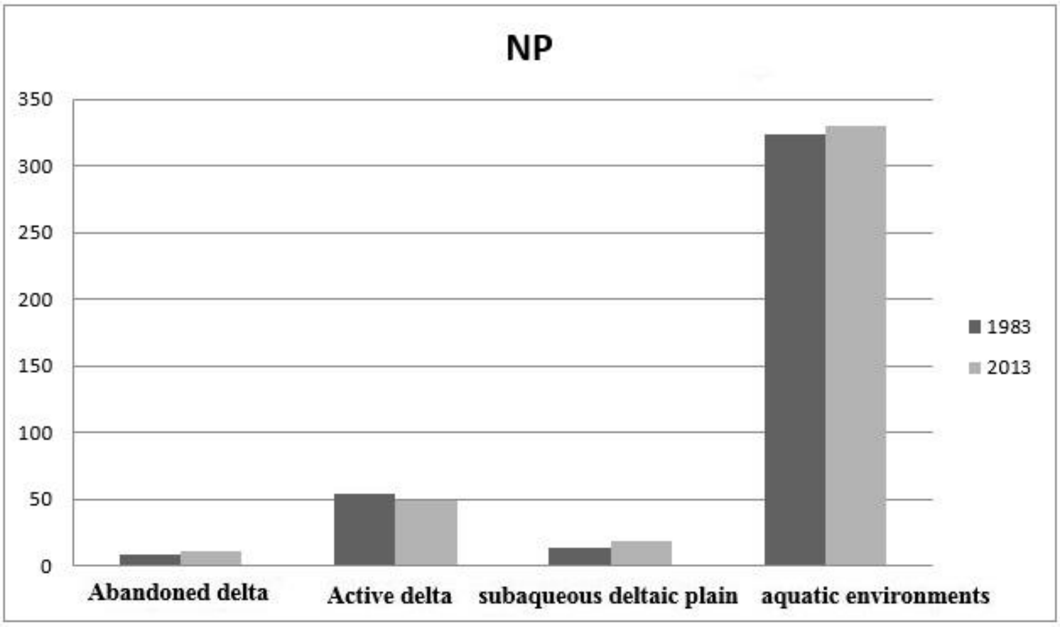

Fig. 4. Number of patch metrics changes (NP)

Table 3. The metric is calculated in the landscape

Metric year	LPI (%)	NP	MNN (m)
z	47.64	389	126.1
2013	49.1	408	408

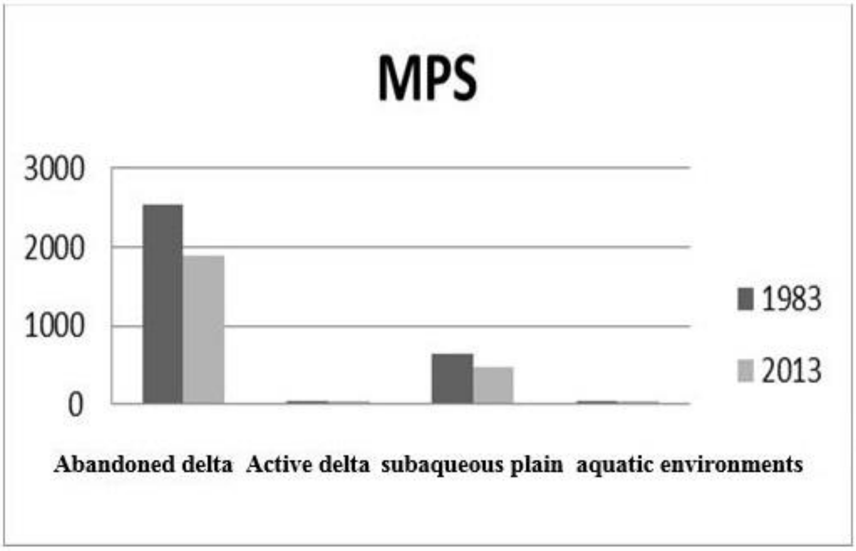

Fig. 5. Mean of patch size metric changes (MPS)

The changing in ecological processes due to spatial pattern changes can have negative effects on environmental quality, thereby resulting in several environmental problems. Delta area is one environment mostly affected by hydrogeomorphical processes on short-term intervals (Azmoodeh Ardalan and Mosayebzadeh, 2003). On the other hand, discovering changes may be understood in general but there is need for the quantity and quality of these changes to be understood also, io order to facilitate their programming. Having knowledge of temporal-spatial changes of delta morphs is indispensable to sustainable management of shores. These changes affect the structure and operation of the ecosystem, and can interrupt ecological processes which depend on it.

The recognition of ecological processes and understanding relations between their components are important factors in life establishment and balance of cycle. Consequently, a change in ecological processes due to change in spatial patterns can reduce the quality of environment and result in several environmental problems. Dam construction in spite of its definite advantages, such as decline in frequency and climax of floods, accessibility to water in dry years, upset the balance of natural system. Hence, changes will take place in hydrogeological, hydraulically and morphical phenomena of catchment.

Scrutiny of satellite images of Minab Delta revealed that the main reason for extent and restriction of delta width is the geological structure, and also the river delta sedimentation, and this extends along the folds, with characteristic smooth and open folds. In contrast, there has been a decline in the width of delta, where a rough surface is extended along shoreline. A very gentle sloping delta surface, sand flow and its aggregation on delta area and drainage net path resulted in surface difference. Minab Dam was launched in 1983 in Hormozgan Province. This operation has had a strong impression on agriculture and economy of region and Minab Delta since then. Erosion and sedimentation motivated morphological changes and this was evident in Minab Delta, with sedimentation change which resulted in changes in various morphs of delta. Briefly, the results from the metrics of the two images of study area signified a decrease in the area of active delta patches. MPS reduction for abandoned delta and subaqueous deltaic plain regarding increase in NP and its area denoted that destruction and fragmentation were prevalent in these classes. MPS served as an index of fragmentation. Impact of landscape fragmentation was evident with an increase in NP and a decrease in MPS.

5. Conclusions

Although the ecosystem is influenced by ecological processes changes structurally and functionally, however delta areas are also affected in short time (Azmoodeh Ardalan and Mosayebzadeh, 2003). Spatial-temporal changes perception of delta is an unavoidable point for management. Detection of changes today is not traditional, and is more precise when modern technologies are engaged. The results of metrics and change matrix attested to the great changes after the construction of a dam. These changes grew from upstream of the delta to its base, with most of the changes in the area resulting in growth of aquatic environment morph, while the least changes were related to subaqueous deltaic plain due sedimentation reduction upstream. The indicated that patches and active delta declined in their area.

Minab Delta was placed between intersections of land powers; this meant that it was influenced by Minab River on one hand and the effect of sea dynamics in company with waves and tide processes on the other hand. In some conditions, obstructive characteristics of dam specifically decreased the river power. Therefore, sea energy will be increased and delta morphs will be placed under its impression. But before constructing of a Dam, sea and river energies had to be balanced. Dam construction affects this balance and its impacts appeared as changes in land shape. Going with the morphological conversion flow of Minab Delta, water movement including waves, tide and finally sea and shore flows exerted a deeper influence after dam construction. Due to declining in land flow products, sea processes role in appearance of shapes and their evolution were more noticeable. Infiltrating sea processes into lands depth grew in this way. Shapes which resulted from these processes would be more distinct than shapes which resulted from river processes, when compared. This clearly points out that each civil activity in coastal region should be done based on this new approach, which was being able to evaluate positive and negative points of these processes and applied them in the management of coastal regions.

It is therefore recommended that images with higher spatial resolution and other image classification methods be used for exact evolution of effect of changes such as delta morphs. Because different phenomena were located in a pixel in low or mean spatial resolution images, this caused a decline in the accuracy of information extraction and affected their assessment. Since each dam creation on river resulted in some changes, such as discharge change, sedimentation volume, grain of sedimentation and slope of delta, in river and delta area, and the most significant consequence of this is a widely distributed sedimentation over the region, therefore the use of high resolution images in capturing these changes is suggested. Finally, an investigation on the reasons of different delta morph changes will provide more information on geomorphologies and delta change maps for optimal management.

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