Temporal and Spatial Variation of Sand Dunes, the Caspian Sea

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Abstract The evaluation of temporal and spatial changes of sand dunes in the southern coasts of the Caspian Sea is the main target in this research. So with periodic satellite images interpretation and field monitoring on beach zone, the physical condition of sand dunes morphology was examined. The results show that from 865 km coastal stripe in the southern coasts of the Caspian Sea there is just 156 kilometers discontinuously sand dunes and the beach zone of the western part of Mazandaran and Gilan and also Golestan province are the most susceptible regions from erosion point of view. There is only 45 kilometers pristine and untouched sand dune along the study area which was located in Miankaleh territory. The results show that the varieties of sand dunes along the southern coast of the Caspian Sea are different. Tendency of erosion vulnerability of these sand dunes have been increased by anthropogenic impact and rapid sea level changes, particularly near Amirabad complex zone in south-east coasts of the Caspian Sea.

Keywords Sand dune; Coast; Caspian Sea; Vulnerability; Erosion

Introduction Control of construction and development of coastal areas for a variety of devastating human and environmental factors such as rising sea level and storm water, are the most important goals of coastal management programs. Today, the focus of human societies in the natural environment of coastal areas, lakes and wetlands has created a hazardous condition. Construction for various land developments varied with the loss of pristine coastal sand dunes and coastal dike area was under the operating conditions for the crisis caused by rising sea levels and storm waves to penetrate dry coastal areas has been provided. Annually frequent sediments which have vital role to coastal protection were eroded by erosion processes associated with human activities and environmental impacts. These processes were not excluded from the Caspian Sea coasts. And it is quite visible in areas prone to have the sand dunes, with the conditions of instability and destruction such as the areas with construction and commercial fishing jetties in the port areas, construction of protective walls to prevent sea water intrusion into coastal dry land, removal of sand from the river estuaries and coastline for construction work, building hydroelectric dams on the rivers leading to the southern coasts of the Caspian Sea, development of residential and tourist towns. Therefore, this study assesses the present condition and the extent of damage to the sand dunes under the influence of erosion processes and human activities as the main issue. Previous studies confirmed the presence of areas of maximum erosion regime in the southern coasts of the Caspian Sea (Khoshravan, 2007). So based on the results of these studies, the coastal area has been classified into three types of erosion, sediment and intermediate (Khoshravan, 2007). The study area was classified into five morphological zones (Khoshravan, 2000). The content of the sediment regime of rivers leading to the southern coast of the Caspian Sea, indicates a sedimentary process in the deltaic areas overlooking the Sefidroud and Gorgan rivers that under the influence of coastal waves and currents their distribution along the coastline has formed the dike cumulative assemblies which are suitable for the formation of natural protection structures (Alizadeh, 2007). There are many suitable places for sand dunes development along the Caspian Sea, which are located in the East part of Mazandaran (Miankaleh territory) and central region of Gilan beach (Khoshravan, 2000). The new documents about sand dune condition in Miankaleh sand barrier show that coastal dunes are classified as active and dormant ones.
Sediments resources conservation in coastal management programs with protective properties such as berm zone and sand dunes are very important. So in this research at the first step the current situation is considered highly vulnerable to erosion and at the next step its extent should be estimated. The severity of the sand dune erosion vulnerability never has been done in the GIS environment yet. So it is expected that this research could provide good answer for recognition of beach susceptibility and vulnerability against human impact and rapid sea level changing of the Caspian Sea.

The Study Area
The study area is located in the coastal area in the southern part of the Caspian Sea, between Gomishan City, in the far East to the coastal area of Astara in the far West. This extensive area with the approximate length of 807 km, has special coastal morphological features that with regard to the northern skirts of Alborz, Mazandaran and Gilan Plain, underwater precipices, overlooking the southern trench of the Caspian Sea, has created a varied morphological aspect in the coastal line. Dynamic sedimentary processes and hydrodynamic in this area have resulted in the formation of different coastal line (erosive-sedimentary), (steep - low slope), (coarse fine gravel-fine grained clay) in various parts of the southern coasts of the Caspian Sea that each of them is known as the coastal morphodynamic features, reflecting the natural property of its own coastal area.

1 Materials and Methods
At first the south coast of the Caspian Sea sediment morphodynamic and divisions in the dry coastal sand dunes were evaluated and eligible areas were identified. Then the spatial and temporal changing condition of sand dunes was studied with the help of aerial images. The sand dunes variation were compared with periodic satellite images associated with the last Caspian sea level rises during 1983-2004. The images of 1983 belong to the aerial photos with scale of 1:10000 and the satellite images are from Landsat sputnik (TM), year 2004 were processed with topography map with 1:25000 scale and with use of GIS software (Arc-GIS 9-2), all vector data of sand dunes were prepared and finally their comparison resulted in the identification and measurement of the sand dunes deformation along the mentioned period. Then coastal protection vulnerability was processed and analyzed by universal ranking model (URSM) in GIS environment. In this model each index of sand dunes associated with important degree and frequently, has been graded and each object was given a special normalized number (Table 1). Then the final degree of vulnerability tendency of sand dune erosion was calculated by overlaying processing on several numbers of categories of sand dune. Finally with classification of study area to 432 zones with 20 meter wide and popularization of each number on them, the erosion vulnerability tendency of the southern coasts of the Caspian Sea was measured. In the next step, on the basis of vulnerability model results the erosion condition of sand dunes, were monitored in the study area. The shape and variety of each sand dune has been controlled and the level of erosion impact on them was analyzed.

2 Results
2.1 Spatial and temporal changes of sand dunes
Results of the aerial and satellite images interpretation show that the southern coasts of the Caspian Sea region lack some forms of sand dunes and the other sand dunes in some areas are pristine and untouched. The sand dunes were dominant in the Caspian regions of Gilan and central part of Mazandaran as the longitudinal dune shaped and in parts of east-central Mazandaran are transverse or crescent shaped. Frequent sand dunes have developed in the Mazandaran province. The coastal provinces of Gilan and Golestan are in the second place without the certain sand dunes (Table 2).

| Normalized number | Value degree | Frequency (%) | Length(km) | Kind of sand dune                |
|-------------------|--------------|---------------|------------|---------------------------------|
| 4                 | 1            | 12.1          | 97.86      | Pristine sand dunes             |
| 3                 | 0.75         | 3.4           | 27.86      | Discontinuity sand dunes        |
| 2                 | 0.5          | 9.0           | 73.04      | Tabulate sand dunes             |
| 1                 | 0            | 75.5          | 667.98     | Without sand dunes              |
| Fuzzy set value degree classification | 100          |               | 865        | Total length of the study area   |
monitoring and the comparison of satellite images indicate that the study area could be classified according to presence of sand dunes, extent of damage or total destruction.

So along the 865 km coastal strip in the southern coasts of the Caspian Sea there is just 156 kilometers discontinuously sand dunes (Table 2). Sand dunes totally have been damaged in the west part of central zone of Mazandaran especially between Neka to Noor. Also they are injured in the eastern part of Mazandaran in Amirabad complex zone (Figure 1). There is only 45 kilometers pristine and untouched sand dune along the study area which was located in Miankaleh territory. Discontinuity sand dunes have 28 kilometer length and 73 kilometers of beach area have been cleaned from sand dune by human impact. Therefore there is not any sand dune in 607 km of study area that is equal 75 percent of beach zones of the Caspian Sea those are without natural protection index. Also final results show that more than 35 percent of sand dunes have been eroded and destructed by rapid sea level changing and land use improvement during 1983-2004 years.

2.2 Erosion vulnerability degree
The results of processing the digital data in a universal ranking system erodible sand dunes show that the total length of 865 km of the Caspian Sea coastline is beach zone with 376 km length qualified as high vulnerability to erosion. This figure is equivalent to 46.6% of the entire southern coast of the Caspian Sea. Only about 14 percent of the coastal areas are not vulnerable, including 111 km of the southern coast of the Caspian Sea (Table 1). Also as it is understood the vulnerability of coastal areas of west Mazandaran, Gilan and west coast overlooking Gomishan port was significant. The coastal areas overlooking the eastern coasts of central Mazandaran, from Larim to central parts of Miankaleh are the least susceptible areas, and the susceptibility of western coasts of central Mazandaran and Gilan is moderate (Figure 2).

3 Discussion
Human desire to extract resources for development in coastal areas has caused chaos and destruction in coastal areas of natural environment. The leveling of sand dunes and beach sand dredging with the purpose of construction on the southern coast of the Caspian Sea during the recent decade has grown increasingly and as a result many of the sand dunes and even other features of natural conservation such as coastal dikes are demolished.

The recent progression of the Caspian Sea during 1977-1994 with 2.5 meter sea level rise in some areas.

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Table 2 Frequency characteristic of sand dunes in southern coastal provinces of the Caspian Sea

| Total frequency | Frequency percent | Sand dunes length (Km) | Beach zone length (Km) | Coastal provinces |
|-----------------|-------------------|------------------------|-----------------------|-------------------|
| 0               | 0                 | 0                      | 110                   | Golestan          |
| 11              | 19                | 98                     | 505                   | Mazandaran        |
| 6               | 22                | 56                     | 250                   | Gilan             |
| 18              | 41                | 154                    | 865                   | Total coasts of Caspian Sea |

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Figure 1 Sand dunes erosion by human impact and Rapid sea level changing in the Amirabad

Figure 2 Sand dune erosion intensity degree, Caspian Sea southern coasts
of the commercial ports, marinas and coastal sediment erosion processes have exacerbated the loss of large areas of sand dunes. Amir Abad multipurpose Port is a clear example of an area which is affected simultaneously both environmentally and by the human factors which have caused the increase in the vulnerability of coastal erosion (Khoshravan and Rouhanizadeh, 2012). Results from field observations and aerial images showed that the southern coasts of the Caspian Sea in terms of having sand dunes and the damage caused by natural and human factors have different eligibility. This changed the degree of vulnerability of the beach in front of the grinding forces. Small amount of sand dunes on the southern coasts of the Caspian Sea indicates the focus and structure of the side overlooking the coast of Mazandaran and Gilan In fact in the study area, the suitability of formation of sand dunes is proved just in these coastal areas, which is to say, the dominant wind and dense vegetation have provided the conditions of formation of dunes (Khoshravan, 2000).

But other coastal regions due to the low width of the berms, and the coarse or very fine sediments and dense vegetation are not suitable for sand dune creation (Khoshravan, 2000). So the condition for the formation of sand dunes is provided only "in some areas of the southern coasts of the Caspian Sea. While changing the physical nature of the prevailing winds (speed and direction) with the density of vegetation in the areas of sand dunes caused different morphodynamic shapes of sand dunes. Longitudinal dunes with tall stature and with a maximum height of 10 meters and width are 100 meters and are located in the central province of Gilan and Mazandaran. In the east regions of central Mazandaran in Miankaleh region, crescent-shaped sand dunes have been developed with a width of more than 1,000 meters (Figure 1). So changing environmental conditions in the South Caspian region caused structural diversity of sand dunes with different morphological forms. From the overall 156 km of sand dunes along the coastline of the Caspian Sea, 98 km is in Mazandaran province and 56 km is in the province of Gilan, which the equivalent figure is 18 percent of the entire sand dunes of southern coasts of the Caspian Sea (Table 2). And the other region lacks any sand dune. Sand dunes in the study area were classified due to variety of human manipulation to healthy 12.1%, Semi-healthy, to discontinuity 3.4% rate, tabulated 9% and the region without any sand dunes 75.4 percent (Table 1). This indicates that the risk of the vulnerability of the southern Caspian coastal erosion in many areas is very high. Results of the comparison of aerial photos during 1983 to 2004 years represent the loss of large areas of sand dunes in the eastern and western part of Babolsar beach. Summarized results of the grading system of sand dune erosion vulnerability of the southern coast of the Caspian Sea shows that the most sensitive place to risk and erosion hazards is located in west coasts of Mazandaran, Gilan, and Golestan provinces. It means that in this region large areas of coastal dunes are destroyed. However, in some protected areas such as Miankaleh Beach, sand dunes are pristine and in untouched form. So focus on programs to protect and prevent the destruction of sand dunes in the current circumstances is very crucial. Based on evaluation of existing conditions in the area of sand dunes and coastal familiarity with the valuable experience of other countries, especially the most appropriate way to protect the coastal hills is putting them under the protection of the stockade and prevents the destruction of natural vegetation on them.

4 Conclusion

Interpretation of the results of this study revealed that the vulnerability of coastal erosion sand dunes in the south-central part of the Caspian Sea region is very high due to several constructions and land usages. Due to lack of sand dunes conditions, west of Mazandaran and Gilan and Coastal areas overlooking Gomishan, are affected by environmental forces and thus in these areas vulnerability to erosion is high. In the study the least vulnerable area to erosion is designated as Miankaleh territory. In total, more than 75 percent of the coastal regions in the study area lack natural protection associated with sand dunes and If not more attention to other areas of sand dunes over the coming years they will be destroyed completely.

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