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Categorizing Sirik headland using Shepard and Cowardin classification methods by the means of satellite imagery

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Aster satellite imageries of the Sirik Headland from the year 2005 were preprocessed using Envi software. Poligonized areas derived from the software were labeled and categorized afterwards, using ArcGis. On this basis, the whole area was divided into nine different categories. According to shepard classification about 70% of the area was primary coasts, mainly alluvium quaternary, and the rest secondary coasts, mainly Sabkha. According to Cowardin method however, the main area of alluvium is considered out from the classification. In this classification 27% of the area is considered as Marine system and 3% as Estuarine system.

[**Keywords:** remote sensing, coastal classification, Shepard, Cowardin, ASTER]

Introduction

Coastal classification is the very first step for planning a sustainable development for coastal areas. Yet there is no consensus among the scientists about methods of classification available. As coastal areas are dynamic and land and marine processes together with man activities affect them continually, the priority to be given to these factors varies with specific situations and the need of the people living there. These issues make the categorization difficult. In this paper, taking into account these difficulties, Geographical Information System (GIS), remote sensing techniques and processed satellite imageries of Aster were used to classify the coastal area Sirik Headland, located in the southern part of Iran. Not to mention that the plenty of field investigations were carried out in order to verify the results derived from the software. Among the classifications represented for the coasts, Shepard and Cowardin methods has been used in this study.

The categorized area under each classification is discussed. Even though Cowardin classification is one of the most specific classifications, it was suggested that, on the basis of coastal area definition by *Bird*[1] Shepard classification can better specify the area.

Materials and Methods

The coastal line of Hormozgan is the longest coastal line in southern Iran. It is started from (25°15'N, 052°30'E) and continued to (27°30'N, 59°00'E). The study area under consideration is located in the eastern part of Hormozgan (Figure 1). The land side of the region covers an area of about 390 km^2 which consists of geomorphologic features such as barrier islands, mangrove forests, tidal flat, sandy edges, wetlands, flood plains, salt marshes and sedimentary environments such as sandy beaches[2].

Figure 1: The area under investigation

From geological point of view the area is called Makran. The bedrock geology of the Makran coast consists of Middle Miocene flysch sequences associated with post-Middle Miocene marls and limestones overlain by Quaternary unconsolidated sediments comprising eolian sand dunes, mud flat and marine terrace deposits in the coastal areas. On the basis of geological feature, Hormozgan can be divided into two general regions. The first part including north, west, northwest and northeast of Hormozgan province, is called Zagros zone. The second part which is called Makran zone includes east and southeast of Hormozgan. The morphological characteristic and stratigraphy of the Makran zone is basically different from the surrounded area including Zagros zone. One main feature of this deviation is the lack of salt dome in Makran zone which is dominated in the Zagros zone[3].

The marine activities in the area are relatively low, with the current mostly parallel to the coasts[4]. It is also mentioned by *Jhones*[5] that the total speed of the current in this area is less than 0.2m/s.

ASTER imageries derived from the TERRA satellite from the year 2005 were the images have been used. These images were collected using different bands and with the different resolution. Thus the first task was to verify the reasonable images in regard with the quality. The proper images then had to be preprocessed until the acceptable format of them, ready for the categorization, were prepared. Afterwards, the images of the area were ready to be classified using one of known methods. On the basis of primary investigations it was found that Shepard and Cowardin classifications are two of the most precise and popular methods for coastal categorizations. They therefore, have been used in this study.

Remote sensors installed in the satellites collect images in different electromagnetic spectra. ASTER sensors contain 14 different bands to collect images useful for different applications. These bands can be divided into three groups. Wave lengths of the first three spectral bands known as visible and near visible infrared (NVIR), are about 0.52 to 0.86 micrometers. The resolution of them is about 15 meters. The next six spectral bands called short wave infrared (SWIR) have the wave length of 1.6 to 2.43 micrometers and the resolution of 30 meters. The last five spectral bands, named as Thermal infrared (TIR), have the wavelength of 8.125 to 11.65 micrometers and the resolution of 90 meters. Imageries of the area derived from the first three bands of ASTER sensors for the year 2005 were employed for this study (Figure 2a). As mentioned the wave length of these bands are between 0.25 and 0.86. The clouds therefore, may not affect the images. Resolution for the images is about 15 meters which made these images proper to detect the geological features of the area down to 15 meters. Software which was used for image processing is known as Envi. Capability to support various formats of satellite imageries is one of the strength points of this software[6&7].

There are two methods for coastal classification including supervised and unsupervised methods[8]. The difference between these two methods is that in the supervised method the results are influenced by the humane vision. In unsupervised method however, the software using pixels and spectral analysis classifies the land. The later one is known therefore, as spectral classification. In supervised method the software results should be conjunct with the information collected at site using GPS device in order to classify the area. In the case of unsupervised method which has been employed in this study, Envi uses two flat clustering algorithms called K-means and Isodata. K-Means algorithm calculates initial class means evenly distributed in the data space, it then iteratively clusters the pixels into the nearest class using a minimum-distance technique. Isodata algorithm however, calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. All of the iterations recalculates means and reclassifies pixels with respect to the new means[9]. K-Means Clustering is the simplest and most fundamental clustering algorithm[10]. Since this algorithm was found to be matched with the geological units of the area, it was employed in this study (Figure 2b). For the resolution, the optional values were 15, 30 and 90. As mentioned the resolution of the images were 15 meters, the same resolution therefore, for the processing was found appropriate. The output images from the Envi can be lunched to the ArcGIS in order to be poligonized, and conformed to the geological map of the area (Figure 3a). Different polygons then should be labeled and categorized on the basis of their colors and the information derived from the chosen classification method (Figures 3b and 3c).

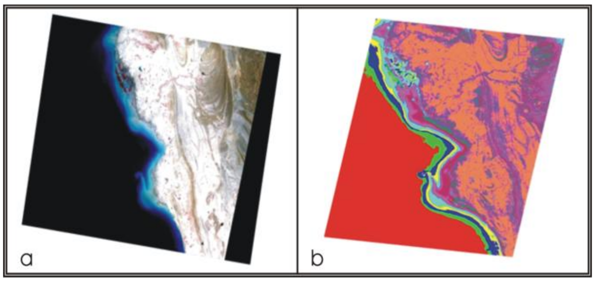

Figure 2: a) Aster Image from Sirik Headland. b) Unsupervised image of the area derived from Envi

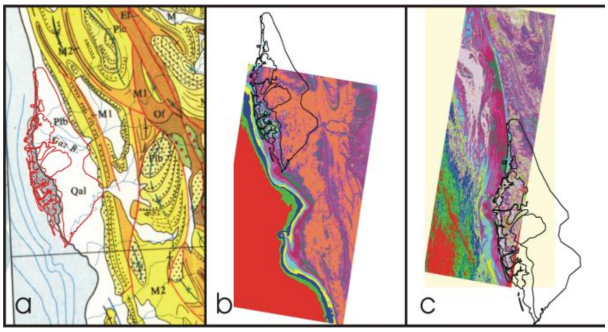

Figure 3: a) Poligonizing geographical map. b and c) Poligonizing satellite images of the area

As mentioned the method was used for the classification of the area was unsupervised one, with no obligation for visiting the area. Yet, a one day survey has been carried out to prevent any software belonging errors in regards with the separating different units. In this visit the where about area of the city zones, estuaries, and mangrove forests as some specific parts of the area were determined (Figure 4).


Figure 4: Part of Azini wetland in Sirik headland

Shepard classification is one of the widely used categorizations, suggested by *Shepard* first in *1937*[11]. This classification however, was redefined and improved by himself as reported in 1973[12]. On the basis of this classification coastal areas are divided into primary agents (Figure 5a), in which land processes are dominant and secondary agents (Figure 5b), in which marine processes and marine organism activities are prevailed. Five categories including land erosion coasts, subaerial deposition coasts, volcanic coasts, diastrophic movement, and ice coasts are among primary agents and three categories consisting of wave erosion coasts, marine deposition coasts, and coasts built by organisms are marine dominated processes. It should be noted that sometimes a primary coast can be converted to a secondary coast due to marine activities and processes[13]. It is also necessary to mention that newly defined category is added to the Shepard classification which is called manmade coasts. These are coastal areas in which nature has got nothing to do with. These are the coasts has been or being shaped by human activities (Figure 5c). Table 1 contains summarized information about this classification.

Cowardin in 1979 defined a new classification, in which was intended to describe ecological taxa, arrange them in a system useful to resource managers, furnish units for mapping, and provide uniformity of concepts and terms. Wetlands are defined by plants, soils, and frequency of flooding.

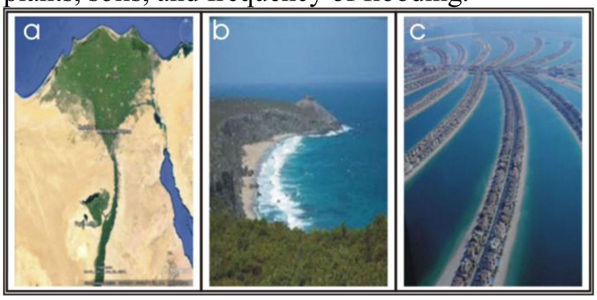

Figure 5: an example of a) Primary coasts, b) secondary coasts, and c) man-made coasts

Ecologically related areas of deep water, traditionally not considered wetlands, are included in the classification as deep habitats[14]. This classification was modified and improved by *Ferren, et al*[15]. The method have been used in this approach is to classify the coastal area on the basis of some systems, subsystems and classes. For this, five main systems are introduced as Marine, Estuarine, Riverine, Lacustrine, and Palustrine. Each of these systems contains several subsystems and classes; by them the area could precisely be defined. For the categorization to be easily determined they assigned digital codes for each section. The result is a hierarchical classification with multiple descriptors (elements) and descriptor states (specific examples) that includes a code generally composed of a 14 digit number, with decimal points and parentheses separating various descriptors, which identifies a particular type of wetland. An explanation of the code follows in Table 2 and the detailed information about each code can be found in Appendix A. Marine and Estuarine system each have two subsystems, including Subtidal and Intertidal; the Riverine system has four subsystems, Tidal, Lower Perennial, Upper Perennial, and Intermittent; the Lacustrine has two, Littoral and Limnetic; and the Palustrine has no subsystems[14]. Within the Subsystems, Classes are based on substrate material and flooding regime, or on vegetative life form, each of them is distinguished by a specific code. The same Classes may appear under one or more of the Systems or Subsystems.

As Marine and Estuarine systems are the two systems dominated in the area under investigation, the primary codes of them are presented here. The Marine System (System No. 10.000) includes two subsystems: Intertidal (wetlands) (11.000), and Subtidal (deepwater habitats) (12.000). It also includes the following six classes: (10.00) Rock Bottom, (10.120) Unconsolidated Bottom, (10.140) Rocky Shore, (10.150) Unconsolidated Shore, (10.210) Aquatic Bed, and (10.220) Reef. The Estuarine System (System No. 20.000) includes two subsystems: Intertidal (21.000), and Subtidal (22.000). It also includes the following ten classes: (20.110) Rock Bottom Wetland, (20.120) Unconsolidated Bottom Wetland, (20.130) Streambed Wetland, (20.140) Rocky Shore Wetland, (20.150) Unconsolidated Shore Wetland, (20.210) Aquatic Bed Wetland, (20.220) Reef Wetland, (20.240) Emergent Wetland, (20.250) Scrub-Shrub Wetland, and (20.260) Forested. Water regime, water chemistry, Hydrogeomorphic Units, and Dominance Type (Dominant Species) are also presented in the parenthesis (see Table 2 and Appendix A). The structure of the classification allows it to be used at any of several hierarchical levels. Special data required for detailed application of the system are frequently unavailable, thus data gathering may be prerequisite to classification. Development of rules by the user will be required for specific map scales[14]. It should be noted that in this study the habitat part of area was not studied, so the last three digits of the code was ignored.

Table 1) Shepard's Classification

Shepard's Classifications	Primary Coasts	Land Erosion Coasts
		Subaerial Deposition Coasts
		Coasts by Diastrophic Movement
		Volcano Coasts
		Ice Coasts
	Secondary Coasts	Wave Erosion Coasts
		Marine Deposition Coasts
		Coasts Built by Organisms
	Man Made Coasts	Include small and large coastal structures

Table 2: Digital code for Cowardin classification[15]

"00"	the system and subsystem descriptor
00."000"	the class and subclass descriptor
00.000.("00")	the water regime descriptor
00.000.(00."0")	the water chemistry descriptor
00.000.(00.0."000")	the hydrogeomorphic descriptor
00.000.(00.0.000."0000")	the substrate, dominance
00.000 (00.0.000.000)	**Specified full codes**

Results and Discussion

The poligonized map of the area was lunched to the ArcGIS for categorization on the basis of the desired classification. Figure 6 shows the area under consideration which has been classified and labeled considering Shepard and Cowardian classification. Table 3 and 4 also contain the detailed information in regard with Shepard and Cowardin classifications representatively. They include specific name, the percentage and the total area of each category.

It should be noted that there are fundamental differences in regard with coastal classification between these two methods of Shepard and Cowardin[16]. As it can be seen in the Fig 6 the dominant part of the Sirik headland, Alluvium, which is known as primary coast in the Shepard classification is not recognized as a part of coastal area in Cowardin method. That is why this area is labeled as eleven zeros, as suggested by *Ferren et al*[15]. The city zone and all other man-made constructions also are not defined in Cowardin classification; thus to digitize them the zero code was used. Another deviation between the Shepard and Cowardin is the categorization of constructions such as small fishing ports. These constructions which are known as man-made coasts in Shepard classification, belongs to marine system in Cowardin classification.

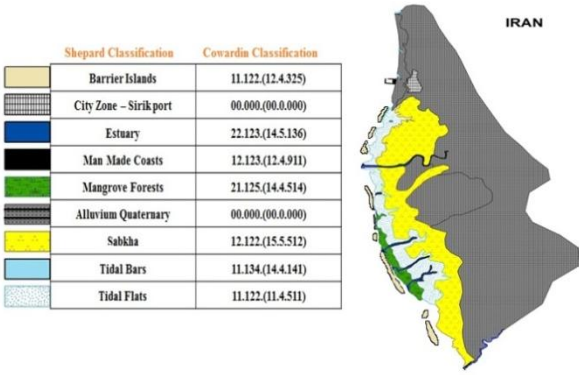

Figure 6: Coastal classification map of Sirik Headland labeled as Shepard and Cowardin methods

Azini Estuary is one of the most known estuaries in the Sirik headland. This estuary is mainly dominated by mangrove forests. The estuarine part of this headland is only about 380.77 hectares or 0.97% of the total area. This area is classified as primary coast in Shepard method which is constructed due to the land erosion activities. In Cowardin classification this area is known as Vegetated Intertidal Estuary with Irregularly-Flooded Regime, and Saline water and Vegetated-Plant Flats.

Tidal flats are the area between the ocean and the land which is affected by tidal conditions. About 3044 hectares of the area (7.8%) is dominated by tidal flat. This area is categorized as secondary coast, constructed by marine deposits, in Shepard method. In Cowardin method this area is known as Marine Sandy Intertidal area, with the Subtidal Regime, Saline water and Mineral Flat.

Table 3: Detailed information about each category of the Sirik Headland on the basis of Shepard method

Category	Shepard's definition	Percentage %	Area (ha)
City Zone	built by human being	0.55	217.557
Barrier Islands	Secondary coasts- marine deposition coasts	0.83	325.9
Estuary	primary coasts- land erosion coasts	0.97	380.77
Man-made coast	built by human being	0.054	21.15
Mangrove Forests	Secondary coasts- built by organism	1.73	675.01
Quaternary Alluvium	Primary coasts- subaerial deposition coasts	69.3	27045.31
Sabkha	Secondary coasts- marine deposition coasts	18.6	7257.06
Tidal Bar	Secondary coasts- marine deposition coasts	0.041	15.95
Tidal Flat	Secondary coasts- marine deposition coasts	7.8	3044.05
SUM	**70.35% primary coasts + 29.65% secondary coasts**	**100**	**38982.76**

Table 4: Detailed information about each category of the Sirik Headland on the basis of Cowardin method

Cowardin's Classification	code	Percentage %	Area (ha)
city zone – sirik port	00.000.(00.0.000)	0.55	217.557
Marine Intertidal (Wetlands). Sand. (Irregularly- Exposed. Saline. Lagoon Beaches)	11.122.(12.4.325)	0.83	325.9
Estuarine Subtidal. Mud. (Irregularly-Flooded. Mixosaline. Dune-Stream Estuaries)	22.123.(14.5.136)	0.97	380.77
Marine Subtidal. Mud. (Irregularly- Exposed. Saline. Jetties/Breakwaters)	12.123.(12.4.911)	0.054	21.15
Estuarine Intertidal. Vegetated. (Irregularly-Flooded. Saline. Vegetated-Plant Flats)	21.125.(14.4.514)	1.73	675.01
Alluvium (quaternary)	00.000.(00.0.000)	69.3	27045.31
Marine Subtidal. Sand. (Seasonally-Exposed. Mixosaline. Precipitate (Salt) Flats)	12.122.(15.5.512)	18.6	7257.06
Marine Intertidal. Mud. (Irregularly-Flooded. Saline. Coves)	11.134.(14.4.141)	0.041	15.95
Marine Intertidal (Wetlands). Sand. (Subtidal Regime. Saline. Mineral (Mud, Sand) Flats)	11.122.(11.4.511)	7.8	3044.05

Avicennia marina and Rhizophora mucronata are two well-known species of Mangrove Forests in this area. Mangrove forests of this area act as a good protector against erosion. They occupy an area of about 675 hectares which is just 1.73% of the total area. This area as might be distinguished is among the coasts which are built by organisms, secondary coast, of Shepard method. In the Cowardin method the Mangrove forests of the area is Vegetated Estuarine Intertidal, with Irregularly-Flooded regime; the chemistry of the area is Saline; and the Flat is covered with the Vegetated-Plants.

Appendix A

00.000(00.0.000) "00" = the system and subsystem 00."000" = the class and subclass 00.000.("00") = the water regime 00.000.(00."0") = the water chemistry 00.000.(00.0."000") = the hydrogeomorphic

SYSTEMS AND SUBSYSTEMS	
10.000 System: Marine	11.000 Subsystem Intertidal (Wetlands) 12.000 Subsystem Subtidal (Deepwater Habitats)
20.000 System: Estuarine	21.000 Subsystem Intertidal (Wetlands) 22.000 Subsystem Subtidal (Deepwater Habitats)

CLASS AND SUBCLASS		
00.100 Classes and Subclasses	00.110 Class Rock Bottom	00.111 Subclass Bedrock 00.112 Subclass Rubble/Boulder
	00.120 Class Unconsolidated Bottom	00.121 Subclass Cobble-Gravel 00.122 Subclass Sand 00.123 Subclass Mud 00.124 Subclass Organic 00.125 Subclass Vegetated
	00.130 Class Riverbed or Streambed	00.131 Subclass Bedrock 00.132 Subclass Rubble/Boulder 00.133 Subclass Cobble-Gravel 00.134 Subclass Sand 00.135 Subclass Mud 00.136 Subclass Organic

		00.137 Subclass Vegetated Streambed
	00.140 Class Rocky Shore	00.141 Subclass Bedrock 00.142 Subclass Rubble/Boulder
	00.150 Class Unconsolidated Shore	00.151 Subclass Cobble-Gravel 00.152 Subclass Sand 00.153 Subclass Mud 00.154 Subclass Organic 00.155 Subclass Vegetated

WATER REGIME	
(10.0) Tidal Water- Regimes	(11.0) Subtidal Regime
	(12.0) Irregularly- Exposed Regime
	(13.0) Regularly-Flooded Regime
	(14.0) Irregularly-Flooded Regime
	(15.0) Seasonally-Exposed Regime
	(16.0) Seasonally-Flooded Regime

water chemistry		
(00.1.000) Fresh Water (Circumneutral)	(00.2.000) Fresh Water (Acidic)	(00.3.000) Fresh Water (Alkaline)
(00.4.000) Saline	(00.5.000) Brackish (Mixosaline)	(00.6.000) Eurysaline
(00.7.000) Hypersaline	(00.8.000) Sulfur-Affected	(00.9.000) Petroleum- Affected

HYDROGEOMORPHIC		
(00.0.100.0000) (Hydrogeomorphic Context)	(00.0.110.0000) Oceans	
	(00.0.120.0000) Exposed Bays	(00.0.120) Large Exposed Bays (00.0.122) Small Exposed Bays
	(00.0.130.0000) Estuaries	(00.0.131) Bay-Estuaries (00.0.132) Lagoonal Estuaries (00.0.133) River-Mouth Estuaries (00.0.134) Canyon-Mouth Estuaries (00.0.135) Structural-Basin Estuaries (00.0.136) Dune-Stream Estuaries (00.0.137) Agricultural Drainage Mouths (00.0.138) Urban Drainage Mouths
	(00.0.140.0000) Coves	(00.0.141) Coves
	(00.0.150.0000) Lagoons	(00.0.151) Lagoons
	(00.0.160.0000) Harbors/Ports	(00.0.161) Large Harbors/Ports (00.0.162) Small Harbors/Ports
	(00.0.170.0000) Tidal Ponds	(00.0.171) Tidal Dune-Swale Ponds (00.0.172) Tidal Marsh Ponds
	(00.0.180.0000) Tide Pools	(00.0.181) Large Tide Pools (00.0.182) Small Tide Pools
(00.0.300.0000) Shores, Beaches, Banks, Benches	(00.0.310.0000) Shores	(00.0.311) Ocean Shores (00.0.312) Exposed Bay Shores (00.0.313) Estuary Shores (00.0.314) Cove Shores (00.0.315) Lagoon Shores (00.0.316) Harbor Shores
	(00.0.320.0000) Beaches	(00.0.321) Ocean Beaches (00.0.322) Exposed Bay Beaches (00.0.323) Estuary Beaches (00.0.324) Cove Beaches (00.0.325) Lagoon Beaches (00.0.326) Harbor Beaches
	(00.0.330.0000) Banks	(00.0.331) Estuary Banks
	(00.0.340.0000) Benches	(00.0.341) Ocean Benches (00.0.342) Exposed Bay Benches (00.0.343) Estuary Benches (00.0.344) Cove Benches

		(00.0.345) Lagoon Benches (00.0.346) Harbor Benches
	(00.0.350.0000) Terraces	(00.0.351) Estuary Terraces
	(00.0.360.0000) Ledges/Ridges	(00.0.361) Ledges (00.0.362) Hogback Ridges
(00.0.500.0000) Flats, Deltas	(00.0.510.0000) Flats	(00.0.511) Mineral (Mud, Sand) Flats (00.0.512) Precipitate (Salt) Flats, Pannes (00.0.513) Vegetated-Algal Flats (00.0.514) Vegetated-Plant Flats
	(00.0.520.0000) Deltas	(00.0.521) Deltas

(00.0.900.0000) Artificial Structures	(00.0.910.0000) Stationary Artificial Structures	(00.0.911) Jetties/Breakwaters (00.0.912) Sea Walls/Revetment (00.0.913) Dams/Levees (00.0.914) Earthern Berms/Dikes (00.0.915) Dredge Spoils (00.0.916) Pilings/Piers (00.0.917) Oil Platforms (00.0.918) Boat Ramps (00.0.919) Wreckage
	(00.0.920.0000) Floating Artificial Structures	(00.0.921) Hulls (00.0.922) Docks (00.0.923) Buoys (00.0.924) Logs

Tidal Bars are those narrow rivers which are filled by water during flood condition. During ebb condition however, the water leave the area and the sedimentation takes place. Tidal bars can be count as once tidal channels in which the sedimentation fill the channel, so the area is relatively shallow. 16 hectares is the contribution of Tidal Bar in the area. According to Shepard's method this area can be categorized as marine deposition coasts which is one of the secondary coasts. In cowardin method this area is Mudy Marine Intertidal with the Saline water. Regime of water is Subtidal and, the area is saline, and coves are dominated.

Salt marsh which is called Sabkha in local dialect is a bare salty land. It contains small lagoons and lakes. About 18.6% of the total area (7257 hectares) is covered by Sabkha. This area is among secondary coasts of Shepard method and like tidal bar its construction is due to the marine depositions. Sandy Marine Subtidal is the definition of the area by Cowardin method. Its regime is Seasonally Exposed, and its chemistry is Mixosaline.

Barier Islands, known as Marine deposited secondary coasts in Shepard classification, occupy an area of about 0.83% (or about 326 hectares). According to Cowardin the area is Sandy Marine Intertidal. Its Regime is Irregularly- Exposed, The chemistry is Saline, and is considered as Lagoon Beach.

Quaternary Alluvium, remains from the third geologic era, is the main part of this area with almost 70% of the total area. This area, as mentioned before, is not considered as part of coastal feauther in Cowardin classification. In Shepard method however, is among subaerial deposition coasts which is one of the primary coasts.

Conclusions

Using Aster images of the Terra satellite, Sirik headland located in the south of Iran was classified. For the classification two different methods of Shepard and Cowardin was used. It was found that the main part of the area is dominated by land and/or land related activities. In regard with Shepard method the contribution of primary and secondary coasts are about 70% and 30% of the total area respectively. On the basis of Cowardin method 27% and 3% of the area was considered as Marine and Estuarine systems consecutively. Taking into account calm nature of the current in the area, this conclusion was found convenient.

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