



## The Study of Geomorphology, Climatology and Hydrology of Sistan Plain

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### ABSTRACT

*Sistan plain is one of the internal plains of Iran's plateau that an average of 475 to 500 meters is placed above sea level. The plain is covered of alluvial of old and current delta of Hirmand River and its surrounding flooding. This land is placed in a smooth plain at the end of the eastern border of Iran. Of highlights of the plain is the existence of Hamoun wetland. This wetland, for its geographical location, and existence almost constant and due to fresh water is considered the most important wetland of eastern part of Iran's plateau. Sistan plain with 8117 square kilometers has an unfavorable and dry climate that sand storms and move of sand dunes are considered its factors threatening. The main aim of this research to study geomorphology determining unit, geomorphology types ie work units that is placed the context against wind erosion. In this study, geomorphological mapping from satellite images Landsat ETM +, satellite images site, Google Earth, geological and topographic maps were used. Climate of Sistan plain includes local and external factors, including latitude, altitude and radiation and hot and cold air fronts. In terms of hydrology massive alluvial fan of flood in the western region of Sistan are the most important factors in underground aquifer feeding of the plain*

**Keywords:** *wind sediments, Hamoun Lake, the origin of sediments, Sistan plain.*

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### INTRODUCTION

Natural desert area cannot be studied and separated just by considering one or two studied environmental factors, because based on studies factors, different regions are considered as desert, which in many cases have little common coverage and their spatial distribution is different. According to multiple studies conducted in different regions, different factors affect the recognition of deserts territory, including climate, geology, geomorphology, soil science, hydrology and vegetation. Sistan region is one of the stormy centers in the world where annual average more than 70 days exist dust storms (Washington et al. 2003). An important part of understanding the dynamics of sand is to detect their origin (Mush, 2000).

In terms of geology, identify the extent and geographical distribution of evaporite formations in order to the importance and their role in the formation of deserts is taken into consideration from the origin of geology that usually is placed in first of geology is to gather information about the stratigraphy, lithology of area to

determine the forms and determine their susceptibility to wind and water erosion. In this study tried by attitude to the objectives of the framework of description of services, content in the form of Department of Public Information, geological and lithological, structural elements, susceptibility to erosion of rock units and providing relevant maps to be prepared.

### 2. The geographic location of the study area

Sistan plain is placed in the northern of province of Sistan and Baluchestan with longitude 61 degrees 31 minutes east and latitude 30 degrees 55 minutes north in hot and dry climate. Of highlights of Sistan plain is existence of Hamoun wetland. This wetland, for its geographical location, and also existence almost constant and due to fresh water is considered the most important wetland of eastern parts of Iran's plateau. This wetland has three areas of Hamoun Hirmand in the west and southwestern, Hamoun Sabori in the northwest and Hamoun Puzak in north-eastern of Sistan. (Figure 1)

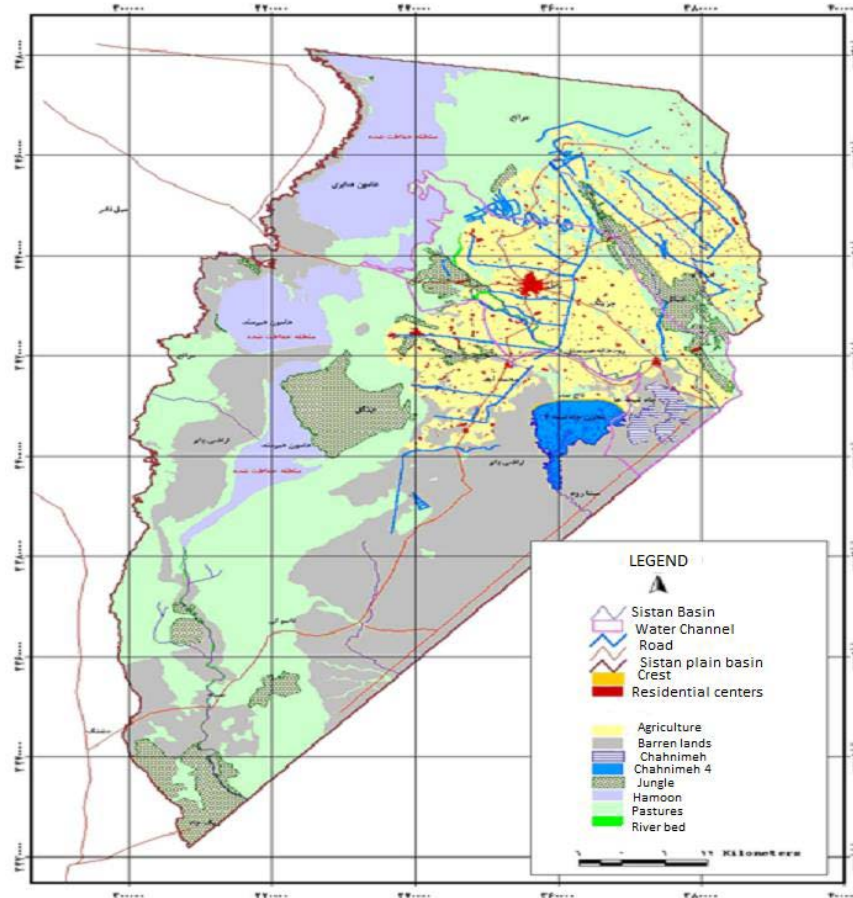


Figure 1: Location of Sistan plain and Hamoun wetlands

### 3. The characteristics of the study area

The study area is affected by severe weather flows that discharge of energy of systems will appear as sand and dust storm. Moving sands and their attack in their area is an important factor for the destruction of agricultural land and vegetation. In this area, several factors can control the air flows. The total flows in different areas have the same direction. Temperature difference in some regions causes local winds that usually these winds have different directions and these flows are not so fast. Another type of winds is front winds that arise primarily because of the region tunnels. The most important airflows of area have been popular as winds of 120 days and most sand storms produce due to winds. Satellite picture of the crucial situation of Sistan is shown in the following figure (Figure 1).



Figure 2. The sensor image of modis from corridors position in Sistan

**4. Determination of region's slope classes**

The slope has a huge effect on the hydrological response of the region, for example the speed of surface currents depends directly on the slope, increasing water intensity increases water momentum and so destructive power and its transport and also the infiltration rate decreases with increasing slope in soil. In the project area to prepare map of slope, digital height model was used. Due to the low height differences in the study area, slope in the range is less than 5.0 percent. In order to better adapt to the physiographic effects in 2 classes (0.2% - 0% and 0.5% - 0.2 %) were classified. The area of each slope classes in Table 1 is provided

**Table 1:** Classes of slope and area of each in the study area

Percentage of area	Area (square kilometers)	Slope classes
95.96	117.83	0 - 0.2%
4.04	4.96	0.2-0.5%
100	122.79	Total

**5. Height classes**

To investigate the position of height classes of region studied, by software ArcGis was acted to prepare map. Due to the low height difference in the total range (10 meters), 3 meters classes for map includes three height classes. Then, using the information obtained from the histogram of the map, hypsometry table includes average height of each class, the area between contour lines, percentage of area and cumulative percentage of area is prepared (Table 2).

**Table 2:** Characteristics of height classes of plot area

Line	Height class	Area (square kilometers)	Average height (m)	Percent of area
1	<480	2.5	482.5	2.0
2	480-483	45.1	481.5	36.7
3	483-486	61.8	484.5	50.3
4	>486	13.5	487	11.0
Total		122.8	*	100

**6. Geomorphological study of region**

By interpreting aerial photographs, satellite images and field operations, units, type and geomorphology facies of region is specified and in each of the units, types and facies of the area is identified; separated and related map is prepared. To prepare

the map, according to the homogeneity of the rock units and satellite images, photo-metric units is not possible to separate so while visiting the area, identifying points in each facies with a Gps are taken and its position on maps with a scale of 1: 50,000 were categorized to determined and using GIS capabilities and use of software ILWIS and Arcview was mapping.

**6.1 units, types and geomorphological facies of region**

The large study area is located in Sistan plain and piedmont type covers the entire range. The study area has three natural landscape of the overview as follows:

1. Lands with vegetated terrain ranging from forest and grassland
2. Vegetation of areas are as natural:

A) Lands with natural cover, including wind erosion facies along with the covers of pasture and seasonal rivers with forest cover.

B) Lands with the cultivation cover with forested sand zones

2. Bare land: agricultural lands abandoned, sand zones and context of seasonal rivers

3. Agricultural lands: according to geological studies, Sistan plain is the result of sedimentation of the Hamoun lake and because of features such as proper soil texture and surface water, all lands of plain are prone for farming and animal husbandry. Due to climatic and environmental conditions of the region, continued periods of drought, winds of 120 days and so on, wind erosion and desertification gone so far as to a part of the agricultural lands become to sedimentation or without user.

**7. The regional average height**

**7.1 The direct average height**

The simplest method in calculating the average height is calculating mean of maximum and minimum height of area. This method not has a high confidence level and distribution of area level with height is ignored and may be increased by limited level at high heights, calculated height unrealistically

$$\bar{H} = \frac{h_{max} + h_{min}}{2}$$

In this equation:

H: direct average height of area (m)

hmax: the maximum height of the area (m)

hmin: the minimum height of area (m)

**Table 3:** Values of direct average height of the study area

Direct average height (m)	minimum height (m)	maximum height (m)
483.5	479	488

**7-2 weighted average height**

The complete method of using map is hypsometry. In this method, after drawing the map, hypsometry of area between

each two contour lines (with a certain distance) is calculated and then to calculate the weighted average of height of the area, the average height of each floor multiplied in its area and sum of them is divided to total area.

$$\bar{H} = \frac{\sum_{i=1}^n H_i A_i}{A}$$

In this equation:

$\bar{H}$  : Weighted average height of area (m)

$H_i$  : Average height between two contour lines (m)

$A_i$  : The area between two contour lines

$A$  : The area: (Km2)

**Table 4:** Weighted average height values by hypsometry

$\sum H_i A_i (m)$	$A_i$	$H_i$	Height classes
11933.5	2.5	482.5	479-480
21692.3	45.1	481.5	480-483
29936.0	61.8	484.5	483-486
6564.8	13.5	487	486-488
59386.6	122.8	Area	
483.6	$\bar{H}(m)$		

**8. Determine wind erosion crisis centers**

Table (5 and 6) shows identifying and prioritizing indicators of crisis centers for wind erosion control and the results obtained of the point in the study area.

**Table 5:** Indicators to identify and prioritize crisis centers for wind erosion control (C)

Priority	Index and point range	Priority 1	Priority 2	Priority 3
1-kind of stage of wind erosion		Picked region 15-20	Sediment region 5-15	Transport region 0.5
2. The amount of activity in each phase of wind erosion		Sensitivity class (I) 15-20	Sensitivity class (II) 5-15	Sensitivity class (III) 0-5
3. damage to biological resources, the economy in the critical focus or in its path from public questionnaire		Damage to the city, village or facilities and main roads and important agricultural 15-20	Damage to agricultural land and secondary roads and facilities, Grade 2 5-15	Damage to pastures, pristine lands without cover 0-5
4. The people request or executive agencies through referring to office of sands or public questionnaires		Strongly requested by the people and Governmental organizations 15-20	Question is limited and only asked in the questionnaire. 5-15	Not requested 0-5
5. Far or near facies of erosion to damage resources and its direction toward the influenced source		<5 Km 15-20	5-10 Km 5-15	>10 Km 0-5
Total Points		75-100	25-75	0-25

**Table 6:** crisis centers for wind erosion control

Geomorphology (areas of picked, transported and sediment)	Kind of stage of erosion	Activity	Region under damage	Request of people	Far or near of facies of sources under damage	Sum of point	Priority
Facies of agricultural land with wind erosion	17	16	10	18	8	69	2
Facies of abandoned agricultural lands with wind erosion	19	20	19	17	13	88	1

Watercourse bed	18	19	18	10	11	76	1
Facies of picked and transport areas of Yardang and Nika	18	19	19	13	12	81	1
Sand zones established (planted and mulching)	10	5	8	5	5	33	2

**8. Climate of region**

**8.1 Rainfall**

Major regional rainfall occurs in winter and rainfall in summer is zero. The seasonal distribution of rainfall in the region also indicates that 75 percent of the annual rainfall in the months of December, January, February and March will be occurred and in other months, the amount of rainfall in the region is very low. The rainfall regime in this area, as in most parts of the Iran

has been a Mediterranean regime and the major rainfall occurs in the cold season and in the summer we saw the lack of rainfall in the region and dry season of region is in accordance with this season. Figure (3) and (4) show changes monthly and the percentage of distribution of rainfall in the static period.

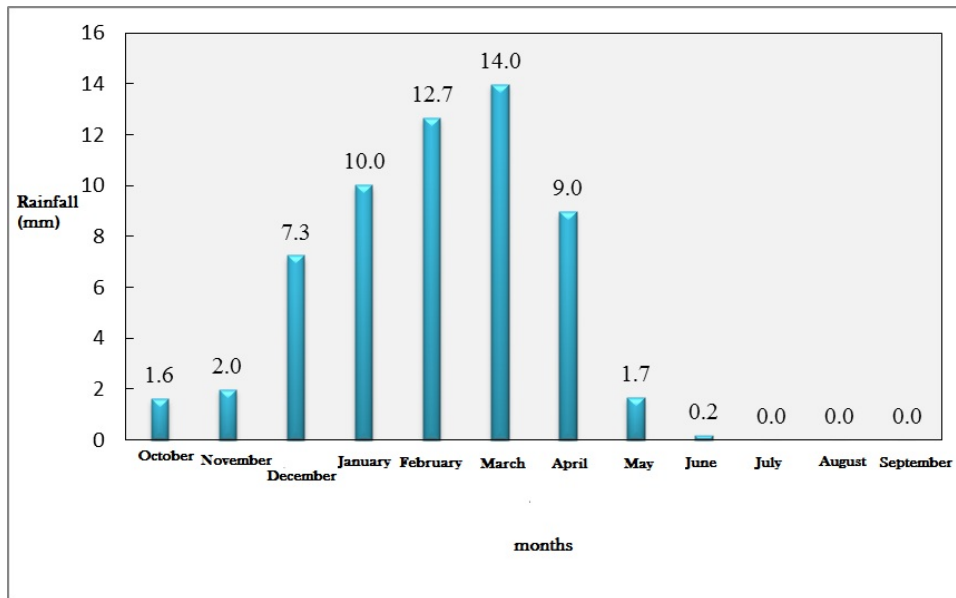


Figure 3: Monthly changes of rainfall in project area according to information of Zabol Station

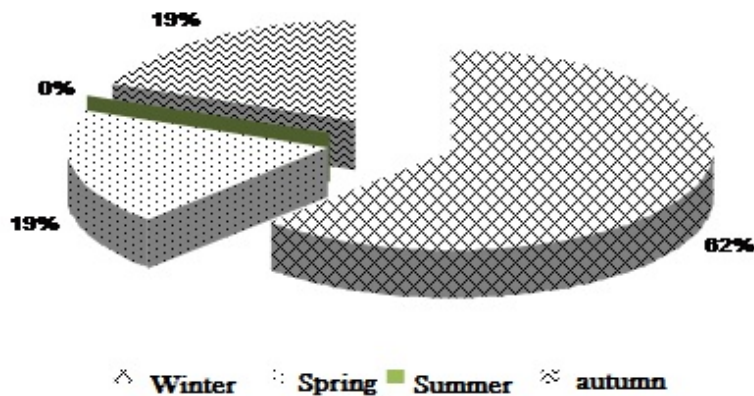


Figure 4: Percentage of distribution of seasonal rainfall in the project range according to information of Zabol Station

8.2 Wind

Several factors such as particle characteristics, moisture, vegetation, ruggedness of ground level and salts in the soil are effective in moving sands in Sistan region (Heydarynasab 2007) that one of them is winds of 120 days in the dry seasons that after the speed of the wind for any reason was lower than threshold of erosion forced to leave its sediments at the foot of trees, bushes, walls, etc. that if their origin not identified and controlled and gradually involve the entire region. In recent years, due to drought caused by water cut of Hirmand River to Sistan and monsoon winds blow 120 days, harvesting sediment is started from the lake context which resulted in the

occurrence of sand storms in the earth and the sky area (Figure 4) and sequester it in rivers, agricultural lands, houses, and so on, so that the area of dunes and sand zones in the area investigated before the drought, 9421 hectares, but in times of drought until 2006 to around 14353 hectares has increased and every year the volume, the extent of their risks it added. Estimates made of the intensity of the wind potential in the country's 60 meteorological stations show that Zabol station has allocated the maximum frequency and speed (Department of Natural Resources of Sistan and Baluchestan, 2004). Wind sediments due to the formation of an oxidative environment may also be red (Mousavi Harami, 1988).

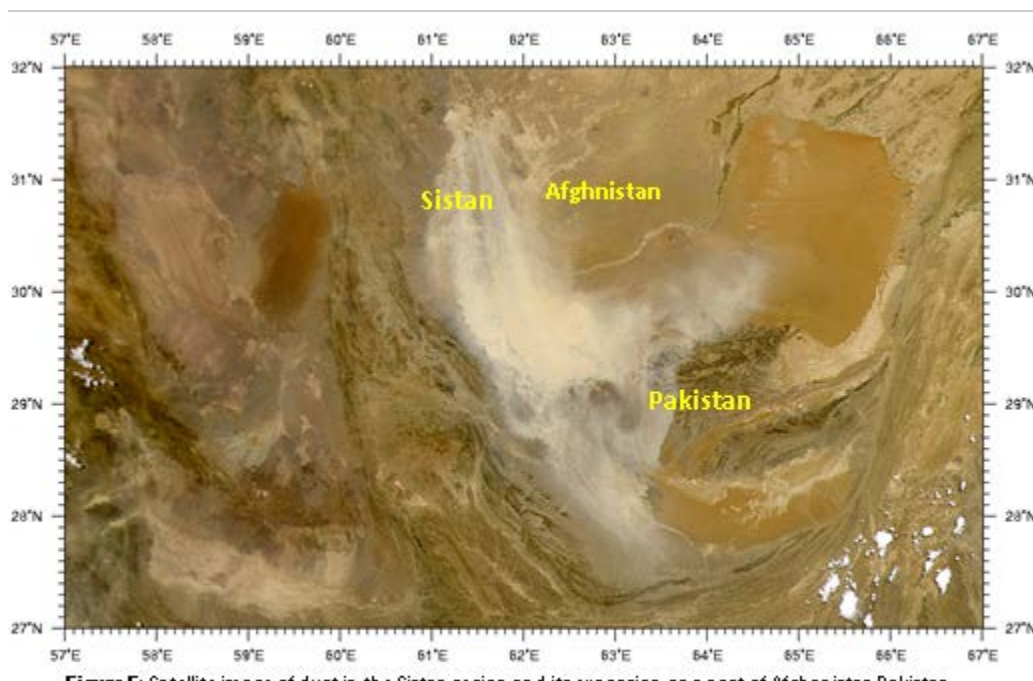


Figure 5: Satellite image of dust in the Sistan region and its expansion on a part of Afghanistan Pakistan

Wind speed monthly in synoptic station in Zabol in the static period in the table (5) is provided. According to the results, the average annual wind speed during the static period in height

10 and 2 m is respectively 5.8 and 4.55 m / s. The highest wind speed at a height of 2 m in July is recorded 8.1 m / s and lowest wind speed in December equal to 2.01 m / s is recorded.

Table 7: Average wind speed (meters per second)

	OCT.	NOV	DEC.	JAN.	FEB.	MAR.	APR	MAY	JUN E	JULY	AUG	SEP.	ANNUA L
Wind speed in 10 m height	5.31	3.09	2.56	2.87	3.68	3.68	4.55	6.40	8.66	10.31	10.07	8.11	5.79
Wind speed in 2 m height	4.17	2.43	2.01	2.26	2.89	2.89	3.57	5.03	6.80	8.10	7.91	5.37	4.55

9. Geological

Sistan plain as Hirmand delta at the last period of geology and by accumulation of sediments and alluvium derived from water, particularly Hirmand is filled and changed to current form. Hirmand river sedimentation in the Hamoun Lake is led to the creation of fertile lands for agriculture, natural

resources, livestock and wildlife but these fertile lands at the time of drought are become context of fine-grained sediments and create dust storms. Sediments include clay, silt and sand that in the range, its clay and silt are more. Because of the drought in the past decade, a part of agricultural lands is abandoned and surfaces relatively hard with clay \_ silt with

cumulative effects of wind sediments can be seen. Since the Quaternary sediments in division system of erosion are considered among very sensitive lands, it can be said that almost the entire area is very sensitive to erosion, but due to the very low slope of region, effects of water erosion is not observed on them and they are mainly windy type.

### 10-hydrology

Sistan plain given the fact that its alluvial sediments are fine-grained and silt and clay sediments, underground aquifers in this area has been formed. Alluvial sediments that over millions of years have been accumulated in this wide and deep pit, resulting in highlands erosion of evaporation and the marl inside Afghanistan soil therefore, these sediments suspended in the water and were transported into Iranian territory and were deposited in a peaceful environment. In fact, the plain can be considered as the stone floor. The volume of water in the river never is able to penetrate in the particles and save. Almost all of the volume of water is spend to evaporation in the place and surface water flows that ultimately evaporated. That's why the aquifer in Sistan plain is not seen and silt and clay sediments to depths of nearly 500 meters are lack of underground water.

### Results and discussion

- In terms of geomorphology, results of this study show that 98 percent of Sistan plain lands are formed with slope less than 2 percent that lack of flatness of the plain and topography factors caused to prepare the proper context for winds of 120 days and erosion accompanying it and are effective in the speed of the prevailing winds.

- In a systematic analysis, the relationship between hydrologic factors of fluctuations in Hirmand water was evaluated with the direct effects of winds. On this basis, it was found that horizontal view and a lot of dust with an annual discharge of Hirmand River has a significant relationship. Reducing the input water of Hirmand River and hydrological droughts are the most important predisposing factors of winds of 1210 days.

- Investigating the climate conditions of Sistan plain in this study showed that in the warm period of year that the 120-days winds are flowing in it, Sistan plain is affected by the subtropical Azores that in all areas except northern part of the hot and dry conditions combined with a lack of rainfalls followed. The average of temperature during these conditions is high and according to low height of plain and rainfall in major part of year, physical dry is governed.

- With respect to the temperature difference of Sistan plain based on the assessment of satellite data, results indicate a sharp drop in the temperature of region in wetland of Hamoun Lake and reservoirs of half well than other areas of the plain.

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