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Anthropogenic Interference in Aeolian Processes in Kerman Plain, Southeastern Iran

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Abstract

Dry climate, poor vegetation and relatively smooth topography are the most important factors that brought about wind erosion processes prevail in the Kerman plain. Aeolian sediments in the Kerman plain can be divided into active and stabilized sediments.

Stabilized sediments show a cross-bedding structure and coarser-grained fluvial sediments are found between layers of aeolian sediments.

Obviously, wind erosion rate and volume of material transfer depends on characteristics of speed and direction also frequency of wind as well as surface and sediment characteristics. The purpose of this study is to investigate the causes of tamarix plantation in aeolian processes and dust storm in the Kerman plain.

Winds speed and velocity characters and sand grain size analysis in order to determine the sand source areas in Kerman plain. The sand samples have been fitted with wind speed threshold and then combined and compared with indicator obtained in laboratory operations. Also dune morphology has been delineated using satellite imagery and aerial photos along with field work. Analysis of seasonal wind directions shows that the dominant winds in the Kerman area mainly blown in two major northern and western vector and play the main role in sediment transferring and dune morphology.

Key Words: Biogeomorphology, Tamarix, Sand Stabilization, Climate Change, Kerman Plain

1. Introduction

Aeolian erosion is a serious problems in arid and semi-arid environments of the world (Zahabnazouri et al, 2021, Yamani et al, 2012; Maghsoudi et al, 2012), it also threatens the arid ecosystems extremely (Dong *et al*., 2012), and huge annual financial losses (Cao et al. 2015) in health, transport and agriculture sectors (Meibodi et al,2015; Wang et al., 2016). Aeolian process have been a major issues in several part of Iran (Ekhtesasi et al, 2006; Miri et al, 2010; Kaskaoutis et al, 2015; Abbasi et al, 2015, 2018 and 2019), since, vast area of Iran is located in arid and semi-arid climate (Broomandi et al., 2017) . Aeolian sediments are spread in different parts of Kerman plain, especially in the southern part of the city of

Kerman, and in some areas they are stabilized by tamarix plantation during decades, but in some regions they are active and cause problems for human infrastructures in the Kerman plain.

Tamarix are native to the drier areas of Eurasia, Africa (Qong et al, 2002; Liu et al, 2008; Lang et al, 2013). it is planted in many part of arid land of Iran in order to stabilized active sands, because the species is highly valued for stabilizing sand dunes due to its fast growth, deep and extensive root system and ability to resist burial by shifting sand (Orwa et al, 2009)

In fact, aeolian processes have been a serious problem in most parts of Southeastern of Iran, KNRWMO (2016) reported that dust storms and active sand dune are among the serious environmental issues in the Rigan, Fahraj and Narmashir in Kerman province. They cause damages to more than 250 rural communities and annually disrupt transport on 160 km of the Kerman-Zahedan railway. According to (Middleton, 1986; Abbasnejad and Zahabnazouri, 2013), aeolian erosion in southeastern of Iran mainly occur in July and August with the south or south-westerly winds . (Kelley et al, 2015) expect drier and potentially dustier situations in the Middle East in the 21st Century

Therefore, the present paper analyses the wind data taken from the main synoptic stations of Kerman province at the seasonal and annual time scales; and identifies the major types of sand dunes using remote sensing satellite images. These data as well as grain size analysis of sediments in different land use will help to understand the impacts of sand stabilization program in the region.

The result would improve understanding of aeolian processes in this regions to develop future management in order to reduce its impacts in the Kerman plain.

2. The study area

The Kerman plain, which is located in southeastern corner of Iran (Figure1) is a tectonic depression surrounded from the south by Joupar Mountain, in the north by Zarand Plain, on eastern by Sirch Mountains and on the west by the Baghin Plain and the Badamoyeh Mountains (Dimitrijevic, 1973). The shape of the plain follows the general structure of the region and its direction is northwestern to southeastern. The topographic slope in the alluvial fans is about 10 to 15 per thousand and in the central parts of the plain is 2 per thousand and on average about 4 per thousand. The average elevation of this plain is about 1830 meters, which decreases slowly from south to northwest (Nazari et al, 2015). The difference in height between the entrance area of the plain (Mahan) to the exit of the plain (Zangiabad) area is about 220 meters.

The sedimentary loads of the mountain basins surrounding the study area were also high, which created a large alluvial plain of Kerman. The plain is mainly formed by a number of surrounding alluvial fans. The Chari River is the only permanent flow which is located in the southwestern of region and shaped the largest alluvial fan in the region.

The study of mineralogy and microscopic structure of sediments on the Kerman outskirts has considered the soils of the region up to 30 meters depth, compose of clay minerals (illite, chlorite, smectite, halvezite and calcite) (Aminzadeh Bazanjani et al, 2013)

The climate of Kerman plain is semiarid to arid, the annual rainfall is less than 150 mm with hot summers and severe winters. The temperature mainly varies between average -8°C in winter to 37°C in summer (Atapour and Aftabi 2002).

Based on geological investigations (Aghanabati 2004), Kerman city and its suburban areas are composed of different geological rock units, some of which can be summarized as follows. Neoproterozoic units of the studied area consist of metamorphosed arenite-conglomerate, rhyolitic tuff, greywacke, siltstone, and turbidite. The Paleozoic rocks in the suburban areas of Kerman city are composed of dolomite, quartzite and marble. The rocks exposures of Cretaceous age are the most widespread rock units in the area. In the basement, they are composed of the lower Cretaceous marly limestone, limestone and calcarenite. The upper units belong to upper Cretaceous reef limestone of Senonian age. The upper unit of the Senonian reef limestone is unconformable covered by upper Cretaceous- Paleocene conglomerate. Tertiary rocks are argillaceous sandstone. Quaternary units on Kerman plain include the following subdivisions:

- Older dasht (bajada), which is composed mainly of old dissected alluvial fans, gravel fans, and terraces
- Younger dasht (bajada), which includes younger dissected gravel fans
- Recent dasht (bajada), which is composed of recent alluvium
- Very recent distal Kavir (silty, clay salt plain).

The upper parts of the salt plain are comprised of minor amounts of gypsum and halite (Atapour and Aftabi 2002).)

The main settled area in this plain is Kerman city which is located in the northern of Kerman plain. According to (Hamzeh et al, 2011), about 77% of sediments of the urban region of Kerman is composed of salt plain (central part, north and northwest), 5% is alluvial (from physical erosion of limestone outcrops in east), and 18% is aeolian sediments (mainly in southern of the city).

The sediments of Kerman are composed of evaporative (salt plain), alluvial and aeolian sediments. These sediments are a mixture of calcite (major mineral in the east, west and north), clay minerals (south) and evaporative minerals such as gypsum and halite (in the west and central parts (Hamzeh et al, 2011). According to (Djokovic and Dimitrijevic, 1972), aeolian sediment spread in great area in southern part of the plain.

Kerman is a region with extensive wind erosion and various types of aeolian hazards, because of the domination of arid climate conditions, flatness of the land surface, relative dryness of soil and the availability of fine-grained materials. Wind processes have intensified aeolian erosion mainly in the southern part of the plain. The area of Kerman erg is about 354/90 square kilometers located along the northwest to southeast direction perpendicular to the prevailing southwestern winds. Djokovic and Dimitrijevic, 1972; Modiri et al, 2012)

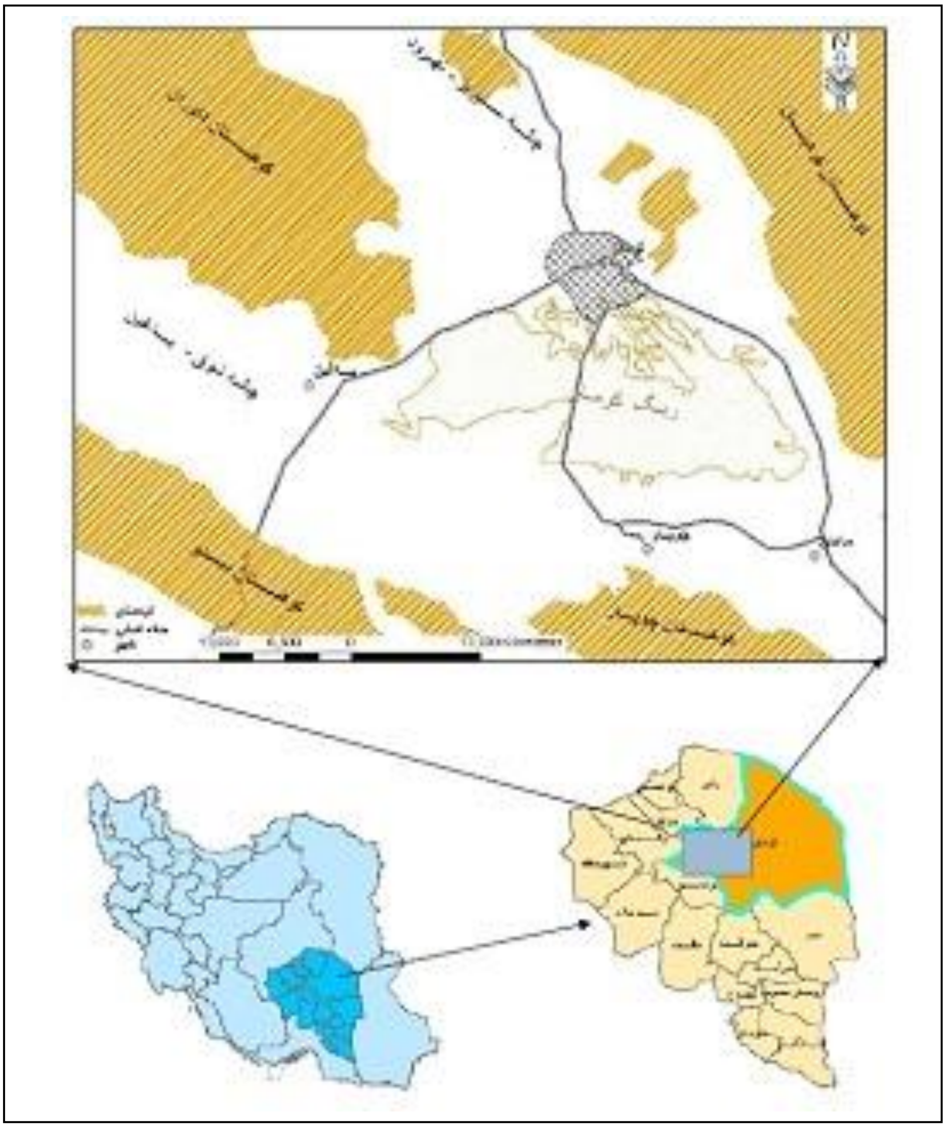


Figure1 Location map of sand field in Kerman

3. Methods

In order to identify and map the geomorphologic units, google earth imagery and 10 meter DEM of Kerman was used. Then the aeolian geomorphological units were identified and classified and finally, the units were ground- proofed.
As part of the analysis, wind rose diagrams for several seasons on the Kerman Plain were generated so that aeolian processes could be analyzed (Figures 2). Thirteen aeolian sand samples were also collected from the plain, and grain size was determined using dry sieve analysis with a set of sieves for the fractions ranging from 63 to 2000 µ (Figure 3).

4. Results

4.1 Winds analysis

Aeolian erosion is affected by several variables such as grain size distribution, wind regime, vegetation, and surface moisture (Tsoar 1978; Iversen and Rasmussen, 1999; Kocurek and Lancaster, 1999, Suskia et al, 2004). Wind is the main important agent in moving and transporting sand. Three important factors wind speed, duration and direction play an effective role in the transportation of sands sediments, and therefore, wind regime has been widely studied to support the aeolian geomorphology landforms classification (Zhan et al, 2015)

High magnitude strong winds had a low frequency, but they played a dominant role in aeolian sand transport (Anderson and Willetts, 1991; Lio et al, 2003 and Lio et al, 2005), these effective winds flow from west and southwest in the Kerman.

Aeolian landforms are mainly dependent on the amount of available sand and wind directions throughout the year (Hermann, & Savermann, 2000), sand ridges, barchans, barchanoid and sief are the main dune forms in Kerman plain that show changes in wind direction and sand supply in different parts of the region.

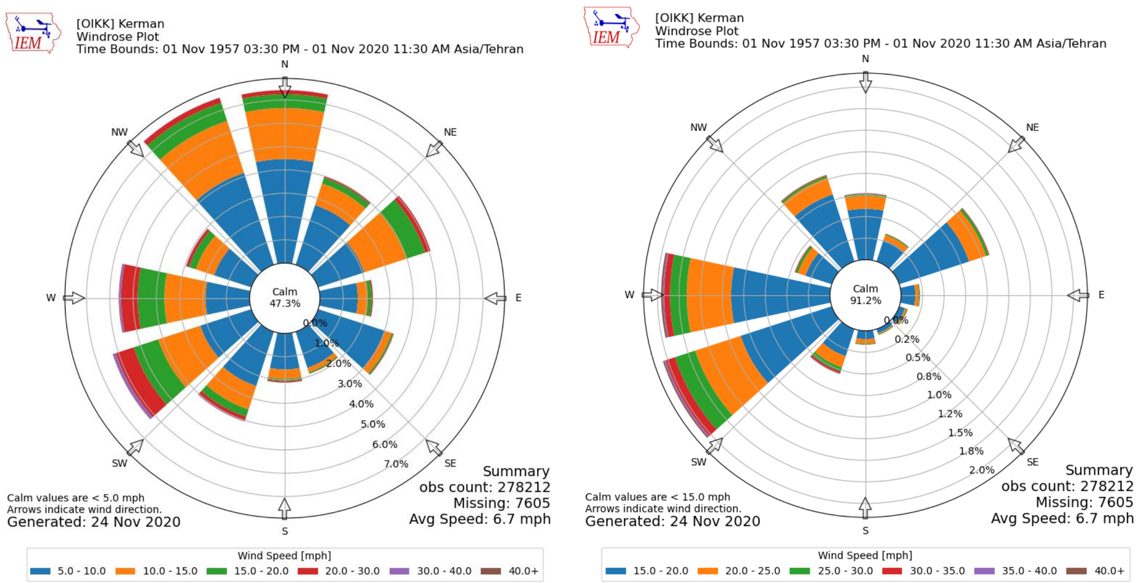


Figure2 Annual wind rose (Left) and high speed winds (Right) in Kerman

4.2. Spatial variability of Sand transport

Drift potential (DP) is an index that shows the potential maximum of wind energy that could be moved sand in a region in a year (Pye and Tsoar, 1999; Lancaster, 2014). The distribution of erosive wind direction for the 16 compass directions is known as “sand rose diagram” (Fryberger and Dean, 1979)

5. Discussion

5.1. Grain size analysis and Sand Sourcing

In order to better understand the aeolian processes on the Kerman Plain, 13 samples of aeolian sediments were identified and analysis of both the grain size distribution (Granulometric analysis) and minerology of the deposits was conducted. Grain size distributions is one of the most basic properties of sediment particles that is effective in aeolian processes and landforms and indicating sediment source, transport and erosion circumstances (Folk and Ward, 1957; Bui et al, 1990), grain size is also play an important role in transfer rate (Wiggs et al, 2004; Zamani and Mahmoodabadi , 2013,. Kamali and zahabnazouri, 2018).

Aeolian sediment transport can occur in several modes, which primarily depend on grain size and wind speed. As wind speed increases, sand particles of ~100 μm diameter are the first to be moved by fluid drag (Bagnold, 1941). Grain size distributions were measured using standard sieving techniques as described by Folk and Ward, 1957. The grain size statistical parameters of Folk and Ward (1957) include the mean grain diameter, sorting, skewness, and kurtosis. These parameters provide a clear description of the grain distribution of the sands. They were calculated using Gradistate program. These parameters were compared in terms of position on different land use in the study area.

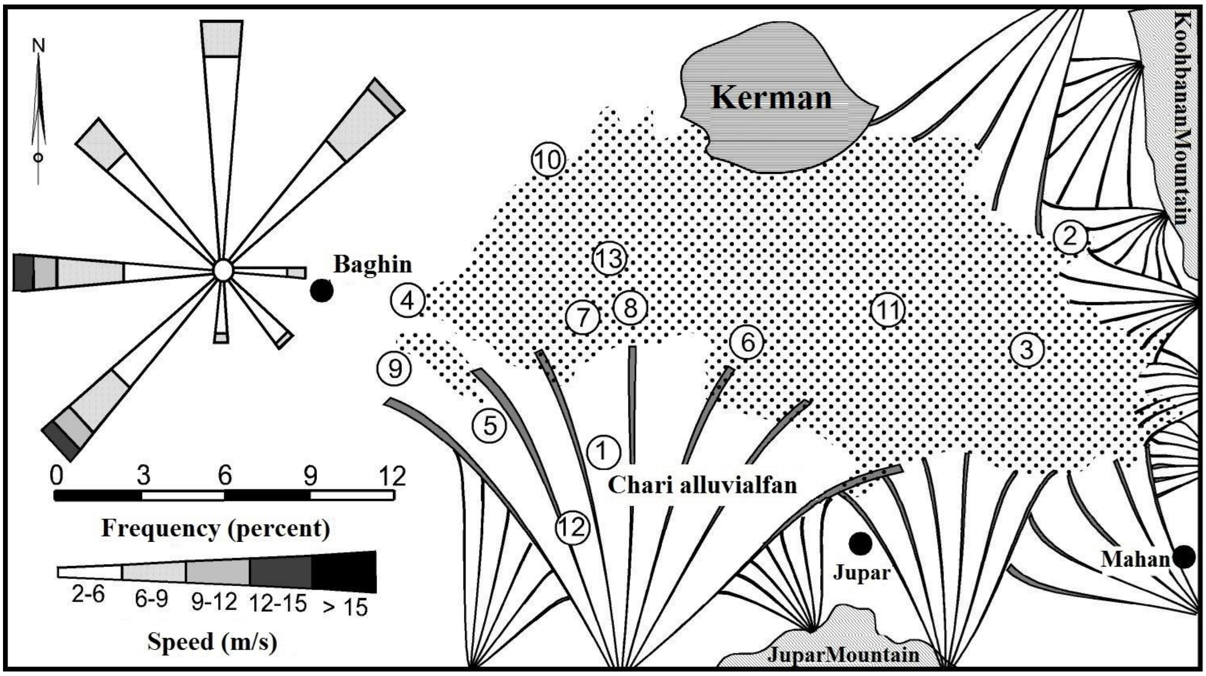


Figure4 location map of sand samples

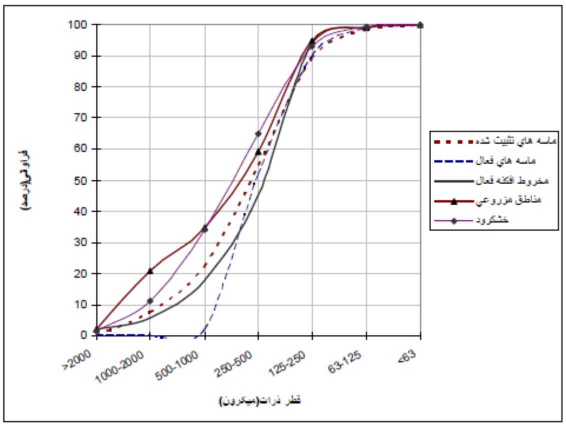
Sand source areas include lake sediments, river sediments, alluvial fans, beaches, glacier oil and sand bed (Ahlbrandt,1979) This study shows that the main source of aeolian sediments are locally derived from the distal ends of the Chari alluvial fan in southwestern of the Kerman playa. The mud-rocks comprising the playa surface, arable lands and dried riverbed are also contain some sand, and these sands, which are released during aeolian sandblasting, are considered to be the secondary source of sand in this area.

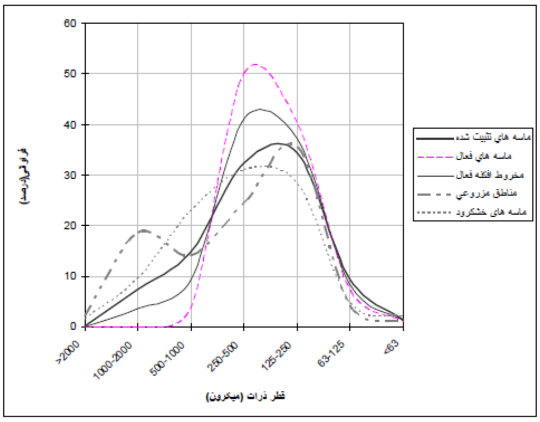
Wind sediments are more widespread in the north, east and southern plains of Kerman and consist of calcite, quartz, chalcedony, opal, gypsum, alkaline feldspars and plagioclase, pyroxene, amphibole, iron oxides and igneous, sedimentary and metamorphic rock fragments (Atapour,)

Table1 Granulometry of sand samples

Sample #	% Particle Size (μ)					
	63	125	250	500	1000	2000
1	3.6%	15.1%	39.5%	25.4%	14.2%	0%
2	1.5%	16.3%	44.6%	36.2%	14%	0%
3	0.2%	4.1%	30.7%	64%	1%	0%
4	1.2%	4.8%	35.9%	29.1%	12.8%	2.4%
5	0.8%	0.5%	45.5%	35.5%	15.4%	0%
6	1.5%	13.5%	46%	37.4%	1.5%	0%
7	1.8%	11.8%	39.8%	27.2%	15%	0%
8	1.5%	13.6%	43.4%	35.3%	5%	0%
9	2%	1.9%	55.3%	21%	7.1%	6%
10	0.4%	2.4%	13.2%	41.8%	33.8%	0%
11	0.8%	3.6%	35.3%	19.8%	15.3%	1.7%
12	1.5%	1%	44.7%	50.2%	2.2%	0%
13	1.8%	5.8%	29.4%	20.1%	19%	0.7%

Given that the predominant winds blow from the southwest and northwest, the sands moving across the western alluvial fans must primarily come from the western bajada surface, and then form major sand dunes. Some of this sediment is then trapped by shrubs and forms parabolic dunes. In this region parabolic dunes are very common landforms in the distal parts of alluvial fans in the southern and southwestern parts of the plain, this erosional U shape dune types (Lancaster ,1995) shows simple wind regimes (Muhs 1985), also reflect the complex interactions between vegetation, wind and sediment transport in the development of these dunes (Hesp, 2002)
Grain sizes of aeolian sands are varied in different parts of a dune and also in different types of dunes, they show some differences with each other (Cook et al, 1993), this difference is the result of the wind power variation in each place.





5.2. Geomorphological Characteristic Parameters

Kerman plain comprises various aeolian landforms, the various type of dune shape depends on wind regimes, sand availability as well as sediment grain size (Bagnold, 1974; Lancaster, 2005), these landforms also classification is the basis for further understanding of aeolian geomorphology (Dong and Lv, 2014).

The general direction of Kerman sand field is from northwest to southeast and this direction perpendicular to the prevailing southwest and west winds of the region. Barhcan and barchanoid, parabolic dune, barchan-sief, seif and zibar were the main sand dune in Kerman plain.

Zibar and parabolic dunes are close to the sand source area, they are usually are formed after sands leave the source area ( ), vegetation play a crucial role to the development of parabolic dunes (Hesp, 2013; Mayaud et al., 2016)

Sand sheets and zibar are often composed of coarse, poorly sorted, often bimodal, sands (Lancaster, 1994). Sand dune can depict sand availability and wind regime in the region because these criteria play a major role on the formation and evolution of transverse or barchan dunes in unidirectional wind regime. Besides, barchans shape in low sand availability, barchanoid ridge in medium availability and transverse dune in high sand availability in laboratory condition (Garcia et al, 2016).

(Mainguet 1983) have attempted to order dunes by including aspects of their mobility and relation to sediment budgets and thus to distinguish between erosional types (parabolic dunes, sand ridges) this kind of dune are available in the onset regions of the sand field in Kerman, and purely depositional forms (barchanoid dunes, transverse chains, linear dunes and star dunes). As sand supply increases, barchans coalesce laterally to form crescentic or barchanoid ridges that consist of a series of connected crescents in plain view (McKee and Douglass 1971; Kocurek et al. 1992), this dune type are more frequent in the middle part of the dune field followed by seif and complex dune of barchan-seif (Livingstone *et al*, 2010)

Seif dunes have been shaped in the eastern corner of the Kerman sand field, the usually form in bidirectional winds condition (Eric et al, 2009), it seems that this part of Reg influence by seasonal change of wind direction, Southwestern wind in the cold season and northeastern wind in the warm season (Fig)

Barchan is the best-known type of dune, which is also of particular concern due to its high mobility: barchans can migrate between 30 and 100 meters in a single year (Bagnold 1941, Pye and Tsoar 1990). Beside the high mobility of this kind of dunes, they don’t have any hazard in Kerman because of artificial stabilization.

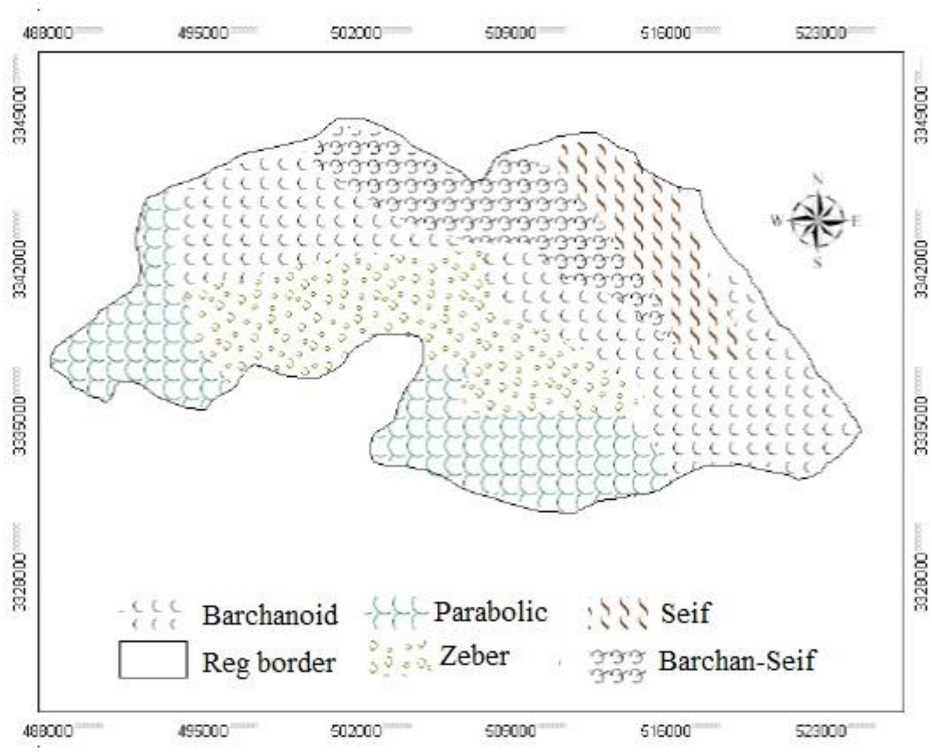


Figure Aeolian landforms in Kerman Plain

Sand Stabilization

In the last century, before Sands stabilized in the region, the city of Kerman and surrounding urban and rural areas, have always been threatened by aeolian erosion and sands movement, in addition to reducing the comfort of the region's residents and disrupting daily activities, it has also led to the spread of diseases. Besides, it has been a threat to arable lands, settlements and communications. Sand stabilization have been started in Kerman region since 1345 and have provided new land use in the southern and southwestern suburbs and the new farms land in the suburbs (Ahmadi and Jafarian Jelodar, 2004)

Tamarix also called (athel tree, tamarisk, salt cedar, eshel, leafless tamarisk), family Tamaricaceae (Orwa et al, 2009), plays an important role in sand stabilization and aeolian control in several arid environment of Iran (Liu et al, 2008; Lang et al, 2013; Zahabnazouri et al, 2020, Zahabnazouri et al, 2021) and the world (Ding et al, 2017), and provides multiple ecosystem services to humans and it functions as an ecological protection against desertification in arid ecosystems (Ma et al., 2009)

Conclusions

Aeolian landforms with larger wavelength and high density in the western corner on the Reg indicate high sand availability and coarse-grained sediments, while successive asymmetric barchan and seif with lower density and wavelength in eastern corner of the Reg are indicator of less sediment availability.

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