

The study of removal (detachment) and transitional regions of wind erosion upon ground indicator (Case study:Khartouran Erg)

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Abstract

The result of wind dynamic (capacity and potential) is transport of soil or sediment particles and subsequent formative desert landforms based on the severity of erosion or sedimentation. The Khartouran region, because of its geology, geomorphology and climatology conditions is a special place in the arid region on the closed basin of Dasht-e-kavir. It is evident that the ecosystem balance of the region is affected by anthropogenic exploitation and wind activity, so this area has a geoecological structure with special features. The wind erosion process in the Khartouran area can be categorized as origin, transport and sedimentation sites. In this research, the studied area was about 200000 ha, southwest of the town of Sabzevar covering sand origin and transport areas. The studies were carried out based on topographic, geologic maps, landsat images, aerial photographs and field observation. Based on these documents, the area was divided into a 9 km² (3×3 km) grid and identity points of each grid were determined (214 points). On each identity point, indices of wind erosion (deflation, abrasion and accumulation), were collected. The results have shown two geomorphologic units (pediment playa) in project area and the geomorphologic facies (landforms) such as desert pavement, small yardang (kalotak), rebdou, nebka and sand ripple have been found by aeolian transport of sand. Based on ground indicators, determined removal and transit zones. Based on studies and results can conclude that these regions were affected by wind erosion in the past more than of current time and khartouran Erg is a result of wind activity in the past. Currently, the rate of sand flux and the balance between erosion and sedimentation are dominant factors in shaping geomorphologic facies (Aeolian landforms).

Key words: Khartouran Erg; Deflation; Abrasion; Wind erosion; Removal zone; Transit zone; Sand dunes; Wind erosion indicators

1. Introduction

The erosion, transport and subsequent deposition of sand dust by wind are the most significant geomorphic processes in many of the earth's arid regions. Characteristic landforms and landscapes evolve according to the dominance of either erosion or sedimentation (Watson 1989).

The wind created facies geomorphologic that result from either deflation and abrasion processes or accumulation of driven sand. These

landforms (facies) are good and suitable indicators for determination of detachment and transit regions.

Khartouran erg with an area of about 170000 ha and complex of sand dunes is supplied action of wind on the area with 400000 ha. Because of its geological (tectonic and lithologic structures), geomorphologic and climatic conditions, this area occupies a special place in the dasht-e-kavir basin. The existing of broad alluvial plains clay-silty flat, relatively strong wind and extensive and far-reaching human activity effects on natural balance of the ecosystem and the geoecological structure is created with special features.

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2. Materials and Methods

2.1. General description of the study area

The studied area is located on the western south of Sabzevar town in the eastern north of Iran and its boundary is approximately in coordinates $56^{\circ} 15'$ to $57^{\circ} 00'$ eastern longitudes and $36^{\circ}, 00', 00''$ to $36^{\circ}, 24', 36''$ northern latitudes (Figure 1). This region is

funded in the western south Sabzevar basin (Figure 2). The area is 5400 ha, its altitudes are varied from 770 to 1150 m above the sea level, consequently the average elevation is 960m from sea level; the climate is arid with the average rainfall 193mm. General slope of this area is less than 3%, but a major part of the study area are covered with topographic slope less than 1%.

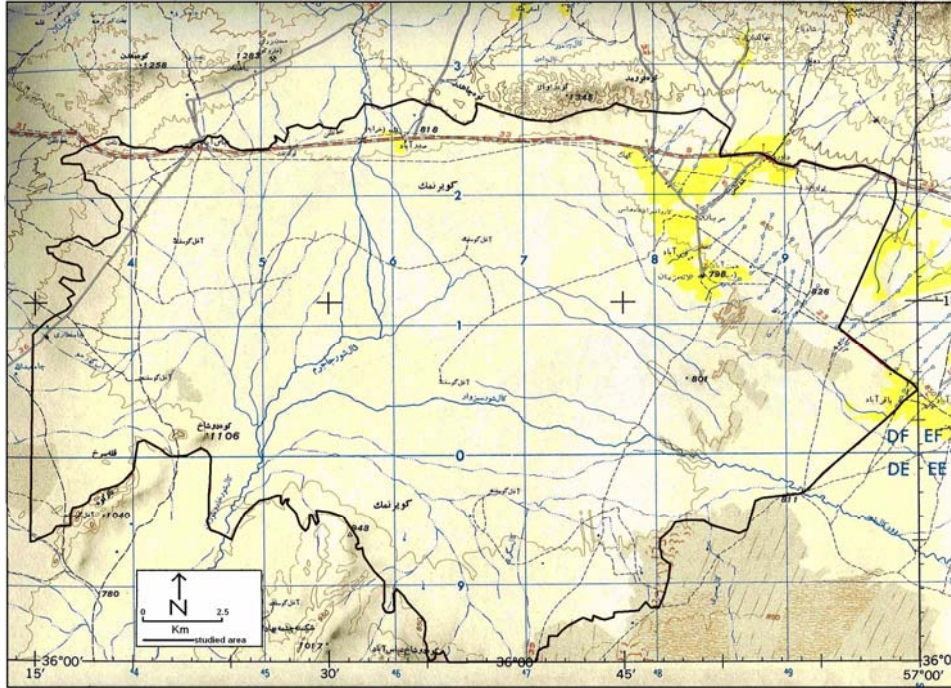


Fig. 1. Topographic condition of study area

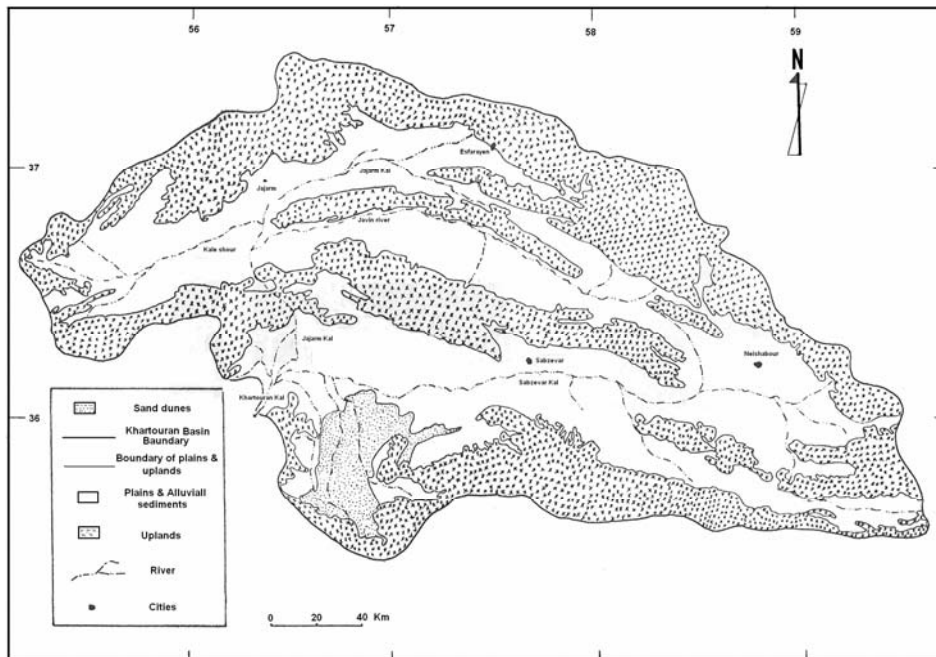


Fig. 2. The Sabzevar basin and studied area

2.2. Materials

The following data were used in the current study:

A. Topographical maps with scale of 1:250000 in order to prepare region base map, physiographical relation among different unevenness shapes including mountain regions, plain regions and kharturan Erg region. These maps include Sabzevar NJ 40-15, Miamei NJ 40-14, Kashmar NI 40-3 and Baghestan NI 40-2 sheets.

B. Topographical maps with scale of 1:50000 These maps are used for more detailed studies as well as determine physiographical characteristics including slope and hypsometric study in the field to obtain geographical characteristics and universal transverse Mercator, these maps include Abas abad 7262-1, Astarband 7362-4, Davarzan 7362-1, Koh e Doshakh 7262 -2, Jonobe Astarband 7362 -3, Chubin 7362-2 sheets.

C. Geologic maps with scale of 1:250000 These maps were to determine the region

lithology, to determine study boundary to study lithology and tectonic characteristics of Sabzevar area and relations of these in shaping studied region. These maps include Sabzevar and Miamei sheets.

D. Aerial photographs 1:55000 were studied on the basis of mosaic of mentioned photographs and interpreting them and geomorphologic characteristics of the region.

E. Satellite images taken from Google Earth in order to consider geomorphologic characteristics of the region as well as to prepare land use maps and changing them (figure 3).

F. Meteorology data and information of available stations in the region and around of it in order to study climatic characteristics and the region climate.

G. Table of ground indicator

H- Field trips for completing interpretation of aerial photographs and satellite images and recording ground index.

I. Using arc view 3.2, Ilwis software to enter information to draw targeted maps and to incorporate the maps.

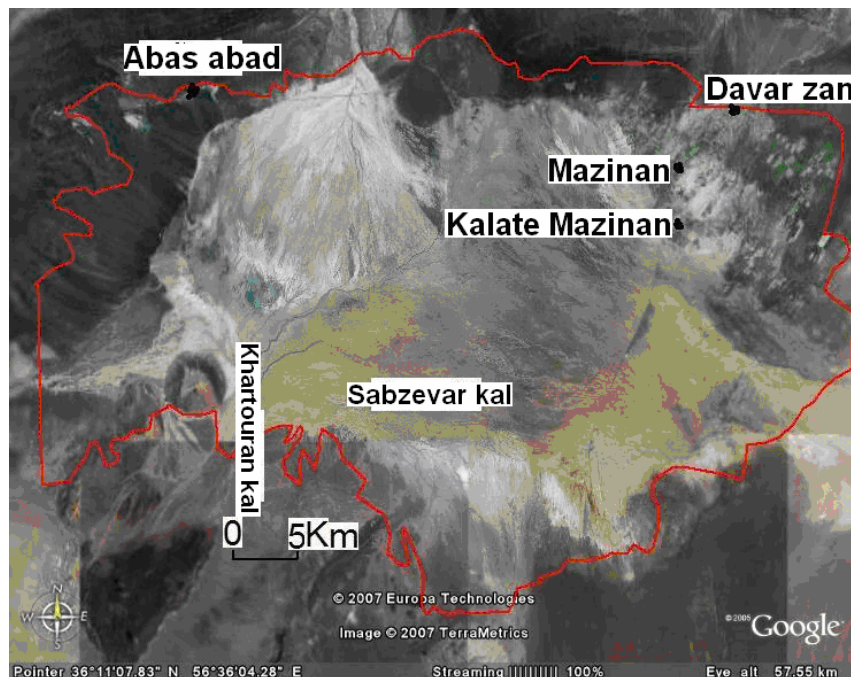


Fig. 3. Situation of the region on the Terra image from Google Earth

2.3. Research methods

The aim of the study and being extensive of studied region and on the basis of document and the following information research method can be stated as follow:

A. To determine the study area boundary on the basis of the wind function

To determine the boundary in which the wind functions and on the basis of its performance, at first a study was made on morphology of Khartouran Erg sand dunes. This study was made on the basis of topographical maps 1:50000, aerial photographs 1:55000 and 1:20000 and satellite image. After studying morphology of sand dune, each of the forms of

sand dunes, were analyzed in order to determine direction of prevailing and strong winds. This analysis was made on the basis of provided models which show the relation between morphology and direction of the wind. On the basis of obtained results from these studies, studied region was determined according to the geologic and topographical maps. This region included the regions of detachment (source) and transport Khartouran Erg (figure 4).

B. To determine sampling points

To following and studying point to point of wind effects on the earth surface, studied region (source and transport region) was networked. Provided network was square and was in distance of 3 kilometers on the earth or 6 centimeter on the topographical maps 1:50000. The network cross was coded after drawing the network on the map and so 214 points were determined (figure 4).

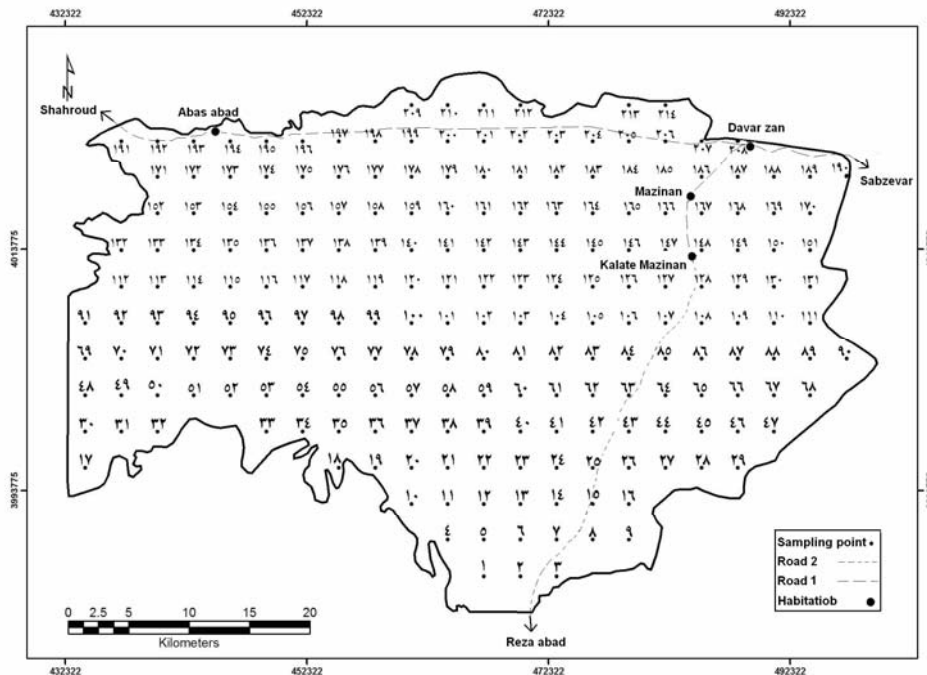


Fig. 4. Base map and sampling points

C. Field interpretation of ground indicator of wind erosion. Ground indicator of wind erosion was determined with study and primary visit of the region and characteristics and information of study points was interpreted.

D. To determine source and transport regions.

3. Results

3.1. Meteorology and climate

Study of the region's climate was made two times on the basis of analysis. First, analysis of Sabzevar station data and the other analysis of adjacent stations data and available in Sabzevar basin and establishing the regression relation among usable parameters in climate. These studies showed that average annual precipitation is 193.2 mm and daily average is 16.9 °c and climate of the region is arid, on the basis of Dumartin method.

3.2. Geology

3.2.1. Genesis of Sabzevar playa

Sabzevar playa was probably closed in Pliocene period and has received its depositions from very extensive basin, it was possible that there has been a lake in Sabzevar playa in Pliocene period due to less persistence of coastal depositions but no signal of coastal line is not seen around the playa (Gasner, 1955). The following geology evidences confirm theory of being close of Sabzevar playa.

A. Great alluvial fan of Moreh River (figure 5) in north-east of salt desert, has been derived from Sabzevar playa. Extent of this alluvial fan is 1392 kilometers and indicates greatness of material rate which have been brought to this region in the last glaciations age. Trench of the Valley of Moreh River in South-west of Sabzevar River basin can cause by establishment of fault on Southern Mountains of

this area. This hypothesis is reinforced by south-north direction of fault in distance of 4 km and parallel with valley of Moreh River (figure 5) belonging to upper Neogene. It is appeared that trench of Moreh River has established in middle Pleistocene (Gasner, 1995).

B. Erosional trench on Sabzevar playa and extensive plates, covered with sand dunes show that these events have established when the region has had high precipitation winter and summer with more wind (Krinsley, 1970).

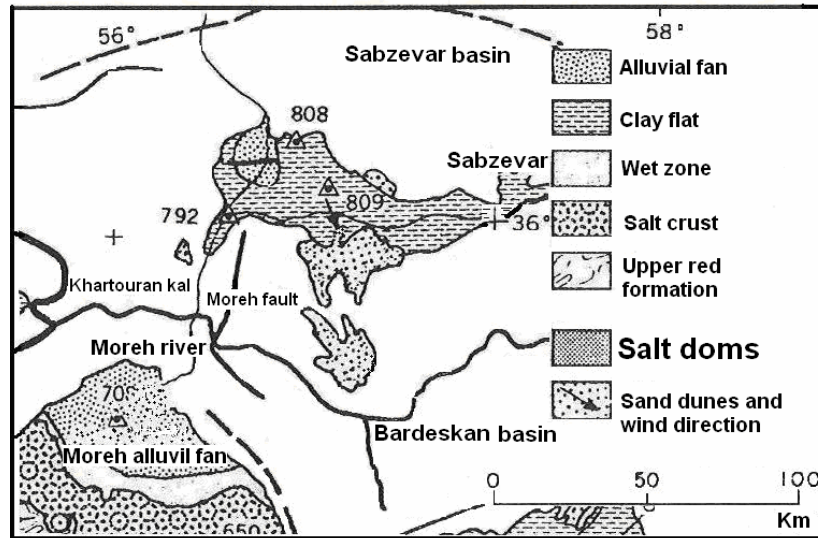


Fig. 5. Situation of the region and Moreh fault (Krinsley, 1970)

3.2.2. Study of depositions

The entire studied region is covered with alluvial depositions (except Inselberg available in the region). These uncountinous depositions are not rough and have not distributed with different ticks in the region. Although whatever

these depositions extend toward south and south-west, they have fine gains but they are clay deposits in sandy deposits, locally in west region and south-west. The most recent depositions are related to alluviums in rivers bed and the oldest of them are related to alluvial depositions of old terraces (figure 6).

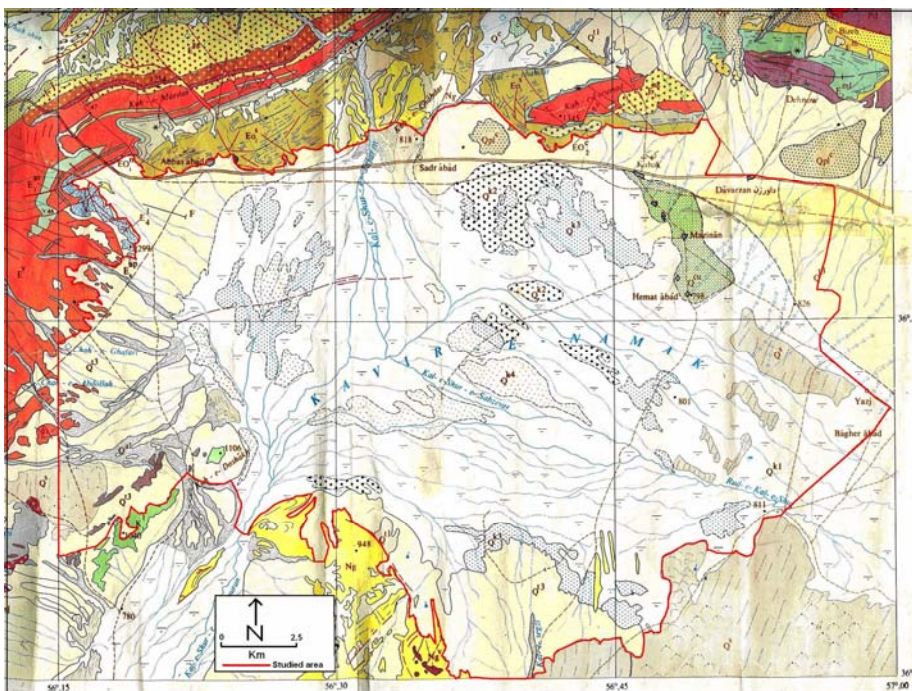


Fig. 6. Geologic map

- Q¹¹ : Older terraces and gravel fan
- Q¹³ : Younger terraces and alluvial plain
- Q^{k4} : Moist and flat area, with soft puffy ground, dissected by numerous braided
- Q^{k3} : Dry and flat area, hard and smooth, with scattered soft puffy ground.
- Q^{k2} : Dry and flat area, hard and smooth, with widespread soft puffy ground.
- Q^{k1} : Dry, soft and puffy ground, containing local salt crusts and channels.
- Q^{cu} : Cultivated area
- Q^s : Various shaped Sans dunes
- Q^c : Clay flat
- Q^{al} : Alluvium in major streams

3.3. Study of morphology of Khartouran Erg sand dunes and determination of study area on the basis of wind performance

The wind is the major element in shaping sandy landforms. Field studies and interpretation of aerial photographs of different shapes of sand dunes showed that the wind play a role in shaping them in two ways: first, the wind direction, a factor which determines the alignment of sand dunes. Dominant winds or strong and local winds establish this alignment. Study of sand dune trend in Khartouran Erg showed that direction of dominant wind is northwards and sometimes local or strong wind direction is from north-west. Majority of the region sand dunes have regulated by northern dominant wind which irregular alignment in some regions are affected by local topography (like the existence of Kalehsabri in the middle of Erg and Kele Hojaj and Sagzi beside it). Second, different wind regions, is the factor which make different forms of sand dune. Under a uni-directional wind, regularly aligned crescent and barchanic dunes, under the influence of two winds blowing from opposite directions but with equal force, transverse dunes with symmetrical slopes will be produced, when the two winds cross obliquely at a lower angle, liner or seif dunes with one long wing will generally be formed. When two winds with equal force cross at right angles, longitudinal dunes will be produced. When wind from three or more directions meet, horn shaped dunes (Star dunes) will be formed.

3.4. Study of ground indicator of wind erosion

In each sampling point, effects resulting from the wind performance on the basis of bench mark and ground indicator was studied and recorded.

3.4.1. Deflation bench mark

Deflation action is made by removing weak material of the soil and deposition due to direct force of the wind studies showed that deflation in studied region does not occur in two

following areas. The first area is upper regions and foot of the mountain in which there are very coarse depositional particles and at the other hand, water erosion is more effective than wind erosion. The next area is lower regions or regions which consist of clay particles. Deflation action is not seen in this area because of much tenacity of clay. At the other hand, existence of salts like carbonate calcium or gypsum crystals in this area can make firm lands against deflation. So area of deflation action can be considered as lower lands of pediment and upper lands of playa. Effect of wind action as deflation includes the following forms:

A: Desert pavement

Desert pavements are surfaces of closely packed angular or rounded rock fragments, commonly only one or two fragments thick, which form a mosaic in a matrix of fine sediment, i.e., sand, silt, and/or clay (definition modified from Cooke and Warren 1973). In the studied region, desert pavements were observed in pediments which are extended in north, eastern, western and south-west regions (figure 7).

Desert pavement of the region are classified to three groups, fine medium and coarse, depending on diameter of rocky article which have covered the land surface. These desert pavements can protect the layer of fine-grain depositions by microtopography.

B: Remaining soil in foot of plants index

The evidences can be seen in desert pavement of the region. The existence of coarse-grain element as well as fine particles and tenacity among them, limit wind or water action and bushes in this region maintain ground elements and over time the soil accumulates in foot of the plant and became a barrier against wind action.

C: Remaining of stem and root of plant, outside of the soil (soil detachment)

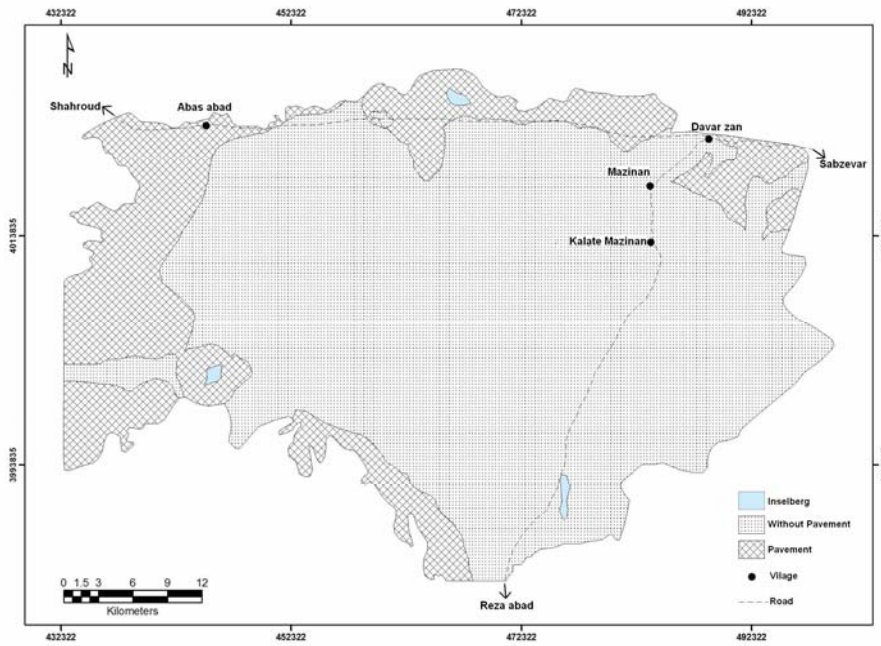


Fig. 7. Map of desert pavement distribution

This shape of plant indicates severe deflation in studied region. This kind of deflation has occurred in a place which the land surface has particles which can move in different velocities of the wind. Due to very high velocities of the wind, terrestrial elements carry and stem and

root of the plant are exposed to the air. Spatially, this situation is located in lower side of the wind, and in fact is seen at the end of pavements area and initiation of clay flats in playa (figure 6).

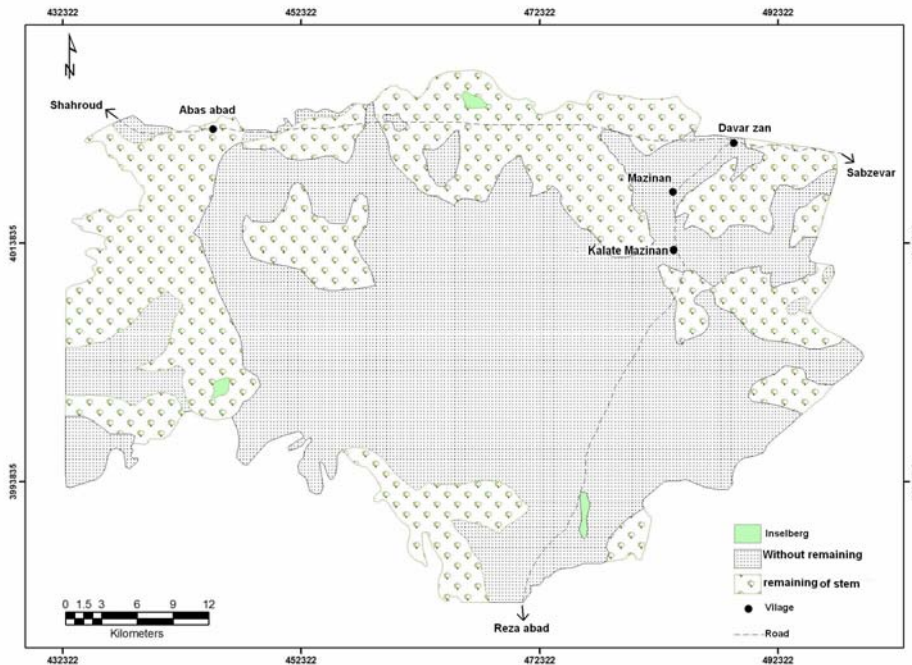


Fig. 8. Map of remaining of stem and root of plant, outside of the soil (soil detachment)

3.4.2. Abrasion bench mark

This action is occurred by abrasion of rough surfaces by wind. Studies in the region showed

the effects of wind performance as abrasion include the following features (figure 9).

A: Ventifacts index

Pavement stones shaped by sand blast abrasion are known as ventifacts (Mabbutt 1976). This wind wearing was observed in distances far from mountain front where wind velocity is carried by the sand.

B: Yardang index

The most spectacular of the forms resulting from selective wind erosion on dry playa are yardangs (Blackwelder 1934). These are parallel ridges of lacustrine sediment between wind-scoured furrows aligned with the dominate wind. The studied yardangs in the region are from types of micro yardangs which are seen with ridges in height of 50 centimeters but more of these ridges have height of less than 20 centimeters, their length is two meters. The spaces among ridges are very small and thin. Forms of yardangs are so that slope with high sleep is facing wind and slope with low sleep is behind the wind.

3.4.3. Accumulation bench mark

The accumulation landforms resulting from wind erosion are relevant indicator for reconnaissance of transitional area. When a sand-transporting wind (saltation specially) meets an obstacle, deposition generally begins some distance upwind and increased turbulence tends to sweep the obstacle clear of sand. The resulting accumulation will have a gentle upwind slope leading to a steep downwind face. These landforms classify two categories;

3.4.3.1. Dunes related to topographic barriers

3.4.3.2. Dunes related to anchorage by vegetation

Vegetation is unique as a sand-trapper, since it not only acts as a barrier in the path of wind-driven sand and changes surface roughness over large area, but has the ability to grow up through accumulating sand.

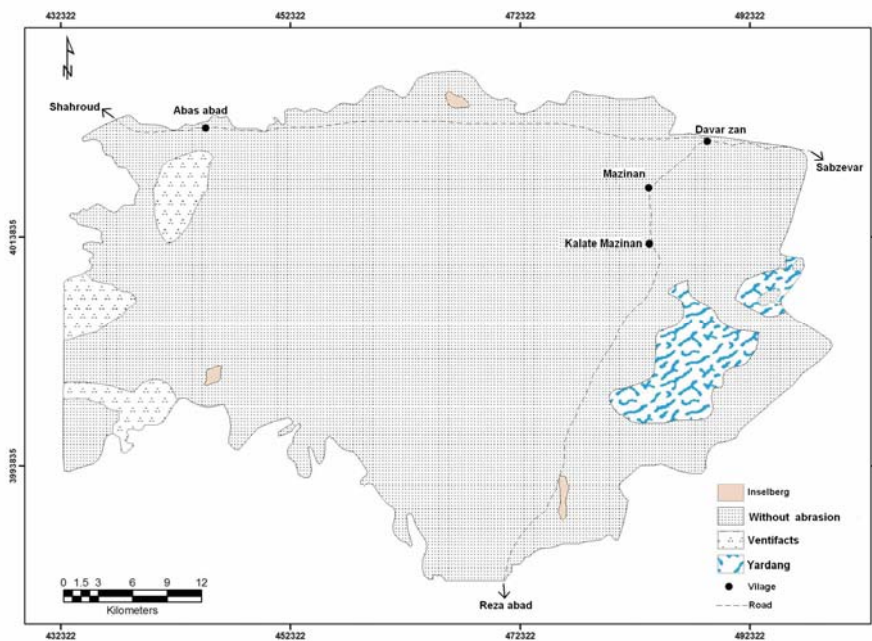


Fig. 9. Map of ventifacts and yardangs distribution

A: Isolated mounds (Nebka) index

These are trapped by shrubs or low trees in open plains with limited sand. This form of sand accumulation was observed in lower parts of pediments and playa (figure 10). Generally, reduction of particles diameter toward lower side of channel (Masil and Kal) is related to increase of wind erosion process. Therefore, accumulation sand can not be seen in upper

parts of the pediments. Because required sand to form this shape of accumulation is not provided by wind. When the wind has sufficient sand regions, removing performance by wind has importance and thus form of sand accumulations can be seen behind bushes. This accumulated shape of sand is cut as cone and is in direction of its height.

In central part of playa and erosional pediment, Nebekas were not observed. Field

surveys showed that nebeka's dimensions depend on carried sand rate by the wind and when carried sand rate is low, shape of sand accumulation is not evolved and does not become conic shaped and only accumulation of

sand is behind the bush irregularly but when rate of sand which has been brought is suitable and very much, this form evolve and became corn-shaped. In this situation, evolution of Nebeka depends on plant height.

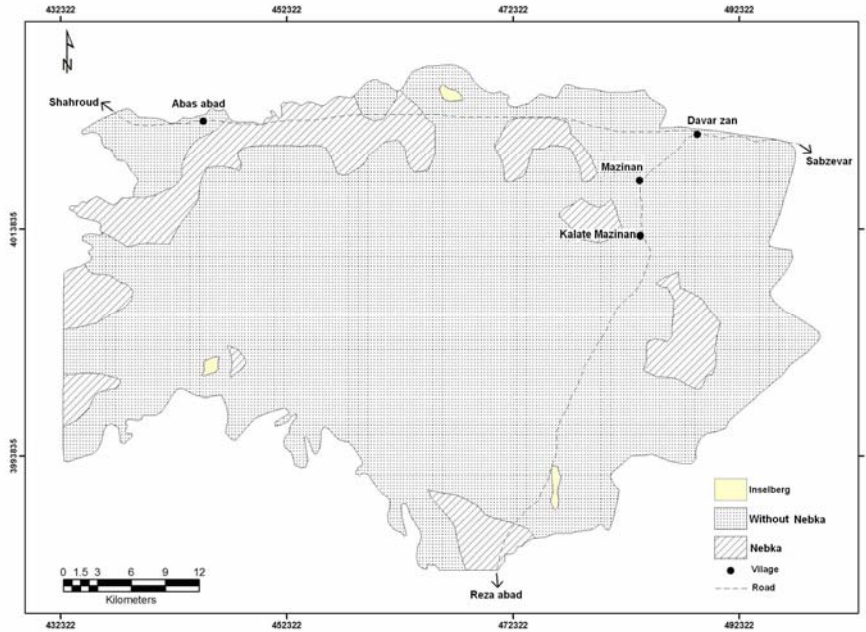


Fig.10. Map of nebka distribution

B: Rebdou

These sand dunes are affected by bushes in open plains and are formed by movement of sand. Study of rebdous in the region showed three types of accumulation (figure11).

- A. Rebdous which have been covered by vegetation cover.
- B. Rebdous which half of them have been covered by vegetation cover.
- C. Rebdous lacking vegetation cover.

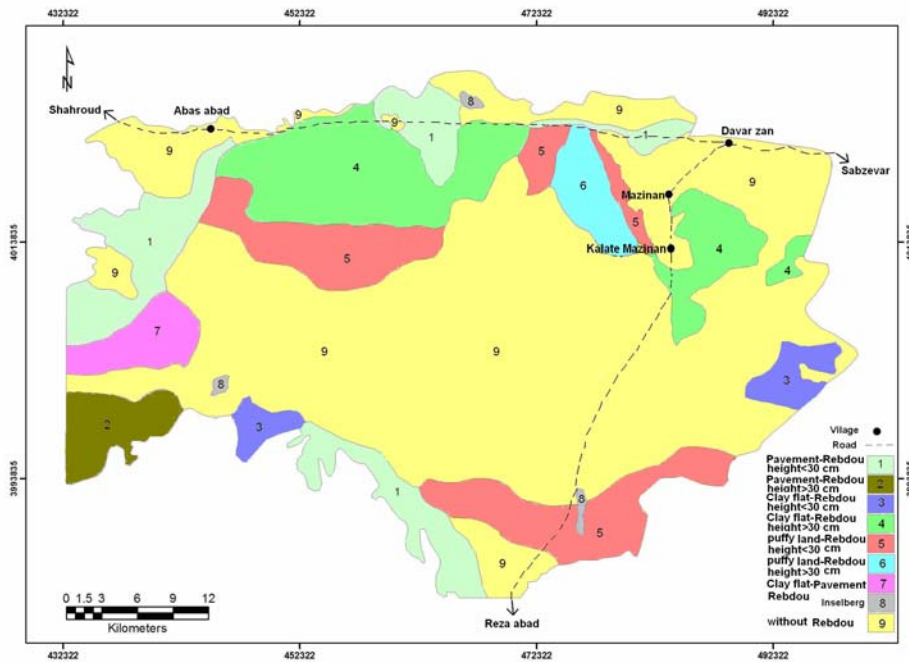


Fig.11. Map of rebdou distribution

3.4.4. Sand ripples

These are regular forms, transverse to the wind. Sand ripples are asymmetrical, with windward slopes of about 10° and leeward slopes near the angle of repose of about 30° . Although sand ripples indicate transportation region but their existence indicates effect of wind flowing characteristic on sand accumulation.

Some parts of ground indicators of wind erosion on the basis of field observations have been sampled, which is provided in table 1.

4. Conclusion and Discussion

The wind has important role in formation and development of desert landforms. Mainguet (1986) studied this role as the wind action in desertification in Sahro-Sahelian and Bagnold (1941) conducted primary researches exactly and partially in relation to sand movement and

morphological change in surface of the land. Field study of wind erosion process shows role of the wind in forming and evolution of desert landforms.

According to this fact that transportation region of every particle begins when the particle is removed from its place and move and so theoretically, isolation of removing region from transportation region is very difficult. But effects of detachment or transport can be observed in large scale as determined landform. At first maps resulting from deflation indicator were incorporated (figure 7, 8) and then this map was incorporated with map resulted from abrasion indicators (figure 9) and the map of removing (source) regions was prepared (figure 12). So, map of transportation provided (figure 13) from incorporation of maps of landforms accumulation (figure 10, 11). Finally, map of removal and transportation regions was prepared by incorporation of detachment region maps and transportation regions (figure 14).

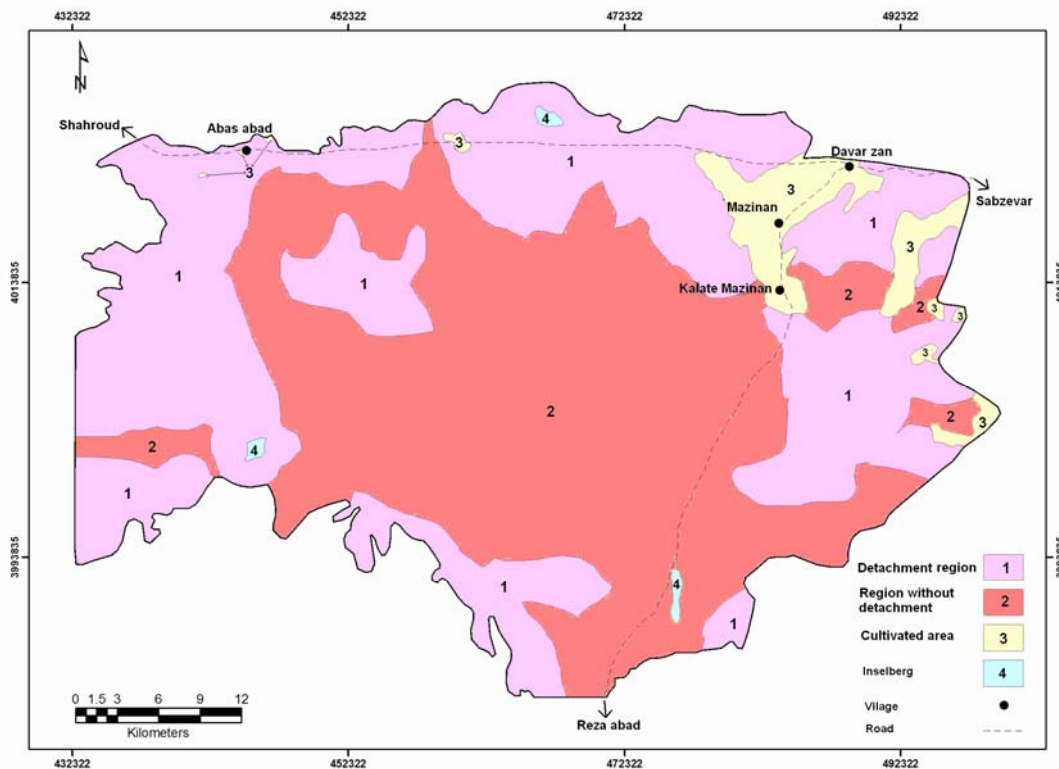


Fig.12. Map of detachment (removal) region

Accumulation						Abrasion			Deflation					Point No.
Nebka		Sand ripples	Rebdou			Ventifacts	Yardang		Remaining of stem and root of plant, outside of the soil (soil detachment)	Remaining soil in foot of plants index	Desert Pavement			
Length of Nebka (cm)	Height of Nebka (cm)		with vegetation/without vegetation	Height without vegetation (cm)	Height with vegetation (cm)		Height (cm)	Exist			Coarse	Medium	Fine	
-	-	-	98	16	20	-	-	-	*	-	-	-	*	1
80	20	*	-	-	-	-	-	-	-	-	-	-	-	2
32	15	*	-	-	-	-	-	-	-	-	-	-	-	3
-	-	-	100	-	25	-	-	-	*	-	-	-	*	4
42	18	*	-	-	-	-	-	-	-	-	-	-	-	5
-	-	-	100	-	20	-	-	-	-	-	-	-	-	6
-	-	-	99	15	18	-	-	-	-	-	-	-	-	7
Inselberg														8
-	-	-	95	20	25	-	-	-	*	-	-	-	-	9
-	-	-	95	18	20	-	-	-	*	-	-	-	*	10
-	-	-	98	25	30	-	-	-	*	-	-	-	-	11
-	-	-	99	23	25	-	-	-	*	-	-	-	-	12
-	-	-	100	-	5	-	-	-	*	-	-	-	-	13
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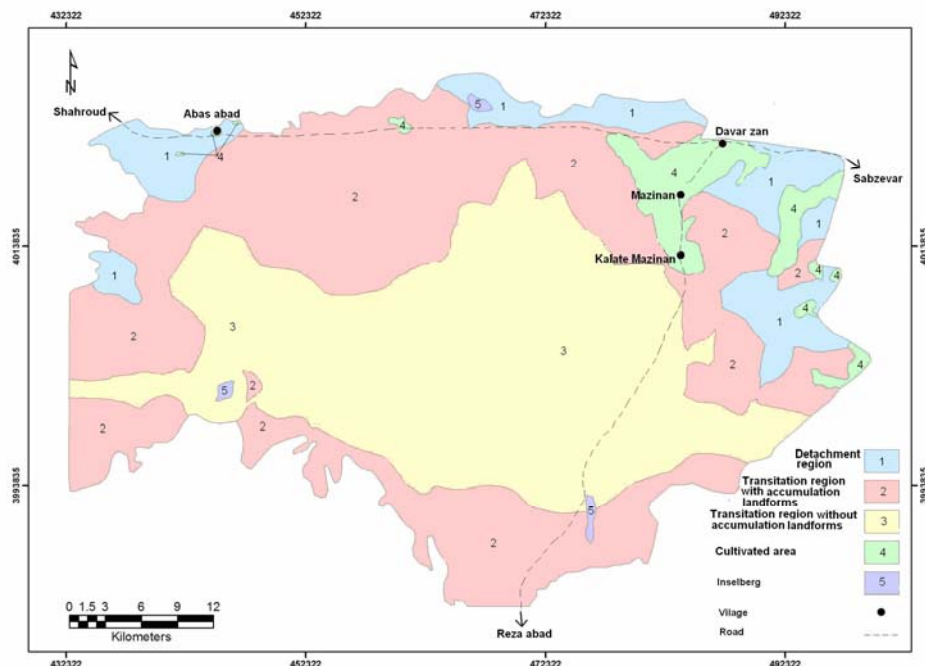


Fig.13. Map of transportation region

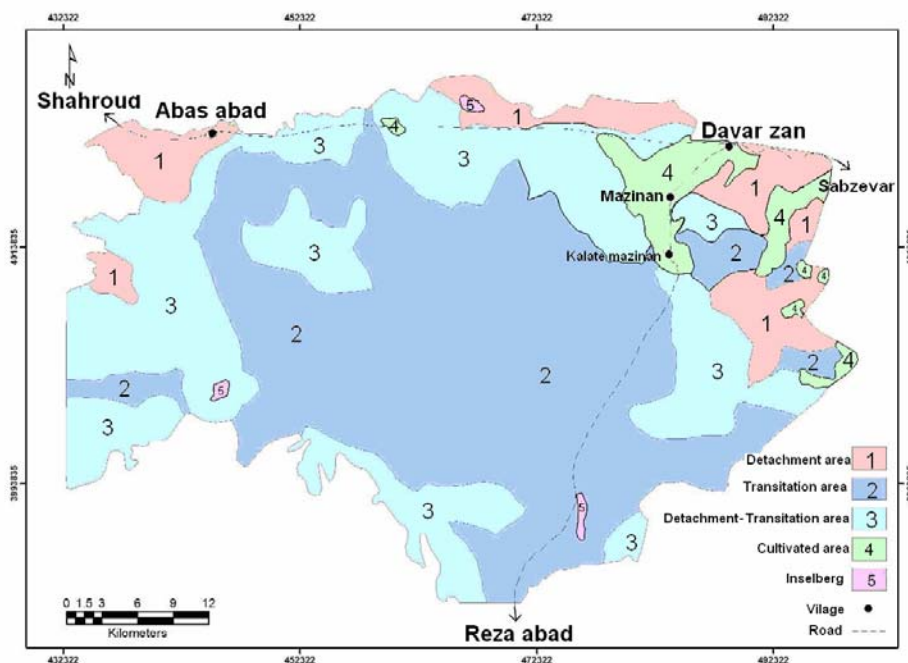


Fig.14. Map of removal and transportation region

The situation of region shows Sabzevar playa has important role in bringing wind accumulation to Khartouran erg but the following studies and evidences showed that major part of playa has no role in wind erosion:

A. Because Sabzevar playa is a playa between drainage networks, so characteristics of this type of playas are dried surface (because of drainage) and non-salt (drainage of salts with high

solution). Snyder (1962) and Motts (1965) used these characteristics in classification of open and closed playa.

B. Fine-grain texture of these surfaces resulted in establishing surface without unevenness and high cohesive. Tricart (1966) believed that the wind functions in insensible manner due to high cohesive and there is no removing of them even in humid form. Bagnold (1941) showed in his

experiments of the wind tunnel that cement powder could not carry by the wind is able to carry particles with 4/6 mm diameter.

C- Because dried weather condition and precipitation storage are dominated, percentage of salts with low solubility become dominated like carbonate calcium (CaCO_3). CaCO_3 , being subject only to particle leaching, tends to concentrated as a subsurface pan beneath dry playas, and so is protected from deflation (Mabbutt 1977).

The studies showed that studied region has reached to proportional balance among spatial variables with characteristics of the wind. Based on studies and results can conclude that these regions were affected by wind erosion in the past more than of current time and khartouran Erg is a result of wind activity in the past. Currently, the rate of sand flux and the balance between erosion and sedimentation are dominant factors in shaping geomorphologic facies (Aeolian landforms).

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