

Analysis of sand dunes to determine wind direction and detect sand source sites (case study: Khartooran Erg, Iran)

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Abstract

Wind regime and sand grain size are two of the factors that determine the morphology and dynamics of sand dunes in desert areas. Regarding the importance of wind effects on sand dunes especially in Iran, in this study, Khartooran Erg was analyzed to determine wind direction and to detect sand source sites. Khartooran Erg is located on eastern north of Iran and lies in Khorasan Razavi and Semnan provinces. The area of Erg was determined based on geological and topographical maps and satellite images. Then, sand dunes of erg were classified, based on aerial photograph and satellite image interpretation. Sand dune forms in the Khartooran Erg are often barchans and combination of barchanic ridges, but there are also complex types of linear sand dunes. Based on field survey findings, the stabilized in the southern part of the Erg were separated, because of these sand dunes having been deformed. According to the presented models relationship between morphology and wind direction, the sand dunes were analyzed. The studies have shown that wind prevailing direction is eastern-north to western-south, the strong wind being in north-south direction. It can also be said that sand dunes which are located in the adjacent of Erg and are simple and separate can be used as the most suitable criteria to determine predominant wind. Also, regarding the Erg location with respect to upper plains and determined wind direction, it can be noted that sand sources mostly come from silt-clay flats of ending parts of Sabzevar Kal River rather than Jajarm Kal River.

Keywords: Khartooran Erg; Sand dune; Wind direction; Barchan; Geomorphology; Prevailing wind

1. Introduction

A dune is usually defined as an accumulation of loose particles, deposited or reworked by the wind, with diameters varying from 2-3 millimeters to tens of micrometers (Mainquet, 1984). In arid climates, wind is the main element responsible for the modeling of the surface relief (Zhenda, 1984). Wind regime and grain size are the factors that determine the morphology and dynamics of sand dunes in desert areas (Cooke and Warren, 1973).

Regarding the importance of wind effects on sand dunes especially in Iran, in this study, sand

dunes were analyzed to determine wind direction and to detect sand source sites. In total, common landforms of Iranian desert zone landscapes are sandy deserts and sand dunes, which cover a considerable area of Iranian deserts. These are called ergs. One of these ergs is Khartooran Erg with an area of about 170000 hectares that is located in North East of Iran (Mashhadi et al., 2006).

2. Materials and Methods

2.1. Study area

Khartooran Erg is located in eastern north of Iran. It lies in Khorasan Razavi and Semnan provinces. This Erg has been formed on alluvial sediments and tectonic depressions from

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35°30' to 36°7' northern latitude and from 55°35' to 56°15' eastern longitude (Figure 1). It is 800 to 1250 meters above sea level.

Geographically, Khartooran Erg is located on a pediment of north direction. It also lies downstream of Kal Segzi and Kal Hajaj basins.

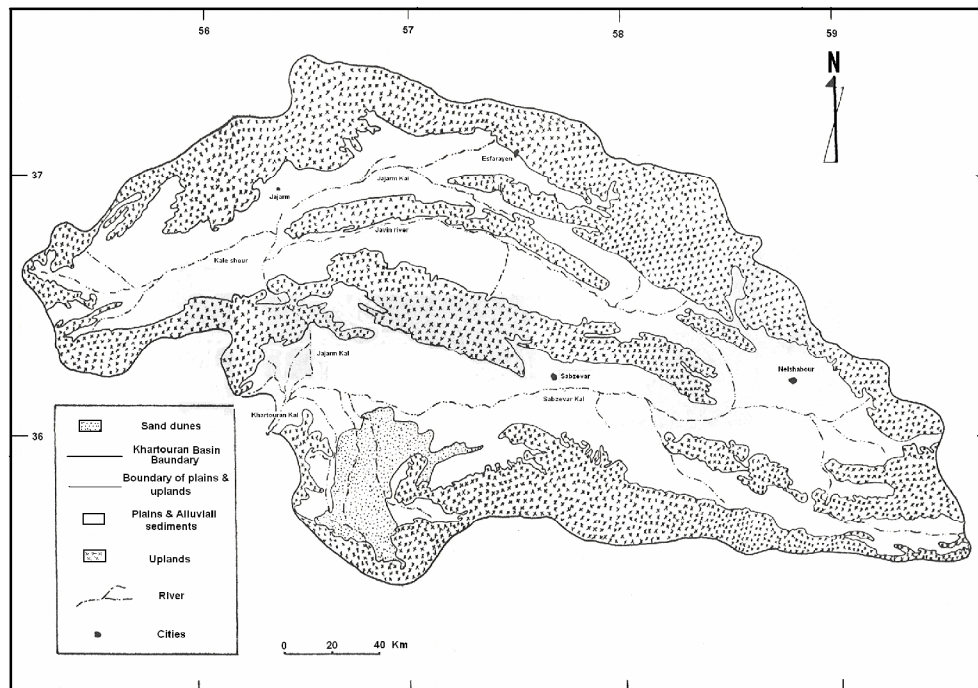


Fig. 1. The location of Erg

2.2. Materials

To do this research, a project was defined. Regarding the vastness of the site area as well as the aim of this project, the followings were employed.

- Topographical maps with scales of 1:50000 and 1:250000
- Geological maps with a scale of 1:250000
- Satellite images (Landsat TM) with a scale of 1:100000, for determining the area of Erg, as well as boundaries of sand dune forms.
- Aerial photos with scales of 1:50000 and 1:20000, for an interpretation of the morphological characteristics of the sand dunes.

2.3. Research methods

The area of Erg was determined based on geological and topographical maps, and satellite images. Then, the areas of sand dune forms were determined on the satellite images, with aerial photograph interpretation, types of sand dunes were studied. In the next stage, wind

directions (predominate, strong) were characterized, regarding the presented models as related to the wind direction, form and alignment. Finally, the sand sources were determined, based on wind direction and erosional landforms existing in the plains of north of Erg.

3. Results

3.1. Classification of Erg Sand Dunes

Several studies have been done to classify sandy edifices. For example, Mainquet classified them based on dynamic criteria (Mainquet, 1984). Mashhadi has used this classification method for studying the morphology of sand dunes (Mashhadi et al, 2006).

Table 1 illustrates the classification features done in this area. However, based on carried out studies, the sand dunes classification map was prepared (Figure 2). Table 2 also represents the area of each feature.

3.2. Analysis of Sand Dunes Morphology and Determination of Wind Direction in Khartooran Erg

Alignment and form of sand dunes are very useful criteria for determination of wind direction and regimes. As such, alignment and form of sand dunes show the wind direction and regime, respectively.

Thus, in this research, these two criteria were employed to analyze various forms of sand dunes in Khartooran Erg.

3.2.1. Analysis of crescent and crescent chain dunes

3.2.1.1. Pre-barchanic landforms

These dunes have been formed before barchans and are composed of shield and dihedral barchanic edifices (Mainguet, 1984).

The shield type edifice remains in its shape as long as it can conserve a modest height, and its slope remains gentle (Mainguet, 1984).

In this case, determination of wind direction and regime is difficult. However, other dunes are accompanied with this one and so we can determine wind regime while using them.

The dihedral dunes have two sides as regards wind.

The upwind side has a gentle slope and shows wind direction.

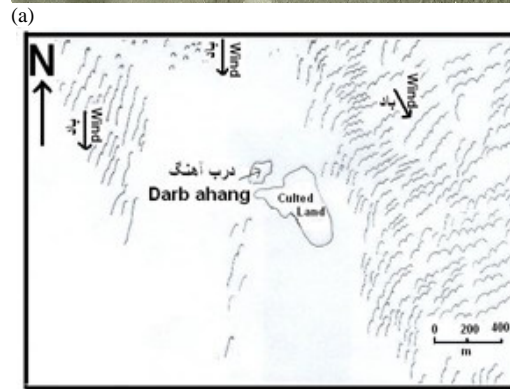
3.2.1.2. Barchans

In this study area, two kinds of barchans were distinguished: Symmetrical and asymmetrical (Figures 3, 4).

Symmetrical barchans are crescent sand dunes, elongated along the predominated wind direction. These barchans will be changed eventually to asymmetrical ones.

3.2.1.3. Barchanoids

These kinds of dunes have two sides with different slopes. The low slope side is based on wind direction (Figures 5, 6).



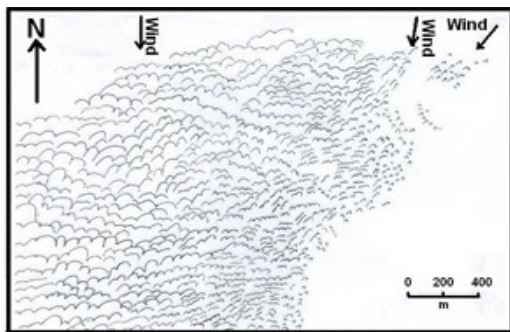
(a) (b) Fig. 3. Two kinds of barchans: a) Aerial photo, b) Interpretation of wind direction on the map



Fig. 4. Barchan



(a)



(b)

Fig. 5. Barchanoids and complex barchans: a) Aerial photo, b) Interpretation of wind direction on the map

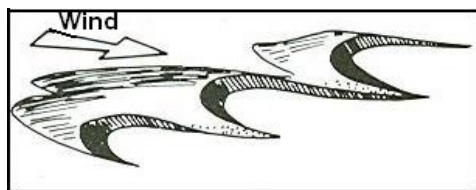


Fig. 6. Barchanoids

3.2.1.4. Transverse dunes

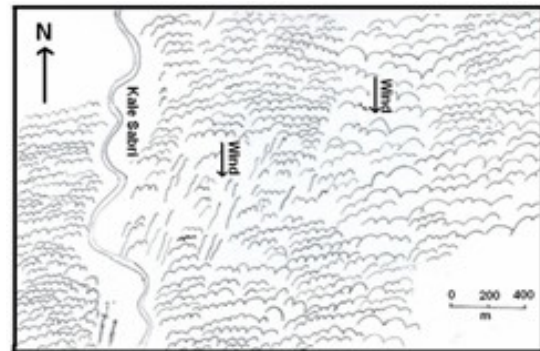
These dunes are also observed in the study area. Their low slope side is based on wind direction (Figure 7).

3.2.1.5. Composite dunes

These dunes have occupied a large area in Khartooran Erg, covering the central part of Erg (Figure 5).



(a)



(b)

Fig. 7. Transverse dunes a) Aerial photo, b) Interpretation of wind direction on the map

3.2.2. Analysis of linear or elongate dunes

3.2.2.1. Simple dunes

They are elongated in one direction, with their length being greater than their width. Their low slope side shows the direction of predominant wind in the region.

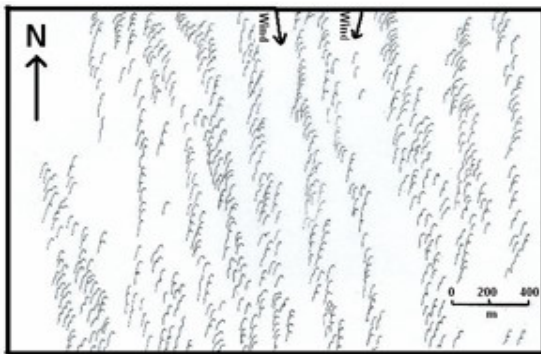
A linear dune is a sandy edifice, elongated narrowly at base, placed in a rectangular direction and sinuous in detail. It is especially elongated in one direction with a profile formed by two steep slip faces that meet in an angular crest.

3.2.2.2. Composite dunes

Two kinds of composite dunes are seen in Khartooran: Parallel Linear Dunes (Figures 8, 9, 10), and Bouquets of Linear Dunes (Silk) (Figure 11).



(a)



(b) Fig. 8. Linear dunes: a) Aerial photo, b) Interpretation of wind direction on the map



Fig. 9. Linear dunes

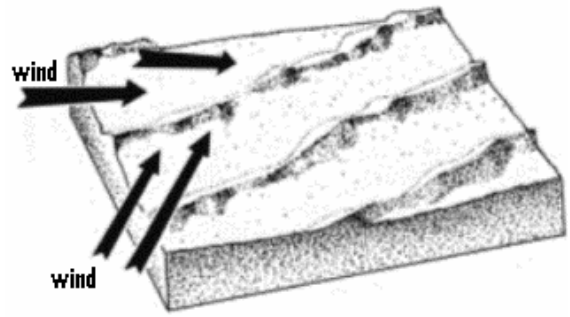
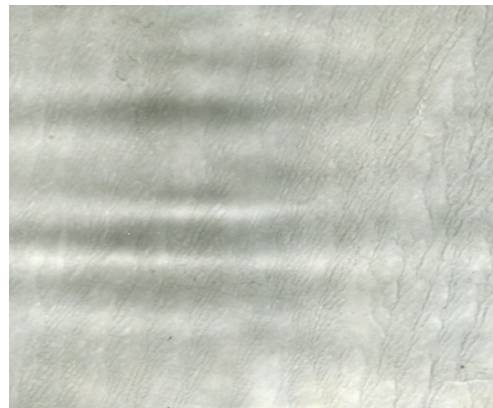
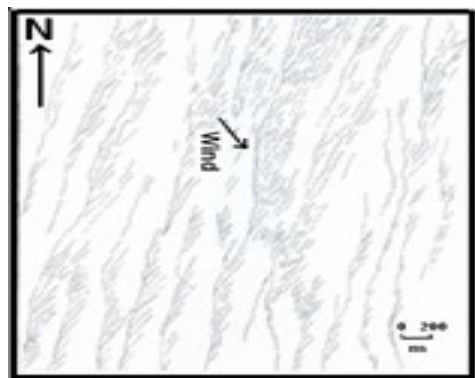


Fig.10. Linear dunes: Arrow shows probable dominant winds (from: McKee1979)

The former is composed of simple linear dunes, penetrating into the site. The latter has two forms: Asymmetrical which serves as barrier against wind and is used as indicator of wind direction, and symmetrical which is located in the center of Erg and shows winds of different directions (Figure 8).



(a)



(b) Fig. 11. Composite dunes (Silk) a) Aerial photo, b) Interpretation of wind direction on the map

4. Conclusion

The research has shown that Khartooran Erg has two groups of sand dunes. The first group is composed of crescent and transverse dunes which have mild and steep slope faces (slip face). In this group, the direction of wind is consistent with mild slope face and the wind regime is unidirectional. The second group is composed of linear dunes with one or two mild and steep slopes. In both cases, the wind is shown in two directions with acute angle.

Studies have shown that in the above-mentioned groups, wind regime and sand supply are the most important factors in formation and development of dunes. That is to say whenever there are enough sand sources for sand supply and unidirectional or bidirectional wind is prevalent the creation and development of sand dunes are inevitable.

Also, based on an analysis of results of wind regime and direction in all various sand dunes in Khartooran Erg, it can be concluded that wind direction is eastern-north to western-south, while the strong wind being in north-south direction. It can also be said that sand dunes which are located in the adjacency of Erg, and are simple and separate, can be used as the most suitable criteria to determine the predominant wind.

Regarding the Erg location with respect to upper plains, it can be noted that sand sources are mostly originated from silt-clay flats of

ending part of Sabzevar Kal river rather than Jajarm Kal river.

In north and western north of the area, different structures can be seen regarding alluvial deposition, soil and land use type which can affect sand transportation rate. Therefore, these lands must be well evaluated before implementation of any plan.

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