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# Assessment of the planimetric morphology of barchan dunes

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ABSTRACT

Migration of sand dunes is accounted as one of the most important natural disasters in arid and desert regions. In this study, high resolution images are combined with field measurements in order to quantitatively study the migration and long term changes in the shape and morphology of barchans. The results indicated a power correlation between height and width of barchans ($R^2 \approx 0.93$). It also indicated that the outline of barchans can approximately be described by a parabola. Besides, the focal length, the curvatures (windward, leeward) and the brink parabola of the barchans were calculated; using differential geometry and mathematical modeling. Surprisingly, there was no significant difference between focal length and mean curvature of barchan parabola from 2001 to 2011 (p-value > 0.05). It seems the general shape of the studied barchans has not changed for long periods of time. The minimum and the maximum annual displacements of the barchans were 9 and 22 m, respectively, in the study area. It was also demonstrated that the best morphologic estimators for migration rate of dunes are in this order: width, mean curvature of windward parabola and height, focal length of windward parabola, and length.



## 1. Introduction

Arid and semiarid areas cover almost one-third of the land surface of the world (OIES, 1991). Barchans are one of the most important land forms in desert regions. They are crescent-shaped dunes that form under limited supply of sand, in approximately unidirectional winds and un-vegetated areas (Wilson, 1973). Sand dune migration is one of the most crucial problems in the southeastern and central arid regions of Iran, which gradually covers roads, farms, villages, urban areas and economic infrastructure. As the first step to manage and prevent catastrophic effects of sand dune migration, it is necessary to assess and monitor dune pattern in a region accurately (Levin et al., 2004).

The majority of studies on the dune migration have focused on the barchans, whose morphology is relatively simpler (Anthonsen et al., 1996; Bishop, 2001; Bristow and Lancaster, 2004; Cooper, 1958; Durán et al., 2005; El belrhiti et al., 2008; Mousavi et al., 2010; Pye, 1982). Because of the potential risk of the dune migrations for the residential areas, settled in the neighborhood, it is essential to understand the physical characteristics of the dunes and their migrations.

As measuring morphological characteristics of barchan dunes and a good understanding of their inter-relationships, helpfully, can explain their further movement behavior, it has been considered the main objective of the research. It is the main hypothesis of the research that employing a high resolution satellite dataset along with intensive field survey will provide a more accurate track of long term dune migration and their physical characteristics. In general, the studies focusing on the morphological characteristics of barchan dunes are very rare, and if any, are based on either short term or year-long studies (El belrhiti and Douady, 2011; Hugenholtz et al., 2012).

Because of expensive and time-consuming methods of studying the dunes and their morphological characteristics based on field surveys, remotely-sensed imageries increasingly offered to determine dune features and their characteristics. Remote sensing and GIS techniques are powerful tools to register land surface changes and to quantify dune migration. Improved spectral and spatial resolution of remotely-sensed data and progressive development of image processing techniques have significantly enhanced the ability of researchers to determine the dune features and their corresponding processes, much of which are neither readily visible in the earlier imageries nor in the original images of current data (Hugenholtz et al., 2012). In this study high resolution images are combined with field measurements in order to quantitatively study the migration and long term changes in the shape and morphology of barchans.

## 2. Methods

### 2.1. Data from field survey

A planimetric map of barchan dunes was produced, by selecting 30 barchans through an intensive fieldwork (Fig. 1). Then, the morphological

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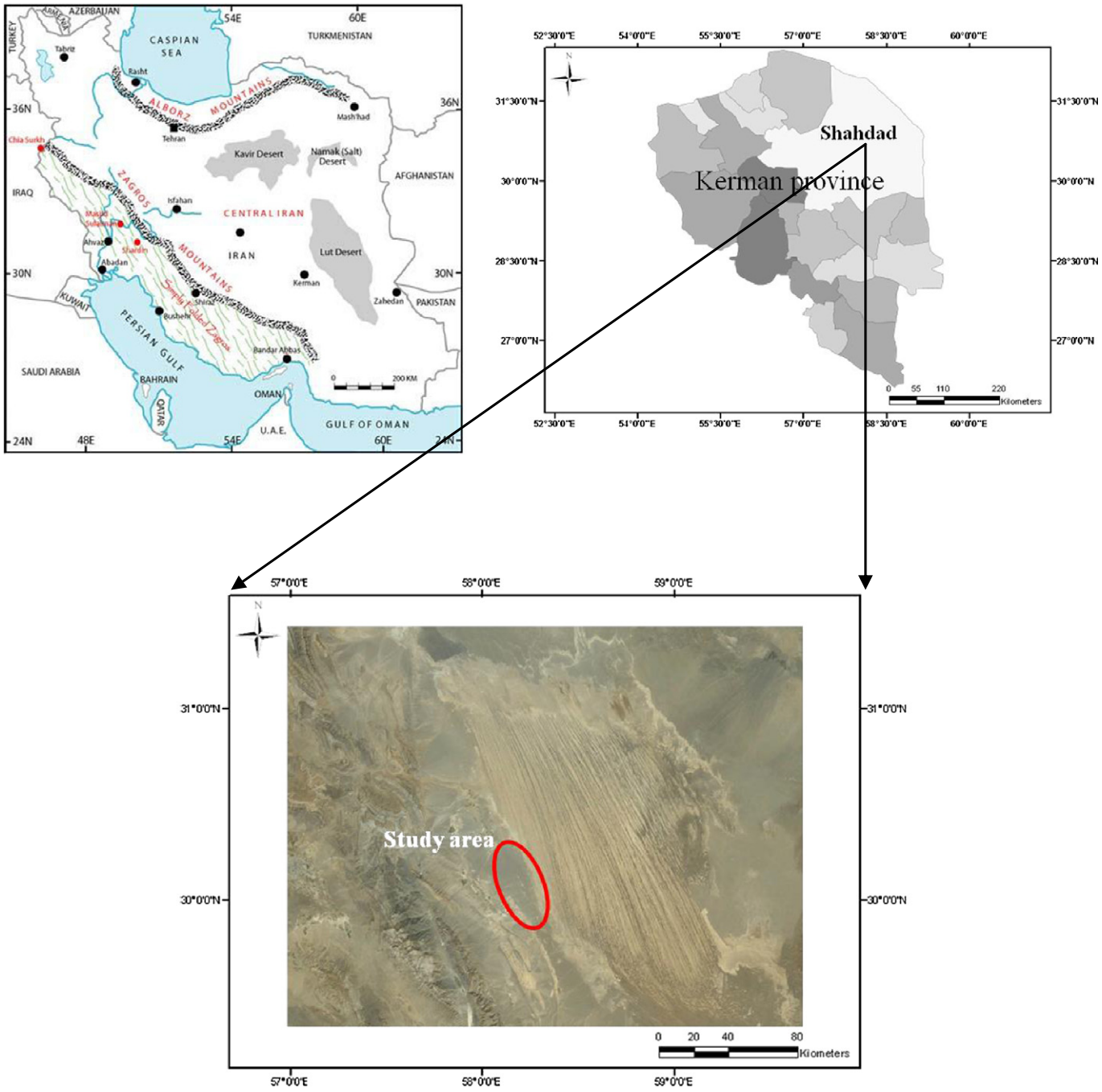


**Fig. 1.** The study area.

parameters of the dunes were measured; as illustrated in Fig. 2. As shown, $w_a$, $w_b$, $l_a$, $l_b$ and $l_0$ are the widths, the lengths of the two horns, the horizontal distance along with the axis of symmetry from the trailing edge to the upper edge of the slip face, respectively.

The survey has been done using a custom designed coordinate system based on the common Cartesian (x, y) axis, where the inflection point of the barchans' parabola was considered the center of the coordinate system. Then, the coordinates were projected on a graph paper and the equations of parabolas were determined using the method described in Section 2.2. In fact, this part was done to validate the equations obtained from the satellite images in Section 2.2 and also to ensure that the planimetric shape of barchans can be approximately described by the equation of parabola.

### 2.2. Mathematical modeling of barchan geometry

#### 2.2.1. The simple geometric modeling

In this step, we tried to describe the planimetric shape of the barchans, using geometric functions. Fig. 3 shows the best and the worst fit to the general equation. The preliminary results show that it can be described by parabola.

In mathematics, a parabola is a conic section, created from the intersection of a right circular conical surface and a plane parallel to a generating straight line of that surface (Lockwood, 1961). It can be described as $y^2 = 4xf$ in which $f$ is the focal length of the parabola. So, if the focal length is calculated, the equation of the parabola will be determined.