SAND DISTRIBUTION IN THE KHARGA DEPRESSION OF EGYPT: OBSERVATIONS FROM LANDSAT IMAGES

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ABSTRACT

Encroaching sands constitute a serious threat to the farmlands and villages of the Kharga Oasis in the Western Desert of Egypt. Landsat images of the region provide a broad overview allowing the identification of areas of future encroachment as well as zones apparently sheltered from the onslaught of the southward moving sand dunes. Five such sheltered sites were explored in the field to determine their feasibility for agricultural and village expansion. Additionally, observations were made on the effectiveness of various kinds of natural obstacles within the region as barriers to sand and wind.

1. INTRODUCTION

Concern over the widespread and unceasing onslaught of sands encroaching on inhabited and vegetated lands in the Kharga Depression of Egypt has prompted a study of the region using Landsat images. The unique perspective from Earth orbit provides a comprehensive view of the entire depression and surrounding region, thus enabling us to better determine the location, extent, trend, source, and possible future targets of the various sand deposits. In addition, the interaction of the sand with large scale obstacles in its path can be easily observed. In this study we have concentrated on the distribution of the Kharga dune deposits. Landsat images used include 1) 1:1,000,000 scale color (bands 4, 5, 7) and black and white (band 7) images, 2) 1:500,000 and 1:250,000 scale band 7 images, and 3) 1:250,000 scale computer-enhanced color composites (bands 4, 5, 7). Selected images spanned the time period from 1972 to 1978.

The Kharga Depression in the Western Desert of Egypt is an elongate hollow oriented in a roughly north-south direction (Fig. 1). It ranges from about 20 to 100 km in width and is bordered on the north and east by a steep disjointed scarp about 200 m high. On the west it opens onto the Dakhla Depression. The southern boundary is not clear-cut, as the depression floor blends gradually into the terrain to the south.

A few isolated hills (e.g. Gebel Tarif, 250 m high; Gebel Ter, 50 m high; and Gebel Ghennima, 150 m high) dot the otherwise basically flat floor (Fig. 2). Structurally, depression strata represent a subtle fold oriented nearly north-south which is delineated by beds with very gentle dips to the west-southwest and east-northeast (Said, 1962). Running down the middle of the depression is a series of steeply dipping faults (Embabi, 1967) along which much of the region's scant vegetation is centered. Other major structures in the region include several roughly northeast-southwest trending faults that cut across the eastern scarp. Although its origin has been debated, the depression is generally thought to have formed by wind erosion of less resistant beds originally exposed by tectonic activity (Beadnell, 1909; Ball, 1927).

Previous work on the Kharga Oasis region includes detailed accounts by Beadnell (1909) and Ball (1900). The prehistoric archaeology of the area is discussed by Caton-Thompson and Gardner (1932) and Caton-Thompson (1952). More recent summaries of the general geology have been presented by Said (1962) and Embabi (1967). Specific studies on the eolian deposits of the depression and their rates of motion include Ashri (1973) and Embabi (1978, 1982).

2. DUNE DEPOSITS

A map of the Kharga dune deposits was constructed using a 1:250,000 scale computer-enhanced Landsat color composite as a base (Fig. 3). Dunes in the Kharga region (as identified at Landsat resolution -- about 80 m) are concentrated in the eastern and central parts of the depression and on the plateau to the north. Sand deposits on the depression floor form a pattern of discrete, roughly north-south trending sand streaks which are composed largely of barchan dunes. Sand from the large Ghard Abu Muharik dune on the north plateau pours into the depression and is channeled into separate bands by wadis along the scarp (Bagnold, 1941; Gifford et al., 1979; Embabi, 1982). Because the wind within the depression comes consistently from the north, the Kharga dunes proceed southward maintaining the form of the individual streaks.

Figure 4 illustrates the monthly wind directions and relative magnitudes, and an annual resultant. Percent frequency of wind has been measured at the meteorological station located within the depression at 25°26'N and 30°34'E. The data were supplied in the form of N-summaries by the U.S. Air Force, Air Weather Service and span the years from 1957 to 1966. The data dramatically illustrate the consistency of the Kharga winds from month to month and at different velocity ranges. The Kharga region is said to be one of the windiest places in Egypt (Beadnell, 1909, 1910). The incessant effective winds move large amounts of sand onto villages, farmlands, and roads, but due to the uniform nature of these winds, they do so in a somewhat predictable manner.

The rate of movement of individual barchan dunes over a wide range of sizes in the Kharga depression was measured in the field by Embabi (1982). He found the rate to vary between 20 and 100 m per year with an average rate of 50 m per year. Dune motion was found to be strongly related to size and shape of the dune with larger dunes traveling slower and smaller ones faster. Good quality Landsat images spanning several years and processed at the same facility (so that they may be easily compared) should provide the capability to observe remotely the rates of motion throughout the entire depression. Rates determined in this manner, however, would not be representative of the very fastest (smallest) dunes whose sizes are below the resolution of the Landsat system. For this reason long timespans (10 years or more) of coverage will be required to observe the progress of the slower moving dunes.

3. SAND BARRIERS

The perspective from Landsat allows examination of the effects of various types of natural barriers that obstruct and influence the distribution of sand streaks. Vegetation, which effects the wind pattern and velocity can be seen to interrupt the regular dune streak configuration. A few isolated hills are also visible as obstacles to the wind-transported sand. The most notable of these are Gebel Tarif which presents a broad face to the oncoming sand, and the narrow Gebel Ter which is elongate in a north-south direction. Beadnell (1909) has noted that streamlined hills generally divert encroaching sands around either side whereas broad obstacles, such as Gebel Tarif, do not deflect the sand, but merely interrupt its progress briefly until it works its way up and over the barrier and continues on its previous course. Beadnell's observations are clearly illustrated on the Landsat imagery (Fig. 2) where sand is seen to travel over Gebel Tarif but not Gebel Ter. At Gebel Ter less sand is present but it is diverted around the hill leaving a clean, nearly sand-free area in the lee. Similarly, another elongate hill (arrow in Fig. 2), found on the plateau in the southern extremities of Ghard Abu Muharik, is a very efficient barrier creating a distinct sand shadow which extends down the scarp and along the depression floor. Despite their smaller size these elongate obstacles appear therefore to be the more efficient sand barriers.

The isolated hills, as well as the scarps bounding the depression, may also have large-scale effects on sand streak orientation. The sand streaks deviate from their regular parallel pattern between Gebels Tarif and Ter where they are diverted to the west, presumably by winds channeled between the two structures. The streaks also verge to the west in two places where the depression widens. Sand is diverted around the depression scarp at the point where the narrow northeast segment gives way to the main body of the depression (A in Fig. 1). At the southern edge of the Abu Tartur Plateau the depression again widens and winds can move, unobstructed, farther west. At this point a prominent sand streak also expands to the west (B in Fig. 1). This westward enlargement may be in response to the increase in depression width. Local slope may, however, be another factor influencing streak morphology (Embabi, 1982).

Observations also indicate that positive topographic features such as hills and scarps are not the only factors that effectively influence the patterns of sand distribution. In addition, negative topographic features such as wadis may be efficient sand barriers. The wadis along the northern Kharga scarp channel both wind and sand (Bagnold, 1941) and thus initiate the pattern of discrete streaks of dune accumulation and alternating interdune corridors. On an adjoining Landsat frame, just east of the region shown in Figure 1, wadis perpendicular to the path of oncoming sand can be observed to obstruct wide sand streaks which attempt to cross them. In several cases the entire streak is halted. In another example a streak becomes successively narrower as a series of wadis block part of the encroaching sand. These differing responses of sand to both negative and positive natural obstacles may have implications for the study of the interaction of manmade structures and encroaching sands.

4. FIELD CHECKS

Given the average rate of motion of the dunes and the unidirectional nature of the wind in the depression, it is possible to forecast dune positions in the future as well as determine the most likely places to remain dune-free for extended periods of time. We identified several such areas on Landsat imagery and were able to check five of them in the field. The field surveys to determine the suitability of these regions as sites for villages and farmlands were conducted in November 1981 by the second author with assistance from staff of the Geological Survey of Egypt and Ain Shams University, Cairo, Egypt. The sites, as indicated in Figure 3, are as follows:

Site 1 is located between sand streaks west of Gebel Tarif. It is a clear corridor extending about 40 km south from the northern scarp. Two very different types of soil were found in this area. The southern part exhibits carbonate-rich soil covered by chips of desert-varnished sandstone. The northern third is sparsely vegetated in places and is composed of thick playa deposits mixed with small amounts of sand. The presence of the sand increases the porosity, resulting in a soil which, if properly irrigated, would be suitable for agricultural projects such as the introduction of crops for grazing. Field observations indicate that near the north scarp the potentially productive zone is as much as 6 km wide. The presence of meter-size mudcracks (Fig. 5) indicates the occurrence of occasional rainfall. A nearby spring, more than a kilometer from the northern scarp, suggests the possibility of the existence of retrievable groundwater in the region.

Sites 2 and 3 are situated between narrow sand streaks south of Gebel Tarif. The terrain here was found to be quite rugged and the soil was sandy and unproductive.

Site 4 is located about 7 km east of Gebel Ter near the main road. It is made up of lacustrine deposits which have been carved by the wind into yardangs three or four meters high and tens of meters long. The area does not appear suitable for farming due to this rough topography. To the west of the road that runs southwest of site 4, however, are scattered patches of lake deposits about 1 or 2 kilometers square, which exhibit reasonably good soils.

Site 5, by virtue of its size, location, and soil, exhibits excellent potential for the expansion of villages and agricultural activities. There does appear to be a distant threat of dune encroachment but, given the average rate of movement of 50 m south per year, the northernmost reaches of this area should not be affected by the dunes visible on Landsat imagery for more than a century.

5. CONCLUSION

The perspective gained through the use of Landsat imagery of the Kharga depression allows the relatively rapid identification of areas of dune accumulation and sand-free interdune zones. Furthermore, the remarkably consistent nature of the Kharga winds creates a "natural laboratory" for observing the interactions of wind-blown sands with barriers of different shapes and properties. The information gained from study of the images, with accompanying groundtruth, is exceedingly important to the planning of agricultural expansion in the region and to the selection of new village sites. The contribution from Landsat is timely in view of the fact that the Government of Egypt is planning further development of this region as part of the New Valley Project during the coming decades.

ACKNOWLEDGMENTS

The help and cooperation of H. E. Mahmoud El-Prince, Governor of the New Valley Province and Dr. Bahay Issawi of the Egyptian Geological Survey and Mining Authority are much appreciated. All field work was performed through their courtesy. We wish to thank Rosemary Aiello for aid in the preparation of figures and Donna Slattery for typing the manuscript.

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Figure 1. The Kharga Depression

This Landsat image (frame number 1110-07651), processed by the Earth Satellite Corporation, shows the Kharga Depression (lower left) and the surrounding plateau. The image is 185 km across. The Nile Valley is seen in the upper right. The uplands and scarps around the depression are deeply incised by wadis which are remnants of old drainage systems. The plateau also exhibits long wind-carved lineations trending in a roughly NW-SE direction. The scene is from November, 1972, and clearly shows the numerous sand streaks which endanger the vegetated lands (dark regions in center of depression).

Figure 2. Portion of Landsat frame acquired November, 1975.

Image displays interaction of sand with small hills in its path. Arrow designates elongate hill mentioned in text.

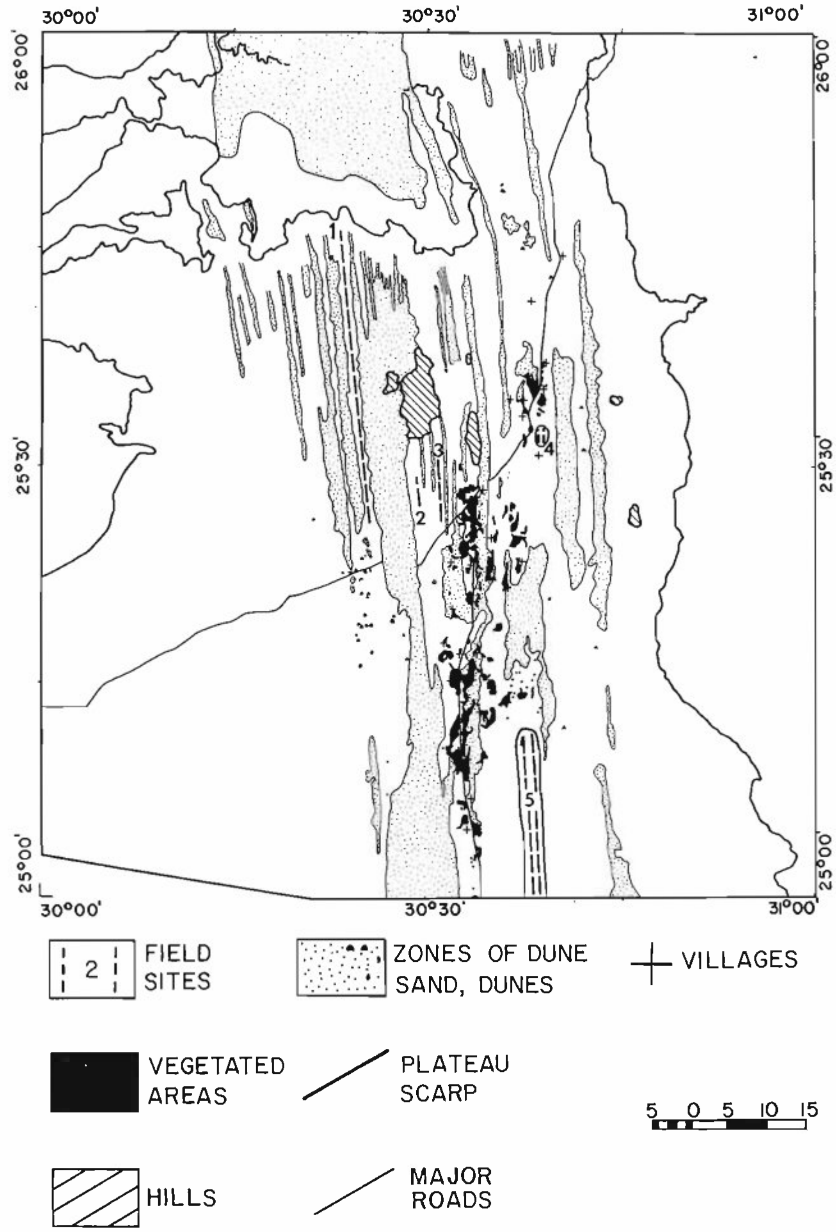

Figure 3. Map of distribution of sand dunes in the Kharga region as visible on Landsat imagery.

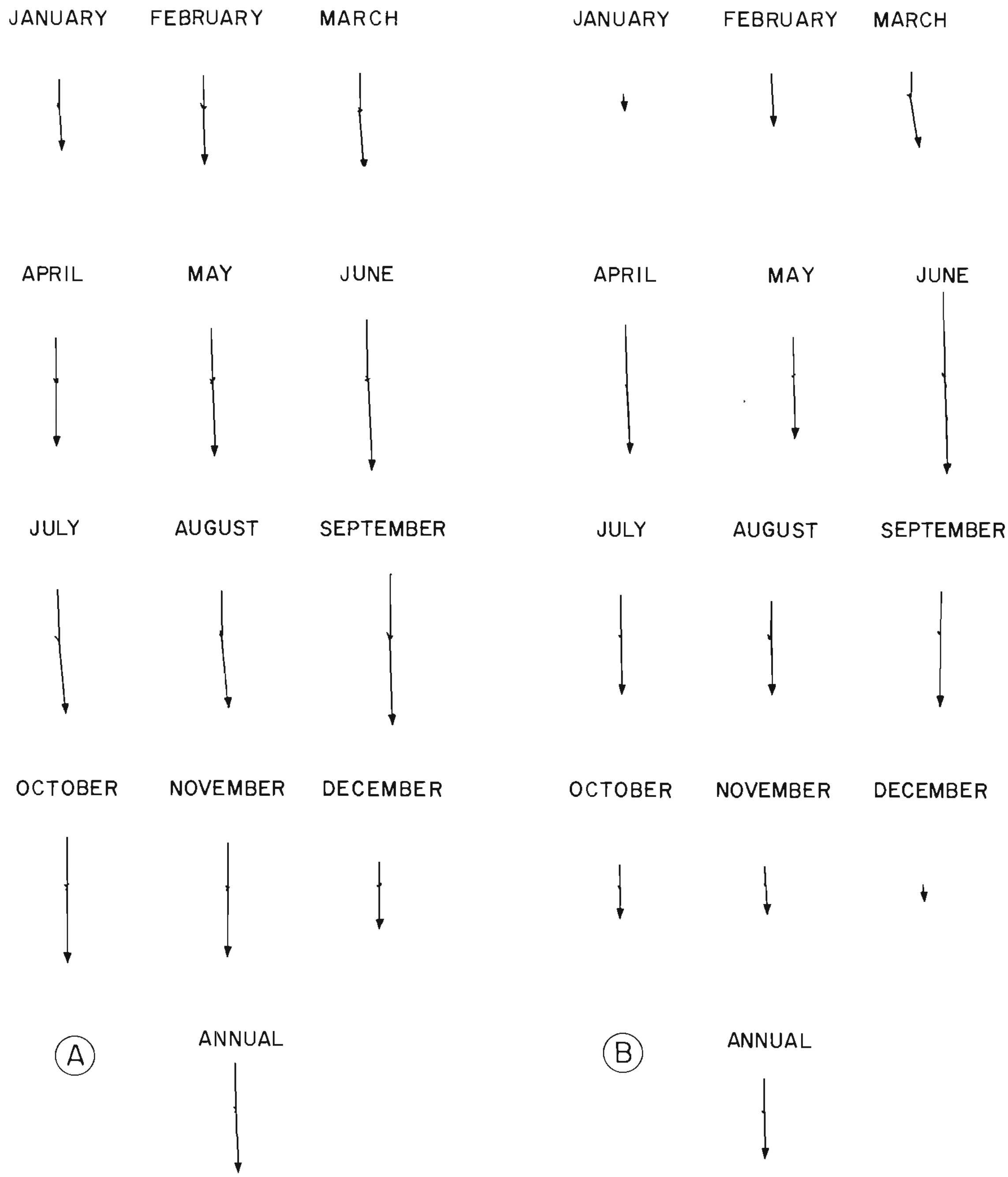

Figure 4. Relative wind magnitude and direction in the Kharga Depression

Wind roses indicate percent frequency of wind in each of 16 directions. Arrows beneath roses depict the resultant magnitude and direction. A) All winds. B) Winds over 17 knots. Enlargement factor relative to A is 9X.

Figure 5. Meter-size mudcracks in lake deposits in the northern section of Field Site 1.