Abstract. Serious geological hazards have been recognized in the new development urban areas and road construction in west of El-Kawamel area, Sohag, Egypt. These geological problems are due to the presence of sand dunes, sand sheets, and sand accumulations. Three different types of sand dunes, sand sheets, and sand accumulations have been detected including, sand dunes (Barchan type), sand sheet (cover flat area), and sand accumulations (along the mountain slopes). Three strip zones of sand dunes/sheets/accumulation were recognized and mapped by using remote sensing techniques. Decorrelation stretch methods associated with parallelepiped image classification were the best techniques for mapping and isolating these sand dunes/sheets/accumulations. Detailed field investigations showed that barchan dunes are dominant in zone 2 and sand sheets/accumulations in zone 1 and 3, also sand accumulations are dominated along the slopes of the cliffs and deposited behind the obstacles in the area. Our findings showed that sand dunes/sheets/accumulation pose some geological hazards on roads, surrounding buildings and constructions in the new development areas. Different remediation methods have been assigned to protect and minimize these geological hazards in the study area.

Keywords: Remote sensing, Sand dunes/sheets/accumulations, Mapping, Hazards, Remediation.
**Introduction**

In most of arid environment throughout the world, the geologic processes of sediment weathering, transport, and deposition are constantly ongoing within active sand-transport pathways. The analysis of sand accumulation composition and movement is critical for the interpretation of past climatic conditions, local geology, environmental hazards, and future desertification potential. This type of comprehensive study typically involves many years of data collection, mapping, and sample classification (Sharp, 1966 and Muhs et al., 1995). Although detailed field and laboratory studies of this nature are extremely valuable, their magnitude and temporal dependency can clearly lead to generalizations in both the source and amount of mineralogic heterogeneity within a large dune field.

Recently, the use of remote sensing over the past several decades as a tool to study dynamic features such as dunes and sand accumulations has given the geologist a synoptic view of entire eolian systems as well as their sediment sources (Breed and Grow, 1979; Blount et al., 1990 and Edgett and Christensen, 1995). In addition, the ability to examine changes over time allows for the extrapolation of past climatic regimes and the monitoring of marginal areas susceptible to future desertification (Otterman, 1981 and Tucker et al., 1994).

Sohag Governorate is one of the highly populated areas in Egypt. Its climate is dry and hot in summer with temperatures often ranging from 35°C to 44°C and cold in the winter with average temperatures falling 10°C. Humidity ranges between 10% and 13% in summer and from 40% to 44% in winter. In the last decade the development of Sohag governorate has been increased to cover most of the old flood plain areas (located between the recent flood plain of the Nile and the Limestone Plateau from east and west). These developments include reclamation areas (to increase the agricultural lands), urban areas (that will decrease the dramatically increase in the urban areas existing in the Nile Valley), and desert highways (to facilitate the connection between different parts of Egypt). Most of the new development areas have invaded hazard prone areas. One of these new development activities is the new urban projects at west of El-Kawamel village include establishing a new urban city called New Sohag city and a new Sohag University as well as many different roads (Fig. 1).
The aim of this study is to map, extract, and examine the sand dunes/sheets/accumulations in the area and their impact on the new development area. A detailed objective includes 1- mapping the sand dunes/sheets/accumulation distributions along the study area using remote sensing technique. 2- mapping the main zone directions of these sand dunes/sheets/accumulations, 3- field investigating to determine the characteristics of sand dunes/sheets/accumulations and their geological hazards to the study area. Several characteristic parameters were used including, satellite images, field study, and laboratory analysis.

**Physiographic Features**

The physiographic features in the area under investigation can be divided into four main types (Fig. 1b); 1) Limestone plateau; a monotonous plateau of resistant limestone deeply incised by the different drainage system; 2) The recent flood plain of the Nile River that is characterized by a flat region occupied by many urban areas, agricultural areas and canal and road systems; 3) The old flood plain (Low desert zone) which represents the fringes of the Nile valley and is characterized by elevation 75 to 200 m above sea level; and 4) Drainage pattern (transverse channels): There are many drainage systems that cut the limestone plateau and discharge their waters towards the low desert zone and the flood plain of the River Nile.

![Fig. 1. a) Egypt satellite image mosaic showing the location of the study area. b) Shows the different physiographic units in the area west of Sohag. Note the stripped box is the study area in which the two development areas, the new Sohag University to the north and the New Sohag city to the south, are in rose color.](image-url)
The study area is very important because it has a new urban development which includes new Sohag city, New Sohag University, and other infrastructures facilities such as roads and highways.

**Methodology and Results**

**Using Remote Sensing for Sand Dunes/Sheets/Accumulations Mapping**

Satellite images have been used as effective exploration tools in detection of structural elements and lithological mapping (Drury, 2001; Gupta, 2003 and Jensen, 2000), as well as the detection and mapping of clay deposits (Youssef, 2008a) and mapping the aggregate deposits (Youssef, 2008b). The spectral resolutions of new Remote Sensing data can help in the differentiation of varieties lithological units. Digital image processing such as band ratio, principal components analysis, and decorrelation stretch are the techniques perhaps most commonly applied in the analysis and interpretation of satellite data for geologic hazards studies as mentioned and used by Youssef 2008a&b. Many authors have reported the application of Remote Sensing on exploration and study of sand dunes such as (Balduzzi et al., 2006; del Valle et al., 2008; Paisley et al., 1991; Tucker et al., 1991; Blount, 1988; Karnieli, 1997; Ben-Dor et al., 2006 and Ramsey et al., 1999).

The original data for the west of El Kawamel region were acquired on September 2007, which include two data types 1) enhancement thematic mapper data with a resolution of 15 m and 2) QuickBird imagery with a ground resolution of ~61 cm/pixel. The QuickBird images are commercial high resolution satellite, has been launched in 2001 with a meter to sub-meter spatial resolution (0.61 meter for the panchromatic band). The main technical characteristics and specification of the sensors used with Enhanced Thematic Mapper and QuickBird sensors are shown in (Table 1). Digital Globe, the provider of QuickBird data, offers different image data products with varying corrections. Corrected imagery has been used in this research. QuickBird panchromatic and multi-spectral images in 'Ortho Ready Standard' format from 2007 were acquired.

A visual interpretation was performed on the high resolution QuickBird data to obtain a more detailed derivation of the development in the area on a larger scale. For this purpose a fused image, from the panchromatic and the multi-spectral channels, has been generated. In
other hand, the data of enhanced thematic mapper with a resolution of 15 m have been used. The results of the Enhanced Thematic Mapper (ETM+) were integrated into the

Table 1. Technical characteristics of QuickBird Digital Globe satellite sensors (after Kramer, 2002) and ETM+ data.

<table>
<thead>
<tr>
<th>Satellite sensor; Provider</th>
<th>Spectral Bands</th>
<th>Spatial resolution</th>
<th>Average revisiting time; off-track viewing angle/swath width</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuickBird DigitalGlobe</td>
<td>Panchromatic: 450-520 nm</td>
<td>0.61 m</td>
<td>1-3.5 days ±30°</td>
</tr>
<tr>
<td></td>
<td>520-600 nm</td>
<td>2.44 m</td>
<td>16.5 km</td>
</tr>
<tr>
<td></td>
<td>630-690 nm</td>
<td>2.44 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>760-900 nm</td>
<td>2.44 m</td>
<td></td>
</tr>
<tr>
<td>Enhanced Thematic Mapper</td>
<td>Band 1, 2, 3, 4, 5, 7, Band 6, Band 8</td>
<td>30 m, 60 m, 30 m, Panchromatic 15 m</td>
<td>16 days, 183 km wide swath at an altitude of 705 km</td>
</tr>
</tbody>
</table>

GIS environment for identifying the distribution of sand dunes/sand sheets/sand accumulations. In addition, a decorrelation stretch (DS) of the data (bands 742 in RGB of the ETM+) showed significant color variations throughout the study area, indicating spectral and therefore compositional differences between sand dunes/sheets/accumulations and the surrounding materials (Fig. 2). Decorrelation stretch is a color enhancement technique that is based on a principal component transformation. It is particularly useful when displaying multispectral data that are highly correlated. DS involves exaggeration of the least correlated information in an image, primarily in terms of saturation, with minimal change in image intensity and hue. It has been used for a long time (Soha and Schwartz, 1978; Gillespie et al., 1986; and Abrams et al., 1988). DS has been applied on the selected band triplet (742 in RGB of the ETM+). The decorrelated image obtained from stretched data gave an image with better color saturation. Figure 2 shows the resulting image in which the sand dunes/sheets/accumulations can be recognized (yellow color) from the surrounding materials.
Image classification is the technique of assigning pixels of the image to classes based on the spectral reflectance characteristics of each image pixel. The parallelepiped method was used to implement the supervised classification. Richards (1999) mentioned that parallelepiped classification uses a simple decision rule to classify multispectral data. The decision boundaries form an n-dimensional parallelepiped classification in the image data space. The dimensions of the parallelepiped classification are defined based upon a standard deviation threshold from the mean of each selected class. If a pixel value lies above the low threshold and below the high threshold for all n bands being classified, it is assigned to that class. If the pixel value falls in multiple classes, ENVI assigns the pixel to the last class matched. Areas that do not fall within any of the parallelepiped classes are designated as unclassified. The supervised classification, parallelepiped, was used on the decorrelation stretch image and the data were shown in Fig. 3. The results showed the distribution of the sand dunes/sheets/accumulations in the selected area.
Fig. 3. Distribution of sand dunes/sheets/accumulations in the area under investigation appeared in yellow color and the surrounding areas in black color due to parallelepiped supervised classification. Note the location of the new development projects and the highway in the area.

Field Investigation

Many authors classify dune type according to morphological criteria among them Breed and Grow (1979), and McKee (1979). In the current study, many field trips have been accomplished to determine the different factors affecting these sand dunes/sheets/accumulations. It was found that there are three different types including 1) sand dune (Barchan type); 2) sand sheet type; and 3) sand accumulation type. Field analyses of the sand dune (Barchan type) have been done to identify its geometrical characteristics and its impact on the area.

Field investigation shows that the Barchan dune type has a parabolic face type (slip face) with long tail. The highest point on the slip face side is about 8 meter with a slope angle reach 32 degree. The distance from the center of the crest to the end of each limb (horn) about 52 m. the windward slope angle (lee face angle) ranges from 7.5 degree close to the crest and reach 10 degree for the rest as appeared in Fig. (4).

The prevailing wind direction in the study area is mainly from the NW–SE with speeds ranging between 2 and 50 km/h. Field observations,
however, indicate that the general sand movement in the study area is from northwest to south east, from north to south and sometimes from west to east depending on the different obstacles. The dominant dune type in the area is the barchans type (zone 2). The rate of the barchan dune movement is relatively high and it is a function of dune height and wind velocity. The sand-grain size plays a major factor that affects the value of the threshold velocity and, consequently, the overall rate at which sand moves (Howard et al., 1978).

Fig. 4. a) Plane view diagram showing the real geometry of one of the Barchan dune type. b) sketch for the longitudinal section showing the changes in the angle along the central line from crest to toe of the dune.

Bagnold (1941), and Lettau and Lettau (1969) included the grain size in their sand movement equations together with the wind speed and the threshold velocity. Shehata et al. (1992) believe that the grain size and other parameters such as relative density, mineralogical composition and consequently the sand specific gravity, salt and moisture content, affect the threshold velocity of sand. Irtem et al. (1989) showed that the amount of drifting sand depends also on the dune type. The rate of dune
movement depends mainly on its height, wind speed, and presence of vegetation.

Barchan dunes move faster than dome dunes and those are still faster than the parabolic dunes (Shehata et al., 1990b). However, it was interesting to notice that the sinuous nature of the crest line played an important role in sand transport. Bagnold (1941) indicated that the threshold velocity of the drifting sand increases with the increase in grain sizes for sand greater than 0.1 mm in diameter. The reversal nature of the dunes and the energy consumed in their winding movement could have retarded their forward movement. The sand dune which is existing in the Western Desert in Egypt, the Great sand sea, covering an area of about one third of the Egyptian territory. Within the sand seas, the wind speed is generally 4.0 m/s or higher during the months May through September (Anon, 1984) as reported by the meteorological stations.

Discussion

Based on the field geology, physiographic, and urban and road development features in the study area, the potential of active sand dunes/ sand sheets/ sand accumulations are located in the study area which can be called local sand dunes/sheets/accumulations. These sand dunes/sheets/accumulations are active and they impose hazards for the area where many sections of the roads and the development areas are closed and covered by these sand deposits. Field and high resolution satellite images showed that these sand dunes/sheets/accumulations are distributed in three parallel strips (Fig. 5). The zone 2 dune type is related to barchan dune type (Fig. 6). On other area, sand sheets/accumulations are located to cover flat areas (sand sheets) and the mountain slopes (sand accumulations). These sand sheets and accumulations can reach the low desert zone and cause some problems (Fig. 7).

Many problems are associated with sand dunes/sheets/accumulations where building foundations may completely cover (Fig. 8). Figure (9) shows different problems related to sand dunes/sheets/accumulations in which the university fence wall was completely covered by a barchan dune type, partial closure for roads and other areas.
Fig. 5. High resolution satellite images showing the three main sand-transport pathway of the sand dunes/sheets/accumulations of the West El-Kawamel, which are derived from the western desert plateau. The prevailing southeast wind direction is the predominant winds that keep the dunes active, overlapping the recent alluvial fans in the low desert region.

Fig. 6. High resolution satellite image showing barchan dune type in zone (2) which crosses the New Sohag University.
Fig. 7. High resolution satellite image shows sand sheets/sand accumulations along flat areas and on the mountain side in the study area.

Fig. 8. a) High resolution satellite images shows zone (3) sand sheets and accumulations partially close the western road of the new Sohag city. b) High resolution satellite images show zone (1) sand sheets/accumulations partially close the northern road surround the new Sohag city.
Fig. 9. (a & b) Photographs showing barchans dune collected behind the new Sohag University wall fence in the study area, (c) Photograph shows sand accumulations partially close the road, and (d) Photograph shows sand sheets/accumulations on the flat areas and mountain sides.

Mitigation and Remediation Processes

As remedial measures, dunes were stabilized by vegetation, by fences, by chemical spraying or by other mechanical means. Watson (1985) reviewed different methods of sand control with special reference to the Kingdom of Saudi Arabia. In the current study the sand dunes/sheets/accumulations are not covered by large areas and can easily be controlled.

The use of vegetation and/or naturally occurring stabilizers usually shows better performance than man-made chemicals or fences. The design of a remedial measure is usually based on quantitative estimates of the magnitude of the affected area, the amount of drifting sand or dune movement rate, the prevailing wind direction, and the types and rate of growth of the selected vegetations.

Stabilizing the drifting sand is a costly continuous process. It involves various disciplines and requires good coordination to obtain reasonable results. Although there are several methods of stabilizing sand
dunes/sheets/accumulations, they cannot be generalized for every case. Each area requires its own unique method of solution based on the complexity of various factors involved. Different methods for stabilizing sand dunes/sheets/accumulations will be highlighted here. All these methods are applicable and are easily used.

(1) Using fences which have been studied and tested in the field and gives its effective action to stop sand movement in many areas before.

(2) Sand stabilization by waxy oil also proved to be successful method and should be applied to cover the active areas. It forms a relatively firm crust that protects the sand surface and prevents sand movement.

(3) Solid covers such as asphalt, concrete pavement, and gravel are efficient but expensive for a wide area application.

(4) Mechanical removal of sand is a common practice especially for roads.

(5) Other measures include trenching to destruct the dune natural shape.

(6) Another method such as vegetation is the most desirable and permanent solution to blown sand, but the availability of water and type of plant may hinder its benefit to be used for stabilization.

For the study area some methods for stabilizing sand dunes/ sand sheets/ sand accumulations, will be highlighted here. These methods are applicable and easily used including (1) Using fences such as walls that will accumulate sands behind them and protect the areas from the sand movement. These fences need to be maintained from time to time. (2) using waxy oil especially above the areas of sand accumulations that located away from the development areas. (3) using asphalt, concrete pavement, and gravel inside the development areas. (4) Mechanical removal will be effective from time to time to remove sands from roads. (5) Vegetation of the development areas along roads and other green areas that will stop the blown sand.
Conclusion

The present study deals primarily with the use of Remote Sensing techniques and field investigation to map different types of sand dunes/sand sheets/sand accumulations in the study area. A decorrelation stretch method associated with parallelepiped image classification technique were succeeded in detecting, mapping, and isolating sand dunes, sand sheets, and sand accumulations in the study area.

Detailed field investigations showed that barchans dunes are dominant in the area especially in zone (2) and sand sheets and sand accumulations in zone (1) and (3), especially to cover flat areas as sand sheets and along the mountain slopes as sand accumulations. The study also indicating that sand dunes/sand sheets/sand accumulations, may occur in/and around the new development projects west of Sohag City, Egypt, impose serious geological/environmental problems.

These problems appeared as the pressures of an expanding population, urban, and infrastructure activities encourage the use of more hazard-prone areas. Different types of remediation methods have been introduced to prevent and avoid this type of the geological/environmental hazards.

References


تخريج الكثبان الرملية باستخدام الاستشعار عن بعد وأخطارها المحتملة في المشروعات الجديدة
غرب منطقة الكوامل - سوهاج - مصر

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المستخلص: تم التعرف على المخاطر الجيولوجية في المناطق الجديدة للتنمية العمرانية وبناء الطرق في غرب منطقة الكوامل - سوهاج - مصر. هذه المشاكل الجيولوجية ناتجة عن تواجد الكثبان الرملية وتراكم الرمال. تم اكتشاف ثلاثة أنواع مختلفة من الكثبان Barchans والترامكات الرملية والتي تمثل على الكثبان الرملية (Type) الملائات الرملية وانحراف الرمال. تم تحديد وتخيريط ثلاث نطاقات تمثل اتجاهات تراكمات الرمال باستخدام تقنيات decorrelation stretch الاستشعار عن بعد. ولقد تم استخدام طريقة parallelepiped مع عملية التصنيف الموجهة للتصورة باستخدام ووجد أنها من أفضل التقنيات لتخيريط وعزل الكثبان والترامكات الرملية. وأظهرت الدراسات الميدانية التفصيلية أن الكثبان الرملية من النوع barchans هي المهيمنة في المنطقة وخاصة في المناطق رقم (2)، والملاءات / التراكمات الرملية تظهر في النطاق رقم (1،3) من ناحية أخرى لوحظ أن الانحرافات الرملية تتركز على طول سفوح المنحدرات وتترسب وراء العقبات في المنطقة. وأظهرت النتائج التي توصلنا إليها أن الكثبان الرملية / وترامك
الرمال تظهر بعض المخاطر البيئية / الجيولوجية على الطرق والمباني المحيطة والمنشآت في مناطق التطور الجديدة. وقد يتم تعيين طرق المعالجة المختلفة لحماية المناطق من مخاطر الكثبان الرملية / وتراكم الرمال.