Proceeding of the 7th Conf. Geology of Sinai for Development
Ismailia, 2004, pp. 169-180

DYNAMICS OF SAND DUNES MOVEMENT AND THEIR ENVIRONMENTAL IMPACTS ON THE RECLAMATION AREA IN NW SINAI, EGYPT

G. Philip[1], O.E.A. Attia[1], M.Y. Draz[2], and M.S. El Banna[2]
[1] Geol. Dept., Fac. Sci., Cairo University
[2] Desert Research Center, Mataria, Cairo.

ABSTRACT: The main constraints for sustainable agricultural development in Sinai are essentially the migration of sand dunes that occupy about 5000 Km^2 of the coastal zone. This adversely affects the cultivated lands and the newly reclaimed areas. The study area is located at the NW corner of Sinai Peninsula and it .is subjected to sand dune encroachment. Movement of sand dunes causes severe damage to the human settlements, roads, irrigation and drainage constructions. Migration of aeolian sands results in the migration of longitudinal dunes at a rate of 2.25 m/y for those south of Bir El Abd and 13 m/y at Wadi El Gady. The rate of barchan dunes movement at Wadi El Massaged is 3.5 m/y. Also, a lateral movement of the segments of longitudinal dunes is recorded south of Bir El Abd and at Wadi El Gady. The morphodynamic model of the longitudinal dunes shows that deposition (percent) on the longitudinal dunes south of Bir El Abd is low relative to erosion. However, deposition on the longitudinal dunes at Wadi El Gady is relatively high comparing to erosion.

The movement of sand is towards the SE and E as indicated from the annual sand roses, due to stronger winds from the NW and W. The Resultant Drift Potential (RDP) is relatively high in the western part of the study area, while the lowest RDP is at Bir El Abd. The wind variability, as deduced from the ratio RDP/DP is relatively high at Ras Sudr, and intermediate at the other localities of the study area. Moreover, the physical characteristics of the aeolian deposits, topographic, climatologic and environmental conditions enhance the sand dune movement in the different locations in study area which necessitate their control. The suitable method to control sand encroachment need more studied.

1. INTRODUCTION

Aeolian deposits cover about 160000 Km^2 of the Egyptian land representing about 16% of the total surface area of the country (Mounir 1983). At present, Sinai Peninsula undergoes a phase of reconstruction from the agriculture view point, and is witnessing great efforts for comprehensive development. The main constraints for sustainable agricultural development in Sinai are summarized in the migration of aeolian sand dunes that occupy about 5000 Km^2 of the coastal zone. This adversely affects the cultivated lands and the newly reclaimed areas, also causes severe damage to the human settlements, roads, irrigation and drainage constructions. Consequently, several studies carried out concerning sand dunes characteristics in the study area where Tsoar (1974) studied the transverse and longitudinal dunes of El Arish region and Kamel et.al. (1982) used Landsat satellite images to study transverse, barchan and linear dunes in N Sinai. Moreover, the rate of sand dune movements and possible source of sand were studied (Misak and El Shazly 1982), as well as dune morphology (Miska and Attia 1983). Dynamic processes acting on he linear dunes of Sinai were carried out by Tsoar (1983, 1989). Tsoar and Moller (1986) studied the relation between the dune elongation and the dominant wind direction between Sinai and Negev. In 1990, Abu ElEinein et.al. used Landsat (MSS) images to study dune encroachment. Draz (1997) suggested regional priorities for combating shifting sand. Also, the net annual movement of longitudinal and barchan dunes at Sheikh Zuweid was measured by El Banna (1999).

The present study aims to throw more light on sand drift, rate of dune movement, the dynamics of sand dune movement and related environmental hazards in Sinai.

The study area is located at the NW corner of Sinai Peninsula between Lat. 30° 10′ and 31° 00′ N and Long. 33° 45′ and 32° 30′ E. It is accessible through many asphaltic roads such as Bir El Abd – El Gefgafa and Ismailia –Gefgafa roads. Geomorphologically, the study area can divided into structural highs, structural plateaux, structural plains and fluvial plain.

Structural highs form the main structural element in the study area represented by G. El Maghara, G. Yelleg and G. Um Khishib (Fig. 1), whereas The structural plateaux occupy some of the synclinal areas between the structural highs (Said 1990). Some landforms are associated with the structural plateaux such as, questas, and hamada, also karstification is noted in some areas. Karstification features are recorded in the calcareous plateaux, represented by solution cavities, fissures and overhanging cliffs as seen in Umm Khushayb area.

The structural plains cover most of the study area. They occupy much of the lowland areas between both the structural highs and the elevated structural features and the low coastal plains. The surface of the plains, in some localities is flat and gently undulating, but is sloppy in other localities. The surface is either underlain by barren rocks (inland plain) or covered by alluvium and drifting sand. The structural plains are best

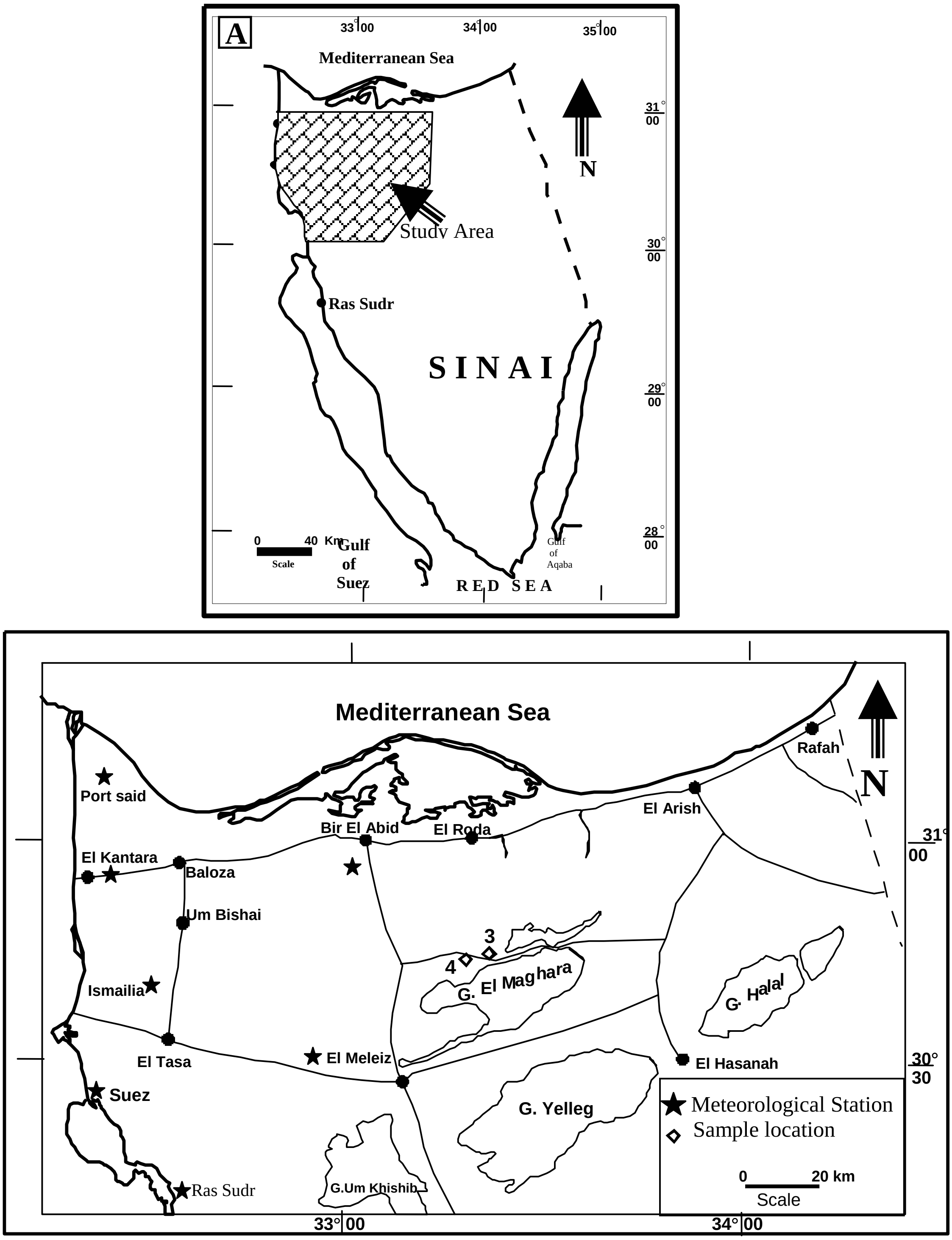

Figure 1. Location maps: A- The study area. B- Location of stations for measurements.

represented by the great El Gifgafa-El Hamma synclinal plain between Yelleg structural high to the southeast and El Maghara structural high to the northeast (Fig. 1). The structural plains comprise the following surface features: 1-Sand dunes forming several lines of seif and isolated barchans, 2- Playas cover many places, especially at the down stream of wadi El Gifgafa (east El Gifgafa village) where they dotted by sand accumulations in the form of hummocks, and 3- Proluvial deposits in some places of El Gifgafa- El Hamma plainwhich suitable for land reclamation where favorable soil potentials exist. Other structural plains occupy the down faulted portion of northwest Sinai. These plains merge into the Nile Delta and the Gulf of Suez plain to the west and the Mediterranean plain to the north (Said 1990). These plains comprise two landforms: Shifting sand dunes and alluvium fans with varying size at the feet of the mountains and in the down streams of the drainage basins. The first landform cover a wide portion of these plains where adjacent to El Maghara high, these sand dunes trend northeast parallel to Gebel El Maghara. These dunes are in the form of seif dunes and isolated barchans of the active type. The active sand dunes encroach on many of the roads in the area.

Fluvial Plain occupies a limited portion of the study area, to the east of Ismailia and El Kantara towns. The surface is not much different from the coastal and foreshore plains. It is affected by the activities of shifting sand (associated in part with the dredging of the Suez Canal), the severe salinization processes and the oscillation of sea level. Halophytic plants dominate the surface.

2. METHODOLOGY

Three methods used in this study. The first one is the calculation of sand drift potential by applying the average effective-wind speed (Fryberger 1979, McKee 1979). Where it is the first time in Egypt to take actual reading from the field. The measurements were taken at El Kantara Shark, Ismailia, El Meleiz, Bir El Abd, Port Said, Suez and Ras-Sudr stations (Fig. 1). Weighting factor is the term used by Fryberger (1979) to represent the values of the relative rates of winds of different average velocities, which can move sand. The weighting factor is calculated by substituting the wind velocity values (average of wind speed velocity) by the weighting formula (Mckee 1979). The calculated weighting factors for the relative rate of transported sand in the study area are given in Table 1. These values can be divided by 100 to reduce the weighting factor size for convenience in plotting of sand roses (Fryberger 1979), representing the potential sand drift from the 12 directions of the compass. The lengths of sand rose arms are proportional to the potential sand drift from a given direction as computed in vector units (Fryberger 1979). Sand roses of the sand drift potential were plotted representing each season as well as the sum of the annual data at each station (Figs. 2 and 3)

The second method is by using the total station method (Leica TPS system 1100), with the aid of two fixed control points of known coordinates (easting, northing and elevation). It is used for the topographic survey of crest lines of the longitudinal dunes to the south of Bir El Abd (Bir El Abd – Gevgava road) and Wadi El Gady, as well as the crest line of barchan dunes at Wadi El Massagid. AutoCAD and Surfer programs that could determine the elongation and lateral movement of the dune were used, the first enabled the construction of a morphodynamic model for both the deposited and eroded material.

The third method used to determine the direction and average amount of movement for the individual dune is by comparing two sets of aerial photographs (scale 1:40000, May 1958) and TM landsat satellite images (1998) as well as topographic sheets (1:50000). Computer programs (Adobe Photoshop, Microsoft Excel) and Erdass Imagine 8.5 for image processing and GIS solutions are also used. The topographic sheets were scanned using Calcomp A0 scanner and VIDAR ection Software, then enhanced spectrally and radiometrically, followed by geometric correction using Erdass Imagine 8.5 software (Raster Module-geometric correction). The selected dunes were traced (in a vector layer) from both the aerial photographs and the TM satellite images in a new vector layer. The vector layers were cleaned, built and all parameters were measured. In the last stage, both vector layers was placed overlying each other for comparison. Tables 2 and 3 give the distance and direction of elongation of the longitudinal and movement of barchan dunes in the study area.

A new technique is used to measure changes in the magnitude and direction of wind near the ground, where the actual sand movement occurs by using micrometeorological measurements where these measurements were carried out by using a portable metrological station produced by Met One Instruments, USA. The instrument contains seven sensors, which measure the wind speed and direction. The sensors are connected to a data logger by cables. The data were retrieved to the computer through Micromet software. Measurements that recorded changes in the magnitude and direction at various points along the dune were taken across the two flanks of the dunes. From the cross section or map, a graph, which presents the wind measurements at various points, is attached. Each measurement unit covers a time of five minutes.

3- RESULTS

Fryberger (1979) used the term resultant drift potential (RDP), expressed in vector units, representing the net sand transport potential when winds come to intersect from various directions. Also, he used the ratios RDP/DP is used as an index of the directional variability of the wind. This ratio approaches unity when wind comes from the same direction while it becomes zero when wind comes from different directions because of the very low RDP (Misak and El Shazly 1982).

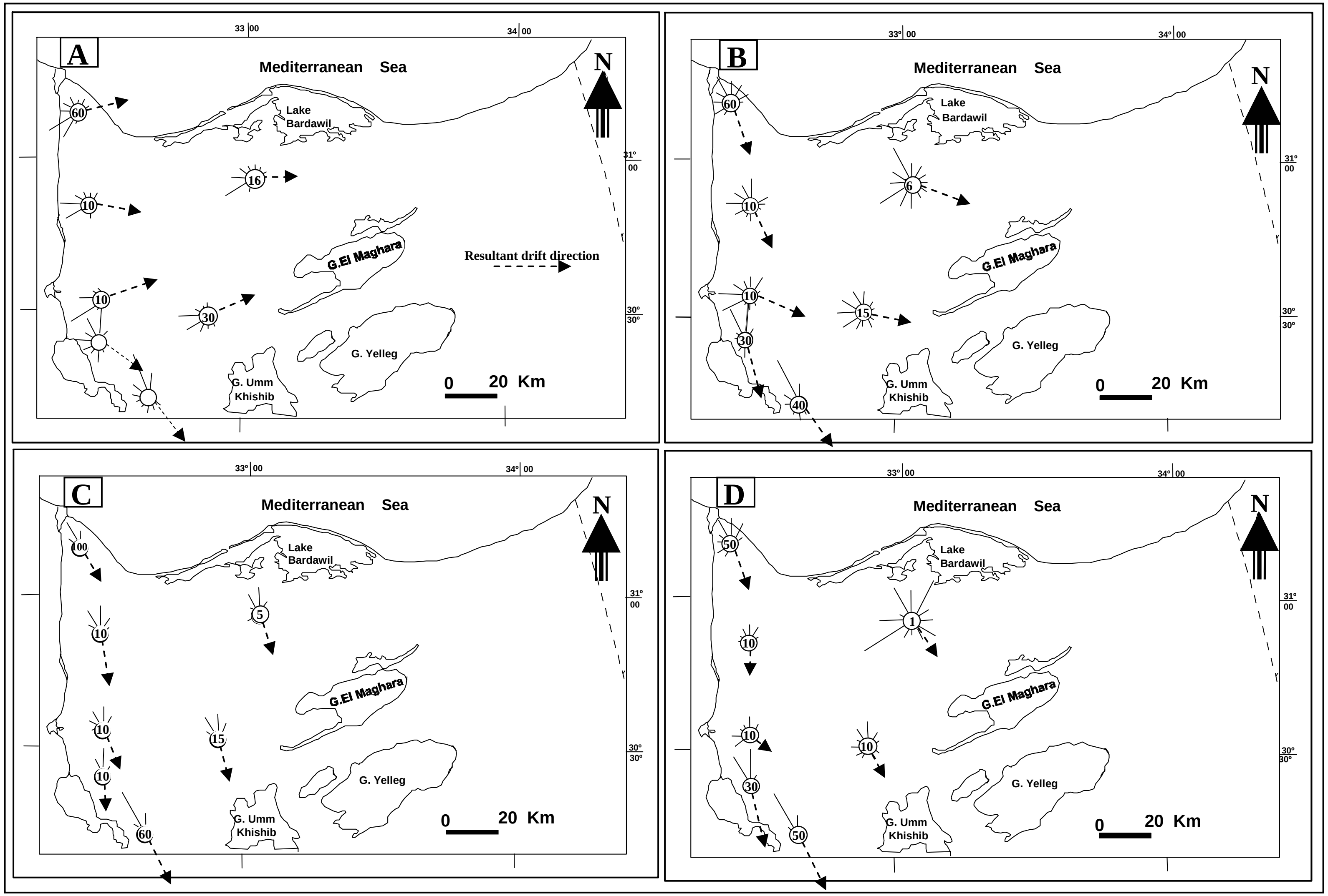

Figure 2. Sand roses of the study area during different seasons. A- Winter, B- Spring, C- Summer D: Autumn. Number in the middle circle is the reduction factor of Fryberger (1979).

Table 1: Threshold velocity and weighting factors of winds in the study area

Threshold velocity (modified after Zhenda et al. 1988)			: Determination of weighting factors for relative rate of sand transport				
Grain Size (mm)	**V_t m/sec**	**Knots**	**Velocity category (knots)**	**Mean velocity of the wind (v)**	**V^2**	**(V - V_t) (V_t = 7.8 knots)**	**Weighting Factor V^2 (V-V_t)/100**
0.1 - 0.25	4.0	7.8	7-10	8.5	72.25	0.7	0.5
0.25 - 0.5	5.6	10.9	11-16	13.5	82.25	5.7	10.4
0.5 - 1.0	6.0	11.7	17-21	19	361.0	11.2	40.4
> 1.0	7.0	13.6	22-27	24.5	600.25	16.7	100.2
			28.33	30.5	930.25	22.7	211.2

Note: the present author calculates the value in knots.
V_t = impact threshold velocity.

Table 2: The distance and directions of longitudinal dunes elongation

Station	Elongation Distance 1958-1998 (m)	Distance /year (m)	Direction of elongation
b4 to bx3 Line	492.1763	12.3	145.1387º
c8 to cx6 Line	887.1264	22.1	165.7020º
c8 to cx6	270.3580	6.7	156.5105º
a to ax2	203.7118	5.1	144.1508º
b3 to bx2	385.1057	9.6	169.1318º
b4 to bx3	384.8451	9.6	142.8273º

Table 3: The distance and direction of movement of barchan dunes

Station	Movement Distance 1958-1999 (m)	Distance /year (m)	Direction of movement
a2 Line	278.1635	6.8	34.1681º
a3 Line	110.5701	2.7	19.7591º
a4 Line	123.0690	3.0	25.1006º
a5 Line	183.5216	4.5	31.8235º
m2 Line	203.1205	5.0	8.5996º
m1 Line	171.0224	4.2	34.4385º
e2 Line	133.3867	3.3	87.0339º
e3 Line	59.1906	1.4	90.2346º
e4 Line	44.3930	1.1	90.2359º

3.1. Winter Drift Potentials

The winter sand roses show that the movement of sand is towards the E, ENE and S (Fig. 2A) due to stronger winds coming from the W and NW. The resultant drift potential (RDP) is accordingly relatively high in the western part of the study area where the highest RDP is at Port Said (727 VU) while the lowest RDP of 120 and 131 VU are at Bir El Abd and Kantara, respectively. The ratio RDP/DP is relatively high at Ismailia, which attests for a low directional variability, while at other regions in the study area the ratio is intermediate denoting that winds blow from variable directions.

3.2. Spring Drift Potentials

The spring sand roses show that the movement of sand is towards the E and SE, due to stronger winds coming from W and NW (Fig. 2B). The resultant drift potential (RDP) is relatively high in the western part of the study area where it is 813 VU at Port Said. The lowest RDP of 69 and 131 VU is at Bir El Abd and Kantara, respectively. The ratio RDP/DP in the study area during spring is intermediate denoting that winds blow from variable directions.

3.3. Summer Drift Potentials

The summer sand roses in the study area (Fig. 2C) show that the movement of sand is towards the E and SE, also due to stronger wind coming from the W and NW. The RDP is relatively high in the western part of the study area, the highest RDP is at Port Said (907 VU), while the lowest is at Bir El Abd and Suez (44 and 81 VU), respectively. The ratio RDP/DP is relatively high at all regions, except at Bir El Abd which is intermediate. This is due to the low directional variability, with prevailing NW winds in summer.

3.4. Autumn Drift Potentials

The autumn sand roses (Fig. 2D) show that the movement of sand is towards SE due to stronger wind coming from NW. The RDP is relatively high in the western part of the study area where the highest is at Ras Sudr (781 VU), while the lowest is at Bir El Abd (9 VU). The ratio RDP/DP is relatively high at Suez and Ras Sudr, intermediate at Port Said, Kantara, El Meleiz and Ismailia, and low at Bir El Abd.

3.5. Annual Drift Potentials

The Annual sand roses in the study area (Fig. 3) show that the movement of sand is towards SE and E due to stronger winds coming from NW and W. The RDP is relatively high in the western part of the study area where the highest is at Port Said (628 VU). The lowest RDP is at Bir El Abd (53 VU). The ratio RDP/DP is relatively high at Ras Sudr and it is intermediate at the other localities of the study area. Figures 4A and 4B show the seasonal and annual variations of sand drift potential (DP) and resultant drift potential (RDP), respectively in the studied locations. It is clear that the study area is of high energy wind desert environment (Fryberger 1979) with sand Drift Potential (DP) value more than 400 VU for all the studied localities.

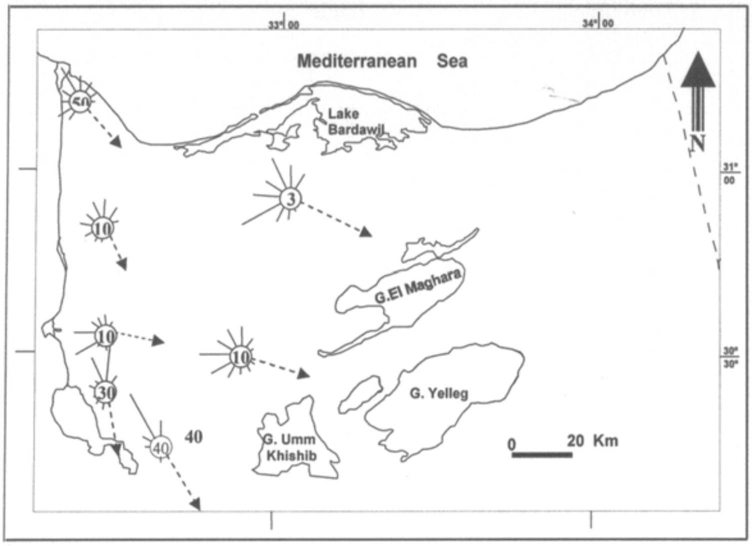

Figure.3. Annual sand roses of the study area.

The total station method indicates that the far end of the dune becomes elongated at different rates. Dunes also move laterally following the wind direction, the lateral movement is only limited to the segments having a slip-face. Where the slip-face is absent, dune elongation is the only movement recorded. The rate of longitudinal movement of dune segments takes place according to changes in the sites of peaks and saddles, the displacement rate being not equal at all points. This phenomenon does not necessarily arise only in the different rates of movement of the various segments, but also from changes in the relative sites of the peaks or saddles on the segment itself. The above analysis shows that the rate of elongation of longitudinal dunes at south of Bir El Abd is 2.25 m/y (Fig. 5A) and 13 m/y at Wadi El Gady. The rate of lateral movement of the segment is about 0.7 m/y at south of Bir El Abd and 2 m/y at Wadi El Gady. The elongation rate of the dune is faster than the rate of movement of the segments comprising it. Therefore, new segments are created on one side of the advancing section at the end of the dune. Also, the movement rate of barchan dunes at Wadi El Massaged is 3.5 m/y (Fig. 5B). The rate of deposition and erosion at the dune crest is calculated by drawing the crest line profile of the dune at different periods using the program AutoCAD version 2002 (Fig. 6A and 6B, Wadi El Gady). Then, by superimposing the constructed profiles over each other, the deposition and erosion areas (i.e. the morphodynamic model) can be elucidated (Fig. 6C). Figure 6C shows the state of the dune after phases of deposition and erosion on the crest line representing a total of one year activity. It is found that deposition (percent) on the longitudinal dune at Wadi El Gady is about 60.1%, whereas erosion is about 39.9%, (Fig. 6C). Also by the same way, deposition (percent) on the longitudinal dune south of Bir El Abd is about 6.7%, while erosion reaches about 39.2 %. Also, sand drift is low in the sabkha and playa areas (Fig. 4).

3.6. Lateral Movement and Cross Section Declination:

Cross sections of longitudinal dunes were constructed by using the total station method (Leica TPS system 1100) at different periods. The section line was determined by connecting consecutive points on both sides of the dune and proceeding perpendicular to the dune axis. Readings give the level of each point and the horizontal distance between succeeding points. It is noticed that the lateral dune movement begins at the crests and could be deduced from the cross sections. The sinuous pattern of the dunes affects the lateral changes with the movement in the elongation direction (Tsoar 1978). The measurements show that the changes in profile at a fixed point arise from addition of sand (deposition) resulting in an increase in volume, or (erosion) resulting in a reduction in volume as a result of the longitudinal movement. The main lateral changes begin at a distance of about 2 m from the crest line where the separation phenomenon is seen to occur at Wadi El Gady. The dune base does not move laterally. The slopes of the dune are above 26º on the windward flanks and above 32º on the leeward flanks.

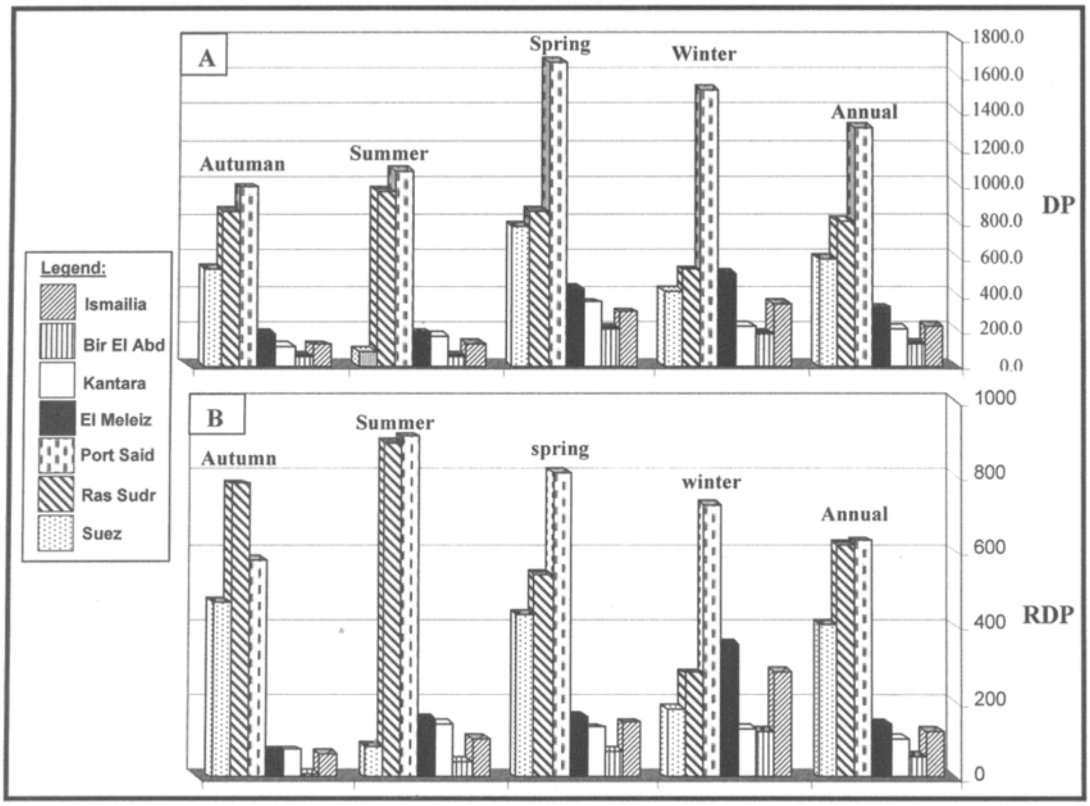

Figure 4. A- Histogram showing the seasonal and annual variations of sand drift potential (DP) in the study area. B- Histogram showing the seasonal and annual variations of resultant sand drift potential (RDP) in the study area.

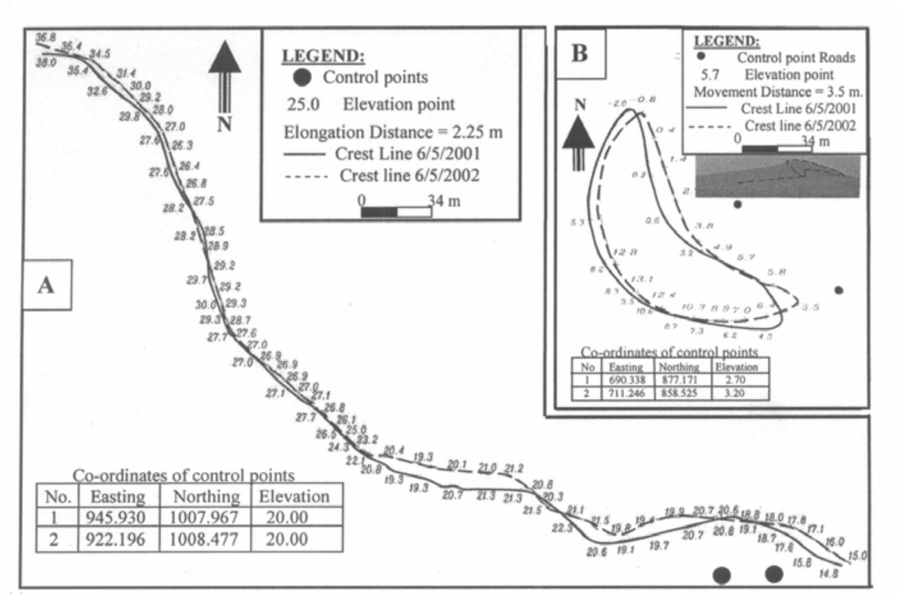

Figure 5. A- Elongation of longitudinal dune at S of Bir El Abd Road. B- Movement of barchan dune at Wadi El Massaged.

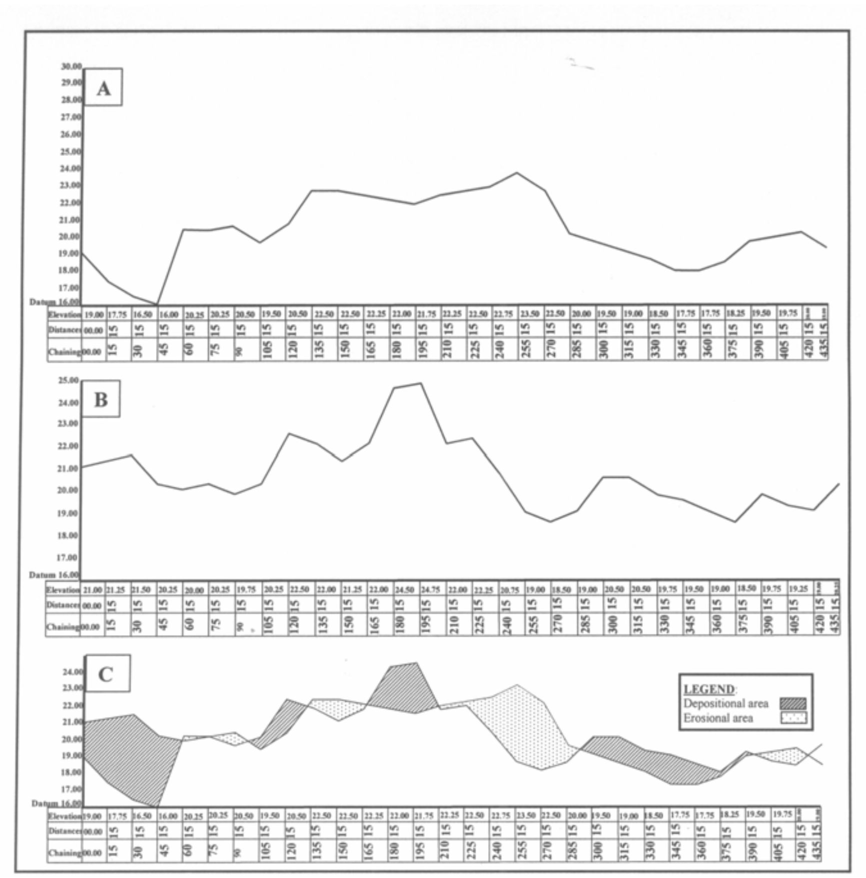

Figure 6. Profile of longitudinal dune at Wadi El Gady A- 2001, B- 2002, C- Morphodynamic models showing the depositional and erosional area of the longitudinal dune at Wadi El Gady.

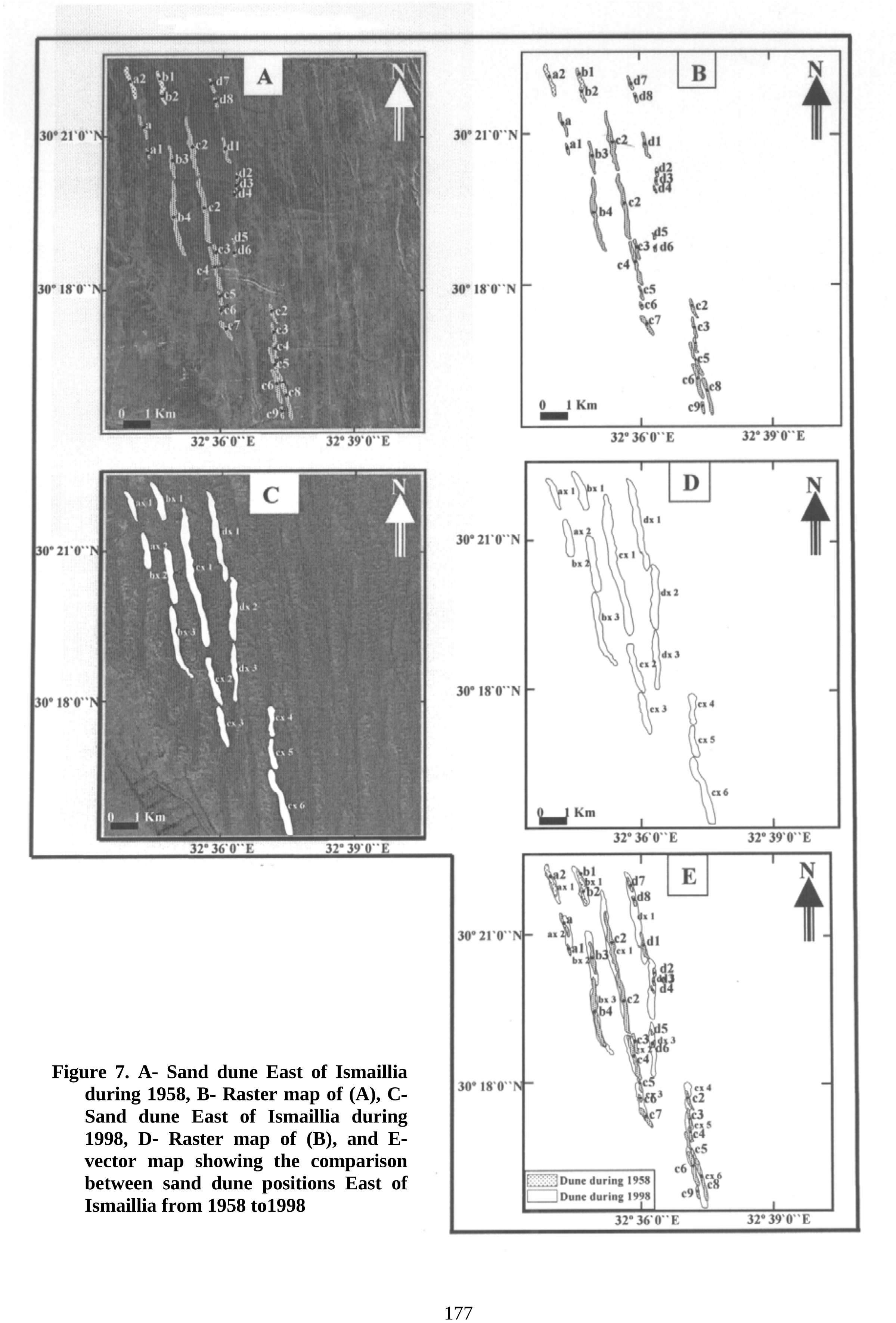

Figure 7. A- Sand dune East of Ismaillia during 1958, B- Raster map of (A), C- Sand dune East of Ismaillia during 1998, D- Raster map of (B), and E- vector map showing the comparison between sand dune positions East of Ismaillia from 1958 to1998

3.7. Microme Teorological Measurements:

The dune as a structure situated in the path of wind, causes disturbances in the wind flow with the formation of eddies. Eddies are formed as the result of the interaction of wind with the dune body and is important in the formation and shaping of sedimentary structures (Allen 1970). Micrometeorological measurements were done across the linear dunes in the study area. Results of this study enable understanding the dynamics of sand movement in sand fields and may be important as a background for sand stabilization and land reclamation work. Measurements that recorded changes in the magnitude and direction at various points along the dune were taken across the two flanks of the dunes (Fig. 8). Air flow in the lee side of linear dunes having a sinuous crestline is complex (Tsoar 1983). This is the case of Wadi el Gady, where the obtained data show that when wind direction is oblique to the dune, the wind velocities are lower and represent 0.3-0.7 of their speed at the crest. But when wind flows parallel to the dune, its speed increases again and may reach 1.01 to 1.30 of those at the crest. The increased velocities and sand transport rates are the result of the concentration of streamlines as the separated flow returns to the dune surface (Lancaster 1995). The increase in wind speed occurs when it is blowing parallel to the dune and when it crosses the crest at an angle of 15º ±1.0 to the dune.

Figure 8. Measurements of changes in the magnitude and direction at various points along the dune across the two flanks of the dunes.

4. HAZARDS

Sand dune encroachments result in several destructive effects in NW Sinai. The hazard effects are mainly invasion of population centers, cultivated lands (Fig. 9A), highways (Fig. 9B), and installations such as water pump stations (Fig. 9C), and the railroad (Fig. 9D) between El Arish and Kantara, by sand dune. Land reclamation areas in NW Sinai are crossed by El Salam Canal. These areas reach about 60000 feddans at Sahl El Tina, 60100 feddans south of El Qantara, 70000 feddans at Rabah village, 135000 feddans at El Sir and El Kawarir area, 70000 feddans at Bir El Abd town and 70100 feddans at the east of Suez Canal project. These areas are irrigated from El Salam Canal, which is subjected to sand dune encroachments at different localities (Fig. 9E).

SUMMARY AND CONCLUSIONS

The wind regime shows clearly that the western part of the study area has higher wind energy where the effective wind (7.8 knots and more) reaches a high percent. The resultant effective wind in the study area is mainly from north and northwest directions for all seasons, however winter winds are WSW at El-Meleiz, WNW at El-Kantara Shark, Ismaillia and Bir-El Abd and NNW at Suez and Ras Sudr. These results are in agreement with the main trends of elongation of sand dunes in the study area. Concerning measurements of elongation and movement rate of sand dunes, the rate of elongation of longitudinal dunes at south of Bir El Abd is 2.25 m/y and it is 13 m/y at Wadi El Gady. The rate of lateral movement of the segment is about 0.7 m/y at south of Bir El Abd and 2 m/y at Wadi El Gady. Consequently, the elongation rate of the dune is faster than the movement rate of the segments comprising it. Therefore, new segments are created on one side of the advancing section at the end of the dune. Also, the rate of barchan dunes movement at Wadi El Massaged is 3.5 m/y. The morphodynamic model of longitudinal dunes in the selected areas shows that deposition (percent) on the longitudinal dune at south of Bir El Abd is about 6.7%, while erosion reaches about 39.2%. However deposition on the longitudinal dune at Wadi El Gady is about 60.1%, whereas erosion is about 39.9%. The annual sand roses in the study area show that the movement of sand is towards the southeast and east, due to stronger winds from the northwest and west. The RDP is relatively high in the western part of the study area where the highest is at Port Said (628VU). The lowest RDP is at Bir El Abd (53 VU). The ratio RDP/DP is relatively high at Ras Sudr, and is intermediate at the other localities of the study area.

Micrometeorological measurements show that air flow in the lee side of linear dunes having a sinuous crestline is complex. This is the case at Wadi el Gady, where the obtained data show that when wind direction is oblique to the dune, the wind velocities are lower and represent 0.3-0.7 of their speed at the crest. But when wind flows parallel to the dune, its speed increases again and may reach 1.01 to 1.30 of those at the crest. The increased velocities and sand transport rates are the result of the concentration of streamlines as the separated flow returns to the dune surface (Lancaster 1995). Barchan dunes in Wadi El Massagid occur in simple forms consisting of chains of crescentric dunes linked together (barchanoid) to form scalloped ridges.

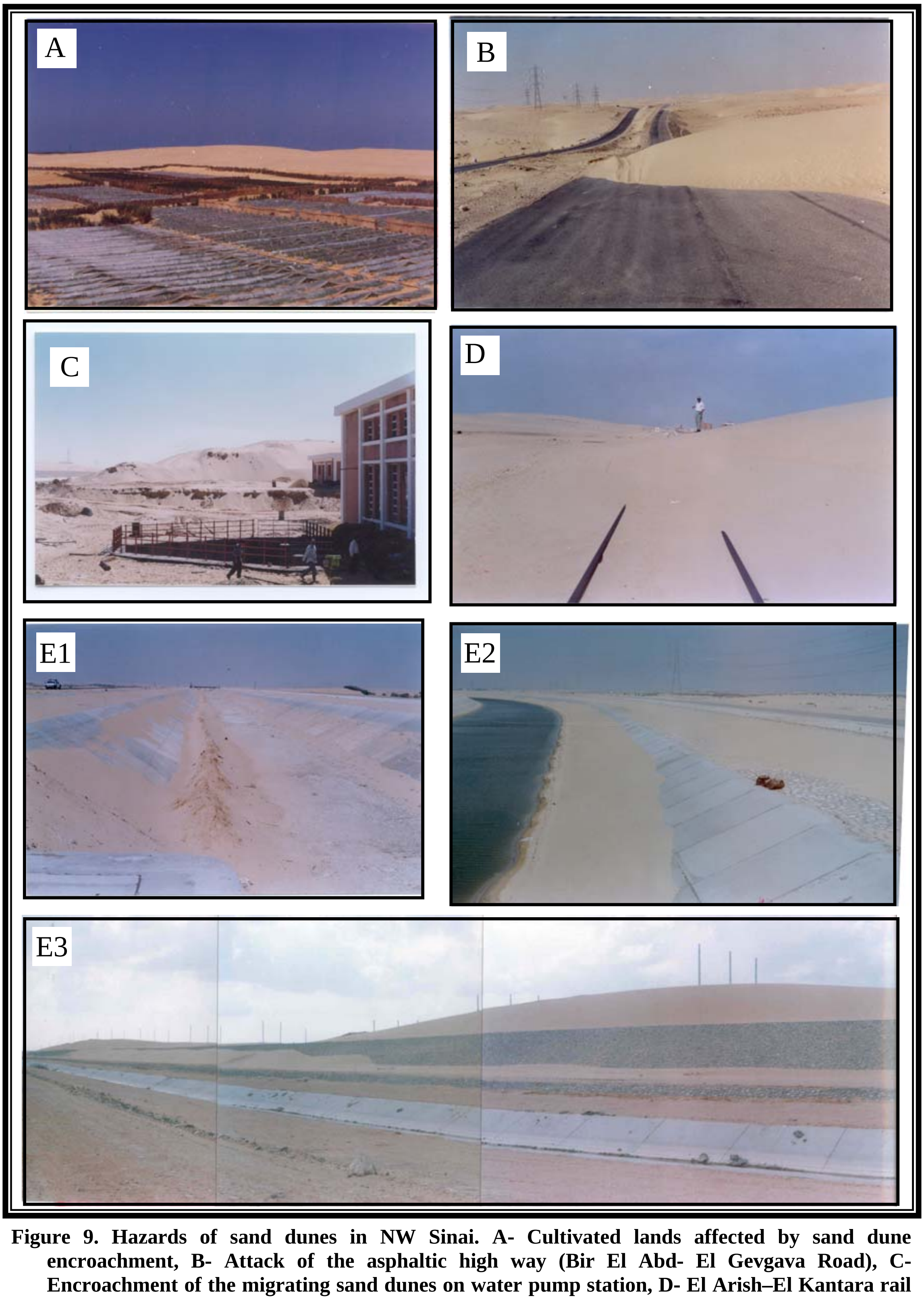

Figure 9. Hazards of sand dunes in NW Sinai. A- Cultivated lands affected by sand dune encroachment, B- Attack of the asphaltic high way (Bir El Abd- El Gevgava Road), C- Encroachment of the migrating sand dunes on water pump station, D- El Arish–El Kantara rail road affected by sand dune encroachment, and E- South El Kantara canal is subjected to sand dune encroachment (1, 2 and 3).

In conclusion it is clear that in the study area all factors enhance the sand movement. Shifting sand adversely affects the development activities in such areas which necessitate the control of sand encroachment. This can be achieved by either

- dispersal of the accumulated sand by the use of the turbulent bar located at the top of the dunes,
- fencing e.g., impounding and diversion sand fences have effective roles in the control of sand movement.

In view of the results of the present study, **it is** recommended that the results of this study should be taken into consideration during the development of Sinai and other areas of similar conditions, especially regarding sand movement and wider scale laboratory and field experiments are required regarding sand movement and the control of shifting sand taking the economical approach into consideration.

REFERENCES

Abu El Einein, S.M.; Dalsted, k.J. and Salem, M.Z. (1990): Dunes encroachment on the cultivated land in Egypt. Desertification Control Bulletin,18: 1-5.

Allen, J.R.L.(1970): Physical process of sedimentation .Unwin University Books, London, 248p.

Draz, M.I.V.I.(1997): Investigation on areas affected by aeolian sand deposits in Egypt and priorities for controlling activities. Annals of Agric. Sci, Moshtohor, 35 (2): 1049-1064.

El Bana, M.S.(1999): Geological studies of the sand dunes of El Sheikh Zuwied area, North Sinai, Egypt. M.Sc. Thesis. Fac. Sci, Cairo Univ. 141p.

Fryberger, S.G.(1979): Dune forms and wind regime. In E.D. McKee (ed.), A study of global sand seas. U.S. Geol. Survey. Prof. Paper 1052: 137-170.

Kamel, A.; El Rakaiby, M.M.; and El Kassas, L.A.(1982): Photointerpretation of Sand Dune Belts in Northwestern Sinai. Egypt. J. Geol., Special Issue (Part I): 57-70.

Lancaster, N.(1995): The geomorphology of desert dunes. Routledge, London.

McKee, E.D.(1979): A study of global sand seas: D.S. Geol. Surv. Prof. Paper 1052, 421p.

Misak, R.F. and El Shalzy, M.(1982): Studies on blown sands at some localities in Sinai and Northern Western Desert, Egypt. Jour. Geol., special issue (part 1): 47-56.

Misak, R.F. and Attia, S.H. (1983): On the sand dunes of Sinai Peninsula, Egypt. Jour. Geol., 27: 115-131.

Mounir, M.M.(1983): Sand dunes in Egypt. Academy of Scientific Research: 60p.

Said, R. (1990): The geology of Egypt. Balkema, Rotterdam, 734p.

Tsoar, H.(1974): Desert dunes morphology and dynamics at El Arish (N Sinai). Z Geomorph. Suppl. Bd. 20: 41-61.

Tsoar, H.(1978): The dynamics of longitudinal dunes. Final Technical Report Da –ERO 76-G-072,US Army European Research Office, London.

Tsoar, H.(1983): Dynamic processes acting on longitudinal (seif) sand dune. Sedimentology, 30: 567-578.

Tsoar, H.(1989): Linear dunes forms and formation. Progress in Physical Geography, 13: 507-528.

Tsoar, H. and Moller, J.T.(1986): The role of vegetation in the formation of linear dunes. In: W.G. Nickling (ed.), Aeolian geomorphology. Binghampton Symposia in Geomorphology, International series, No. 17. Allen and Unwin, Boston: 75-95.

Zhenda, Z.Z.; Benggony, D.; Xinmin,W.; Kangfu, and Jixian. D. (1988): Desertification and rehabilitation case study in Horgin sandy land. Inst. Desert-Res., Academic Sincia, Lnzhou, China: 14-