MAGNITUDE AND CHARACTERISTICS OF SAND DUNES ENCROACHMENT TOWARDS EL-SHEIKH GABER CANAL, NORTH SINAI, EGYPT

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ABSTRACT

This study presents a record of soils, meteorological, landform, sand deposition rate, and hydrographic survey data from 14 sites in El-Sheikh Gaber Canal, North Sinai Development Project (NSDP), from February 2009 to February 2010. Soils were classified into 4 groups, Torripsamments, Psammaquents, Hydraquents, and Salorthids. The landforms are divided into clay and sand regions. The prevailing wind direction was Northern North West during spring, mean wind speed is 3.67 m/s, maximum wind speed is 13.67 m/s observed in March. Utilizing the Auto Cad drawing program to draw the design and actual canal cross-sections and computed cross-sections area, hydrographic survey results showed that,the measured sand deposition percentage as a ratio of canal design cross-section ranged between 1.67 % to 3.69 %, the sand deposition average volume was about 292978 m^3/year. The regions that suffering from sand dunes encroachment were, reach from (km 15.500 - km 24.000) and reach (km 53.000 - km 83.000). It is recommended to design a windbreaker in pilot-scale area using a matrix of three rows of wooden trees (Casuarina and Equistifofia) to control the encroachment of sand dunes towards the study reach.
The measured cross-sections were compared with designed cross-sections.

Keywords: Sand Dunes, North Sinai Development Project, Hydrographic Survey, Canal Efficiency.

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1 INTRODUCTION

Sand dunes are defined as a group of loose sands forming a pile on the surface of the earth. Sand dunes are formed by erosion process of desert rocks by weathering agents great, temperature and incessant blowing wind leading fragment the rocks to different size and shape sand grains (Hiza Redsteer et al. 2011). The source of sand dunes is very composite, but there are three basic situations: 1. Availability of loose sand in a generally free area of vegetation (old lake bed or river delta), 2. Wind power source of transporting sand grains 3-Sand particles lost their momentum and settle by any number of objects, such as shrubs, rocks or fence posts can impede wind power causing sand to accumulate in drifts and eventually, large sand dunes (DeJong-Hughes et al. 2011).It is known that aeolian transport is an active geomorphic reasonof sand dunes (Bourke et al., 2009;Gillies et al., 2009; Lancaster et al., 2010) as shown by the presence of advanced aeolian terrain (Gillies et al., 2012). Strong winds can transfer sediment from sand and dust-sized (0.001 mm to 2 mm) (Pye, 1987; Doran et al., 2002; Nylen et al., 2004).

Creep, saltation, or suspension transports sand dunes, the main weathering parameters that effect on sand dunes movement is, wind speed, wind direction, temperature, humidity, rainfall, and sunrise (Bourkeet al., 2009). Erosion occurs when the drag and lift of the eroded material exceed gravitational, cohesive and friction forces that carry the grains together. The air is slightly more efficient than the water acting as a granular fine particle abrasion agent (Garrels, 1951; and Mitchell and Soga ,2005). grain size of sand played an important role in wind erosion of loose sand and silt size particles, the wind usually removed the smaller soil particles of lower speeds than the large particles. However, fine soils (clay and silts) have a cohesion force between particles that will be resistant to separation. Once the grains are separated, the moving grains deceive the surface of the soil and expel the other particles, intensifying the erosion (Presley and Tatarko, 2009). Sand dunes can be transported without vegetation by wind, and this activity can cause significant harm to landscapes. The North Sinai Peninsula in Egypt represent a huge source of blown sand which travel long distances from the effect of wind to threaten the cultivated lands and watercourses. Many researchers investigated methods of studying, monitoring, and controlling sand dunes movements, locally and worldwide.In Egypt sand dunes encroachment can be categories into:

1. Severe dune migration (more than 15 m / year), this occurs toSouthern Bardawil (North Sinai),east of the Suez Canal and central Sinai.
2. Slight dune migration (less than 5 m / year), This happens tothe northern coast of the Nile Delta and on the both sides of the Nile Delta. In North Sinai, a major obstacles to sustainable agriculture are the movement of sand dunes. The sand dunes have an area 5,000 km^2 of the coastal area, which adversely affects cultivated land and newly reclaimed lands.The migration of longitudinal sand dunes at a rate of 2.25 m / year to the south of Bir al-Abd and 13 m / year in Wadi al-Jadi (Islam et al., 2013). The distribution of sand dunes and related effects on the agricultural resources of the Sinai Peninsula was studied using integrated remote sensing techniques. The sand dunes affected inversely on about 33.7 % of the cultivated south of El Sheikh Gaber Canal command area in the NSDP (Gad, 2016).

Monitoring and assessment of desertification in the Al-Butana region, Sudan as well as investigating the potential use of remote sensing and in the assessment and monitoring of sand encroachments and degradation of vegetation cover as indicators of desertification in the semi-arid environment (Edris et al., 2013). Abdelmoaty (2011) studied impact of sand dunes encroachment towards open canals in Toshka project, Egypt, they concluded that some canals exposed to the risks of sand dunes.In Egypt, the reach between High Aswan Dam and Aswan reservoir on Nile River exposed tohazards by sand dunes encroachment (Abdelmoaty, 2015).

Studying phenomena of sand dunes encroachment towards watercourses is an important issue where, the fallen sand inside watercourse reduces its cross section area, which consequently decrease storage capacity, and constitute a good environment for the growth of aquatic weeds. This study presents a record of soils, meteorological, landform, sand deposition rate, and hydrographic survey data from 14 sites in El-Sheikh Gaber Canal, North Sinai Development Project (NSDP), from February 2009 to February 2010, to identify the most critical reaches along it and estimating the rate of accumulation of falling sand inside watercourse.

2 METHODS

2.1 Site description

The studied watercourse was located in the North Sinai peninsula, El-Sheikh Gabr Canal is the main feeder for the NSDP (figure 1), the annual water resources for the project are 4.5 Millard m^3 (Shaban, 2017). NSDP is located inside a sand dune region, have a characteristics, active wind, rare rainfall, dry land surface, and small vegetated areas.

Figure 1. Location of the study area

2.2 Soil classification

Four boreholes were carried out in the study area, borehole (B1), borehole (B2), borehole (B3), and borehole (B4). The soil samples were collected and testes, Fig. 2 shows the boreholes locations. The predominated soil in the study area is a sandy soil with a deep water table. The clay loamy soil is found in the Tina Plain. Non uniform texture soils with alternately stratified sand and clay layers occupy a transitional area between the Tina Plain and the sandy terrain sandy soils with shallow water table are found at the further inland Sabaka between sand dunes. These soils are classified into for groups according to the USDA Soil Taxonomy as, Torripsamments, Psammaquents, Hydraquents, and Salorthids. The characteristics of the soil type are presented in Table 1 and Table 2.

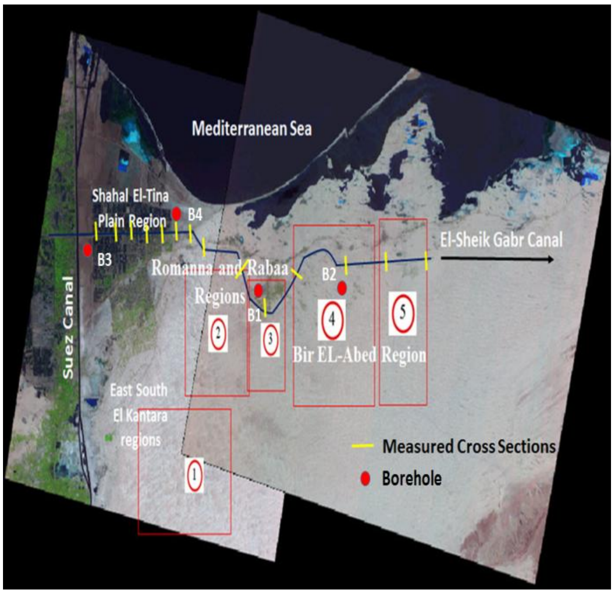

Figure 2. North Sanai Development Project (NSDP) regions.

Table 1. Torripsamments and Psammaquents soil types

Soil type	Soil description
Psammaquents	(Coarse – textured soils with shallow water table) Location: West of Rabaa (Borehole B1) Physiology: in land Sabkha, depression. Slope: flat, less than 1 % Microrelief: many about 3 m high. Parent material: Aeolian sand. Vegetation: common halophytes (Salcornia). Drainage: poor. Water Table: moderately shallow, 70 cm. Surface feature : thin salt crust. Soil strata: 0.0 -20 cm brownish yellow (10 YR 6/6) with black colored surface, medium sand, single grain, moist, friable, few roots, diffuse boundary to: brownish yellow (10 YR 6/6), 20-70 cm brownish yellow (10 YR 6/6) , medium sand, single grain, moist, friable, water table at 70 cm. 70-120 cm brownish yellow (10 YR 6/6) , medium sand, singlegrain, wet
Torripsamments	(Coarse – textured soils with deep water table) Location: Hagf EL Souf (2 km north Nigala) (Borehole B2) Physiology: stable low land dunes (Sand Undulating Terrain). Slope: Undulating 3-5 % Microrelief: many about 5 m high. Parent material: Aeolian sand, deflated. Vegetation: dense desert shrubs Drainage: excessive. Water Table: deep, > 3.0 m. Water holding capacity : poor. Soil strata: 0.0 -45 cm yellow (10 YR 7/6), medium sand, single grain, no consistency, low organic matter, diffuse boundary to brownish yellow (10 YR 6/6), 45-70 brownish yellow (10 YR 6/6), medium sand, single grain, moist, friable, diffuse boundary to: brownish yellow (10 YR 6/6), 70-120 cm medium sand, single grain, moist, friable.

Table 2. Hydraquents and Salorthids soil types

Soil type	Soil description
Type Hydraquents	(Fine – textured soils with shallow water table, sand substratum) Location: Near Tell EL-Farama (Borehole B3) Physiology: Tina Plain, dry Sabkha, Clay Flat. Slope: flat, less than 1 % Parent material: Lucstrine clay, alternately stratified clay and sand layer. Vegetation: none. Drainage: poor. Water Table: Shallow (60 cm), very strongly saline. Soil strata: 0.0 -20 cm Salt crust on the surface (3 cm thick). Dark grayish brown (10 YR 1/2), sandy clay loam, blocky structure, moist, friable, sticky and plastic when wet, abrupt boundary to: 20-100 pale brown (10 YR 1/2), medium sand, single grain, moist, friable, common black spot of organic matter, water table at 60 cm, gradual smooth boundary to: 100-150 cm black (2.5 YR 2/1), silty clay, no structure, compact, gluey horizon, smelling wet, very sticky and very plastic.
Type Salorthids	(Fine – textured soils with moderately shallow water table) Location: 3.0 km east of Tell EL-Farama (Borehole B4) Physiology: Tina Plain, dry Sabkha, (Clay Flat). Slope: flat, less than 1 % Parent material: fluvio Lucstrine deposits. Vegetation: none. Drainage: poor. Water Table: moderately Shallow, 130 cm. Surface features: scattered shells and gypsum needles. Soil strata: 0.0 -10 cm very dark gray (N3), loose fine sand covering salt crust (3-5 cm thick), many gypsum needleson the surface, abrupt boundary to: 10-30 cm Dark grayish brown (10 YR 4/2), silt clay, blocky structure, moist, friable, sticky and plastic when wet, common small pores, clear smooth boundary to: 30-40 brown yellow (10 YR 4/2), medium sand, single grain, moist, friable, common black spot of organic matter, water table at 60 cm, gradual smooth boundary to: 40-90 cm yellowish brown (10 YR 4/2), sandy clay loam, blocky structure, moist, friable, slightly sticky and slightly plastic, common shells, common fine pores, few organic matter, gradually smooth boundary to: 90- 135 grayish brown (10 YR 4/2), heavy clay, wet, very sticky and very plastic, many small shells, water table at 130 cm gradually smooth boundary to: 135-200 very pale brown (10 YR 4/2), medium sand, loose, non sticky nor very plastic smelling.

2.3 Landform

The information about the landform in the study area was collected through the recent field investigation. The landform is varying as follows:

Tina Plain:

- Wet and dry Sabkah (clay flat).
- Level lowland (clay flat).

Sand Terrain:

- Level sand terrain.
- Undulating sand terrain.
- Complex of level terrain and undulating sand terrain.
- Inland Sabkah.
- Mobile sands dunes.

Figure 3 shows the relationship between land uses, landform and the soil classification.

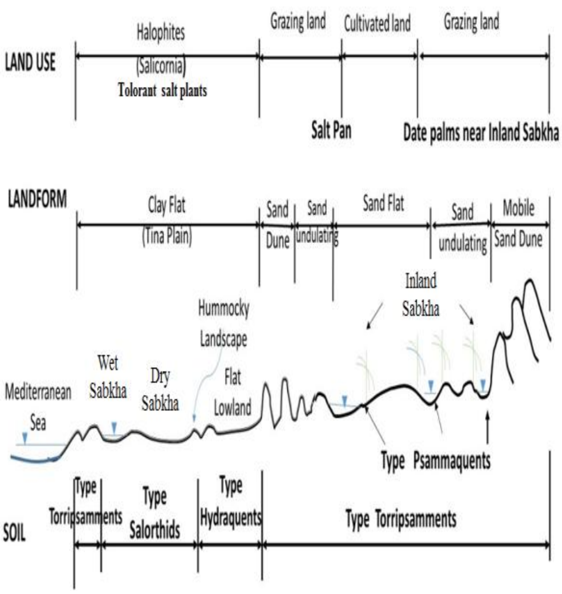

Figure 3. Relationship between Land-form-Soil- Land Use (Vegetation)

2.4 Meteorological Data: Wind Speed and Direction

Sand movement is affected by different climate parameters. Wind speed and direction are considered the main parameters that affect sand movement; the other parameters, temperature, rainfall, and humidity also have a considerable effect. Fig. 4-a shows wind rose presents distribution of wind at El Arish recorded between 1995 and 2004 and Fig. 4-bshows histogram for distribution of wind speed (m/s) at El Arish recorded between 1995 and 2004 (Wind Atlas of Egypt, 2005). The common wind direction was Northern North West direction with percentage of 60 %. From Fig. 5 the average daily mean wind speed over the year is 3.67 m/s with a maximum speed 13.67 m/s, observed in March during the period from Feb. 1993 to Feb. 1994. These values of wind speed were capable to move sand towards the study reach, Fig. 6 shows sand accumulation in EL-Sheikh Gaber Canal at km 63.000.

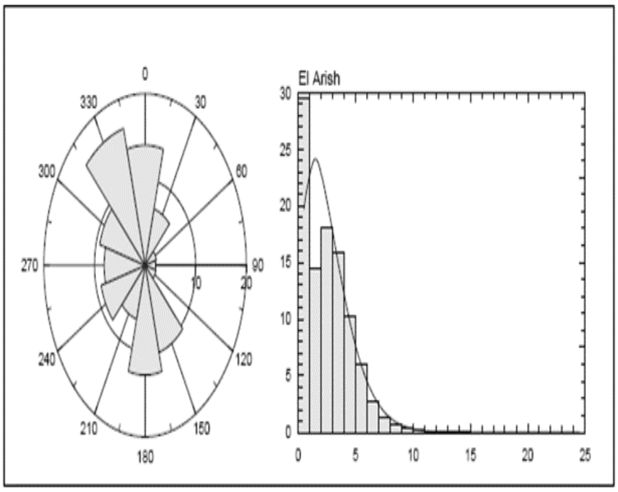

Figure 4. a- The wind Figure 4. b- ELArish wind histogram

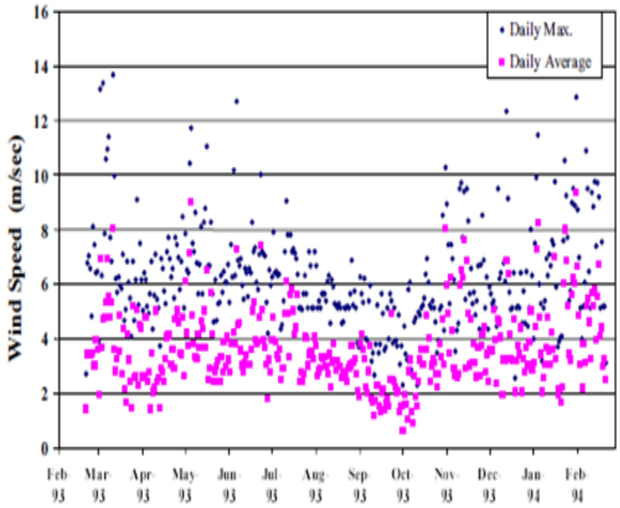

Figure 5. Average of the daily mean wind speed

Figure 6. Sand accumulation in EL-Sheikh Gaber Canal at km 63.000.

2.4 Hydrographic survey

A group of 14 cross-section were selected according to its location in the project, existing hydraulic structures and type of canal lining, Fig. 2. The selected reaches were measured 3 times in one year, during February 2009, August 2009, and February 2010 using an echo sounder and total station survey instruments. A 17 Water depth measurement were carried out along each canal cross-section. The measured cross-sections were compared with designed cross-sections.The Auto Cad drawing program was utilized to draw the design and actual canal cross-section and computed cross-section areas. Annual sand accumulations rate along the studied cross- sections as a percentage ratio of the designed cross- section area were determined. The quantities of accumulated sands were determined Table 3 and presented in Fig. 7, Fig. 8 and Fig. 9 for cross section at km 53.00, km 83.00 and km 73.00, respectively.

Table 3. Yearly sand deposition rates as a ratio of the designed canal cross- section area.

Canal name	Cross-Section No.	Location (km)	Sand Accumulation Rate (% of the designed canal cross- section area)		
			During period from August 2009 to February 2010	During period from February 2010 to August 2010	Yearly Average
El-Sheikh Gaber Canal	1	3.500	2.17	2.31	2.24
	2	6.500	1.61	1.73	1.67
	3	9.500	2.29	2.62	2.45
	4	12.500	2.64	2.77	2.70
	5	15.500	2.83	2.91	2.87
	6	18.500	2.90	3.02	2.96
	7	21.500	2.69	2.88	2.78
	8	24.600	2.88	2.98	2.93
	9	33.000	2.73	2.91	2.82
	10	43.000	2.85	2.70	2.66
	11	53.000	3.46	3.25	3.35
	12	63.000	2.67	3.59	3.13
	13	73.000	3.69	3.68	3.69
	14	83.000	3.44	3.61	3.53

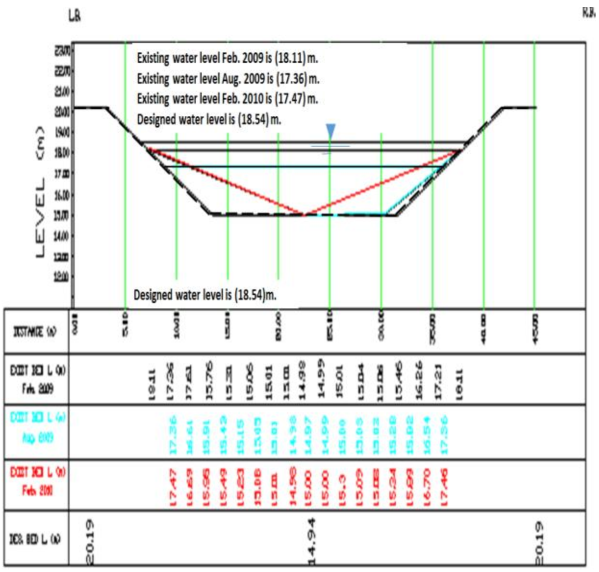

Figure 7. Actual and design cross sections for El-Sheikh Gaber Canal at km 53.000

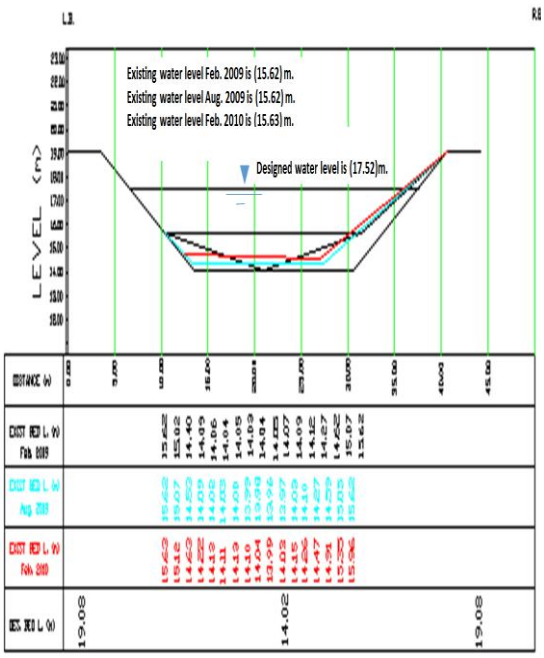

Figure 8. Actual and design cross sections for El-Sheikh Gaber Canal at km 83.000.

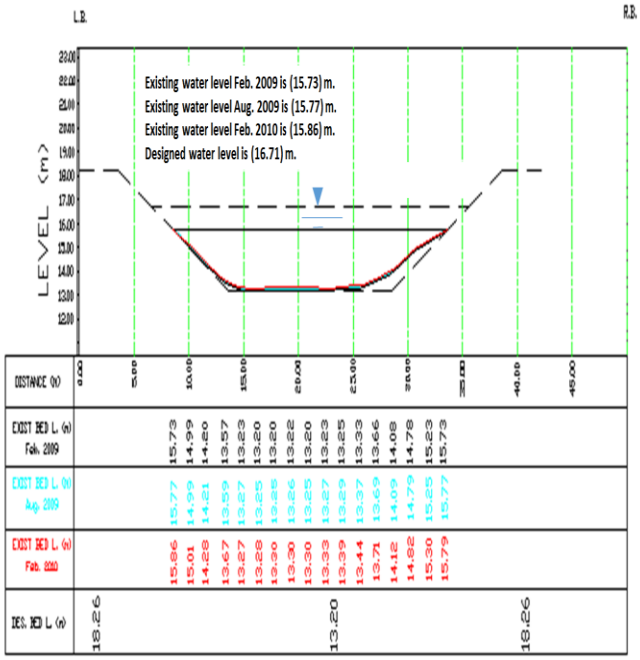

Figure 9. Actual and design cross sections for El-Sheikh Gaber Canal at km 73.000.

3 RESULTS AND DISCUSSION

From the cross sections survey analysis on the studied canal, the most regions exposed to sand dunes encroachment were, reach from (km 15.500 - km 24.000) and reach from (km 53.000 - km 83.000). Wind speed and its direction were considered the main parameter that affects sand movement, the average wind speed through the last 19 year was 3.67 m/s which is capable to move sand towards El-Sheikh Gabr canal**.** The minimum and maximum annual sediment accumulation rates as a percentage of the cross-sectional area are 1.67 % to 3.69% and the average volumes of sand accumulation are ٢٩٢٩٧٨ m^3 / year. According toobtained results, the studied watercourse is exposed to sand deposition by encroachment of sand dunes. several investigators studied how to fix sanddunes encroachment ,using plant beach grass Ammophila breviligulata to fix sand dunes and planting ‘Cape’ American beach grass (National Research Council 1995). Biopolymers effectively increased the cohesion intercept and stiffness of the treated sand (Hamid and Brendan 2013; Ilhan, et al. 2013). Using of biopolymer and vegetation good-natured permanent solution as both of them are techniquescovering both short-term and long-term(Aly-Eldeen et al. 2015). Soil stability is positively associated with plant diversity in salt marsh grasslands and plant diversity effects are more marked in erosion-prone than erosion-resistant soils (Hilary, et al. 2017). In Egypt, using geotextiles mat and chemical materials to fix loose sand dunes encroachment remains unfavorite because of high cost. Sediment accumulated in the suited watercourse can be removed once each two years from the most affected reaches using:

- Hydraulic excavator have blade dredger bowl and suction system.
- Long boom excavator with suitable desalting bucket.
- Amphibious mounted long reach excavator with pontoon.

4 CONCLUSIONS AND RECOMMENDATIONS

Studying phenomena of sand dunes encroachment towards watercourses is an important issue.A record of soils, meteorological, landform, sand deposition rate, and hydrographic survey data from 14 sites in El-Sheikh Gaber Canal, North Sinai Development Project (NSDP) were carried outfrom February 2009 to February 2010.A 17 water depth measurements were carried out along each canal cross-section. The measured cross-sections were compared with designed cross-sections. The Auto Cad drawing program was utilized to draw the design and actual canal cross-sections and to compute cross-section areas. The results showed that, the landform was varied from sand terrain, level sand terrain, undulating sand terrain, complex of level terrain and undulating sand terrain, inland sabkah, mobile sand dune. The soil classification according to USDA soil taxonomy was, Torripsamments, Psammaquents where the properties of sand were medium sand, single grain, no consistency, low organic matter, the sand in transport was medium size. The wind speed and its direction are considered the main parameter that affects sand movement, the average wind speed through the last 19 year was 3.67 m/s (13.12 km/hr) which is capable to move sand towards the study reach.The hydrographic survey results showed that, measured sand deposition was ranged between 1.67 % to 3.69%, the total sand deposition average volume, 292978 m^3/year. The most canal reaches suffering from sand dunes encroachment are, the reach from (km 15.500 - km 24.000) and the reach (km 53.000 - km 83.000). Apply an experiment to apply the protection for the sand sands (mechanical methods - biological methods) to pilot areas of the project to assess their efficiency and usefulness in stopping the sand dunes is recommended. Design a windbreaker in pilot-scale for the study area is recommended by installing a matrix of three rows of wooden trees (Casuarina and Equistifofia) next to the road perpendicular to the prevailingwind direction (Northern North West) to control the encroachment of sand dunes towards the study reach.

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ABBREVIATIONS

The following Abbreviations are used in this paper:

NSDP North Sinai Development Project;
USDA United States Department of Agriculture; and

REFERENCES

Abdelmoaty, M. (2015), "Assessment the hazard of sand dunes encroachment towards Nile River (Reach between High Aswan Dam and Aswan reservoir)", International Journal of Development, Vol.4, No. (1) (2015): 91-99, ISSN: 2314-5536.

Abdelmoaty, M., Ibrahim H., and El Samman T. (2011). "Protection of Open Channels from Sand Dunes Movements (case study - Toshka project)", Fifteenth International Water Technology Conference, IWTC-15 2011, Alexandria, Egypt.

Aly-Eldeen M., Negm A. and Suzuki M. (2015). "Protection of Irrigation Canals at Desert Areas from Sand Dunes Hazards Using Eco-techniques", SSRG International Journal of Civil Engineering
(SSRG-IJCE) – volume 2 Issue 1 Jan 2015.

Bourke, M. C., Ewing,R. C., FinneganD., and McGowan,H. A. (2009). "Sand dune movement in the Victoria Valley", Antarctica, Geomorphology, 109(3–4), 148–160,
doi:10.1016/j.geomorph.2009.1002.1028.

DeJong-Hughes, J., Franzen, D. and Wick, A. (2011). "Reduce Wind Erosion for Long Term Productivity", University of Minnesota, Willmar Regional Extension Office at 320-235-0726.

Doran, P. T., McKay, C. P., Clow, G. D., Dana, G. L., Fountain, A. G., Nylen, T. and Lyons W. B. (2002). "Valley floor climate observations from the McMurdo dry valleys", Antarctica, 1986–2000, J. Geophys. Res., 107(D24), 4772, doi:4710.1029/2001JD002045.

Edris, O.H.A., Dafalla, M.S., Ibrahim, M.M.M., and Elhag, A.M.H. (2013), "Desertification Monitoring and Assessment in Al-Butana Area, Sudan, Using Remote Sensing and GIS Techniques", International Journal of Scientific & Technology Research Volume 2, Issue 3, March 2013.

Gad, A. (2016), "Sand dune distribution and related impacts on agricultural resources of Sinai Peninsula, Egypt, using integrated remote sensing-GIS techniques", Global Advanced Research Western Part of Egypt, Using Remotely Sensed Data and GIS, J. Geographic Inf. Syst.2013, 5: 498-

Garrels, R. M. (1951) "A Textbook of Geology", New York: Harper.

Gillies, J. A., Nickling, W. G. and Tilson, M. (2009). "Ventifacts and windabraded rock features in the Taylor Valley", Antarctica, Geomorphology, 107, 149–160, doi:110.1016/j.geomorph.2008.1012.1007.

Gillies, J. A., Nickling, W. G., Tilson, M. and Furtak-Cole, E. (2012), Wind formed gravel bed forms, Wright Valley, Antarctica, J. Geophys. Res., 117, F0417, doi:10.1029/2012JF002378.

Hamid, R. AND Brendan, c., (2013), "Improving Mechanical Properties of Sand Using Biopolymers", DOI: 10.1061/(ASCE) GT.1943-5606.0000861.

Hilary, F., Angus, G., Cai, L., Jonathan, M., and Martin W. (2016), " Soil stabilization linked to plant diversity and environmental context in coastalwetlands", Journal of Vegetation Science 27 (2016) 259–268.

Hiza Redsteer, R.C., Bogle, J.M., Vogel (2011), "Monitoring and Analysis of Sand Dune Movement and Growth on the Navajo Nation, Southwestern United States", U.S. Geological Survey, Fact Sheet 2011/3085, July 2011.

Ilhan, C., Gye-chun, C., and Carlos, J. (2013) ,"Soil Erosion Control And Vegetation Stabilization Using Biogenic Biopolymers", Proceedings of the 5 th International Youg Geotechnical Engineers' Conferece -5 th iYGEC 2013.

Islam, A., Osman, H., and Sayed, A. (2013), "Quantification of Sand Dune Movements in the South Western Part of Egypt, Using Remotely Sensed Data and GIS", J. Geographic Inf. Syst.2013, 5: 498- 508.

Lancaster, N., Nickling, W. G. and Gillie J. A. (2010), "Sand transport by wind on complex surfaces: Field studies in the McMurdo Dry Valleys", Antarctica, J. Geophys. Res., 115, F03027, doi:10.1029/2009JF001408.

Mitchell, J. K., and Soga, K. (2005), "Fundamentals of Soil Behavior", (3rd Edition ed.). New Jersey: John Wiley & Sons, Inc., 2005.

National Research Council, (1995). Beach Nourishment and Protection, National Academy Press, Washington, D.C., 334 p. Pugh, D.T., Tides, surges, and mean sea-level: John Wiley & Sons, New
York, 472 p.

Nylen, T., Fountain A. G., and Doran, P. (2004), "Climatology of katabatic winds in the McMurdo Dry Valleys, Southern Victoria Land, Antarctica", J. Geophys. Res. 109, D03114, doi:10.1029/2003JD003937.

Presley, D., and Tatarko, J. (2009), "Principles of Wind Erosion and its Control", Kansas State University.

Pye, K. (1987), "Aeolian Dust and Dust Deposits", 256 pp., Academic Press, London.

Shaban (2017). "Statistical Framework to Assess Water Quality for Irrigation and Drainage Canals", International journal of Irrigation and Drainage, 66: 103–117 (2017), Published online 8 July 2016 in Wiley Online Library (wileyonlinelibrary.com) doi: 10.1002/ird.2042.

Webb, N. P., Herrick, J.E., Van Zee, J.W., Hugenholtz, C.H., Zobeck, T. M., and Okin, G. S. (2016), "Standard Methods for Wind Erosion Research and Model Development", Protocol for the National Wind Erosion Research Network, USDA-ARS Jornada Experimental Range P.O. Box 30003, MSC 3JER, NMSU Las Cruces, New Mexico 88003-8003.

York, 472 p. Journal of Agricultural Science (ISSN: 2315-5094) Vol. 5(1) pp. 042-050, January 2016 Issue.