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Field Observations and Some Properties for the Coastal Sand Dunes of the Nile Delta in the Past Thirty-One Year, Egypt

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ABSTRACT

The coastal sand dunes of the Nile Delta change strongly and removed from more than thirty years ago. But in the fact the all geomorphologic units of the coastal areas of the Nile delta changed due to the construction of Aswan High Dam in 1964. This change in geomorphologic units occurred due to the lack of sediments arrived to the Mediterranean Sea. This manuscript showing the types and the occurrence of sand dunes in the past and in the present as well as showing the relationship between the sand dunes and the beaches from sedimentological point of view in each zone in the study area. In general, Mz and sorting of dunes is better than the corresponding beaches.

Keywords: Coastal sand dunes, New Damietta, Burg EL-Burullus, Sorting, Grain size

1. Introduction

The area of study extended from New Damietta City to Burg EL-Burullus are continually changed with time. All geomorphologic units in the study area are annually changed according to the geoenvironmental conditions prevailing in the Nile Delta. The beach and sand dunes are the important units to studied in the study area. The formation, occurrence and properties of the coastal sand dunes in the Nile Delta depends on the human and natural activities.

The study of the beach and sand dune required many geoenvironmental parameters such as grain sizes, mineralogy, waves and wind.

From about 60 years, before 1964 (construction of Aswan High Dam) about 134 Millions tons of sediments were arrived to the Mediterranean sea and about 55.5 Billion m^3 of water yearly (Abu-Zeid and ElShibini, 1997; Sharaf El Din, 1977). When the Aswan High Dam constructed in the period from 1964 to 1971 the huge quantity of these sediments arrived to the Mediterranean sea have decreased dramatically but the quantity of water still as it (55.5 Billion m^3). Egypt loses 22–34 billions cubic meter per year of Nile water throughout the flood period in the Mediterranean before the construction of AHD. Nile River carry about 134.0 million tons of silt, corresponding to a volume of about 92 $*10^6$ m^3 per year, out of which 125.0 million tons came during the flood months. Most of this amount was conveyed to the sea, but around 12% use to settle on cultivated lands. Most of these suspended solids settle in the lake since the AHD construction, and only 3% of them travel downstream from the dam (Negm and Abdel-Fattah, 2019). Aswan High Dam (AHD) is considered the reason for all geoenvironmental changes in the coastal area of the Nile Delta, thus some facts about the construction steps of AHD must be known such as in 1960 start of construction, in 1964 complete the first dam construction stage and start filling the reservoir, in 1970 completed The High Dam, in 1976 reservoir is filled completely (Negm and Abdel-Fattah, 2019).

The lake's total storage capacity (reservoir) is 162 billion cubic meters of water, and the dead storage capacity is 32 billion cubic meters between level from 85 to 147m. The term "dead storage" means the amount of water that cannot be transported through the dam's openings, as this amount falls below the level of the dam's body openings. About 91 billion m3 is the live level between 147m to 175m, about 40 billion m3 full capacity level between 175m to 182m. Lake Nasser loss about 10 billion

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m3 of water by evaporation due to its large surface area (El Gamal, Zaki, 2017; Negm and Abdel-Fattah, 2019).

When AHD constructed the problems in Egypt especially in Nile Delta were occurred, what about the size of problems which occurred by the construction of Grand Ethiopian Renaissance Dam (GERD). The negative effects of the construction of AHD on the Nile Delta well be increased by the construction of GERD.

Many authors studied the properties of the Nile Delta coast such as (Anwar *et al.,* 1979; El-Bousely and Frihy 1984; Frihy and Komar 1993; EL-Asmar, 2000; Ahmad, 2002; EL-Bady, 2007 and others). They were stated that most of sand sizes are finer with high heavy minerals near the river promontories and the coarser sand transported with longshore currents, where the coarser sands have little quantity of heavy minerals. EL-Bady, (2007) studied the coastal area of the Nile Delta between the Rosetta and Damietta Nile branches, He suggested that the areas of sand dunes, wetland, Burullus Lagoon and natural vegetation are decreased and the areas of urban and new cultivations are increased from 1984 to 2005. The area of coastal sand dunes changed from 11.88% to 0.84% during the period from 1984 to 2005, where the area calculated as a percent from the total coastal plain of Nile Delta between the two Nile branches. The area of urban area was 5.68 % in 1984 from the total coastal area between the two Nile branches, with geoenvironmental conditions it become about 6.93% in 2005 as well as new cultivations increase from 4.56% in 1984 to 21.86% in 2005 (EL-Bady, 2007).

The coastal strand plain of the Nile Delta from Port Said to Alexandria contain a belt of coastal sand dunes and many geomorphologic units. The coastal plain consists of five units such as coastal dunes and barren soil, urban areas, water body, fish farms and agricultural land (El-Banna and Frihy, 2009). The coastal sand dunes and barren soil decrease by about 45%, from 1897 km^2 to 846 km^2 in the period from 1990 to 2014 (Ali and Abu El-Magd, 2016).

Many authors stated the eroded area followed by the accreted area in the shoreline of the Nile Delta. EL-Bady, (2007) calculate the erosion and accretion in the two promontories, the erosion is 104.6 m/yr. and 11.4 m/yr. at Rosetta and Damietta promontories respectively in the period from 1984 to 2005. Ali and Abou EL-Magd, (2016) calculate the erosion at Rosetta and Damietta promontories, where the maximum erosion at Rosetta promontories was 823.2m and at

In the past centaury, many authors study the coastal dunes from Gamasa City to Edku and classified them to many types (El Fishawi and El Askary, 1981; Stanley *et al.,* 1992; El-Bady, 2001). The berms are formed due to the accumulate of sands by obstacles, these berms become more height and width to form the coastal sand dunes due to the obstacles on the berms. Thus the foredunes were built up due to growing the berms and the presence of vegetation as obstacles (OKeefe, 1978). Hesp, (1999 and 2002) saied that the foredunes formed on backshore and defined as foremost vegetated sand dunes by aeolian sand deposition among the random cultivations as well as they may be occurred with other dunes types or only in individual foredune. They distinct from beach ridges, where, the beach ridges formed during storm wave and elevated water level events (Psuty, 1965).

Sand resources to sand dunes formation in the Nile Delta derived from the old dunes, beaches and from sediments of the Old Nile Sebennitic Branch, where, the Sebennitic Nile Branch was one of the principal Nile River distributaries during 7000 to 3000 B.C (Stanley *et al.,* 1992) transformed from west to the east by longshore current and by aeolian processes.

To know the history of coastal dunes in the north of Nile Delta during the past thirty-one years, the sedimentology of the beaches and sand dunes and its relationship between each other must be carefully studied.

2. Materials and Methods

The area of study extended from New Damietta City to Burg EL-Burullus were studied to know the present conditions of beaches and sand dunes. The main sites of the coastal sand dunes occurrences are in the area between Baltim and Burg ELBurullus (Fig.1). About 35 samples were collected from the coastal sand dunes in Baltim and Burg EL-Burullus and from the beaches in the same areas (27 samples of Beaches and 8 samples of Dunes). Beach samples collected from the shoreline and the dunes samples were collected from bottom stoss side, top stoss side, bottom lee side, top lee side and the crest of coastal sand dunes.

About 100 grams of each samples were first soaked in water to facilitate their desegregation. The carbonate content were removed using HCl (10%), each samples was treated with H_2O_2 (Fuchtbauer

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and Muller, 1970) to remove organic matter. The sand was separated by sieving using 0.063 mm sieve. The sand fraction weighted and subjected to dry sieving using Ro-Tap shaker and set of standard sieves of one Phi intervals. The values of mean sizes (Mz) and sorting (ʒ) were obtained from the formulas of Folk & Ward (1957) and they were classified according to Folk, (1968).

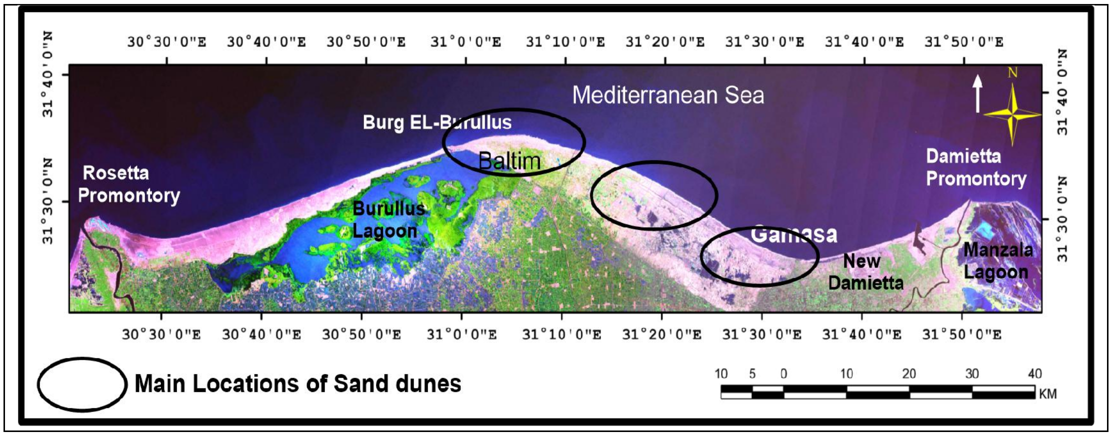

Fig. 1: The study area between New Damietta City and Burg EL-Burullus (modified after EL-Bady, 2007).

2.1. Occurrence and origin of coastal sand dunes

The promontories of the Nile River branches are considered the main sources of sediments in the Nile Delta, these promontories of branches are three two of them are still filled by water come from Sudan (Rosetta, Damietta) and the old Sebennitic branch which was one of Nile River distributaries during 7000 to 3000 B.C. (Stanley *et al.,* 1992).

The wind in the study area arrived from WNW, NW and N and the strong wind showed in the winter (from December to March). The wind comes from E and NE is minor (El-Fishawi and El_Askary, 1981). The winter is characterized by the stronger wind that mainly comes from NW and WNW, and the wind is less frequently from N and NE over the eastern Mediterranean coast, while in the summer months especially in July, the wind is grater and coms from WNW and W over central and eastern Mediterranean coast of the Nile Delta (Sesteni, 1992).

When the sands of the bottom sea are moved by longshore current (currents and waves) to the beach of the sea, the raw materials (sands) are ready to form the sand dune. Then, this moved sands transported on the beach by winds until stopped by obstacle or vegetation to form berms and mounds. The berms are grow to form dunes parallel to the shoreline by continues transportation of sands to the berms (Fig. 2). Thus three formations are formed due to the transportation of sand which stopped by obstacles and vegetation, these formations are berms, mounds and sand dune. When the berms are grow, foredunes or/and the coastal sand dunes are formed. The foredunes are called as the vegetated sand dunes parallel to the shoreline, as well as it near the shoreline on the backshore, where they may be stabilized by vegetation. The coastal sand dunes, foredunes, sand ridges, mounds sand and berms may by occurred on backshore or foreshore zones (Fig. 2, 3).

The coastal dunes were occurred in the study area especially in Gamasa, Baltim and Burg EL-Burullus where the conditions of dune formation are present. The sand accumulation occurred near the sea as in Baltim and Burg EL-Burullus and far from the sea as in Gamasa.

Thus, due to combination of berms and mounting them, the many coastal land forms are formed (Coastal sand dunes and Foredunes) (Fig. 3). The small dunes formed near the shoreline but the large dunes formed after the backshore. When the coastal plain is wide the large dune occurred far from the shoreline, while the small dune formed in narrow coastal plain near the shoreline.

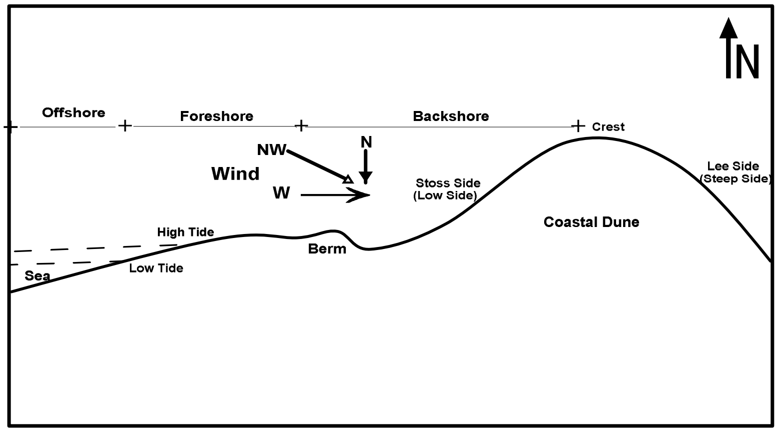

Fig. 2: The steps of sand dune formation

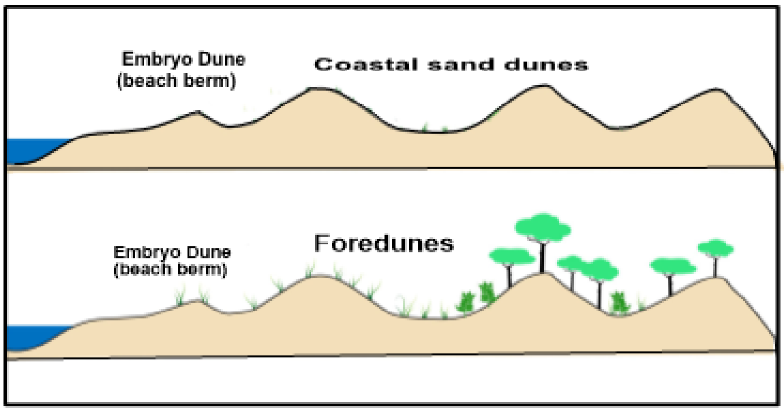

Fig. 3: differences between coastal sand dunes and foredunes

Finally, there are five factors that control the type, alignment, and size of dunes :- wind, sand quantity, grain size, vegetation and the time, these approximately agree with Lancaster (1995).

2.2. Observation fields

From 1990 to 2005, the area between New Damietta City and Baltim have many formations and activities such as coastal sand dunes (Longitudinal and Barchan), berms, mounds, old dunes, beach ridges, and little human activities (industrial, commercial, urban, and tourism) (Figs.4,5,6,7). The area between Baltim and Burg EL-Burullus have longitudinal belt of dunes on the beach adjacent to the shoreline and international high way (Figs 8, 9, 10). The coastal plain is different in width from New Damietta City to Burg EL-Burullus, where it is wide in the east (New Damietta, City Gamasa, area between Gamasa and Kitchener Drain) and narrow toward the west (Baltim and EL-Burullus)(Figs.11,8).

From 2005 to 2021, when the sand supply increases due to the increase of the width of the strand plain as in the east, the longitudinal dunes were occured near Gamasa, also velocities of wind in the east is lower than that at the west (Baltim and El-Burg) (El-Asmar, 2000). While, the sand supply is low in the west (from kitchener to Burg EL-Burullus), the narrow strand plain, and the higher wind velocity take the barckan dunes.

From 2005 to 2021, the area between New Damietta City and El Hammad Village (before Baltim directly) have many formations and activities such as some berms, mounds, and many human activities such as industrial (industrial Gamasa City, electricity, water, waste and cement stations), urban, education and tourism activities (Marina Delta Village, New Mansoura City, Hours and Delta Universities, Markets, Youth Housing), while the agricultural activities are decreased (Fig.12,13,14,15,16,17,18). The berms and mounds sand are removed due to the quickly human activities, thus there is no any complete sand dunes in the east but the sand dune in the west are approximately stable. The area between Baltim and Burg EL-Burullus have longitudinal belt of dunes on the beach adjacent to the shoreline. The coastal plain is different in width from New Damietta City to Burg EL-Burullus, where it is slowly decreased due to many human activities in the east (New Damietta, City Gamasa, area between Gamasa and Kitchener Drain) and narrow toward the west (Baltim and EL-Burullus) crowded by sand dunes and populations.

Now, in 2021, the coastal sand dunes of the study area are occurred only in the area between Baltim and Burg EL-Burullus as well as they decreased and removed with time (Figs. 19,20) The coastal sand dunes in the area from New Damietta City to Baltim are recently removed by many human activities, except little sand vegetated mound due to the digging channels for new cultivations . Thus the collected samples of sand dunes only from of Baltim and Burg EL-Burullus zone. The coastal sand dunes in this zone with longitudinal shape adjacent to the shoreline and the international high way. The size of these sand dunes are decreased due to many industrial and urban activities. The beach of the study area (from New Damietta City to EL-Burullus) from 1990 to 2021 suffering many changes, these observation fields agree with El-Banna, (2004).

With the natural hazards point of view, when the coastal sand dunes were removed, the agricultural, urban and industrial activities increased as well as the pollution by heavy metals increased by the industrial activities. In some areas as El-Shehabea the sand dune removed for agricultural and industrial purposes (Figs 21, 22). The remove of sand dune may also destroyed the some cultivation between dunes and palm tree (Figs 23,24). The remove of sand dunes beside the international high way may be decrease the hazard of sand on the high way (Fig. 25) as well as many of sand dunes especially in the area between New Damietta City and Baltim replaced with some cultivations beside the urban, industrial, and tourism activities (Figs 12 to 17 and Fig. 26).

Fig. 4: Longitudinal sand dune in Gamasa before 2005 (EL-Bady, 2007)

Fig. 5: Small longitudinal sand dune in Gamasa before 2005 (EL-Bady, 2007)

Fig. 7: Barchan sand dune in Gamasa before 2005 (EL-Bady, 2007)

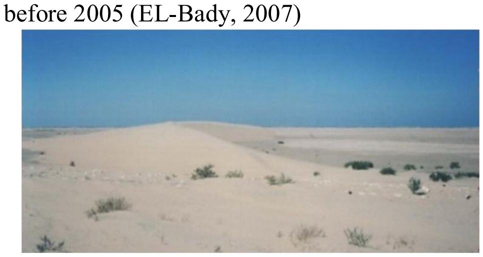

Fig. 6: New Barchan sand dune in Gamasa before 2005 (EL-Bady, 2007)

Fig. 8: Belt of longitudinal dune in EL-Bur and narrow coastal plain (EL-Bady, 2007)

Fig. 9: Belt of longitudinal sand dune adjacent to the international high way

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Fig. 10: Coastal sand dunes adjacent to the inlet of Baltim resort

Fig. 11: Coastal plain in area between New Damietta City to Baltim

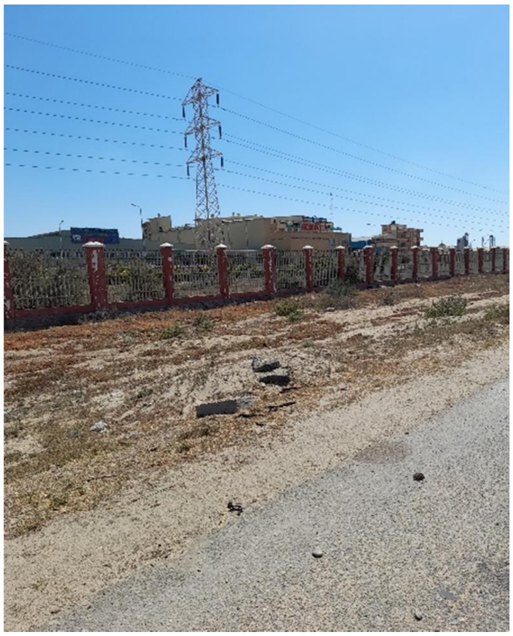

Fig. 12: Electricity station in the area between Gamasa and Baltim

Fig. 13: Marina Delta Village in the area between Gamasa and Baltim in the front EL-Hammad Village

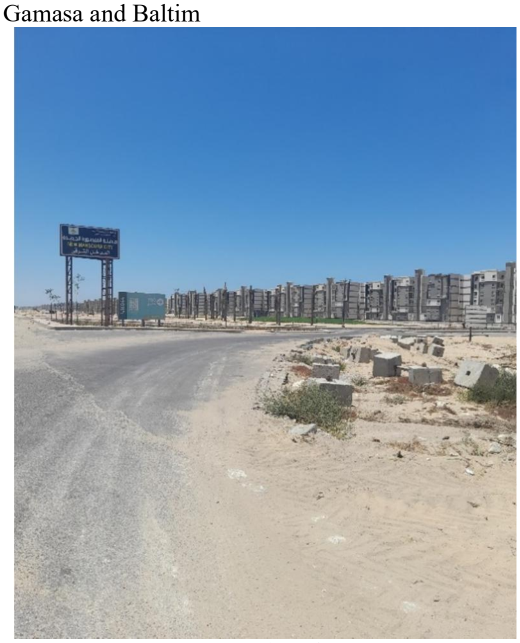

Fig. 14: New Mansoura City after Gamasa

Fig. 15: Nile Delta University after Gamasa

Fig. 16: New Mansoura University in New Mansoura City

Fig. 17: Some cultivation in th3e area between Gamasa and Baltim in 2021

Fig. 18: Large barren uncultivated areas between gamasa and Baltim in 2021

Fig. 19: Belt of longitudinal sand dunes adjacent to international high way in 2021

Fig. 20: decreased belt of longitudinal sand dunes due to human activities in 2021

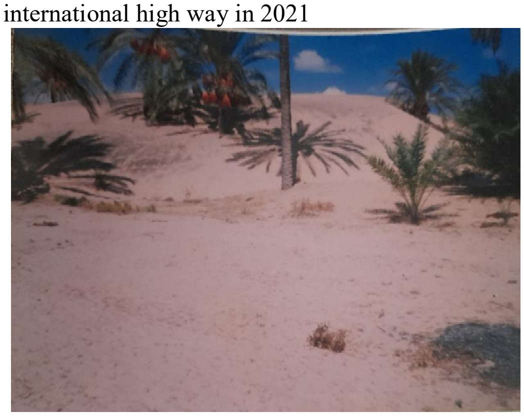

Fig. 21: Sand dune with palm trees in EL-Shehabea before baltim before 2005

Fig. 22: Cultivated areas in EL-Shehabea after remove the sand dunes in 2021

Fig. 23: Remove of sand dunes destroy palm tree after 2005

Fig. 24: Cultivation between sand dunes before

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2005

Fig. 25: Sand dune encroachment on the international high way before 2005

Fig. 26: some cultivation after remove sand dunes in 2021

3. Beach and Dune Relationship
3.1. Sedimentological properties

The collected samples of sand dunes only from of Baltim and Burg EL-Burullus zone and the collected beach sample are from Gamasa, Baltim and Burg EL-Burullus. The coastal sand dunes in this zone with longitudinal shape adjacent to the shoreline and the international high way. The size of these sand dunes are decreased due to many industrial and urban activities.

3.2. Mean size (Mz) and Sorting (δ_I):

Mean size and sorting are calculated according to Folk and Ward (1957) and Folk, (1968) by following equations:

$$\mathbf{Mz} = 1/3\ (\Phi_{16} + \Phi_{50} + \Phi_{84})$$
$$\mathbf{Sorting}\ (\delta_I) = \Phi_{84} - \Phi_{16}/\ 4 + \Phi_{95} - \Phi_5/\ 6.6$$

Mean size of El-Burg, Baltim and Gamasa beaches range from fine sand to medium sand, while the sorting range from very well sorted to moderately well sorted (Table. 2).

El-Burg and Baltim coastal sand dune zone stated that mean size (Mz) of top lee side is finer than the bottom lee side, as well as the Mz of top of stoss side is finer than the bottom of stoss side (Table. 3). Sorting of El-Burg dunes ranges between moderately well sorted to very well sorted, while in Baltim ranges from moderately well sorted to well sorted. Thus, the finer sand occurs in the top and in the lee side of the dunes more than that in the bottom and in the stoss side of the dunes (Table. 3).

Mostly, the mean size (Mz) values of the sand beach is used to known the beach type (accreted or eroded beach), the beach and dune samples in the study area ranges from medium to very fine sand. The relation between mean size of sand beach and sand dune in each zone showing that the mean size of beach is coarser than the corresponding dune.

In the past before 2000 the difference between the mean sizes of beaches and corresponding dunes are very large but now the differences is very small although the relationship between them not changed. Where the size of sand was decreased from the shoreline passing to backshore and to bottom of dune to the top of dune (finest sizes) these results agreed with Anwar *et al.,* (1979), Frihy and Lotfy (1994) and EL-Askary and Lotfy (1995) where, they stated that the accreted beaches have coarser sand than eroded beaches as well as, the accreted beaches are less well sorted and the eroded beaches are more sorted. The mean size and sorting are improved toward from the shoreline to the top of sand dunes (Fig. 26, 27).

Table 2: The mean size and sorting of the beach

Samples	**Location of beach**	**Mz**		**δ**	
1	EL-Burg Beach	2.23	F.S	0.55	M.W.S
2		2.22	F.S	0.39	W.S
3		2.21	F.S	0.56	M.W.S
4	Baltim beach	2.33	F.S	0.57	M.W.S
5		1.86	M.S	0.59	M.W.S
6		1.75	M.S	0.38	W.S
7		1.67	M.S	0.49	W.S
8		1.53	M.S	0.52	M.W.S
9		2.55	F.S	0.57	M.W.S
10		1.81	M.S	0.46	W.S
11		1.66	M.S	0.31	V.W.S
12		1.65	M.S	0.38	W.S
13		1.88	M.S	0.46	W.S
14		1.88	M.S	0.43	W.S
15		2.31	F.S	0.46	W.S
16		1.75	M.S	0.28	V.W.S
17		2.16	F.S	0.43	W.S
18	West Baltim Beach	1.85	M.S	0.32	V.W.S
19		2.09	F.S	0.30	V.W.S
20	East Baltim Beach	1.89	M.S	0.67	M.W.S
21		1.99	M.S	0.63	M.W.S
22		2.27	F.S	0.32	V.W.S
23	Gamasa Beach	1.93	M.S	0.58	M.W.S
24		2.35	F.S	0.67	M.W.S
25		2.33	F.S	0.84	M.S
26		2.37	F.S	0.58	M.W.S
27		2.35	F.S	0.33	V.W.S

F.S = fine sand M.S = medium sand V.W.S = very well sorted W.S = well sorted M.W.S = moderately well sorted

Table 3: The mean size and sorting of the sand dune

Samples	**Location of Dunes**			**Mz**		**δ**	
1	Burg el-Burullus Dunes	Linear	Stoss side bottom	2.25	F.S	0.45	W.S
2			Stoss side top	2.54	F.S	0.35	V.W.S
3			Lee side bottom	2.25	F.S	0.45	W.S
4			Lee side top	2.66	F.S	0.37	W.S
5	Baltim Dunes	Linear	Stoss side bottom	1.56	M.S	0.37	W.S
6			Stoss side top	2.33	F.S	0.46	W.S
7			Lee side top	2.42	F.S	0.45	W.S
8			Lee side bottom	2.35	F.S	0.54	M.W.S

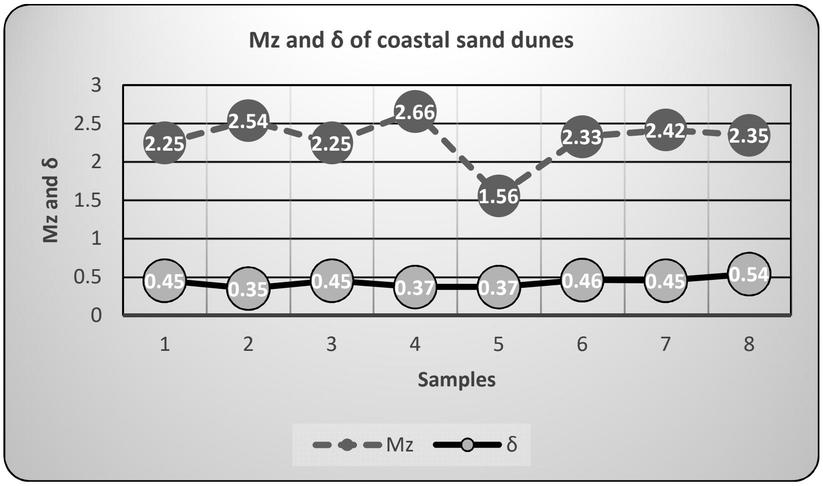

Fig. 28: Mz and Sorting of the coastal sand dunes of the study area

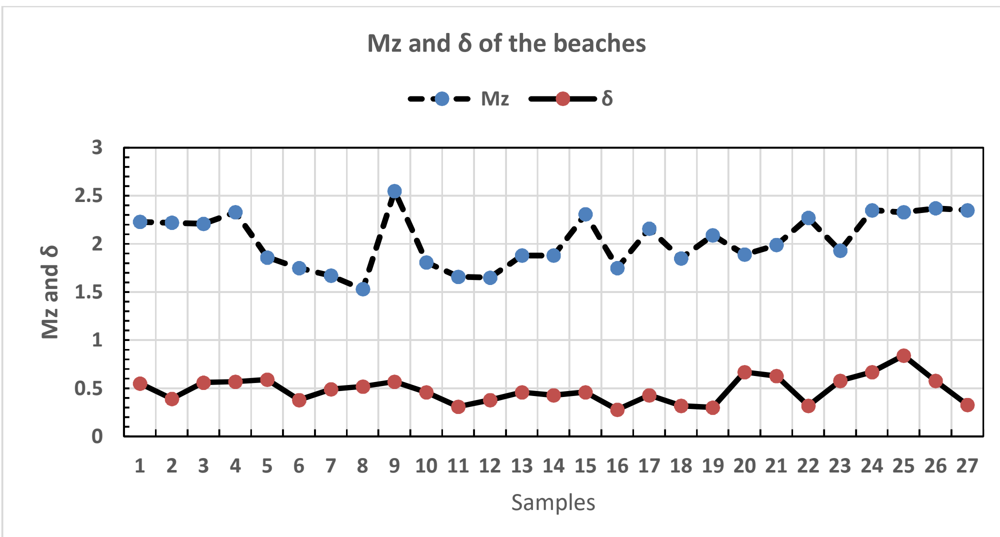

Fig. 27: Mz and Sorting of the beaches of the study area

4. Conclusions

The coastal sand dunes areas are decreased from 1990 to 2021, where the dunes of the area between New Damietta City and EL-Hammad Village are removed by many human activities and national projects.

The coastal sand dunes are occurred in the zone between Baltim and Burg EL-Burullus adjacent to the shoreline. The area between Gamasa and Baltim recently have many human activities and nation projects such as urban projects New Mansoura City, tourism projects such as Marena Delta Village and educational projects such as Hours and Delta Universities.

The relation between beach and dune is agree the previous authors especially Anwar *et al.,* (1979), Frihy and Lotfy (1994) and EL-Askary and Lotfy (1995), where the mean size and sorting improved from shoreline to the top of sand dune.

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