The Dynamics of Sand Dunes and Their Impact on the Capability of Soil in El-Qasr Village, El-Dakhla Depression: A Study in Applied Geomorphology

Dr. Hewyda Tawfek Ahmed Hassan
Lecturer of Geomorphology
Faculty of Education, Ain Shams University
hoydatawfek@edu.asu.edu.eg

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Abstract

El-Qasr Village is considered one of the villages of El-Dakhla Depression that are most affected by sand dunes, which are characterized by continuous dynamic activity, particularly with the increase in human intervention represented, in turn, in the increase in the areas of cultivated lands. This change has a significant role in affecting its soil mechanically and chemically. This has been tracked by studying the movement rates of sand dunes, and their morphometric and morphological characteristics, as well as the factors affecting them, whether physical or human, which led to a decrease in their numbers and area. Furthermore, the study monitors the agricultural expansion along with the correlation between the dynamics of sand dunes and cultivated lands, which was reflected on their characteristics and capability, using the Land Evaluation program. Accordingly, suitable means were identified so as to increase its capability, and choose the best crops that are suitable for cultivation and that have a significant economic return in the region.

***Keywords*:** Sand dunes, capability, soil, El-Qasr Village, El-Dakhla, geomorphology.

ديناميكية الكثبان الرملية وتأثيرها على القدرة الإنتاجية للتربة بقرية القصر بمنخفض الداخلة: دراسة في الجيومورفولوجيا التطبيقية

د. هويدا توفيق أحمد حسن
مدرس الجيومورفولوجيا
كلية التربية، جامعة عين شمس

مستخلص

تعد قرية القصر من أكثر قرى منخفض الداخلة تأثرًا بالكثبان الرملية والتي تتسم بنشاط ديناميكي مستمر وخاصةً مع زيادة التدخل البشري والمتمثل في زيادة مساحات الأراضي الزراعية، وكان لهذا التغير دورًا مهمًا في تأثر خصائص تربتها ميكانيكيًا وكيميائيًا، وتم تتبع ذلك عن طريق دراسة معدلات حركة الكثبان الرملية وخصائصها المورفومترية والمورفولوجية والعوامل المؤثرة فيها، سواء الطبيعية أو البشرية والتي أدت إلى انخفاض أعدادها ومساحتها، ورصد التوسع الزراعي والعلاقة الارتباطية بين ديناميكية الكثبان الرملية والأراضي الزراعية، والذي انعكس على خصائصها وقدرتها الإنتاجية وذلك باستخدام برنامج Land evaluation، وبناءً عليه تم تحديد الوسائل المناسبة لزيادة قدرتها الإنتاجية واختيار أفضل المحاصيل التي تتناسب زراعتها ولها عائد اقتصادي مهم بالمنطقة.

الكلمات المفتاحية: الكثبان الرملية، القدرة الإنتاجية، التربة، قرية القصر، الداخلة، الجيومورفولوجيا.

Introduction:

Sand dunes are characterized by continuous dynamic activity. Their movement leads to the formation of a new form or the concealment of an old one (Mosbah, 2013), particularly since they do not remain still, but are exposed to movement due to the kinetic energy of the wind. This, in turn, leads to the expansion of the affected areas (Al-Jumaili, 2010), and threatens the existence and stability of human communities and cultivated lands.

The encroachment of sand dunes on cultivated lands is considered one of the most serious problems, as it leads to burying lands suitable for cultivation, changing the characteristics of their soil, spreading disintegrated dry soils, eliminating their vegetation, exposing them to various erosion factors, and then converting them to lands where production is low or non-existent (Al-Gawthari and Jaber, 2014).

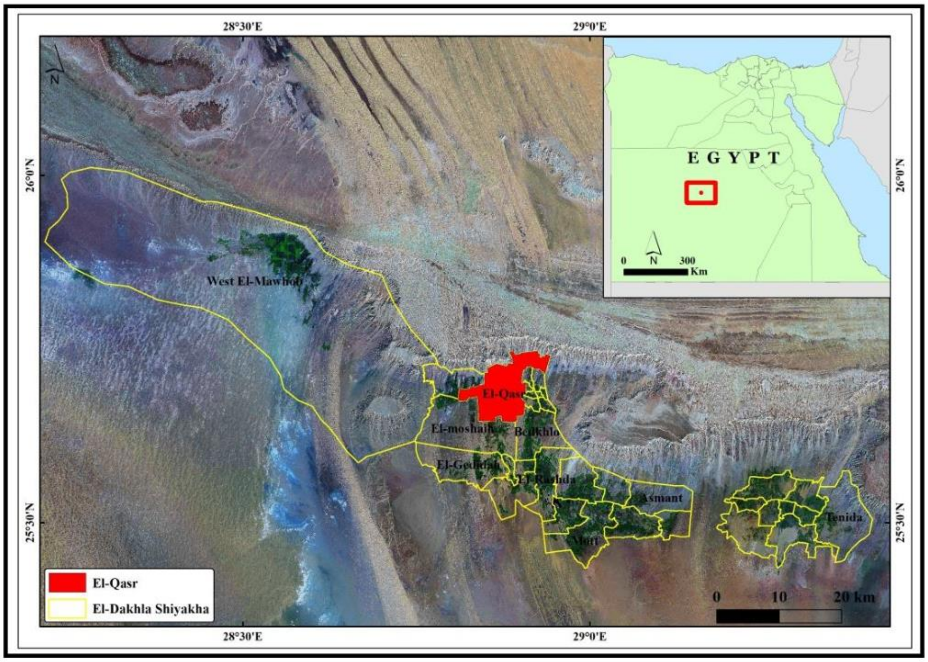
The research aims to study the dynamics of sand dunes, whether morphometric or geomorphological, and to analyze the factors that control these changes. In addition, it aims to identify the correlation between cultivated lands and sand dunes, determine the ranges of the dangerous movement of sand dunes and its impact on the qualitative change of soil texture, as well as determining its capability and selecting the most suitable agricultural crops.

Location of Study Area:

El-Qasr village is located in the northernmost part of the middle of El-Dakhla Depression, and it extends between latitudes 25° 38' 45″ and 25° 44' 50″ N, and longitudes 28° 48' 35″ and 28° 56' 32″ E, with an area of 69.08 km^2 (Fig. 1). Owing to the fact that the location of the village is close to the northern edge and is at the forefront of the winds coming from the north, it is considered one of the depression villages that are most affected by the movement of sands that fall from the escarpment (the source of sand), forming more than one range of sand dunes and overlapping with its cultivated lands. This has affected their capability, whether by the direct encroachment of sand dunes on them or by their sand drift, which has subsequently reflected on the characteristics of soil mechanically and chemically, and caused its quantitative and qualitative degradation.

Materials and Methods:

The study relies on Google Earth visuals (60 cm) in tracking the movement direction of sand dunes as well as estimating their movement rate and morphological characteristics, given that most of the dunes of El-Qasr Village are small in size. The front and side movement of 15 dunes are monitored during two different periods (2003-2020).



Source: Google Earth, Topographic Maps 1: 25000, 1930.

Fig. 1: Location Map of El-Qasr Village

In order to track the development of the area of cultivated lands, Satellite Images are relied on for three different periods (TM 1984, ETM 2003, OLI-ETM 2020), and a supervisor classification with

Signature Editor is made for those Images so as to indicate the change in the area of cultivated lands.

To study the impact of sand dunes on the characteristics of agricultural soil in El-Qasr Village, 11 sectors are analyzed with two samples from each sector, except for two sectors: one of them with three samples and the other with four ones. The total is 25 samples analyzed to study their physical and chemical characteristics in order to assess their capability using Storie method (SYS, 1991), and then determine the suitable crops for cultivation in the village lands using the Land Evaluation program following the method of SYS (1993). What follows is a classification of the research into the following topics:

First: The Dynamics of Sand Dunes in El-Qasr Village

15 dunes are selected to monitor the movement of sand dunes in El-Qasr Village (Fig. 2). Their patterns vary between embryonic, dome, compound and human-modified dunes, and the compound Barchan dunes is dominating (Fig. 3) by 10 dunes with a percentage of 66.7% out of the number of the studied dunes. In addition, the maximum and minimum movement of each dune, the annual movement rate, the change in the areas of those dunes, and the amount and percentage of loss during the comparison period are calculated (Table 1).

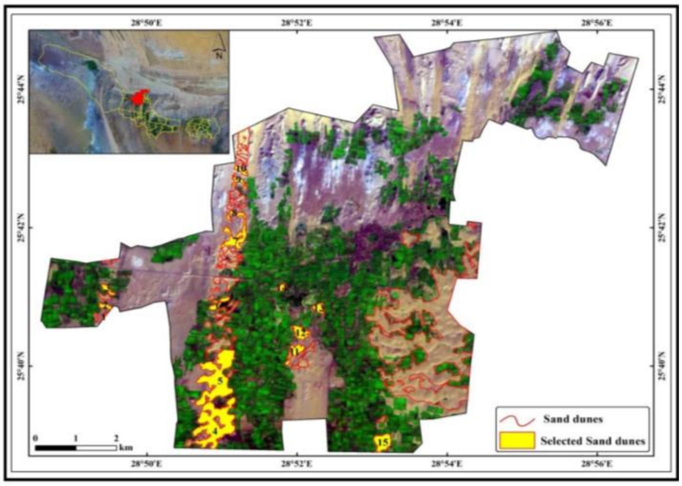


Fig. 2: Movement Rates of Selected Sand Dunes in El-Qasr Village

Source: Field Study, 2020.

Fig. 3: Compound Barchan Dunes South of the Escarpment in the North of El-Qasr Village

Table 1: Movement Rates of 15 Sand Dunes in El-Qasr Village

Dune	Maximum Movement (m)	Minimum Movement (m)	Average Movement (m)	Movement (m)/Year Rate	Dune Area 2003 (m^2)	Dune Area 2020 (m^2)	Loss Amount (m^2)	Loss Percentage (%)
1	166	100	140	8.2	15288.2	9707.1	5581.1	36.5
2	165	93	120	7.1	35788.5	31724.3	4064.2	11.4
3	110	79	92	5.4	45705.4	38231.5	7473.9	16.4
4	145	60	83	4.9	700932.1	661471.0	39461.1	5.6
5	200	80	94	5.5	633400.5	625320.5	8080.0	1.3
6	209	68	134	7.9	85384.6	57792.9	27591.7	32.3
7	225	71	142	8.4	234402.3	165813.5	68588.8	29.3
8	297	220	254	14.9	61532.4	45813.2	15719.2	25.5
9	320	201	273	16.1	77789.0	43368.2	34420.8	44.2
10	324	263	313	18.4	34842.4	34122.4	720.0	2.1
11	82	40	63	3.7	125672.4	89504.6	36167.8	28.8
12	80	34	52	3.1	450079.4	87295.6	362783.8	80.6
13	47	25	27	1.6	201290.8	50796.6	150494.2	74.8
14	88	36	59	3.5	450079.4	29417.5	420661.9	93.5
15	101	43	82	4.8	186351.9	134093.0	52258.9	28.0

Source: Based on Quick Bird Images with differential resolution (60 cm) downloaded from Google Earth Pro for the years 2003-2020.

Fig. 2 and Table 1 indicate the following:

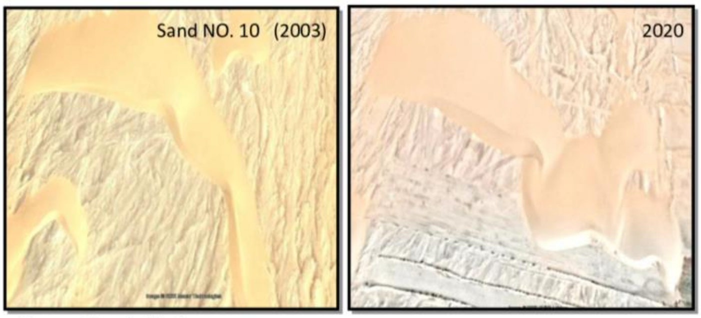
The general average of the movement of the Barchan sand dunes in El-Qasr Village was 7.6 m/year[1], which ranged between 1.6 and 18.4 m/year. Based on the classification of Zhenda et al. (1986)[2], the sand dunes in El-Qasr Village are among the fast dunes (based on the general average), although this speed varies from one dune to another, ranging from moderate speed in dunes number (4, 11, 12, 13, 14 and 15) and fast movement in the rest of the studied dunes. This, in turn, reflects the impact of the movement of dunes on the cultivated lands, even if this impact varies according to a number of factors affecting that movement such as size, location, wetness, vegetation and other factors that are to be mentioned later.

The movement rate of sand dunes within El-Qasr Village varies from one region to another, as the maximum annual rate of the movement of dunes reached 18.4 m/year in Dune No. 10 northwest of El-Qasr Village (Fig. 4). It is located in one of the sand paths coming from the northern edge, the abundant supply of sand, which is characterized by relative distance from cultivated lands and relative spacing of dune sites, facilitating movement and making it free. On the other hand, the minimum annual rate of the movement of dunes reached 1.6 m/year in Dune No. 13 located in the middle of the study area in the center of cultivated lands.This was the main reason for its low rate of movement, in addition to the role of human intervention in cutting off many of its parts and planting them, as 74.8% of its area was lost in favor of agriculture (Fig. 5).

[1] By comparing this with previous studies that dealt with sand dunes in El-Dakhla Depression as a whole, it is found that they converge with the results of Srougy (2011) that the movement rate was 8 m/year. However, it differs with the results of Ghadiry and Koch (2010), where the movement rate was 5 m/year, and the results of Hereher and Ismael (2015), where the movement rate ranged between 5.9 m/year in the dunes north of the escarpment and 3.6 m/year in the dunes in the depression floor.

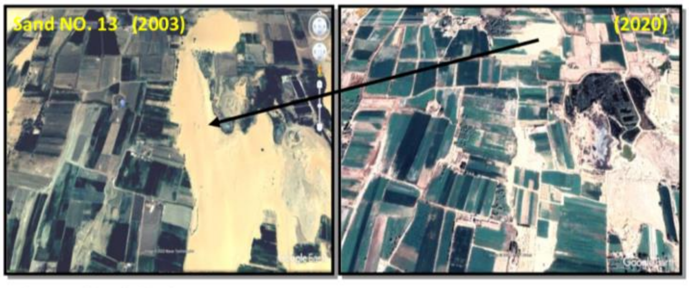
[2] Zhenda et al. (1986) divided the movement rate of sand dunes according to their speed into four groups: slow dunes (less than 1.0 m/year), moderate dunes (1.0 - 5.0 m/year), fast dunes (6) 20 m/year), and very fast dunes (20 m/year and more).

El-Qasr Village dunes witnessed a noticeable change in their numbers and areas. Although this change differs from one dune to another, all of them decreased in number and area from 2003 to 2020. To illustrate, the number of dunes decreased from 96 to 59 dunes (Fig. 6), i.e. a decrease of 38.4%, and Dune No. 14 recorded the highest decrease, as it lost 93.5% of its area, followed by Dune No. 12 with a loss of 80.6%, while Dune No. 5 recorded the lowest amount of loss with 1.3%. This also applies to the entire village and not just on the level of the studied dunes, as the area of sand dunes decreased significantly from 11.74 km^2 in 2003 to 8.71 km^2 in 2020, i.e. a decrease of 23.5%. As a matter of fact, the human intervention had an evident impact on the decrease of the sand dune areas in the village, as the total area of the dunes that were removed and levelled for cultivation, used in construction or agriculture and building upon them, or used to establish service facilities and for other purposes reached 2.6 km^2 and concentrated northwest and west of El-Qasr Village, even though they are characterized by their spread in all the sand dune paths in the study area.



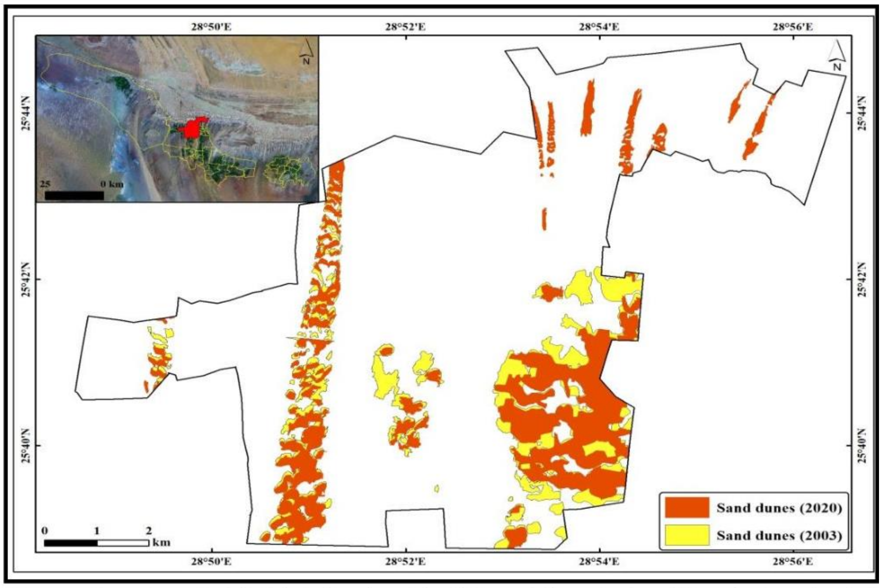
Source: Google Earth

Fig. 4: The Morphological Change of Dune No. 10 Northwest of El-Qasr Village



Source: Google Earth

Fig. 5: The Role of Human Intervention in the Decrease of the Movement Rate of Dune No. 13 and Its Area



Source: Based on Quick Bird visuals with differential resolution (60 cm) downloaded from Google Earth Pro for the years 2003-2020.

Fig. 6: The Change in the Areas of Sand Dunes in El-Qasr Village

Second: Factors Affecting the Movement of Sand Dunes

The movement of sand depends on several factors, the most important of which are the availability of sand, wind speed and direction, and the absence of obstacles preventing their movement, such as ponds, sabakhas, and agricultural reclamation. What follows is a study of the most important factors affecting the movement of sand dunes in El-Qasr Village.

1. Wind:

Wind is one of the most important climatic elements responsible for forming sand dunes and determining their directions and patterns. The analysis of Tables 2 and 3 and Fig. 7 and 8 indicate some wind characteristics at El-Dakhla station, which can be summarized as follows:

- Winds blow on El-Qasr Village from all sides, but at varying rates. The northern winds recorded the largest percentage of 27%, followed by the northwest winds with a percentage of

23.9%. Accordingly, this was reflected on the sand dunes, whose axes took the same direction as the prevailing winds.

- The north and northeastern winds prevail during the winter season, recording together a percentage of 65%, while the northwestern winds prevail in the rest of the seasons with percentages ranging between 17.7% and 26.5%. Accordingly, these directions have the ability to move sand dunes in the direction of their wind, as the formation and movement of sand dunes require a large period of time in which winds prevail from one direction for most months of the year without change (Al-Jilani, 2020).
- The annual average wind speed reached 16.2 km/h, as the maximum wind speed was recorded in the summer, particularly in June, at a rate of 20.5 km/h, while the lowest wind speed was recorded in the winter (14.0 km/h) in December at a rate of 12.6 km/h.
- The wind speed in the study area is classified between weak and moderate[1]. Concerning the moderate wind, it occupies 67%, and it is the wind affecting the dynamics of the dunes of El-Qasr Village, as this speed is able to move and transport sand grains between moderately coarse and very coarse sands (0.50 and 1 millimeters). As for the weak wind, it is able to move only fine sands, which has a grain size of 0.25 millimeters (Gouda, 1997).

Table 2: Percentages of Seasonal Wind Directions at El-Dakhla Station

Directions	North	Northeast	East	Southeast	South	Southwest	West	Northwest	Calm
Winter	44.1	20.9	3.2	3.0	2.7	2.6	6.8	14.5	2.2
Spring	17.7	12.8	8.9	8.5	9.9	6.9	11.6	21.5	2.2
Summer	26.5	10.5	2.2	1.5	2.9	3.8	19.8	31.6	1.2
Autumn	19.7	15.0	3.7	3.1	4.5	6.7	16.9	28	2.4
Average Annual	27.0	14.8	4.5	4.0	5.0	5.0	13.8	23.9	2.0

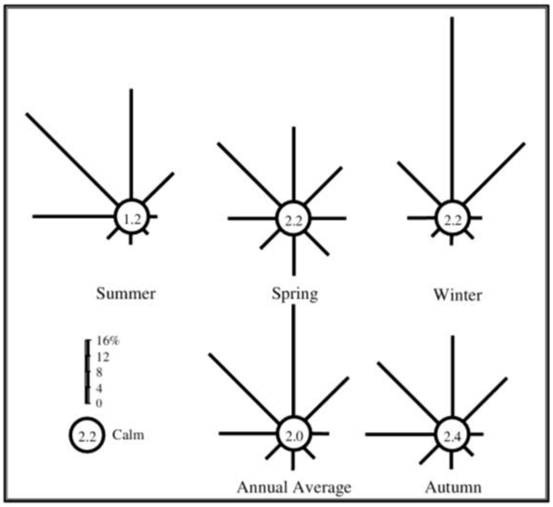
Source: The General Meterological Authority, Climate Devision, 1970-2005 (Hafez, 2015).

[1] The moderate wind speed ranges between 15.4 km/h and 19.2 km/h (Farghaly, 2007).

Table 3: Monthly and Seasonal Rates of Wind Speed at El-Dakhla Station

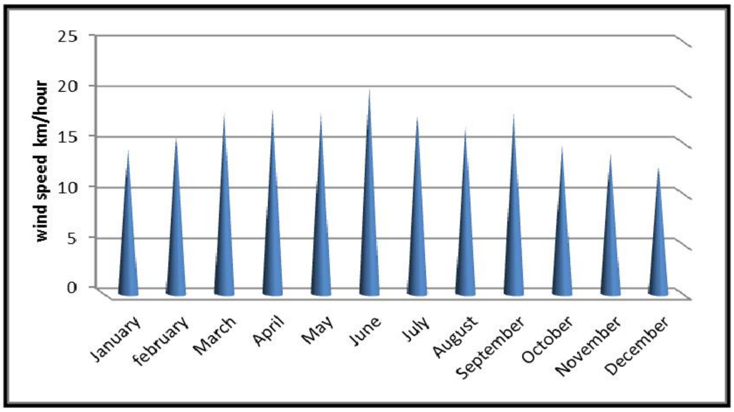
Year Months and Seasons	Wind Speed (Km/h)	Year Months and Seasons	Wind Speed (Km/h)
December	12.6	June	20.5
January	14.4	July	17.6
February	15.5	August	16.6
Winter	14.0	Summer	18.4
March	18.0	September	18.0
April	18.4	October	14.8
May	18.0	November	14.0
Spring	18.0	Autumn	15.5
Annual Rate	16.2		

Source: The General Meterological Authority, Climate Devision, 1970-2005 (Hafez, 20



Source: Based on Table No.2

Fig. 7: Wind Rose at El-Dakhla Station 1970-2005



Source: Based on Table No. 3

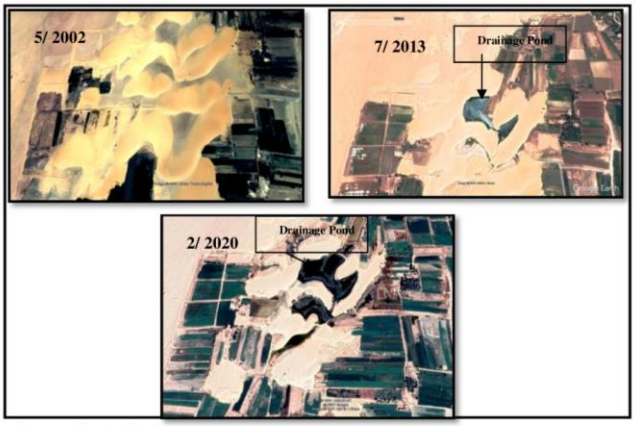
Fig. 8: Month Rates of Wind Speed in the Study Area

2. Wetness:

Wetness affects the dynamics of sand dunes through two factors: the wetness of surface on which they move and rain, each of which has an impact on the cohesion of sand grains and the reduction of their movement. Therefore, sand grains saturated with wetness need faster winds to be transported and moved (Thomas, 1997).

The annual average of relative humidity in the study area reached 29%, as the lowest rates were recorded in May at 19%, and the highest in December at 42%. As for rain, it has a small role in affecting the movement of sand dunes, as the annual total of the amount of rain falling during the year at El-Dakhla station was 0.5 mm, and the largest amount of rain was in February of 0.2 mm (Hafez, 2015).

The field study monitored the impact of water-saturated lands represented in ponds and sabkhas in decreasing the area of sand dunes in El-Qasr Village, and the best example is manifested in the pond located west of El-Qasr Village. This pond appeared in 2013 at the beginning of its formation as small spots located in the inter-spaces between the sand dunes, and then gradually its area increased at the expense of the area of sand dunes, as the area of Dune No. 6 decreased from 85384m^2 in 2003 to 57792m^2 in 2020, with a loss percentage of 32.3% (Table 1), (Fig. 9).



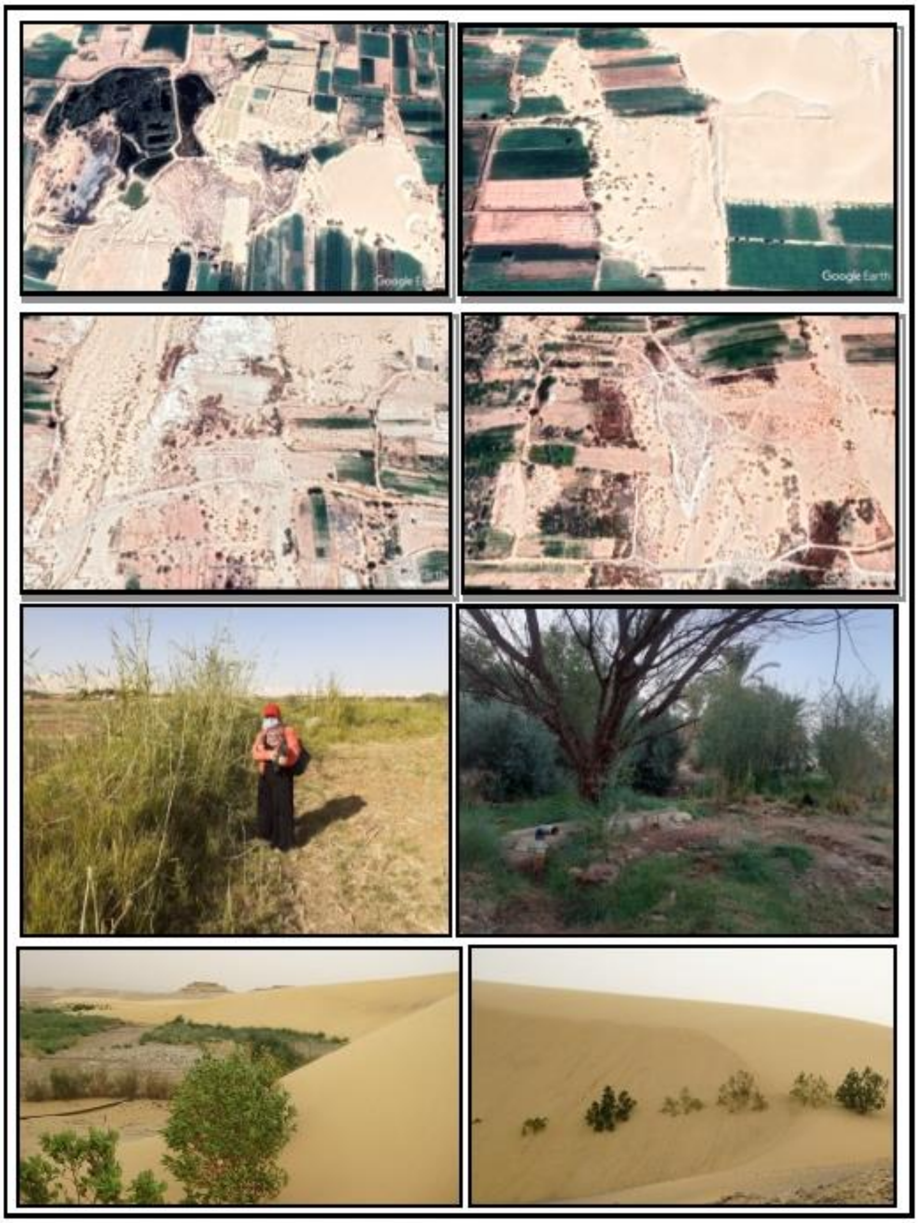
Source: Google Earth
Fig. 9: The Spread of Sand Dunes before the Formation of the Drainage Pond West of El-Qasr and the Decrease of Its Area after Formation

3. Vegetation:

El-Qasr Village is characterized by a moderate natural vegetation, although its spatial distribution differs from one region to another. The location of El-Qasr Village at the depression floor, its proximity to the ground water level in most of its parts, and the expansion of agricultural land reclamation had a role in the emergence and spread of natural vegetation. This is mainly due to the fact that its distribution is linked to areas of saline sabkhas and ponds where it grows on its edges. It also grows on the margins of some sand dunes and above them, particularly in areas where agricultural soil overlaps with the axes of sand dunes, as a result of leaching from agriculture and irrigation processes (Fig. 10). Moreover, vegetation appears within cultivated lands or on their edges, which represent the low parts in which agricultural soil drains its excess water. Accordingly, the impact of the natural vegetation on the movement of sand dunes takes two forms, either by fixing the sand, which is considered as a trapping for sand, or by increasing its accumulation. Besides, the role of vegetation and its ability to trap sand depend on its type and density (Masbah, 2013).

4. Topography of the Earth's Surface:

The topography of the earth’s surface on which the sand dunes move in the study area plays a role that has an impact on the rate of sand movement in the direction of the wind, as sand gathers in low areas. Besides, the presence of physical obstacles such as small hills, hummocks or others... changes the paths of sand movement. Accordingly, the topographical characteristics of the study area are studied. The analysis of Fig. (11 and 12) and Table (4) indicates the following:

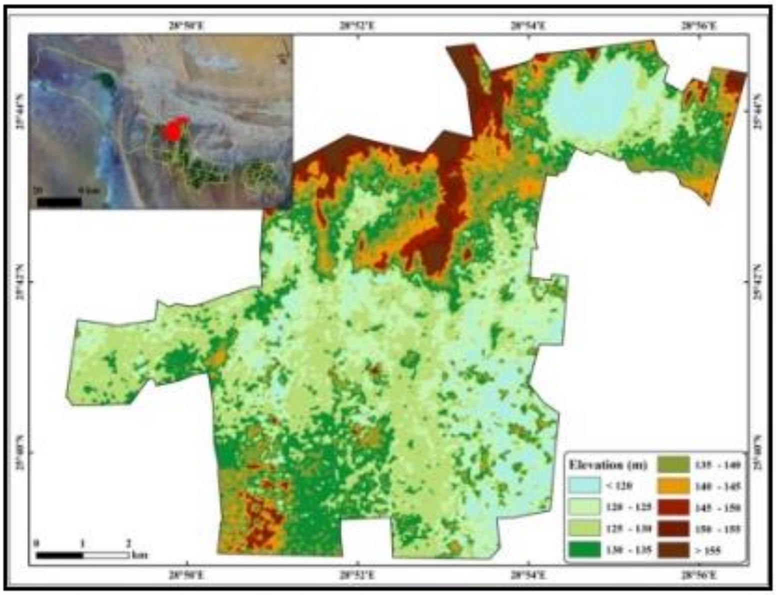


Source: Google Earth and Field work, 2020

Fig. 10: The Spread of Natural Vegetation in the Margins of Sand Dunes and above Their Surfaces, Salinity Areas, the Edges of Ponds, and Cultivated Lands in El-Qasr Village

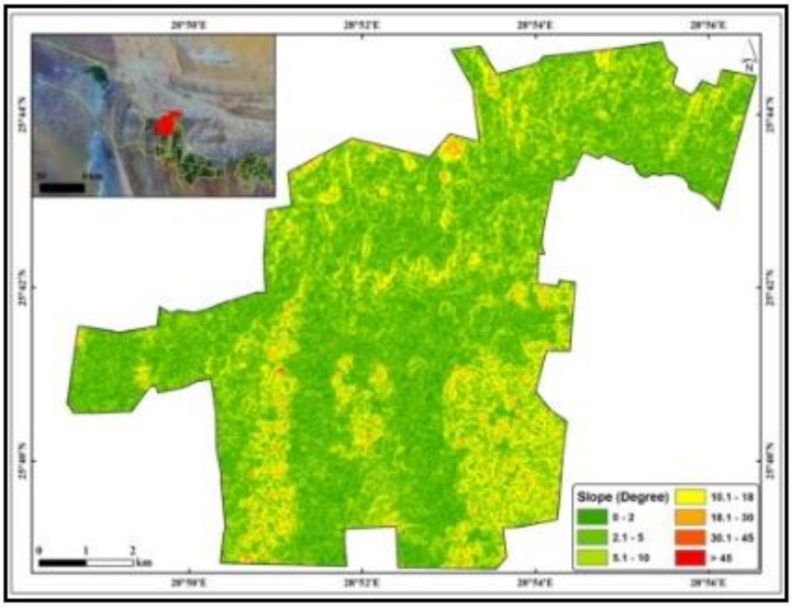
- The higher areas, which range between 145 and 472 m, represent the lowest percentage (8.1%), and they are represented in the northern and northwestern margins (the escarpment) and limited parts southwest of El-Qasr Village. On the other hand, elevations between 100 and 135 m occupied the first place with a percentage of 74.1%, and are represented in the old cultivated lands and sand dune ranges.
- The slope categories from zero to ^{5}5 occupied a percentage of 90.1%, hence the study area is characterized by relative levelling in most of its parts, and this is reflected in the formation of sand dunes.

The northwestern and northern winds, after the sand fell on the northern escarpment coming from El-Farafra sand sea (sand source), were able to transport it through the low areas, represented here in the beds of dry wadis and Khors, and deposit it inward in the form of longitudinal paths or ranges that overlap with the agricultural lands extending from the northern escarpment to the depression floor towards the south, where El-Qasr Village is located. It is worth mentioning that the low degree of slope along with the few elevations helped in sand deposition.



Source: Digital Elevation Model (14.5m)

Fig. 11: Elevation Categories in El-Qasr Village



Source: Digital Elevation Model (14.5m)

Fig. 12: Slope Degrees in El-Qasr Village

Table 4: The Relief Characteristics of El-Qasr Village

Elevation			**Slope**		
Categories(m)	**Area km²**	**Area %**	**Categories (degrees)**	**Area km²**	**Area %**
120 <	5.96	8.50	0 - 2	12.53	18.10
120 – 125	11.63	16.80	2 - 5	31.96	46.00
125 – 130	20.34	29.40	5 - 10	17.85	26.00
130 – 135	13.30	19.40	10 - 18	5.80	8.50
135 – 140	7.88	11.40	18 - 30	0.90	1.30
140 – 145	4.45	6.40	30 - 45	0.0417	0.100
145 – 150	2.39	3.50	> 45	0.0023	0.003
150 – 155	1.44	2.20	SUM	69.08	100.00
> 155	1.69	2.40			
SUM	69.08	100.00			

Source: Based on (Fig 9-10) Using Arc map (10.5)

5. Relative Locations of Sand Dunes:

Relative locations affect the distances that the dune moves, as each dune affects the other by its impact on wind speed and direction

(Imbaby and Ashour, 1985). The analysis of satellite Images and the field study shows that the distances between the sand dunes are increasing towards the northwest, which had an impact on the high rate of their movement, particularly in Dunes No. 1, 8, 9 and 10. On the other hand, dunes in the eastern side of the study area are characterized by their density and the very small distances between them, which led to their Coalescence and made it difficult for the researcher to study their movement (Fig. 13).

Source: Google Earth, 2020

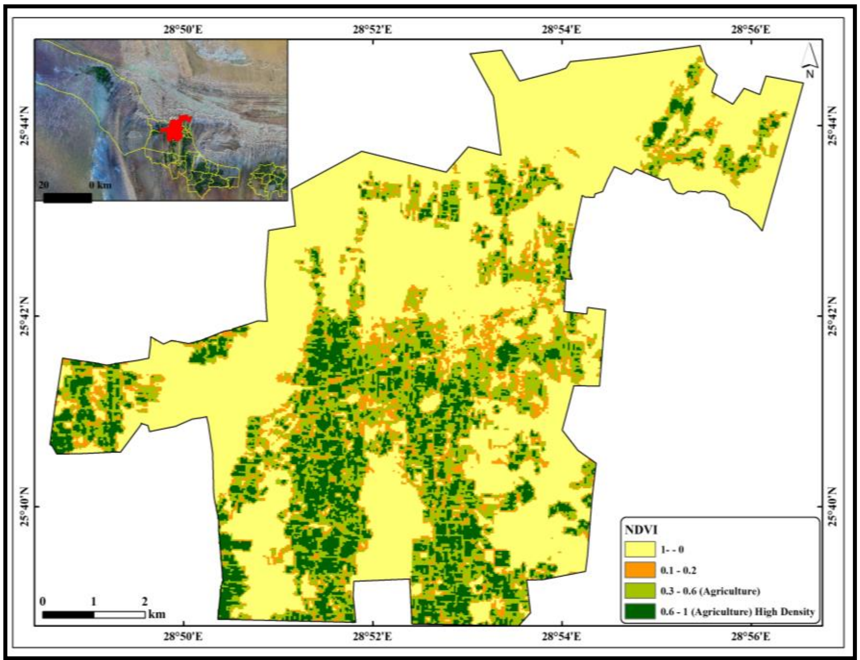
Fig.13: Relative Locations of Sand Dunes in El-Qasr Village between Spacing and Compaction

Third: Cultivated Lands in El-Qasr Village

El-Qasr Village witnessed an evident increase in the areas of cultivated land, as it is one of the leading villages in El-Dakhla Depression involved in this regard. This change had a significant role in the dynamics of sand dunes, as the analysis of Table 1 and the field study indicates that the movement of sand dunes decreased in the areas adjacent to the cultivated lands, particularly after human intervention in removing and cutting parts of the dunes for cultivation.

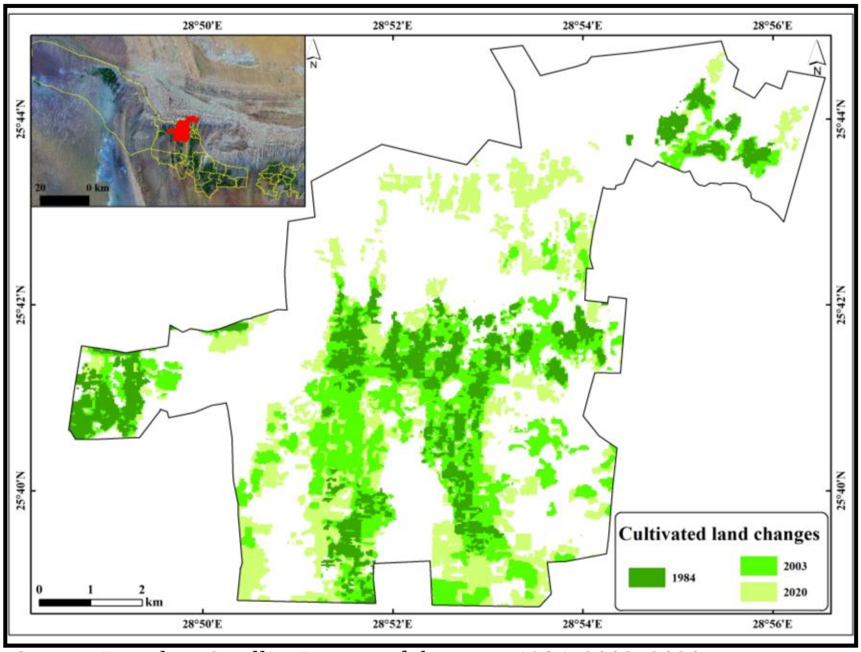
The development of the cultivated land area was tracked by applying the Normalized Difference Vegetation Index (NDVI)[1] and the supervisor classification of satellite Images of different years (1984, 2003, 2020), with the aim of identifying the natural and cultivated vegetation and its impact on the movement of sand dunes. Figures 14 and 15 indicate that the areas of cultivated land in El-Qasr Village witnessed an evident increase from 1984 to 2020. In 1984, the area of cultivated lands reached 6.45 km^2 with a percentage of 9.24% of the study area, and it represents the old lands that were away from the sand dune paths in most of its parts. In 2003, the area of cultivated lands was more than twice in size, reaching 16.26 km^2 with a percentage of 23.54%, and it is considered an extension of the old lands towards the south. With the expansion of agricultural land reclamation and the trend towards cultivating sand dune surfaces, cultivated land increased to 24.93 km^2 in 2020 with a percentage of 36.1%. Therefore, its growth direction overlap with sand dune paths and in many cases their areas increase at their expense, by cutting off parts and planting them. Moreover, the density of vegetation, particularly the cultivated area, had an impact on the decrease in the movement of the dunes.

[1] Normalized Difference Vegetation Index: NDVI is an index to find out how much of the study area is covered by vegetation. The index gives a number between -1 and 1, representing the density of vegetation. Generally, the index approaches to 1, it means dense vegetation and less than zero represents water, and cloud equation is used to calculate NDVI where R= red band radiance & NIR= infrared band radiance (Entezari,et al., 2019). NDVI= (NIR-R)/(NIR+R)



Source: Based on Satellite Images Landsat 8, 2020.

Fig. 14: Normalized Difference Vegetation Index (NDVI) in El-Qasr Village



Source: Based on Satellite Images of the years 1984, 2003, 2020.

Fig. 15: The Change in the Areas of Cultivated Lands in El-Qasr Village

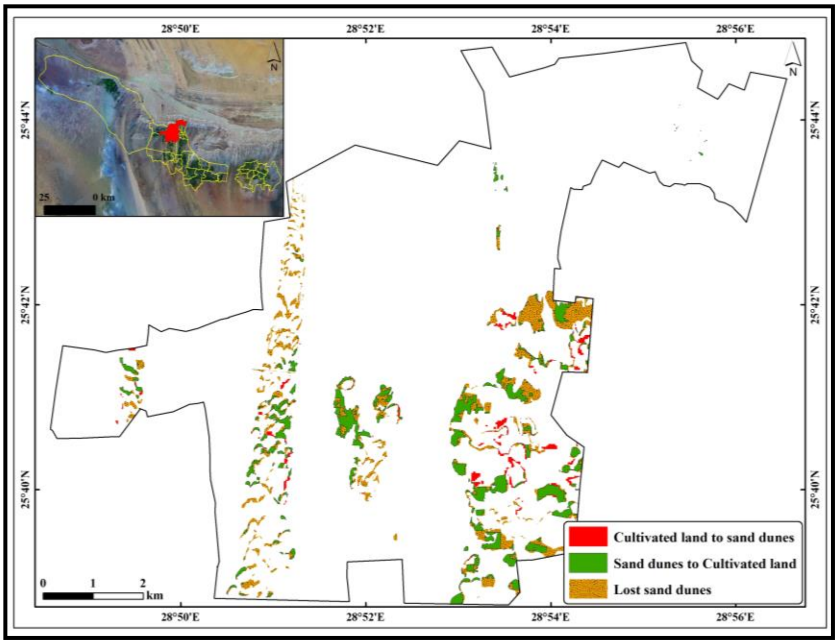
Fourth: The Impact of Sand Dunes on the Capability of Cultivated Soils in El-Qasr Village

The sand dunes in El-Qasr Village are one of the most significant factors that threaten Cultivated lands, as the proximity of cultivated lands to sand dune locations negatively affects their texture. The process of sand deposition on the soil of cultivated lands and their mixing with their layers lead to a qualitative and quantitative degradation in its characteristics, particularly the mechanical ones, and accordingly lead to a decrease in its capability and the productivity of cultivated crops. Figures 16 and 17 and Table 5 indicate the following:

- The total areas that were cultivated lands in 2003 and were covered by sand dunes in 2020 reached about 0.3 km^2, and were mainly concentrated in areas where modern agricultural reclamation lands extend within the sand dune ranges, particularly in the eastern side of El-Qasr Village.
- The areas that were dunes in 2003 and were turned into cultivated lands reached about 2.0 km^2. This is mainly due to the trend towards cultivating the surfaces of sand dunes, so we find them spread in all the sand dune paths in the study area, and most of them have proven successful. The most important crops that were cultivated were alfalfa and fruits such as mango, although in some areas cultivation failed and those areas were covered with sand.
  - The total area of cultivated lands exposed to sand encroachment[1] to an extremely dangerous degree reached

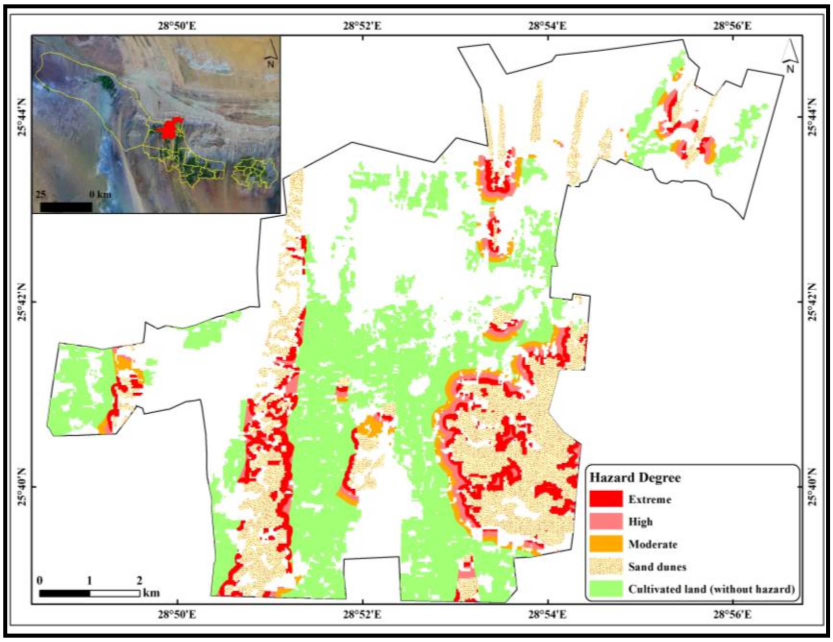
[1] The study relied on the classification of the hazard degree of sand movement on cultivated lands in El-Qasr Village on the methodology of Serougy (2011), as he determined the degrees of hazard by specifying the spatial range surrounding the dunes from its sides and front. The hazard increases as the cultivated lands approach the dunes, and decreases as we move away from them. In addition, the ranges of hazard were determined using Analysis Proximity, but the study differs in this regard as it chooses a 100-meter interval, as a boundary separating each hazard range from another. This has been done with the aim of identifying cultivated lands exposed to potential damage, within a period of 10 years, in conformity with short-term development plans. Many variables have also been taken into account in this classification, represented in the topography, wind direction, and movement direction of the dunes

3.61 km^2, with a percentage of 14.5% of the total cultivated lands in El-Qasr Village. Cultivated lands exposed to a high danger occupied 1.71 km^2, with a percentage of 6.9%. As for the lands that are far from the movement of sand dunes with a distance ranging between 200 and 300, they reached 1.45 km^2, with a percentage of 5.8%, and they represent a moderate danger to cultivated lands. The lands that are more than 300 meters away from the sand dune movement represent the largest percentage of the total cultivated lands in El-Qasr village, reaching 72.8%. During the field study, it was found that the farmers insisted on reclaiming their lands near the dune paths, despite their constant exposure to the danger of embedment (Fig. 18).



Source: Based on Quick Bird Images with differential Resolution (60 cm) downloaded from Google Earth Pro, 2020.

Fig. 16: The Spatial Relationship between Cultivated Lands and Sand Dunes



.Source: Topographic Maps 1: 25,000, and Satellite Images from Google Earth Pro, 2020

Fig. 17: Classification of the Hazard Degree of Sand Movement on Cultivated Lands in El-Qasr Village

Table 5: Range of the Hazard Degree of Sand Movement on Cultivated Lands in El-Qasr Village

Hazard Degree	Distance from Dunes (m)	Area km^2	Area %
Extreme	0-100	3.61	14.5
High	100-200	1.71	6.9
Moderate	200-300	1.45	5.8
Cultivated Land (without hazard)	>300	18.16	72.8
Total		24.93	100

Source: Based on Fig. 17.

Source: Filed Study, 2020.

Fig. 18: The Impact of Sand Movement in Threathening the Cultivated Lands and Irrigation Channels by embedment in Separate Areas in El-Qasr Village

Accordingly, cultivated lands were affected by sand dunes and are still affected, and this can be clarified through the following elements:

1. The Impact of Sand Dunes on the Qualitative Change of Soil Texture:

The study adopts the methodology of Saleh (2006)[1] and Atyya (2018) to study this topic, by taking profiles of the soil of cultivated

[1] The study adopts the methodology of Saleh (2006) in comparing between the cultivated lands near and far from the dune locations, but the current study differs from it in the way

lands close to the locations of sand dunes or located within their range, and profiles of cultivated lands far from the dune locations, in order to compare them in terms of texture.

The analysis of Appendix (1) and Fig. (19, 20 and 21) indicate that:

- The impact of agricultural soils in the study area differed from one profile to another, according to the proximity or distance from the ranges of sand dunes and sheets, as the proportion of sand in profiles (1, 6 and 10) increased in the surface layer only, ranging between 76.92 and 96.95%, while the subsurface layers were dominated by loam and clay texture. This is due the fact that these profiles were affected by the process of sand drift from the sand forms close to them, which led to a change in the soil texture to sand in the surface layer.
- Profiles (2, 4, 5 and 8) were characterized by the dominance of sand along the layers of the profile, and the reason is that these profiles were sand dunes that were leveled and their surfaces were cultivated (newly reclaimed lands), and therefore their main component is sand. It is worth noting that profile (4) is exposed to sand encroachment from the neighboring dunes that have not been levelled, and profile (8) as well, as it was part of sand dune lands from 25 years that were levelled with a layer of clay and cultivated. Therefore, it is relatively less than its formers in the proportion of sand, as its profile is mixed with clay.
- Most of the soil profiles of cultivated lands far from the range of sand forms and located in the middle of cultivated lands were characterized by a low percentage of sand compared to those of clay and silt, as the percentage of clay ranged between 19 and 67% in the subsurface layers.

It is worth noting that it was found from the field study that most of the soil profiles did not represent the original soil, but rather a

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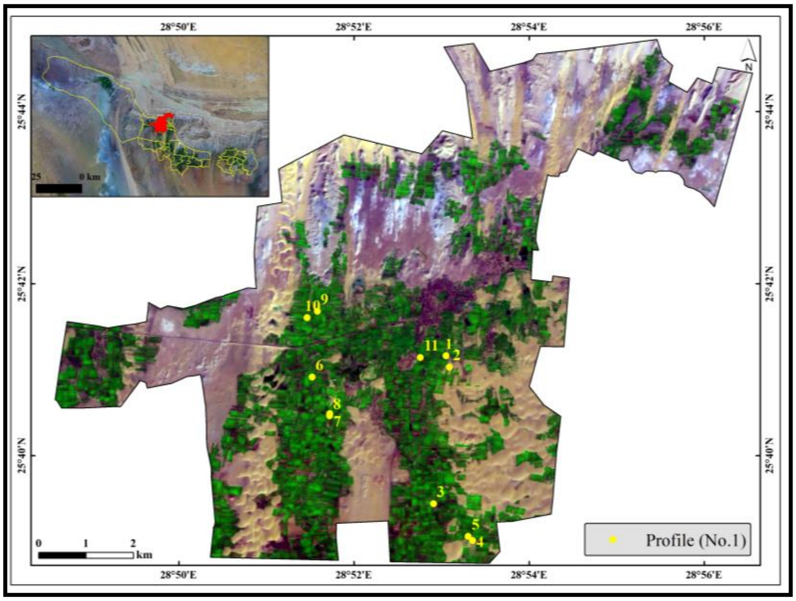
it was approached. Saleh's (2006) study relied on the geochemical analysis of the micro-elements of the soil profiles, and the analysis of the surface layer only of cultivated land soil samples. As for the current study, it relied on the mechanical characteristics and qualitative change in the layers of soil texture as adopted in the study of Atyya (2018).

backfill. That is, the farmer is forced to bring red clay or shale transported soil, which is scattered in El-Dakhla Depression, particularly in the Mut road, so as to increase the fertility of the soil.



Source: Google Earth, 2020

Fig. 19: Distribution of Locations of Soil Profiles in El-Qasr Village

Source: Field work, 2020

Fig. 20: Variation in Soil Texture in El-Qasr Village

Source: Field work, 2020

Fig. 21: Locations of Soil Profiles in El-Qasr Village

2. Land Capability of Soil Profiles in El-Qasr Village

Capability is the potential of land for use in specified ways, or with specified management practices. The purpose of land capability classification systems is to study and record all data relevant to find the combination of agricultural and conservation measures, which would permit the most intensive and appropriate agricultural use of the land without undue danger of soil degradation.

There are several methods of evaluating the capability of soil including Sys et al. (1991), Asel program, Microlies program, and the use of GIS environment to build an evaluation model. The study adopts the method of Sys et al. (1991) (using the Land Evaluation program) (Fig. 21). This is mainly due to the fact that this method is widespread and suitable for arid and semi-arid areas, and therefore it is one of the most suitable methods that can be applied to the soil profiles of El-Qasr Village.

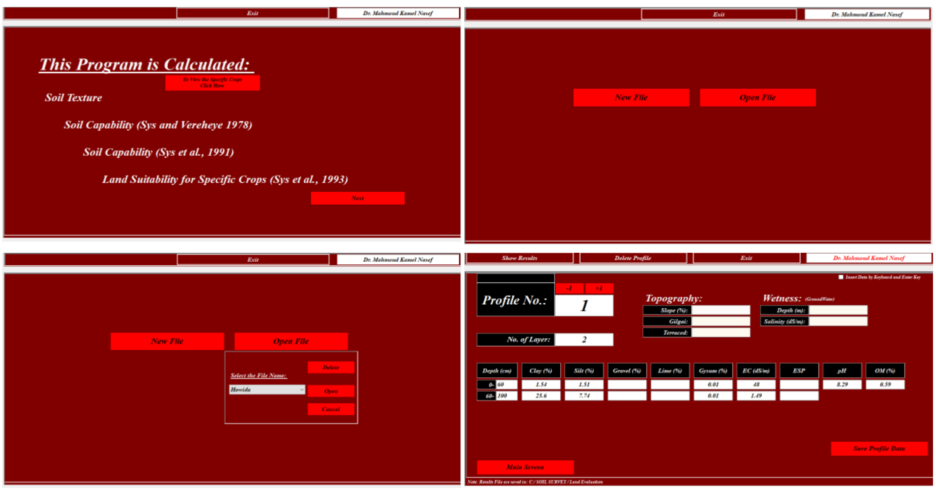


Fig. 21: The Interface of Land Evaluation Program

The evaluation of the soil capability index is based on the mechanical and chemical characteristics of the study area profiles (Appendix 1). The characteristics entered in the program are the following: topography (t), wetness (w), soil texture (S1), soil depth

(S2), calcium carbonate (S3), gypsum (S4), and salinity and alkalinity (n). To obtain the soil suitability index for cultivation, the following equation is applied:

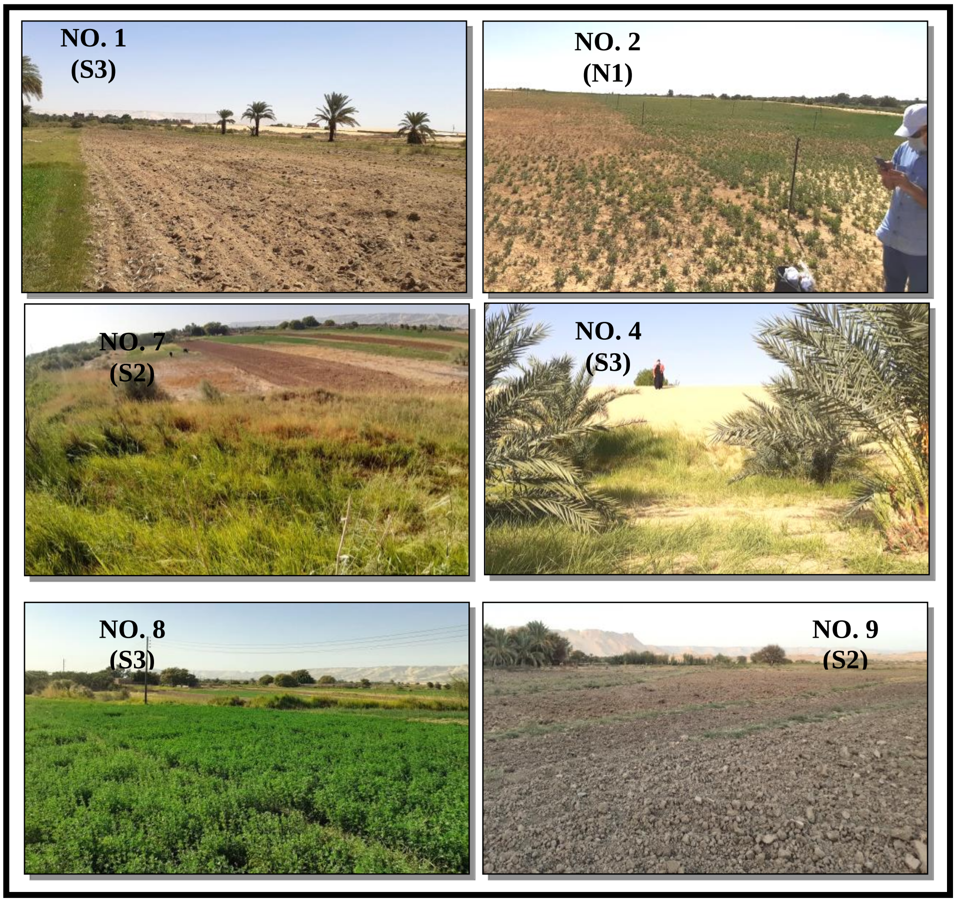
$$Ci = t \times \frac{w}{100} \times \frac{S1}{100} \times \frac{S2}{100} \times \frac{S3}{100} \times \frac{S4}{100} \frac{n}{100}$$

(Sys et al, 1991)

By applying the suitability index equation, it was possible to calculate the current and potential capability of the soil profiles of the study area. The results are indicated in Appendix (2) and Fig. (22), and are addressed as follows:

- **The current capability of soil:** the profiles of the study area for the suitability index fall into three classes: lands of moderate capability (S2), lands of marginal capability (S3), and unsuitable lands for cultivation (N). S3 lands had the largest number of the studied profiles, with a percentage of 54.5%, followed by S2 lands with a percentage of 17.3%, while N lands recorded the lowest percentage of 18.2%. The moderate productive lands were represented in three profiles (7, 9 and 11), where the suitability index value (CI) ranged between 53.35 and 62.33. They are lands of moderate texture, and are suitable for most agricultural crops. The marginal productive lands occupied the largest number of profiles, which were represented in six profiles (1, 4, 5, 6, 8 and 10), and the values of the suitability index (CI) ranged between 27.25 and 47.74. They are lands of moderate texture and moderate salinity, and are suitable for cultivation, but under certain conditions as they require great effort and attention as well as special treatment. Unsuitable lands for cultivation appeared in only two profiles, namely 2 and 3. This is mainly due to the sandy soil texture and the increase in the degree of slope in profile 2, and the high percentage of salt and the high level of ground water in profile 3 (where rice is cultivated).
- **The potential capability of soil:** The potential capability was calculated based on the current capability, by making a treatment of some soil elements that can be modified, such as topography and salt concentration, which are called non-permanent elements.

As for the permanent elements whose characteristics cannot be improved, they are represented in the texture and depth of the profile, calcium carbonate and gypsum (Atyya, 2013).The results of Appendix 2 indicate that the studied profiles were classified into three classes of lands of high suitability (s1) with a percentage of 18.2%, lands of moderate suitability (s2) with a percentage of 72.7%, and lands of marginal suitability (s3) with a percentage of 9.1% Thus, all profiles are suitable for cultivating most crops.



Source: Field study, 2020 & the Results of the application of the Land Evaluation Program.

Fig. 22: Variation in the Capability of Soil in El-Qasr Village

3. Land Suitability for Specific Crops

Land suitability classes for several crops were predicted on the bases of matching land qualities and characteristics and crop standard requirements using the parametric land index as mentioned by Sys et al. (1991 and 1993). The land suitability for selected crops (field crops, vegetables and fruit trees) (11 crops) were investigated (Soliman, 2016). The results of current land suitability are shown in Appendix 3.

- Lemons and beans are among the most common crops that are not suitable for cultivation in the profile soils of the study areas, although profile 4 is where lemons are grown, but its productivity is low (Fig. 23).
- Olive trees occupy the largest percentage of their suitability for cultivation in all profiles studied, except for profile 3, followed by the onion crop, which can be grown in the study profiles except for four profiles in which it is not preferred to be cultivated (2, 3, 4 and 5).
- The tomato crop is one of the crops that farmers prefer to grow in the El-Qasr Village. However, it was found that profile 9 has lands of moderate suitability for most crops, but the farmer stays away from growing tomatoes because they need a special service due to infection and disease, which in turn reduce its productivity.
- Field crops, particularly alfalfa, cotton and Maize, are among the most important crops that are well cultivated in most of the studied soil profiles, and have an important economic return in the region.
- Profile (3) is one of the profiles whose soil is not suitable for the cultivation of all the studied crops, followed by profile (2), which is suitable only for the olive crop. On the other hand, profile 10 is one of the best profiles in which all the studied crops are cultivated, except for lemon trees, and the suitability of profile 10 varies between moderate to marginal suitability, and by modifying its (non-permanent) characteristics, it will reach the

high degree of suitability (S1) to have all the studied crops cultivated.

Source: Field Study, 2020

Fig. 23: Cultivation of Lemons in Profile No. 4 in the far southeast of El-Qasr Village

Results and Recommendations:

The study of the dynamics of sand dunes and their impact on the capability of soil in El-Qasr Village reveals several Results as follows:

1. The sand dunes in the study area vary between Barchan dunes of different types and falling dunes from the escarpment, and the compound Barchan dunes are the most common type.
2. The general average of the movement of the Barchan sand dunes in El-Qasr Village is 7.6 m/year, and thus they are considered one of the fast dunes, although this speed varies from one dune to another due to many factors affecting that movement.
3. The human intervention had an evident impact on the decrease in the areas of sand dunes, as their areas decreased from 11.74 km^2 in 2003 to 8.71 km^2 in 2020, and the percentage of loss in the

area of the studied dunes ranged between 1.3 and 93.5% in favor of agriculture.

4. The areas of cultivated land increased from 6.45 km^2 in 1984 to 24.93 km^2 in 2020, and this had an impact on the decrease in the movement rates in the adjacent dunes.
5. The sand dunes affected the mechanical characteristics of the soil of the cultivated lands, particularly their texture, which led to a qualitative degradation of the soil that appeared in the high proportion of sand along the soil sectors in regard to the cultivated lands close to it. As for the ones far from it, the proportion of sand decreases, and accordingly the proportions of clay and silt rise.
6. The degrees of the current capability of soil of El-Qasr Village ranged between unsuitable and moderately suitable, and with the improvement of the characteristics of non-permanent soils as well as the calculation of the potential capability of soil, the degrees ranged between marginal and high suitability.
7. Most field and vegetation crops are cultivated in El-Qasr Village. However, fruitful trees are of less suitability, except for olive trees, followed by mango trees. Besides, alfalfa is considered one of the most used field crops in cultivation, followed by Maize and wheat, and onion is among the most vegetation crops that are well cultivated in the soil of El-Qasr Village.

Recommendations:

- In reclamation of cultivated lands, the distance from sand paths is to be taken into account, particularly since the village has an area that allows this and cultivated lands are spread in most of its parts.
- Aiming to reduce the wind speed or change its course, it is recommended to expand in erecting barriers or the so-called temporary fences, which are palm fronds or Maize sticks. However, the study advises to follow this method in areas exposed to sand drift, and not in the ranges of large dunes in large areas, otherwise it will do more damage than good. The

field study monitored this method being used in the southeast and middle of El-Qasr Village (Fig. 24).

- The use of permanent fixing methods, such as the process of afforestation around the dune, is a method followed near the northern escarpment, and the cultivation of dune surfaces is a successful method and widely followed in El-Qasr Village. Nevertheless, it is recommended to choose the suitable crops for those lands because they do not have many crops, and therefore it must be studied in detail and the most suitable crops are to be determined in order to yield successful results.
- It is recommended to cultivate cabbage and sorghum crops on a large scale, as it was found from the application of Suitability of Crops that they are among the crops that are best grown in the current and potential soils of El-Qasr Village, and their suitability for agricultural soil ranged between a high and moderate degree (S1-S2).

Souce: Field Study, 2020

Fig. 24: Following the Method of Temporary Fences to Limit Sand Drift in El-Qasr Village

Appendices:

Appendix 1: Particle Size Distribution and Chemical Characteristics of the Soil Profile

Profile No.		Depth (cm)	Texture ٪ Sand	Silt	Clay	Class	caco3	Om٪	EC	Ph	caso4 ٪	SAR	ESP ٪
Lands Adjacent and Relatively Close to Sand Dunes	1	0-60	96.95	1.51	1.54	sand	3.2	0.59	0.48	8.29	0.005	0.78	2.75
		60-100	66.67	7.74	25.58	sandy Clay Loam	6.88	0.61	1.49	8.85	0.008	7.00	9.16
	5	0-30	98.42	1.29	0.29	sand	5.6	0.32	0.72	9.18	0.005	1.98	3.99
		30-60	98.51	1.29	0.2	sand	5	0.4	0.6	9.3	0.005	1.8	3.2
	6	0-50	84.47	14.20	1.33	loamy Sand	2.4	0.67	3.02	8.46	0.004	7.16	9.32
		50-70	69.55	10.35	20.10	Sandy Clay Loam	4.8	0.50	3.80	9.25	0.004	3.63	5.69
	8	0-35	71.88	12.34	15.78	sandy loam	3.52	0.34	2.22	8.71	0.018	9.37	11.6
		35-70	72.44	7.26	20.29	sandy clay loam	5.12	0.42	7.64	8.74	0.007	12.97	15.31
	10	0-40	76.92	3.98	19.1	sandy loam	9.65	0.9	0.25	7.86	ND	2.05	13.78
		40-80	54.91	3.99	41.1	sandy clay	16.9	0.56	0.40	8.29	ND	2.66	12.45
		80-100	52.91	7.99	39.1	sandy clay	13.68	0	0.44	8.49	ND	3.32	12.51
Lands far from Sandy Forms	3	0-50	42.47	25.22	32.31	clay loam	2.08	0.96	44.65	8.13	0.09	19.77	22.31
		50-90	27.31	25.22	47.47	clay	1.6	1.43	14.94	8.05	0.003	19.42	21.95
	7	0-60	49.48	13.50	37.02	sandy clay	5.12	0.67	4.29	8.16	0.004	8.32	10.52
		60-100	46.23	21.52	32.25	sandy clay loam	8.32	0.67	2.77	8.37	0.004	11.12	13.41
	9	0-60	72.75	9.12	18.14	sandy loam	6.4	0.69	1.56	8.54	0.003	6.00	8.13
		60-100	63.56	5.89	30.55	sandy clay loam	7.2	0.99	1.30	8.65	0.0087	6.51	8.66
	11	0-30	41.3	13.9	44.8	clay	7.24	0.58	6.17	7.44	2.92	3.33	12.42
		30-50	23	10	67	clay	7.24	0.36	5.76	7.56	2.37	3.81	14.18
		50-70	48.9	4	47.1	sandy clay	6.44	0	5.36	7.55	1.23	3.54	12.4
		70-100	77	4	19	sandy loam	9.65	0	5.34	8.08	ND	2.03	12.16
Cultivated Sand Dune Lands	2	0-30	95.17	2.58	2.25	sand	3.52	0.24	3.11	8.89	0.003	4.58	6.66
		30-60	96	2	2	sand	3	0	3.15	8.9	0	4.4	6.53
	4	0-50	96.80	1.40	1.80	sand	4.32	0.15	15.77	8.91	0.007	10.81	13.08
		50-100	96.93	1.67	1.40	sand	5.6	0.07	1.18	9.11	0.005	0.87	2.85

Source: Based on Samples Analysis in the Central Laboratory, Faculty of Agriculture, Tanta University, (Yousif, 2014).

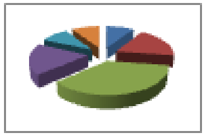
Appendix 2: Limitation Rating and Capability Index for Evaluating Soil Profiles of El-Qasr Village

Profile NO.	Sys et al., 1991																		
	Topography (t)		Wetness (w)		Soil Physical Characteristics (s)					Salinity/alkalinity (n)		Current Suitability				Potential Suitability			
					Depth	Texture		Lime	Gypsum										
	CS	PS	CS	PS		CS	PS			CS	PS	Ci	M.class	S.class	Class	Ci	M.class	S.class	Class
1	100	100	100	100	95	50	70	100	90	100	100	42.75	S3	S	S3s	59.85	S2	S	S2s
2	65	90	100	100	85	50	70	100	90	100	100	24.86	N1	ts	N1ts	48.2	S3	S	S3s
3	80	100	40	80	95	90	100	100	90	58	80	14.28	N1	twn	N1twn	54.72	S2	wn	S2wn
4	75	100	100	100	95	50	70	100	90	85	100	27.25	S3	ts	S3ts	59.85	S2	S	S2s
5	75	100	100	100	85	50	70	100	90	100	100	28.69	S3	ts	S3ts	53.55	S2	S	S2s
6	100	100	100	100	85	65	80	100	90	96	100	47.74	S3	S	S3s	61.2	S2	S	S2s
7	100	100	100	100	95	90	100	100	90	90	100	69.26	S2	-	S2	85.5	S1	-	S1
8	100	100	100	100	85	65	80	100	90	90	100	44.75	S3	S	S3s	61.2	S2	S	S2s
9	100	100	100	100	95	65	80	100	90	96	100	53.35	S2	S	S2s	68.4	S2	S	S2s
10	90	100	100	100	95	65	80	90	90	96	100	43.22	S3	S	S3s	61.56	S2	S	S2s
11	90	100	100	100	95	90	100	100	90	90	100	62.33	S2	-	S2	85.5	S1	-	S1

Source: Based on Land evaluation program.

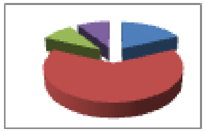
S2		S3		N1	
27.3		54.5		18.2	
S2S	S2	S3S	S3TS	N1TS	N1TWN
9.1	18.2	36.3	18.2	9.1	9.1

Current suitability



S1	S2		S3
18.2	72.7		9.1
	S2S	S2WN	S3S
	63.6	9.1	9.1

Potential suitability



Class	Order	Ci (٪)	Soil Grades
S1	S	100-75	Highly suitable
S2		75-50	Moderately suitable
S3		50-25	Marginally suitable
N(N1-N2)	N	>25	Unsuitable

Source: FAO, 1985.

Appendix 3: Land Suitability Classes for Soil Profiles of El-Qasr Village

profile No.	Field Crops					Vegetables Crops			Fruit trees		
	Barley	Maize	wheat	Cotton	Alfalfa	Tomato	Onion	Beans	Mango	Citrus	Olives
1	N1	S3	N1	S3	S3	N1	S3	N1	S3	S3	S3
2	N1	N1	N1	N1	N1	N1	N1	N1	N1	N2	S3
3	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
4	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1	S3
5	N1	N1	N1	N1	N1	N1	N1	N1	N1	N2	S3
6	S3	S3	N1	S3	S3	N1	S3	N1	N1	N2	S3
7	S2	S3	S2	S2	S2	S3	S3	N1	S3	N1	S3
8	S3	N1	N1	S3	S3	N1	S3	N1	N1	N2	S3
9	S3	S3	S3	S3	S3	S3	S3	N1	S3	N1	S3
10	S3	S3	S3	S3	S2	S3	S3	S3	S3	N1	S2
11	S2	S3	S3	S2	S2	S3	S3	N1	S3	N1	S2

Source: Based on (Appendix 1) using Suitability of Crops, Sys et al, 1993.

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