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Terrain Modelling and Its Impact on the Productive Capacity of Soil Using Geomatics Techniques in Baltim Area, Egypt

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ABSTRACT

The Baltim area is located in the north-central part of the Delta. It was part of Lake Burullus, whose surface is mostly flat and has little slope, except for areas of sand dunes. The Baltim area differs in its current state from what it was in previous periods, as its features changed to account for human uses on physical phenomena that are heading towards decreasing or disappearing completely. This is as a reflection of human intervention through agricultural reclamation, which only succeeded through a radical change in the terrain characteristics, particularly the levels of the earth's surface during the period from 1947 to 2020. This has been done by filling the low-lying areas primarily, which were studied using geomatics techniques, causing the decrease and disappearance of many wetland phenomena such as ponds, swamps, and sabkhas. In addition, there was a phsical impact represented by the availability of sand dunes north of the Baltim area, which caused the level of the lands adjacent to it to rise as well, as well as the exploitation of their sand in the process of filling low-lying areas. The application of geomatics techniques has shown that all of these changes in the terrain characteristics are reflected in the physical and chemical charcteristics of the soil. As a result, there was an increase in the area of agricultural land and its fertility and production capacity, owing to many reasons, particularly its distance from groundwater and its low degree of salinity. Accordingly, the second and third classes appear from productive capacity of the soil, which were not monitored in 1962, and there was an increase in the area of the second to the fourth classes. This only happened by continuing to change the terrain characteristics to reclaim new areas and improve the characteristics of old agricultural lands.

1. Introduction

The study of terrain characteristics is of great importance due to its connection to various areas of development, particularly agricultural development. Recent years have been characterized by the development of information technology, which has contributed to the analysis and processing of terrain features in an advanced technical manner. This has been conducted through geomatics techniques that have been characterized by speed, achievement, and accuracy in results compared to traditional methods, and revealed the correlation between variation in land surface levels and soil quality for sustainable agricultural development.

The study area is located in the north-central part of the delta, from the main Gharbia drain (Kitchener) in the east to the Burullus Bogaz in the west. It is bordered by the Mediterranean coast in the north, and the coast of Lake Burullus and the Sea of Tira in the south. Its maximum length from the west to the east is 20 km, its average width from the south to the north is approximately 4.5 km, and its area is 81,788 km^2 in 2023. The area extends coordinately between latitudes 31° 30′ 40″ and 31° 36′ 30″ north and between longitudes 30° 58′ 10″ and 31° 11′ 10″ east (Figure 1).

The Baltim area has been subjected to extensive human interventions, the most important of which is the process of agricultural reclamation, which was imposed in the presence of a change in the terrain characteristics, particularly the levels and degree of slope of the earth's surface. This has led to the removal and change of some phenomena such as ponds, sabkhas and sand dunes to prepare the land for this, resulting in major physical changes occurring in a short period of time because of this human intervention.

Source: It is based on SAS. Planet and topographic maps, scale 1:50000, 2020.

Figure 1. The General Features and Locations of the Study Area Samples in Baltim Area

2. Sources and Methodology of the Study

2.1. Previous Studies

The current study is considered one of the first geographical studies that address the relation between terrain and soil quality for agricultural development in detail. However, there have been many studies, whether geographical or non-geographical, that have dealt with this relation in general, and these studies have used some models and laboratory experiments. Examples of these studies are El-Baroudy (2005), Abdo (2012), Abo Al-Soud (2016), El-Shami (2018), El-Sayed (2018), Abo Raya (2020), Einar (2022), Saber (2022), Elsebaei (2022), and Belal (2003).

2.2. Methodology of the Study

The study adopts the causal-effect method. This method highlights the relation between humans and the environment, and the relation between multi-faceted geographical phenomena and the influence between them (Gamal El-Din, 2007). To achieve this, it is necessary to adopt variables in different time periods, whether the terrain characteristics or the soil characteristics (physical and chemical), using geomatics techniques to reach rules and results that clarify the relation between them.

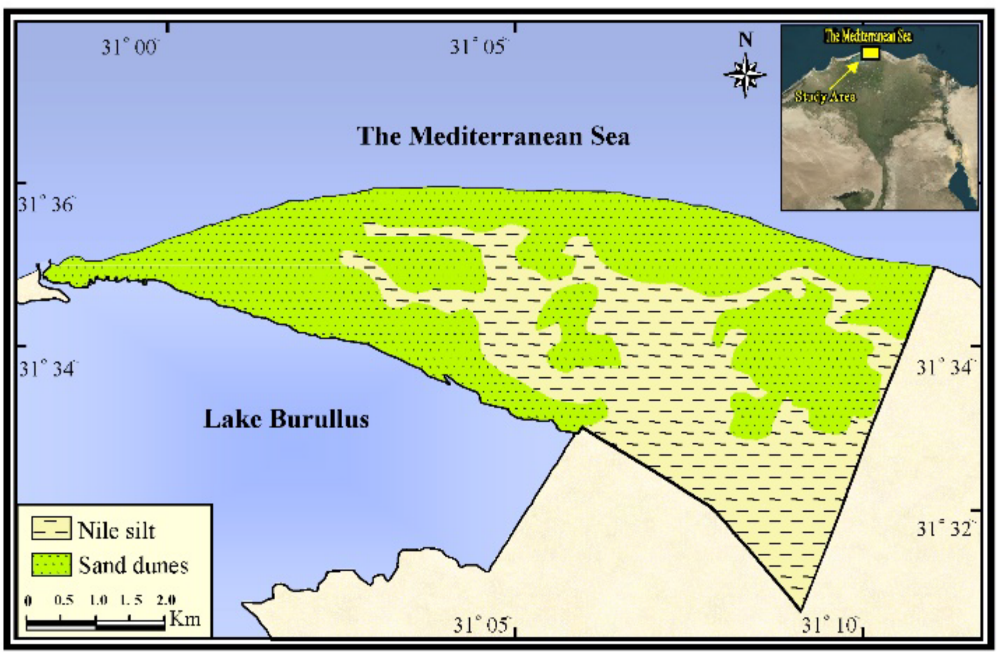
3. Aim of the Study

The study aims to use geomatics techniques to study the changes that have occurred in the terrain characteristics, particularly the levels of the earth's surface and degree of slope, over a period of more than 70 years. Moreover, it aims to study the impact of these changes on the productive capacity of the soil, and accordingly find out the quality of the soil for growing various crops in the Baltim area. On this basis, the study is classified into the following topics:

4. General Characteristics

4.1. Geology

About 2500 years BC, the Nile began to flow permanently, with water flowing throughout the year, and the Nile and the silt deposits it carried were used to build the current floodplain and delta (Embabi, 2004), of which the Baltim area represents a part. Accordingly, the surface deposits in the study area belong to only one era, which is the Quaternary era. The rush of sea currents towards the east helped direct a large amount of deposits carried by the Nile water to the Mediterranean Sea towards the east. Hence, the study area was characterized by its loose sand and sand dunes (Figure 2). Besides, the analysis of the geological map of the study area in 1987 shows that the predominant deposits are sand dune deposits, with an area of 49.352 km^2 representing 60.34%, and they are located in areas adjacent to the Mediterranean Sea and Lake Burullus. They are followed by Nile silt deposits, with an area of 32.436 km^2 representing 39.66%, and they are spread in the east, southeast and center of the study area, particularly south of the villages of El-Shehabiya and Baltim.



Source: Geological Maps (CONCO) 1: 500000, 1987.

Figure 2. Surface Geological Deposits in Baltim Area

The ancient deltaic branches are considered the main factor in bringing these deposits, then the marine currents carry them and deposit them on the coast, and the winds transport them and deposit them in various sand forms. During the Holocene era, the area was exposed to long periods of severe drought and increased wind activity that was able to carry the deposits from their location and deposit them in other places in the form of different sand forms. These forms are classified into moving sand, which are the areas covered with dense windy deposits in the north from west to east in the form of an intermittent strip, and still sand that does not move at the present time, particularly in the south due to the high percentage of water in it and its coverage with plants, trees, and residential units (Figure 3), and it consists of quartz and lime grains (Al-Saadani, 2006).

The thickness of the deposits varies with depth according to the difference in the amount of deposits in the eras of their formation. Drilling operations that took place in the Burullus and Baltim areas revealed that the thickness of the Nile deposits ranges between 25.6 m and 23.1 m, and that they are deposits of Nile clay and coarse sand mixed with fine sand of marine origin (Attia, 1954). Moreover, with the absence of clay deposits and the abundance of sand deposits, particularly towards the north, soil fertility decreases, but the southeastern parts of the region are dominated by clay deposits that are found up to a depth of 4.5 m from the surface. This, in turn, explains the higher fertility of their soil than the soil of the northern parts of the area (Gamal El-Din, 2007).

Source: Field Study, 2024.

Figure 3. Sand Dunes in Baltim Area

4.2. Climate

The impact of climatic characteristics on the quality of soil for agricultural development changes with the change in terrain characteristics, as they together influence the physical and chemical characteristics of the soil. For instance, high temperature leads to an increase in evaporation rates, particularly in low-level areas where ponds and swamps are widespread, or which are close to groundwater. As a result, this leads to a high percentage of salts in them, and may lead to the formation of sabkhas that weaken the productive capacity of the soil.

It is evident from the geographical location that the Baltim area is located in the far north-central part of the delta with a long front on the Mediterranean Sea, which had an impact on the climatic characteristics of the Baltim area (Table 1). It leads to a moderate temperature, with a decrease in temperature during the winter, reaching14.3˚, and a decrease in evaporation rates, reaching 3.5 mm. As a result, there is a spread of swamps in the low-lying areas on the eastern side of the Baltim area, particularly in the village of El-Shihabiya, whether resulting from rainfall or through water leakage from neighboring lands (Figure 4). In addition, when the temperature rises during the summer months (27.8˚) and the evaporation rates increase (5.3 mm), salt deposits accumulate and their percentage increases in the surface layer of the soil (Figure 5), thus making these areas uncultivable due to their reduced productive capacity.

Table 1. Some Climatic Characteristics in Baltim Station during the Period 1985-2022

Season	Average Temperature (c)	Evaporation (mm)	Rain (mm)
Winter	14.3	3.5	108.1
Spring	19.8	4.9	19.4
Summer	27.8	5.3	0.29
Autumn	20.1	4.1	17.4
Annual rate	20.0	4.45	145.9

Source: General Authority of Meteorology, Climatic Data Department (1985-2022).

Source: Field Study, 2024.

Figure 4. The Spread of Ponds and Swamps in Low-lying Areas in Winter in El-Shihabiya Village

Source: Field Study, 2024.

Figure 5. The Accumulation of Salt Deposits in the Surface Layer of the Soil of Low-lying Areas in Baltim Area

Wind speed ranges between 7.3 and 10.5 km/h, and the north-western and western winds predominate, reaching 23.8% and 22.8%, respectively (El-Tohamy, 2014). With the presence of sand dunes extending along the Mediterranean coast, which are a source of fine, moving sand carried by the wind, and thrown on adjacent agricultural areas, there has been a change in their mechanical characteristics and a decrease in their agricultural quality (Figure 6).

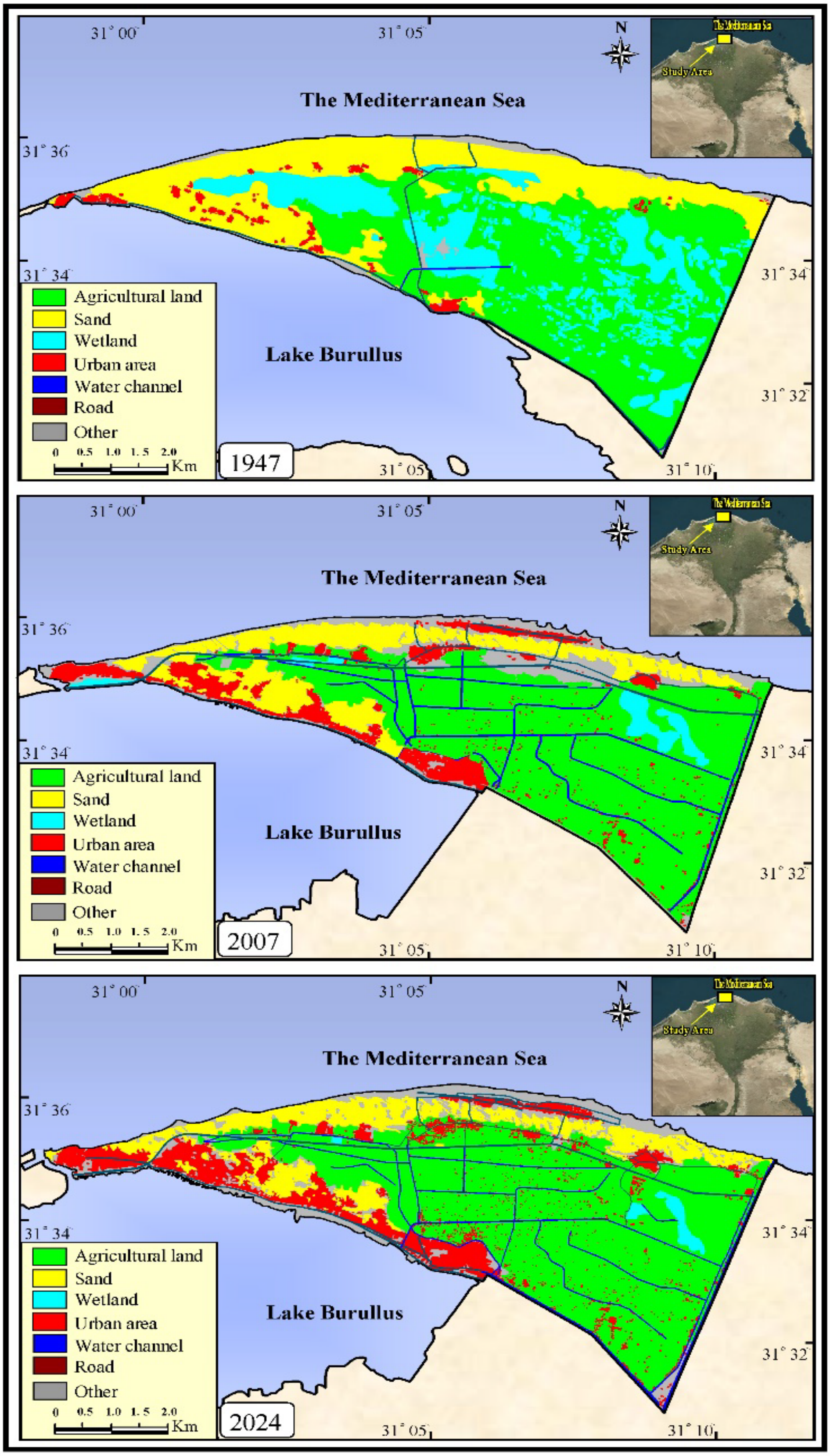
Moreover, the coastal areas of the Baltim area are also characterized by more rain than the interior areas, which also varies between the seasons of the year, ranging between 0.29 mm in the summer and 108.1 mm in the winter, with an annual total of 145.19 mm. This makes it the delta area that receives the most rainfall, which is collected in low-lying areas in the form of ponds and swamps, particularly east of the study area in the central and northern part of El-Shihabiya area, directly south of the sand dunes.

Source: Field Study, 2024.

Figure 6. The Impact of Sand Movement on Agricultural Lands in Baltim Area

4.3. Land Uses

The Baltim area is part of Lake Burullus, which differs in its current state from what it was in previous periods, as its feature have changed whether the physical or human characteristics. In fact, the idea of monitoring change is based on comparing a set of maps and images from 1947 to 2024, in order to know the development of land uses. The field review (field study), which helped in identifying various phenomena from satellite images and correcting the coordinates to draw accurate maps that can be relied upon in interpretation, was relied upon. The analysis of change in Figure 7 and Table 2 reveals the following:



Source: Topographic maps, scale 1:25000, 1947; satellite images, 2007 and 2024.

Figure 7. Land Use in Baltim Area from 1947 to 2024

Table 2. Land Uses in Baltim Area from 1947 to 2024

Use \ Year	1947	2007	2024
Agricultural	45.75	59.61	62.73
Sand	28.02	13.72	10.34
Urban	1.44	8.82	12.33
Wetland	19.71	2.62	1.08
Water channel	0.90	1.29	1.88
Road	0.79	1.31	1.91
Other	3.39	12.63	9.73
Total	100	100	100

Source: It is based on Figure 7.

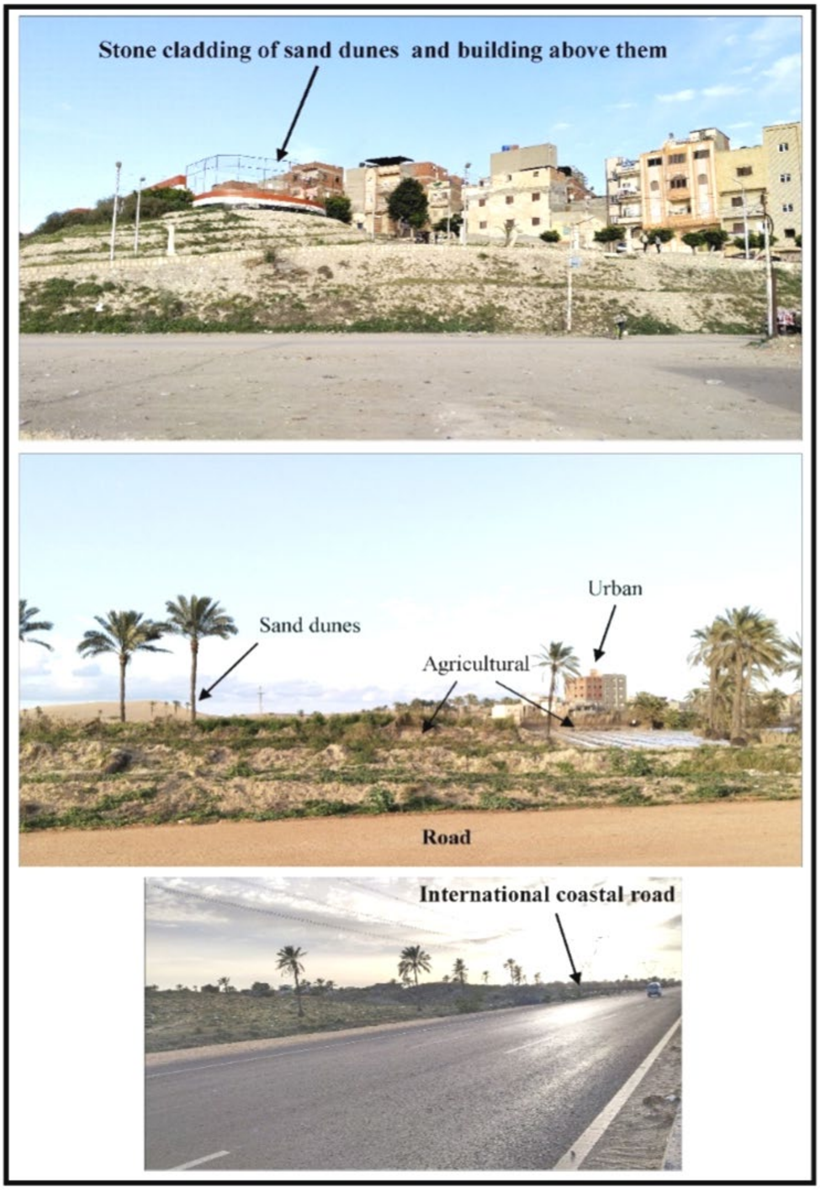
The lands of the Baltim area are characterized by the presence of a series of medium-height sand dunes with an average width of 1.5 km, and in some northern areas the height of these sand dunes exceeds 15 m in the form of an intermittent strip. As for the middle part of the area, which is confined between the sand dunes located in the north and south, it is a low plain whose lands slope gently from south to north, where ponds, swamps and sabkhas abounded in 1947. However, they decreased significantly and almost reached the point of extinction after human interventions in favor of agricultural and urban development. The following is a study of the changes:

- The spread of sand dunes decreased during the comparison period from 28.02% in 1947 to almost half, reaching 13.72% in 2007, and the decrease in area continued, reaching 10.34% in 2024. In fact, this decrease in the area of dunes is because a large part of this area has been cultivated and another part has been removed and replaced with urbanization, noting that most of this area was primarily exploited for agricultural activity. Moreover, the longitudinal dunes in the study area are divided into two categories: the first is in the north, south of the Mediterranean coast, and the second is in the south, north of Lake Burullus. They are separated by a low, flat area. On the one hand, the dunes of the first category are characterized by being moving depending on the direction of the prevailing winds. On the other hand, the dunes of the second category are still as a result of the rise in groundwater levels resulting from rainwater or their proximity to Lake Burullus, in addition to the spread of urbanization there as aforementioned (Figure 8).
- The area of agricultural land increased significantly from 45.75% in 1947 to 62.73% in 2024, of the total study area. It is the highest percentage during the comparison period, and this increase was at the expense of many phenomena, the most important of which are ponds, swamps, and sand dunes (Figure 9).
- There is an area located between the Mediterranean coast in the north and the longitudinal sand dune unit in the south in some areas north and northeast of the study area. This unit is characterized by a flat surface, and its width does not exceed 1.0 km, particularly in the Baltim resort area. However, it narrows in some places so that the beach line disappears completely in the villages located northwest of the study area, particularly in El-Bana'in area, where sea water meets the lower parts of the longitudinal dunes, and their length is approximately 6.0 km.
- The urban area increased significantly from 1.44% in 1947 to 8.82% in 2007, and 12.33% in 2024 of the total study area. This increase was at the expense of sand dunes in the first place, particularly the southern and western sand dunes, which are represented in the southern and western villages, including the villages of El-Rub', El-Sahil Al-Qibli, and El-Bana'in, in addition to the rapid growth of the cities of Baltim and El-Burj. It is worth noting that there was a spread of vacant lands, which represent areas between residential blocks and beach areas. Their percentage increased from 3.39% in 1947 to 12.63% in 2007, and then it decreased due to its exploitation for urban development to 9.73% in 2023 (Figure 10).
- Ponds and swamps represented the lowest areas in 1947, and with the spread of the backfilling process to reclaim new areas for agriculture, their area decreased

significantly. In particular, during the 70 years in the period from 1947 to 2007, their area decreased from 19.71% to 2.62% and then decreased again to 1.08% of the total study area in 2024, most of which turned into sabkhas in the summer.

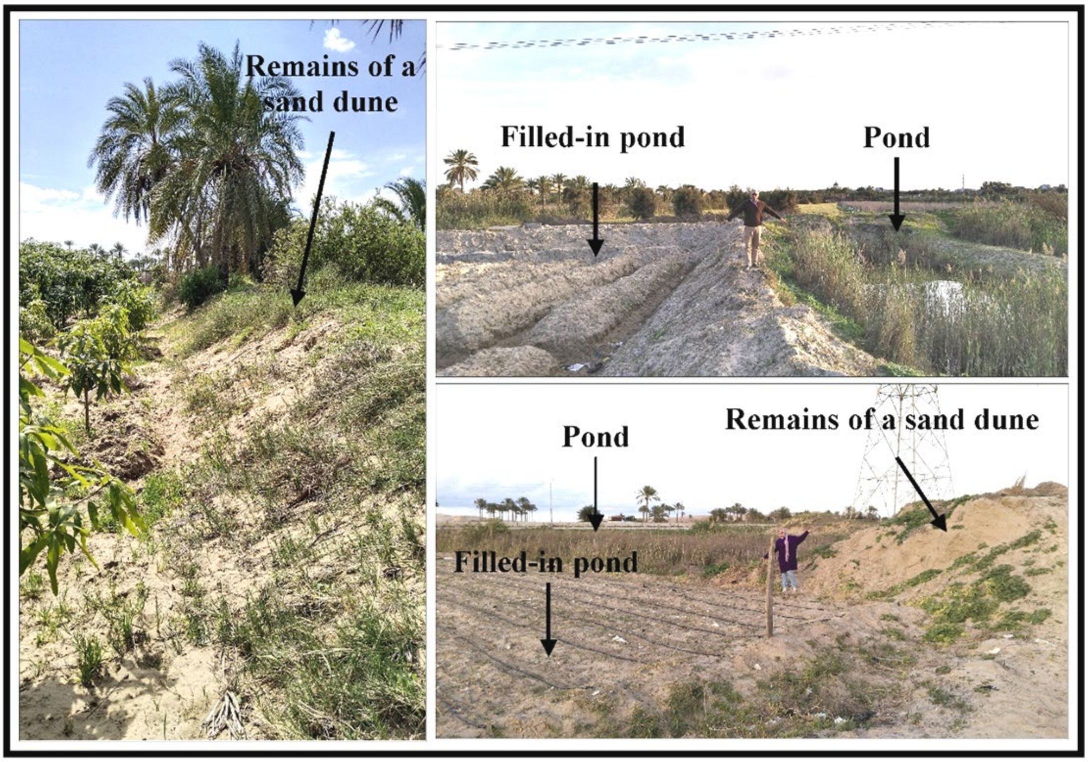
- It was normal with the increase in agricultural and urban development to be followed by an increase in canals, drains and roads, reaching 0.90% in 1947 and 1.88% in 2024. The field study revealed that there was great negligence in maintaining and cleansing the canals and drains in the entire Baltim area, which had a significant impact on the increase in groundwater levels and their salinity (Figure 11).

It is concluded from the previous analysis that the general direction is towards the increase and the predominance of human uses, particularly the agricultural and then the urban uses, over physical phenomena that are directed towards decrease. In particular, the area of ponds and swamps, which are about to disappear completely in favor of agricultural lands.



Source: Field Study, 2024.

Figure 8. Exploitation of Sand Dune Areas in Urban, Agricultural and Road Activity in Baltim Area

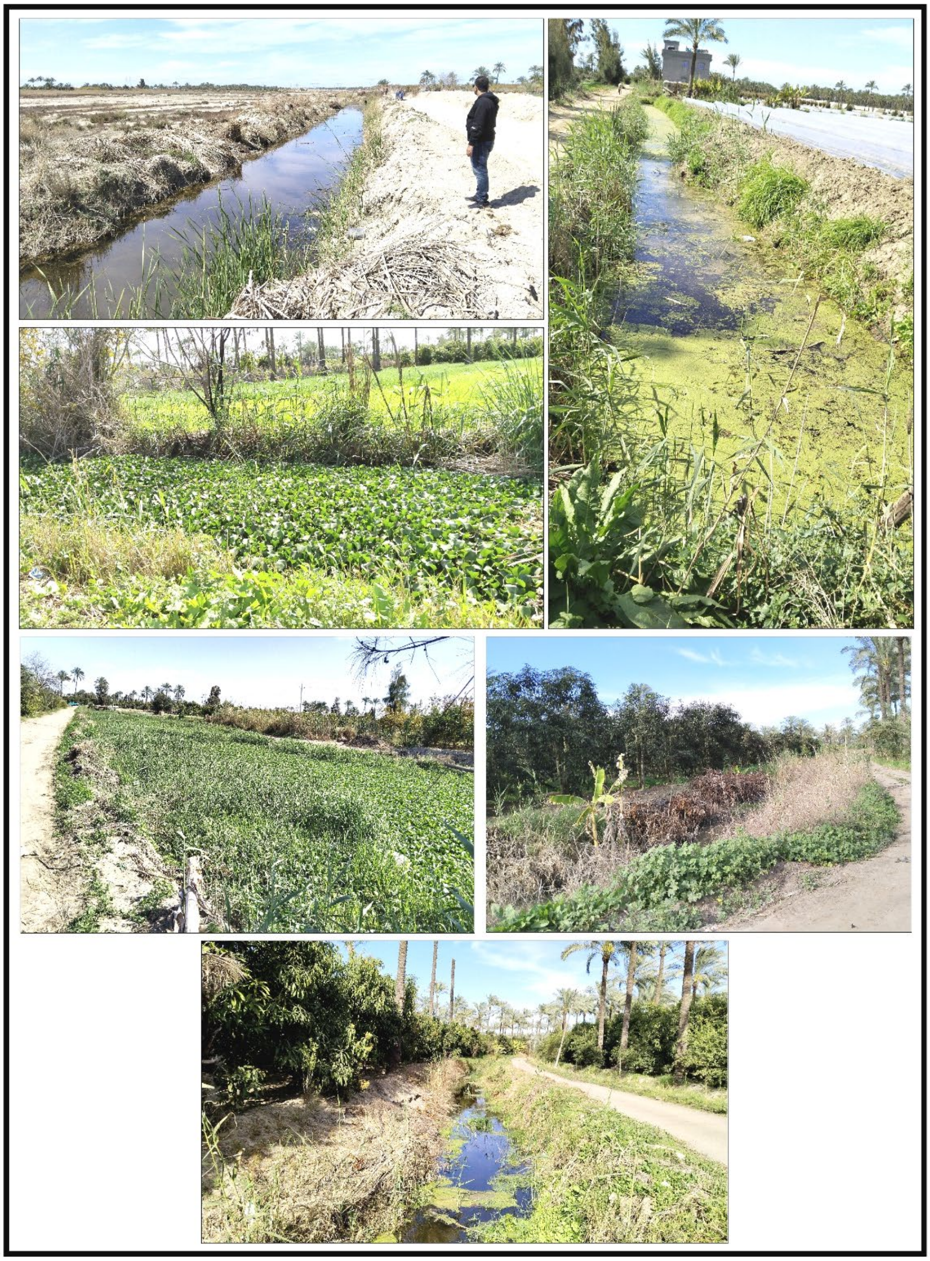


Source: Field Study, 2024.

Figure 9. Increasing the Area of Agricultural Lands by Backfilling Ponds and Swamps, and Removing and Levelling Sand Dunes in Baltim Area

Source: Field Study, 2024.

Figure 10. The Spread of Vacant Lands among Residential Blocks in Baltim Area



Source: Field Study, 2024.

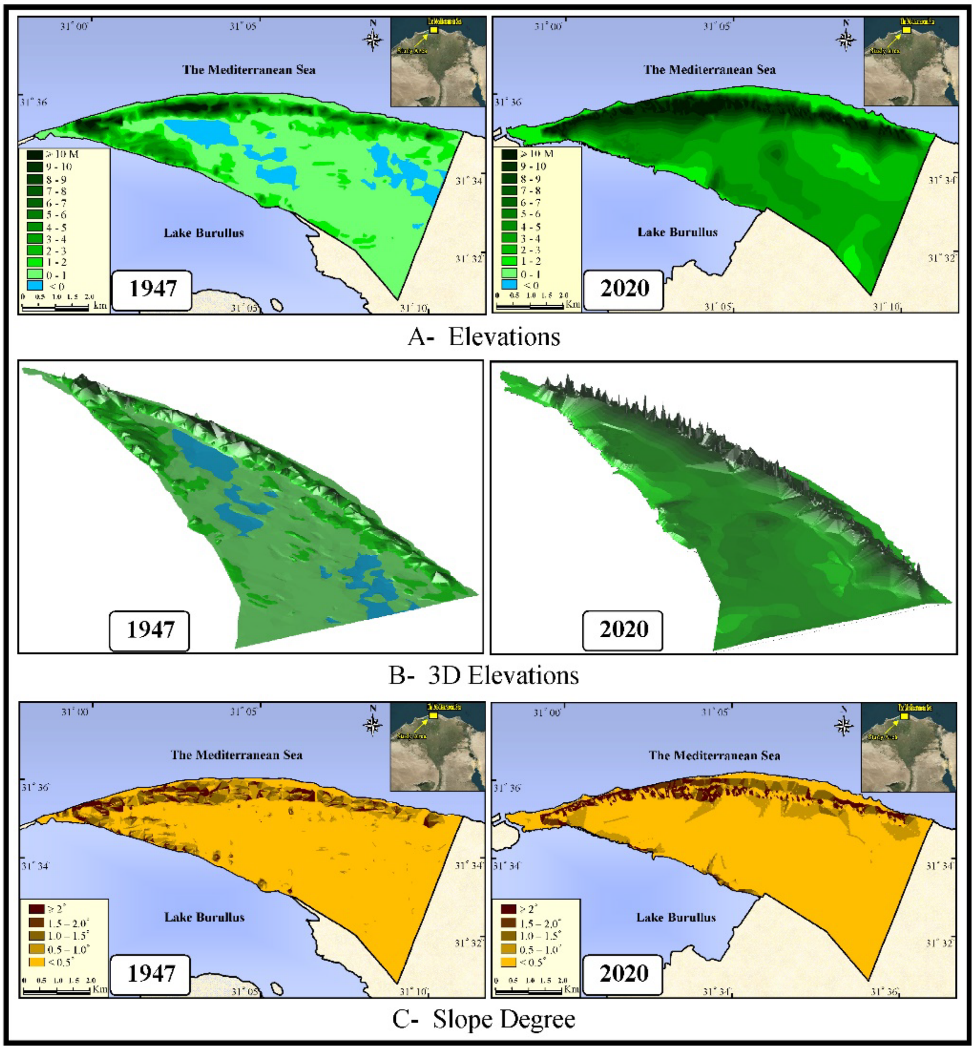
Figure 11. Canals and Drains in Baltim Area, Noting the Negligence in their Cleansing and Maintenance

5. Terrain Modelling of the Baltim Area

The aim of studying the terrain characteristics in the Baltim area is to detect the change in the levels and degree of slope of the earth's surface and thus determine the locations and characteristics of erosion, removal, deposition and backfilling. In addition, it aims to link them to the mechanical and physical characteristics of the soil and thus its productive capacity. The study is as follows:

5.1. Elevations and Degree of Slope and Curvature of the Surface of the Baltim Area

The Baltim area is characterized by levelling to a large extent. A study of the terrain characteristics, whether elevations, degrees of slope or curvature, has shown that they are almost homogeneous. Figure 12 and Table 3 show the terrain characteristics of the Baltim area.



Source: It is based on topographic Maps, Scale 1:25000, 1947 and Scale 1:50000, 2020.

Figure 12. Some Terrain Characteristics of Baltim Area 1947-2020

Table 3. Elevations and Degree of Slope in Baltim Area in 1947 and 2020

Elevation (m)	Area (%)		Slope	Area (%)	
	1947	2020		1947	2020
< 0	11.23	0.0	< 0.5	77.76	76.06
0 - 1	57.14	3.47	0.5 – 1.0	7.94	9.16
1 - 2	12.78	4.76	1.0 – 1.5	6.84	7.41
2 - 3	4.82	17.15	1.5 – 2.0	3.92	3.25
3 - 4	3.79	32.12	≥ 2.0	3.54	4.12
4 - 5	3.08	14.51	Total	100	100
5 - 6	1.94	5.40			
6 - 7	1.32	3.90			
7 - 8	1.06	3.51			
8 - 9	0.90	3.41			
9 - 10	0.74	6.65			
≥ 10	1.20	5.12			
Total	100	100			

Source: It is based on Figure 12.

The analysis of Figure 12 and Table 3 shows the following:

- If the sand dunes in the study area, whose level exceeds 20 m, are excluded, their surface lies at a level between -0.8 and 2 m of sea level in 1947, representing more than 80%; and between 2 and 4 m in 2020, representing approximately half (49.27%) of the total area of the Baltim area.
- The levels of earth's surface gradually decreased from west to east in the direction of the main Gharbia drain, and from north and south to the center, with the highest percentage recorded for the category of 3-4 m above ground level in 2020, representing 32.1%.
- The areas with a level below zero are spread only in 1947. They represent ponds and swamps, reaching 11.23% of the total study area.
- The dominant characteristic of the surface of the Baltim area in 1947 was levels ranging between 0 and 1 m, exceeding 57%. They had a negative impact on the productive capacity of the soil due to the high degree of salt concentration in them because of their proximity to the groundwater surface level.
- The terrain characteristics changed completely in 2020: the first category, which is less than zero, completely disappeared; there was a very significant decrease in the second category ranging between 0 and 1 m, and the third category ranging between 1 and 2 m, from 57.15 to 3.47% and from 12.75 to 4.76% respectively. This is a reflection of human intervention through agricultural reclamation, which was only successful in one case, and that is the rise in the levels of the earth's surface through backfilling in the first place, which resulted in the rise of all the following categories.

The previous analysis shows that there is a significant change in the levels of the earth's surface during the comparison period (about 70 years). Human intervention is the main factor in the process of change by backfilling low-lying areas, particularly those that are less than 2 m in 1947, which were the cause of the extinction of many wetland phenomena such as ponds, swamps, waterlogged lands, and sabkhas. In addition, there is a physical impact represented by the availability of sand dunes north of the Baltim area, which causes the level of the lands adjacent to it to rise as well, and this is confirmed by the high percentage of sand in soil samples, which are to be mentioned later.

Moreover, the convex (low-lying) areas, particularly those located south of the sand dunes in the north and northeast of the study area, namely north of the villages of El-Shihabiya and Baltim (Figure 12), are also exploited to dig many artificial ponds to collect water leaking from irrigation water in the concave areas for reuse in irrigation (Figure 13). The field study shows that the area of the pond does not exceed 300 m^3, due to the lack of other means of irrigation, particularly the lack of canals in those areas. In spite of the high salinity of the water of these ponds, exceeding 20000 ppm and causing a lot of damage to agricultural crops along with the decrease in their productivity, this method is imposed on farmers because there is no other alternative.

In general, the surface of the study area is predominated by levelling, lack of slope, and scarcity of relief, whether in 1947 or 2020, due to the area's lands being located in the far north of the Nile Delta, which caused its uncomplicated surface development. That is, the degree of slope of less than 0.5 degrees is recorded on more than 75% during the comparison period, while the degree of slope increased for the second (0.5 - 1.0) and third (1.0 - 1.5) categories, ranging between 6.84 and 7.94% in 1947 and between 7.41 and 9.16% of the total area in 2020. There are also some areas that deviate from this in the northern range, where their degree of slope exceeds 2 degrees, as fine elevations are abundant due to the presence of sand dunes. Their height reaches 20 m or more, and their percentage also increase during the comparison period from 3.54% to 4.12% due to the increase in sand dune levels and thus an increase in their degree of slope.

Source: Field Study, 2024.

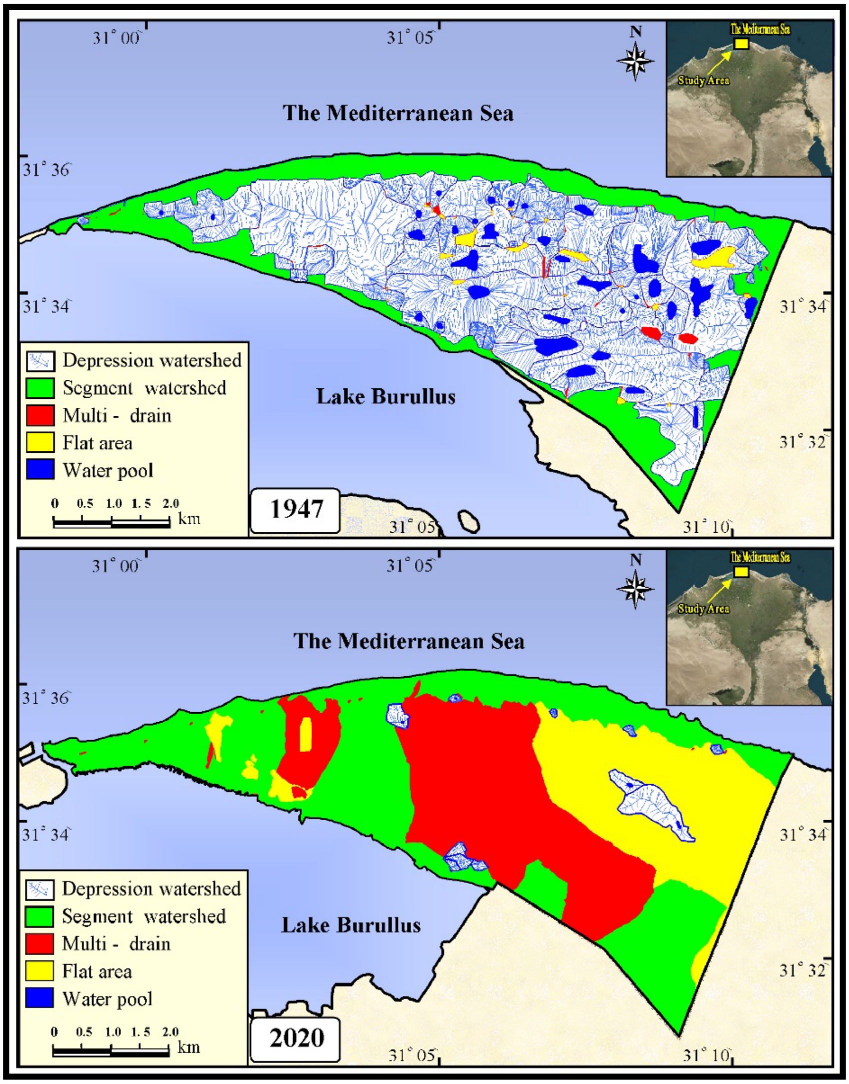
Figure 13. Artificial Ponds in Convex (Low-lying) Areas to Exploit Their Water for Irrigation North of the Villages of El-Shihabiya and Baltim

It is evident from the aforemention that there is an increase in the degree of slope, particularly the second and third categories. This increase has a positive impact on soil fertility and thus an increase in its productive capacity, provided that excess water is drained outside the study area (segment watershed towards water bodies). Moreover, the Baltim area is classified into five areas according to the movement of surface water, but that differs completely during the period from 1947 to 2020 (Table 4 and Figure 14).

Table 4. Classification of the Study Area according to the Surface Water Movement in 1947 and 2020

Classification	Number of Basins		Area (km^2)	
	1947	2020	1947	2020
Depression Watershed	72	18	59.94	2.53
Segment Watershed	41	15	18.86	36.77
Multi-drain	62	41	0.24	21.65
Flat Area	33	32	1.05	21.44
Water Pool	—	—	1.79	0.03

Source: It is based on Figure 14.



Source: It is based on topographic Maps, Scale 1:25000, 1947 and Scale 1:50000, 2020.

Figure 14. Classification of the Study Area according to the Surface Water Movement in 1947 and 2020

The analysis of Figure 14 and Table 4, which shows the impact of slope degree and direction on the method of discharging excess or leaking water whether from rainwater or irrigation water, indicates the following:

- The number of drainage basins reached 175 basins in 1947, but it decreased significantly in 2020 to reach 74 basins. This indicates the lack of relief during this period, which is a characteristic of areas formed over old lakes or ponds in general, in addition to backfilling low-lying areas to level them and make them valid for agriculture.
- The highest area recorded was that of depression watershed, reaching 59.94 km^2 in 1947, but it decreased significantly in 2020 to reach 2.53 km^2. This decrease was in favor of other types, particularly segment watershed, which is considered one of the best types for increasing the productive capacity and reducing all dissolved salts and the groundwater level, as its area increased from 18.86 to 36.77 km^2. As for the flat areas, as well as the multi-drain areas that are similar to the characteristics of flat areas, their areas were 1.05 and 0.24 km^2 in 1947 respectively, while they reached 21.44 and 21.65 km^2 in 2020 respectively.
- The increase in the number of depression watersheds (72 basins) and the increase in the area (59.94 km^2) in 1947 led to an

increase in the areas in which water accumulates (water pools), particularly the central and eastern areas, which embrace some low-lying lands, whether in degree of slope or levels. Accordingly, they are used as reservoirs for rainwater in the winter season and irrigation water leakage, and they turn into ponds and swampy lands. The area of water pools reached 1.79 km^2.

- The decrease in the area of depression watersheds (2.53 km^2) and the increase in the area of segment watersheds (36.77 km^2) in 2020 led to the disposal of excess water for agricultural crops outside the study area, as the area of water pools decreased to 0.3 km^2 in 2020. As a result, their productive capacity increased.

All these changes has reflected on the physical and chemical characteristics of the soil, as well as the increase in its fertility and productive capacity, due to a number of reasons, particularly its distance from the groundwater. This, in turn, has caused the area of agricultural lands to increase from 45.75% in 1947 to 62.73% in 2024.

5.2. Relief Profiles in Baltim Area

The analysis of Figures 15 to 18 and Tables 5 to 7 indicates the following:

- The length of study profiles varies between 1.154 and 18.221 km, with a total of 81.315 km and an average of 9.04 km.
- The levels of the earth's surface in 1947 ranged between -0.8 and 19.06 m, and between 0 and 27.11 m in 2020. The highest levels were recorded in Section Aa, which is represented in the sand dune area north of the Baltim area.
- The highest degrees of slope exceeding 30 degrees are recorded in the northern section (Aa) in either 1947 or 2020, with a significant increase in the degree of slope, reaching 32 and 67 degrees respectively. In addition, there is an increase in the degree of slope in the middle section (Bb) from 4 to 45 degrees during the comparison period, noting that this increase occurs on the western side of the section in the sand dune area.
- The profiles with the lowest slope are located in the east, southeast, and center of the study area, as the average slope does not exceed two degrees.
- Some profiles are characterized by complete predominance of deposition and backfilling rates, as no part subjected to the process of erosion and removal is recorded in 3 profiles, namely: Ff, Gg and Hh. On the other hand, rates of erosion and removal are recorded at very simple rates in Profiles Cc and Ii.
- Deposition and backfilling are predominant in the study area. The average vertical area in the relief profiles is 0.316 km^2, while the average area of erosion and removal is 0.019 km^2.

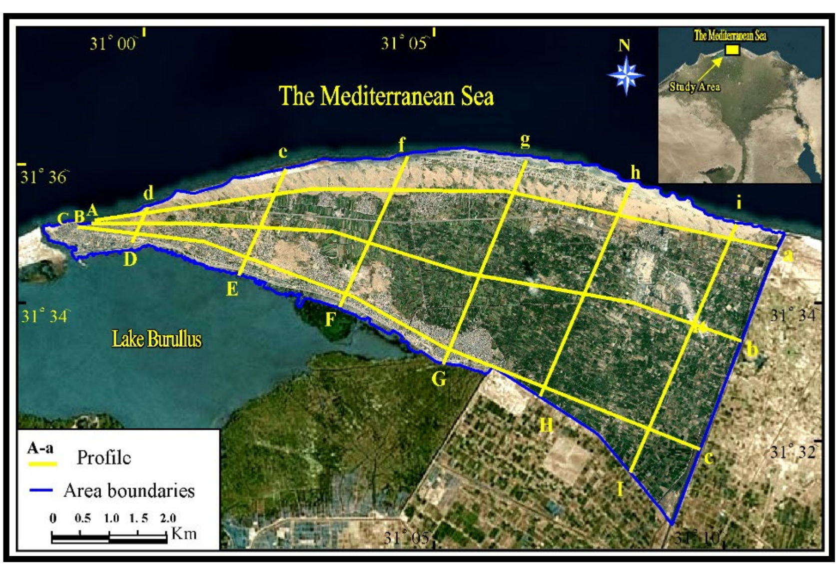
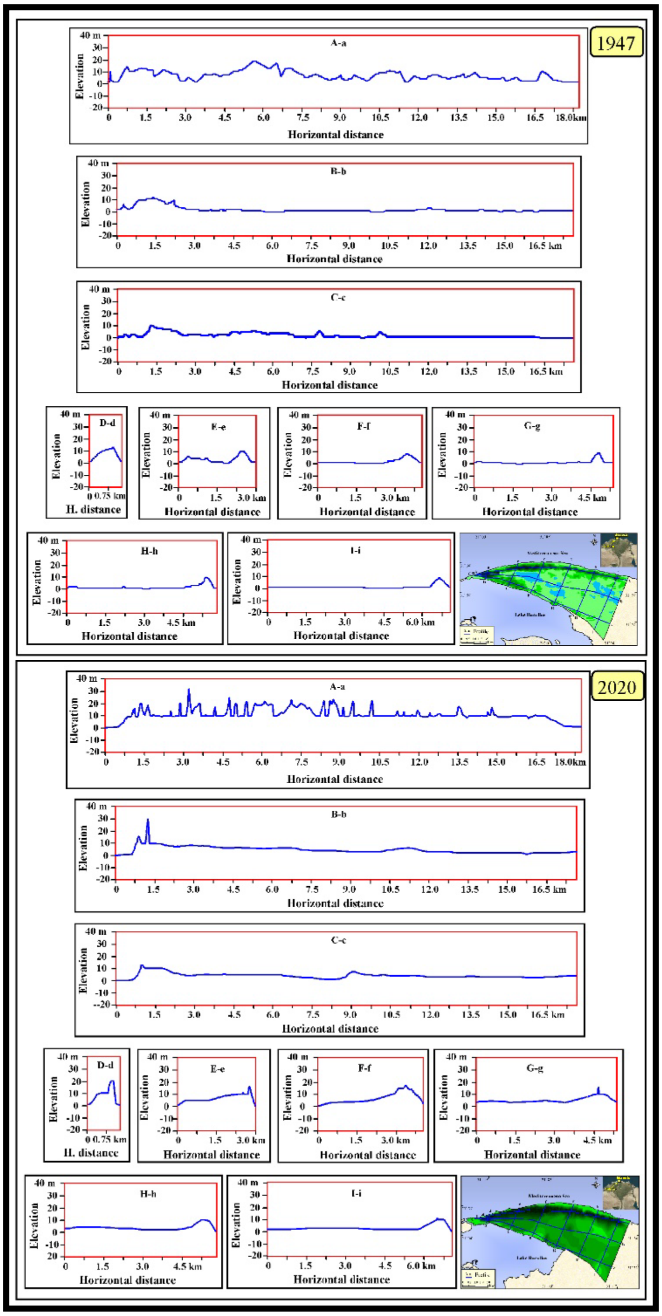
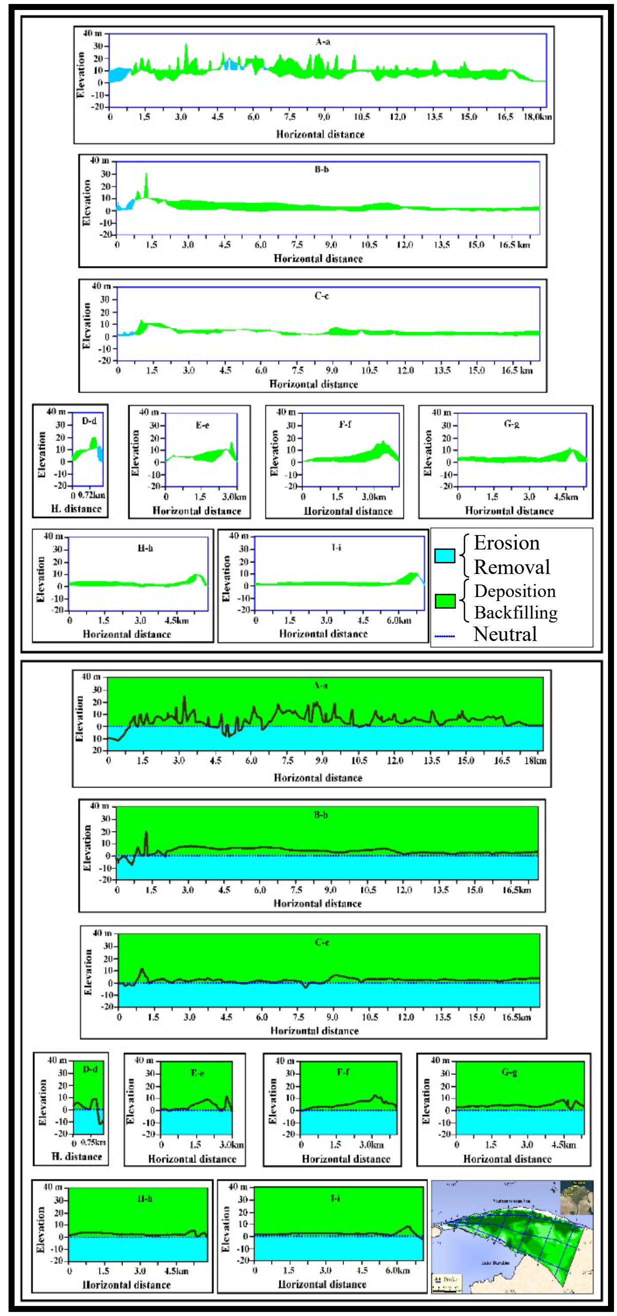


Figure 15. Locations of the Relief Profiles in Baltim Area



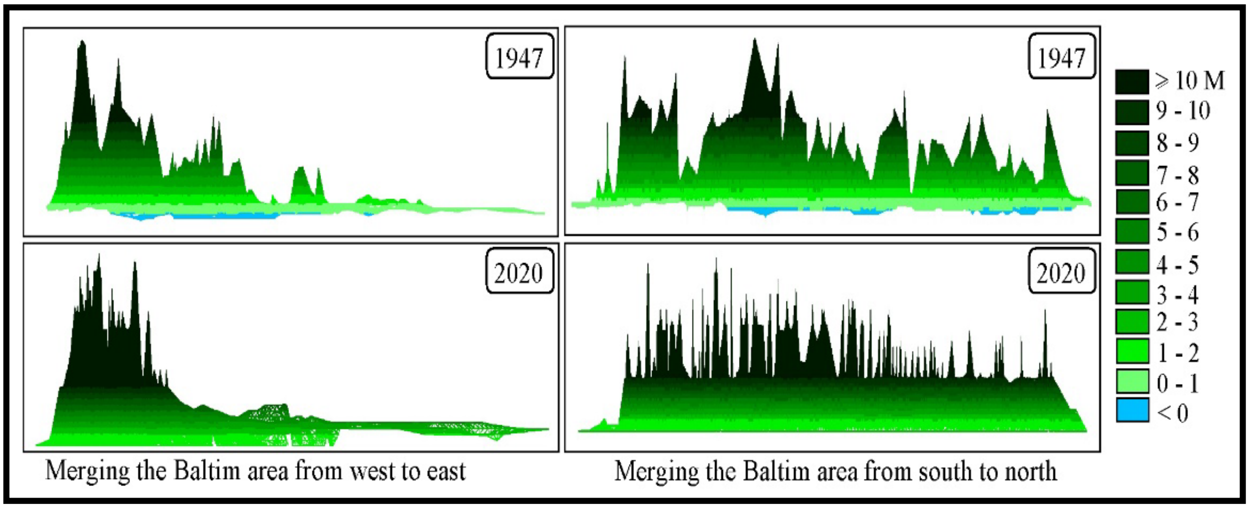
Source: It is based on topographic Maps, Scale 1:25000, 1947 and Scale 1:50000, 2020.

Figure 16. The Characteristics of Relief Profiles in Baltim Area during the Period 1947-2020



Source: It is based on topographic Maps, Scale 1:25000, 1947 and Scale 1:50000, 2020.

Figure 17. The Area of the (1D and 2D) Erosion and Deposition Layers in Baltim Area during the Period 1947-2020



Source: It is based on topographic Maps, Scale 1:25000, 1947 and Scale 1:50000, 2020.

Figure 18. Merging Relief Profiles in Baltim Area during the Period 1947-2020

Table 5. General Characteristics of Relief Profiles in Baltim Area in 1947 and 2020

No.	Year	Profile length (km)	Highest level (m)	Lowest level (m)	Average levels (m)	Highest degree of slope	Lowest degree of slope	Average degree of slope	Area- Vertical (m^2)	
									Erosion	Deposition
Aa	1947	17.976	19.06	0.98	7.21	32	0	1.73	113987	925974
	2020	17.976	27.11	0.0	12.85	67	0	6.08		
Bb	1947	18.080	10.50	-0.80	2.49	4	0	0.55	27473	660178
	2020	18.080	27.01	0.0	7.74	45	0	3.01		
Cc	1947	18.221	10.45	0.05	1.47	14	0	0.57	9745	380231
	2020	18.221	12.99	0.18	5.39	15	0	0.62		
Dd	1947	1.154	12.59	0.83	7.36	3	0	2.62	17194	31861
	2020	1.154	20.02	0.14	11.35	27	0	7.41		
Ee	1947	2.981	10.09	0.33	3.42	2	0	1.20	359	102574
	2020	2.981	16.25	0.0	7.26	13	0	1.90		
Ff	1947	4.187	7.97	-0. 40	2.25	2	0	0.50	0	209719
	2020	4.187	17.52	0.29	10.48	5	0	1.47		
Gg	1947	5.577	9.07	-0.50	1.39	3	0	0.65	0	227763
	2020	5.577	15.82	2.85	6.82	42	0	2.84		
Hh	1947	5.942	9.65	0.0	1.94	5	0	0.67	0	142227
	2020	5.942	5.49	0.86	5.74	4	0	1.01		
Ii	1947	7.197	8.19	-0.74	1.12	4	0	0.30	2752	171130
	2020	7.197	11.07	0.0	5.06	5	0	0.89		
Average		9.040	13.94	0.26	5.63	16.22	0	1.89	19057	316851

Source: It is based on Figures 16 & 17.

Table 6. Characteristics of Longitudinal Profiles in Baltim Area in 1947 and 2020

No.	Degree Range	Length (m)				Total (m)		Total (%)	
		Direction: South - North		Direction: North - South					
		1947	2020	1947	2020	1947	2020	1947	2020
Dd	0 (Straight)	—	—	—	—	7.93	56.10	0.69	4.86
	> 0 – 0.5	490.67	358.52	41.48	307.55	532.15	666.07	46.09	57.69
	0.5 – 1.0	88.87	6.63	0.00	0.00	88.87	6.63	7.70	0.57
	1.0 – 1.5	56.26	3.51	0.00	0.00	56.26	3.51	4.87	0.30
	1.5 – 2.0	199.11	123.31	0.00	0.00	199.11	123.31	17.24	10.68
	≥ 2.0	9.95	249.58	260.35	49.42	270.3	299.00	23.41	25.90
	Total	844.85	741.54	301.83	356.97	1154.62	1154.62	100.00	100.00
Ee	0 (Straight)	—	—	—	—	81.59	1191.96	2.74	39.98
	> 0 – 0.5	297.81	55.84	1252.67	1088.12	1550.48	1143.96	52.01	38.37
	0.5 – 1.0	447.03	2.09	83.11	318.86	530.14	320.95	17.78	10.77
	1.0 – 1.5	273.17	7.35	50.73	7.63	323.90	14.98	10.87	0.50
	1.5 – 2.0	180.49	16.08	314.41	2.27	494.90	18.35	16.60	0.62
	≥ 2.0	0.00	231.00	0.00	59.84	0.00	290.84	0.00	9.76
	Total	1198.50	312.35	1700.91	1476.70	2981.01	2981.01	100.00	100.00
Ff	0 (Straight)	—	—	—	—	16.05	564.70	0.38	13.49
	> 0 – 0.5	1524.61	2321.05	1880.07	323.18	3404.68	2644.23	81.32	63.15
	0.5 – 1.0	232.05	100.46	386.13	173.74	618.18	274.20	14.76	6.55
	1.0 – 1.5	71.39	77.85	51.49	185.18	122.88	263.03	2.93	6.28
	1.5 – 2.0	25.21	133.57	0	123.37	25.21	256.94	60.00	6.14
	≥ 2.0	0	37.81	0	146.09	0.00	183.90	0.00	4.39
	Total	1853.26	2670.74	2317.69	951.56	4187	4187	100.00	100.00
Gg	0 (Straight)	—	—	—	—	469.46	495.28	8.42	8.88
	0 – 0.5	2202.52	3122.43	2424.01	1516.68	4626.53	4639.11	82.95	83.17
	0.5 – 1.0	39.33	0.06	14.36	214.77	53.69	214.83	0.96	3.85
	1.0 – 1.5	43.67	15.52	14.05	151.42	57.71	166.94	1.03	2.99
	1.5 – 2.0	133.59	0.20	6.25	0	139.84	0.20	2.51	0.00
	≥ 2.0	59.34	28.21	171.25	33.26	230.58	61.46	4.13	1.10
	Total	2478.44	3166.4	2629.91	1916.13	5577.80	5577.80	100.00	100.00
Hh	0 (Straight)	—	—	—	—	1967.59	2719.53	33.11	45.77
	> 0 – 0.5	1602.31	975.69	1704.53	1659.88	3306.84	2635.57	55.65	44.35
	0.5 – 1.0	242.32	321.80	94.91	0	337.22	321.80	5.68	5.42
	1.0 – 1.5	26.66	14.59	35.7	0	62.36	14.59	1.05	0.25
	1.5 – 2.0	0	0	98.89	104.5	98.89	104.50	1.66	1.76
	≥ 2.0	53.25	0	115.90	146.09	169.14	146.09	2.85	2.46
	Total	1924.53	1312.07	2049.92	1910.47	5942.04	5942.04	100.00	100.00
Ii	0 (Straight)	—	—	—	—	3915.41	3359.64	54.40	46.68
	> 0 – 0.5	1299.83	1784.31	1313.07	1071.81	2612.90	2856.12	36.31	39.68
	0.5 – 1.0	38.76	645.94	33.94	16.59	72.70	662.53	1.01	9.21
	1.0 – 1.5	249.72	0	306.41	1.075	556.13	1.075	7.73	0.01
	1.5 – 2.0	27.92	0	0	269.77	27.92	269.77	0.39	3.75
	≥ 2.0	11.965	8.64	0	39.25	11.97	47.89	0.17	0.67
	Total	1628.19	2438.89	1653.41	1398.49	7197.01	7197.01	100.00	100.00

Source: It is based on Figures 16 & 17.

Table 7. Characteristics of Cross Sections in Baltim Area in 1947 and 2020

No.	Degree Range	Length (m)				Total (m)		Total (%)	
		Direction: West - East		Direction: East - West					
		1947	2020	1947	2020	1947	2020	1947	2020
Aa	0 (Straight)	—	—	—	—	690.21	3093.12	3.84	17.21
	> 0 – 0.5	4541.275	3928.7	4447.735	3458.225	8989.01	7386.93	50.01	41.09
	0.5 – 1.0	2505.225	673.595	2497.23	1081.86	5002.46	1755..46	27.83	9.77
	1.0 – 1.5	932.025	652.195	658.145	514.055	1590.17	1166.25	8.85	6.49
	1.5 – 2.0	310.44	458.075	128.5	388.785	438.94	846.86	2.44	4.71
	≥ 2.0	533.49	2026.875	731.82	1700.59	1265.31	3727.47	7.04	20.74
	Total	8822.455	7739.44	8463.43	7143.515	17976.10	17976.10	100.00	100.00
Bb	0 (Straight)	—	—	—	—	3143.045	4182.845	17.38	23.14
	> 0 – 0.5	4899.73	5809.01	7652.985	7549.01	12552.72	13358.02	69.43	73.88
	0.5 – 1.0	456.955	31.1	948.97	4.585	1405.93	35.69	7.78	0.20
	1.0 – 1.5	381.385	6.05	251.61	4.2	632.99	10.25	3.50	0.06
	1.5 – 2.0	106.525	31.92	87.27	12.655	193.79	44.58	1.07	0.25
	≥ 2.0	104.635	274.285	46.89	174.405	151.53	448.69	0.84	2.48
	Total	5949.23	6152.365	8987.725	7744.855	18080.0	18080.0	100.00	100.00
Cc	0 (Straight)	—	—	—	—	5033.41	5057.69	27.62	27.76
	> 0 – 0.5	6006.96	4984.10	6029.93	7165.85	12036.89	12149.95	66.06	66.68
	0.5 – 1.0	317.36	259.30	261.40	327.67	578.76	586.97	3.18	3.22
	1.0 – 1.5	246.89	205.62	103.81	15.43	350.70	221.05	1.92	1.21
	1.5 – 2.0	104.88	47.17	10.91	8.81	115.79	55.98	0.64	0.31
	≥ 2.0	25.88	102.86	79.63	46.60	105.51	149.46	0.58	0.82
	Total	6701.95	5599.04	6485.67	7564.34	18221.1	18221.1	100.00	100.00

Source: It is based on Figures 16 & 17.

The following is a study of cross sections and profiles in detail:

5.2.1. Longitudinal Profiles

The analysis of Figures 16, 17 and 18 and Table 6 indicates the following:

- There is an increase in straight sections in longitudinal profiles from 1947 to 2020 in five profiles, particularly the western and middle profiles such as Profiles Ee and Ff, from 2.74% to 39.98% and from 0.38% to 13.49% respectively. This is consistent with the previous cross sections, which in turn indicates that the center of the study area has significant human intervention that was a major reason for levelling the lands of the Baltim area. In fact, this intervention has a direct impact on the predominance of the first-class slopes in all profiles during the comparison period, as they exceed 80% in Profile Gg in the center of the study area. As for the rest of the profiles, they exceed 35% whether in 1947 or 2020.
- There is a difference in the direction of slope during the comparison period between the different profiles, as it is found that the general direction is from north to south in 1947 in all profiles except the western profile (Dd) only. However, the predominant direction in 2020 is from south to north in four profiles, particularly the middle one, and from north to south in only two profiles: Ee and Hh.
- There is an increase in the vertical area of the deposition and backfilling over the erosion and removal in all longitudinal profiles, namely in three profiles, which are located approximately in the center of the Baltim area, reaching 0.89 km^2 and 0.02 km^2 respectively.

5.2.2. Cross Sections

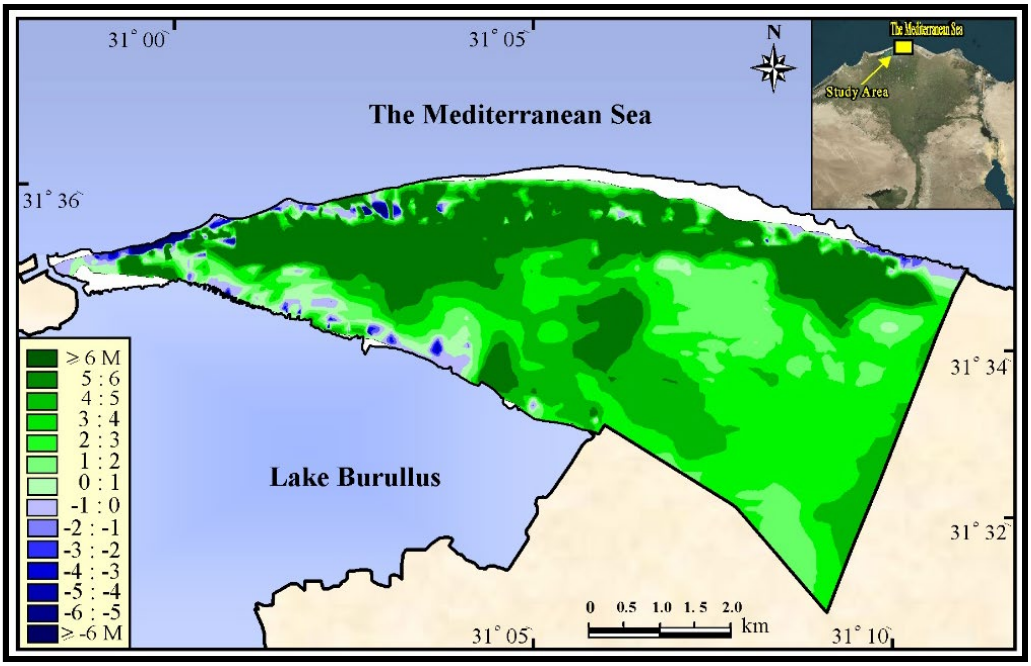
The analysis of Figures 16, 17 and 18 and Table 7 indicates the following:

- There is an increase in straight sections in the cross sections from 1947 to 2020, particularly in the middle section (Bb), which indicates an increase in human intervention in levelling the lands so that they are valid for agriculture. This intervention has had a direct impact on the predominance of the first-class slopes, which range between 0 and 5 degrees in all profiles during the comparison period, exceeding 50% in all profiles, particularly in the middle profile.
- There is a predominance of slopes whose direction is from west to east in the northern section (Aa) whether in 1947 or in 2020. As for the middle section (Bb), which is the one with the most human intervention, directions from east to west predominate during the comparison period. However, there is a change in the southern section (Cc), as directions from west to east predominate in 1947, but they change to being from east to west in 2020. The reason for this change is the removal of many parts of the southern sand dunes in favor of urban development.
- There is an increase in the vertical area of the deposition and backfilling over the erosion and removal in all cross sections, particularly the northern section (Aa). The distance between them reaches 1.8 km^2, as the total area of deposition and backfilling reaches 1.97 km^2, and the total area of erosion and removal reaches 0.15 km^2.

5.3. The Area and Volume of Erosion, Removal, Deposition and Backfilling

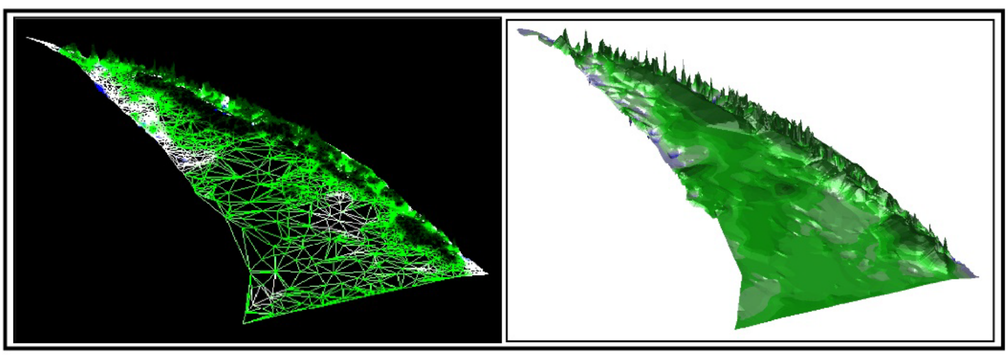
This method is considered the most accurate method when calculating physical rates (erosion and deposition) and human rates (removal and backfilling) and comparing them, particularly the volume (m^3). This is mainly due to the fact that it depends primarily on the three dimensions of the area: length, width, and elevation (Saber & Hassan, 2024). The analysis of Figures 19, 20 and 21 and Table 8 indicates the following:

- The areas that are backfilled at an elevation ranging between 2 and 3 m occupy the largest horizontal area, covering 30.05% of the total area of the Baltim area. In addition, the total volume of backfilling reaches 48.98 million m^3, representing 17.75%. These areas are spread in the middle of Baltim village through backfilling some ponds, and they cover the northern sand dune areas because of their continuous movement due to the wind, as well as the increase in the process of deposition, the process of levelling and backfilling the low-lying areas adjacent to the sand dunes. They cover all the villages of the study area except the villages of El-Ruba' and El-Sahil El-Qibli.
- The areas that are backfilled at an elevation ranging between 3 and 4 m rank second in terms of area, as they cover 20.14%, with a total backfilling volume of 28.51 million m^3, representing 10.33%. They are represented in the backfilling process for low-lying areas, particularly the center and east of the study area.
- The areas that are backfilled at an elevation of less than 2 m occupy 18.22% in terms of area, with a volume of 142.64 million m^3. They are spread in all villages, particularly the villages of El-Shihabiya and Baltim. This is logical due to the lack of backfilling components within the study area other than sand (of low productivity), which is not preferred by farmers. On the other hand, bringing backfill from outside the area is very expensive, and accordingly what is available to farmers is a backfill of one meter or two at most. With the large area, a total large volume of backfill results, representing 51.69% (Figure 22).
- The areas of erosion and removal are spread in very limited areas, as their area does not exceed 5.0% of the total study area. As for the volume, it reaches 4.67 million m^3, representing 1.69%. They cover the sand dune areas located northwest of the study area in the villages of El-Rub', El-Bana'in, and El-Sahil El-Bahari, in which the removal elevation exceeds 6; and the southern areas of the villages of El-Rub', El-Sahil El-Qibli, and El-Bana'in. This is in addition to the area located in the far northeast of the study area in the village of El-Shihabiya (Figure 22).



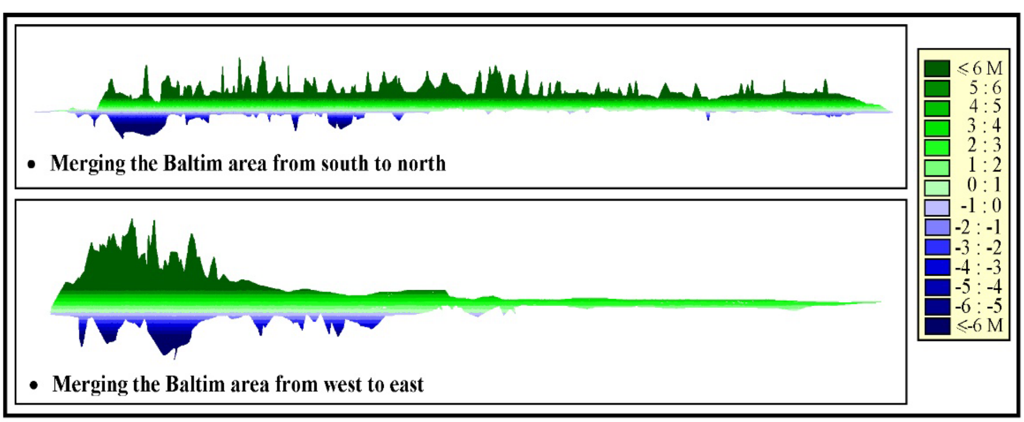
Source: It is based on topographic Maps, Scale 1:25000, 1947 and Scale 1:50000, 2020.

Figure 19. The Thickness of (1D) Erosion and Deposition Layers in Baltim Area



Source: It is based on Figure 19.

Figure 20. The Volume of (3D) Erosion and Deposition in Baltim Area



Source: It is based on Figure 19.

Figure 21. Merging Relief Profiles in Baltim Area (1947-2020)

Table 8. The Area and Volume of Erosion, Removal, Deposition and Backfilling in Baltim Area (1947-2020)

Process	Category (m)	Area- Horizontal		Volume	
		(m^2)	%	(million m^3)	%
Deposition & Backfilling	≥ 6	10.76	13.57	20.27	7.35
	5 : 6	4.32	5.45	12.83	4.65
	4 : 5	6.64	8.38	18.09	6.55
	3 : 4	15.97	20.14	28.51	10.33
	2 : 3	23.82	30.05	48.98	17.75
	1 : 2	11.24	14.18	68.19	24.71
	0 : 1	3.21	4.04	74.45	26.98
Erosion & Removal	-1 : 0	2.20	2.78	2.04	0.74
	-2 : -1	0.53	0.67	0.80	0.29
	-3 : -2	0.19	0.24	0.47	0.17
	-4 : -3	0.10	0.13	0.34	0.12
	-5 : -4	0.05	0.06	0.27	0.10
	-6 : -5	0.04	0.05	0.23	0.08
	≥ -6	0.21	0.26	0.53	0.19
Total		79.27	100.00	276.00	100.00

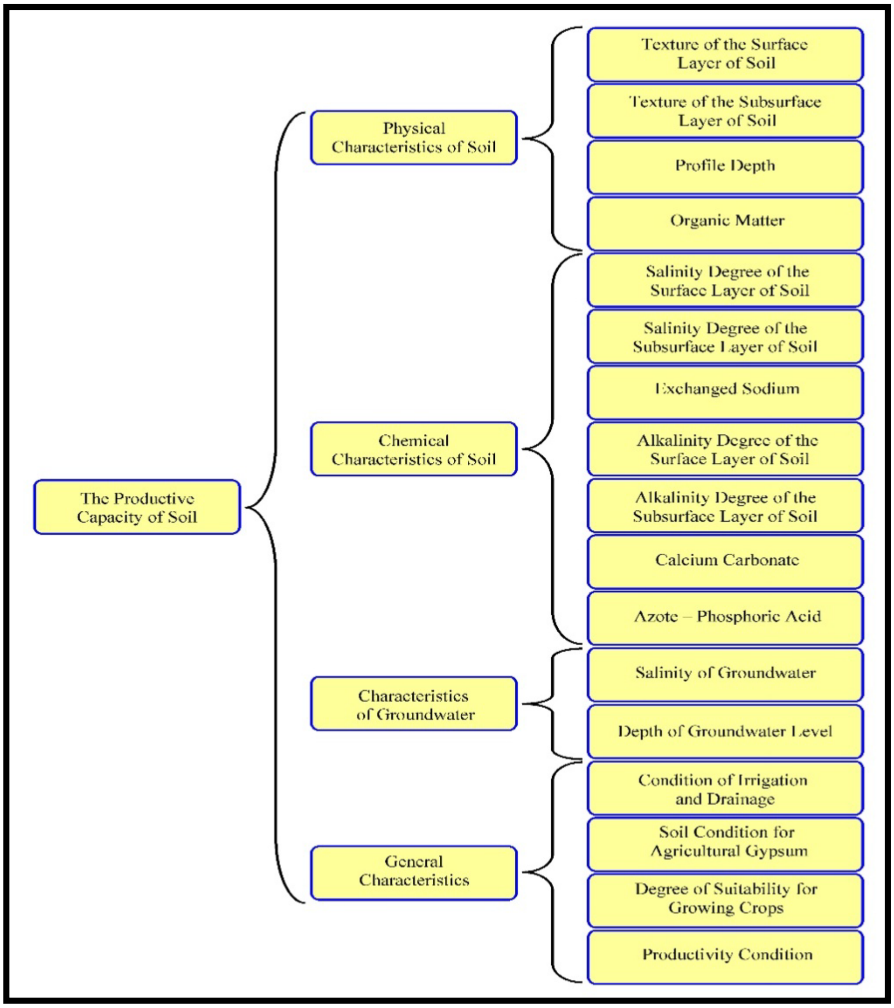
Source: It is based on Figure 19.

Source: Field Study, 2024.

Figure 22. The Impact of Human Interventions on the Terrain Characteristics in Baltim Area

6. The Impact of Terrain Characteristics on the Inputs of the Productive Capacity Model in Baltim Area

Lands in Baltim area are classified based on the productive capacity considering the following factors, according to the system followed in dividing Egyptian lands, which are shown in Figure 23.



Source: It is based on the Soil Classification Inventory, 1962.

Figure 23. Indicators for Determining the Productive Capacity of Soil

It is worth noting that the field work occupied the largest part of the process of collecting the required data and samples, and comparing them with what the Ministry of Agriculture did regarding the soil classification inventory in 1962. This is in order to obtain information regarding the model's inputs, which included the mechanical and chemical characteristics of soil as well as the chemical characteristics of water (groundwater, drains, canals and ponds) (Figures 24 and 25) and (Appendixes 1 to 3), and then link these characteristics with the terrain characteristics to determine their impact on the productive capacity of soil.

Source: Field Study, 2024.

Figure 24. Locations of Soil and Water Samples in Baltim Area

Source: Field Study, 2024.

Figure 25. Collecting Soil and Water Samples in Baltim Area

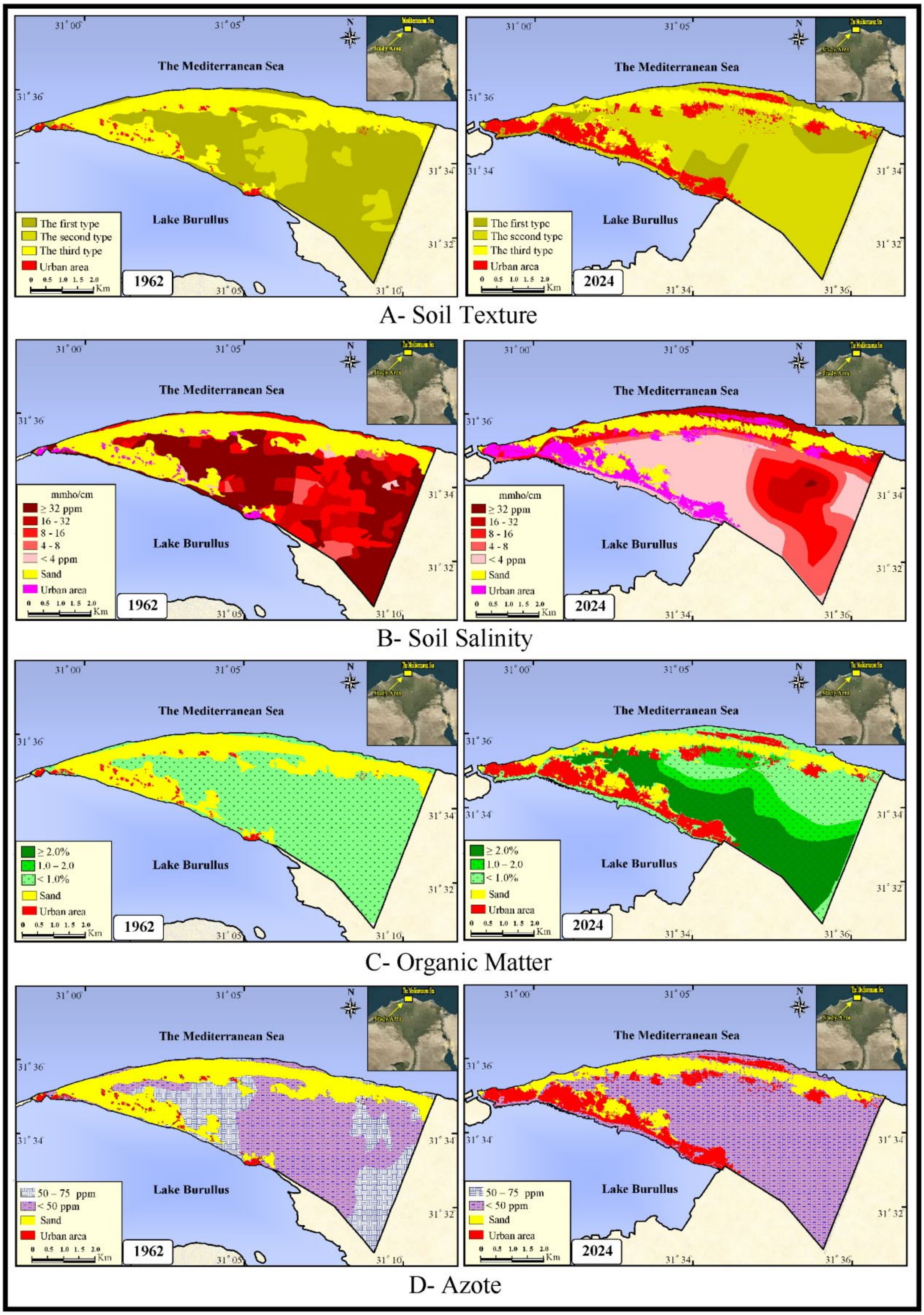
The Egyptian Ministry of Agriculture has classified the productive capacity into six classes, the fifth and sixth of which are not linked to any laboratory analyses, whether chemical or mechanical. They include areas that can be reclaimed in the future and areas that are impossible to cultivate. They were identified from the maps of 1962 and 2024, and were represented in sand dunes, ponds, roads, water canals, buildings, and waste lands. These areas were excluded from the area of other classes, for ease of comparison during the two periods so as to reach accurate results that illustrate the relation between the terrain characteristics and the productive capacity of soil. As for the remaining part of the study area, represented here by agricultural lands, its classification from the first to the fourth class was based on laboratory analyzes of the soil and water, in addition to obtaining other data such as the productivity of acres, the quality of crops, the efficiency of irrigation and drainage, and others.

The following are a study, analysis and interpretation of the change in the input data of the productive capacity model and linking it to the change in the terrain characteristics in the Baltim area. This is carried out by comparing the data and maps of 1962, which were conducted by the General Land Administration at the Ministry of Agriculture, with the data and maps of 2024, which were conducted through the field study as shown in Figure 26, Table 9 and Appendixes 1 to 3. They can be discussed as follows:

Table 9. Some Chemical Characteristics of Soil and Water in Baltim Area during the Period between 1962 and 2024

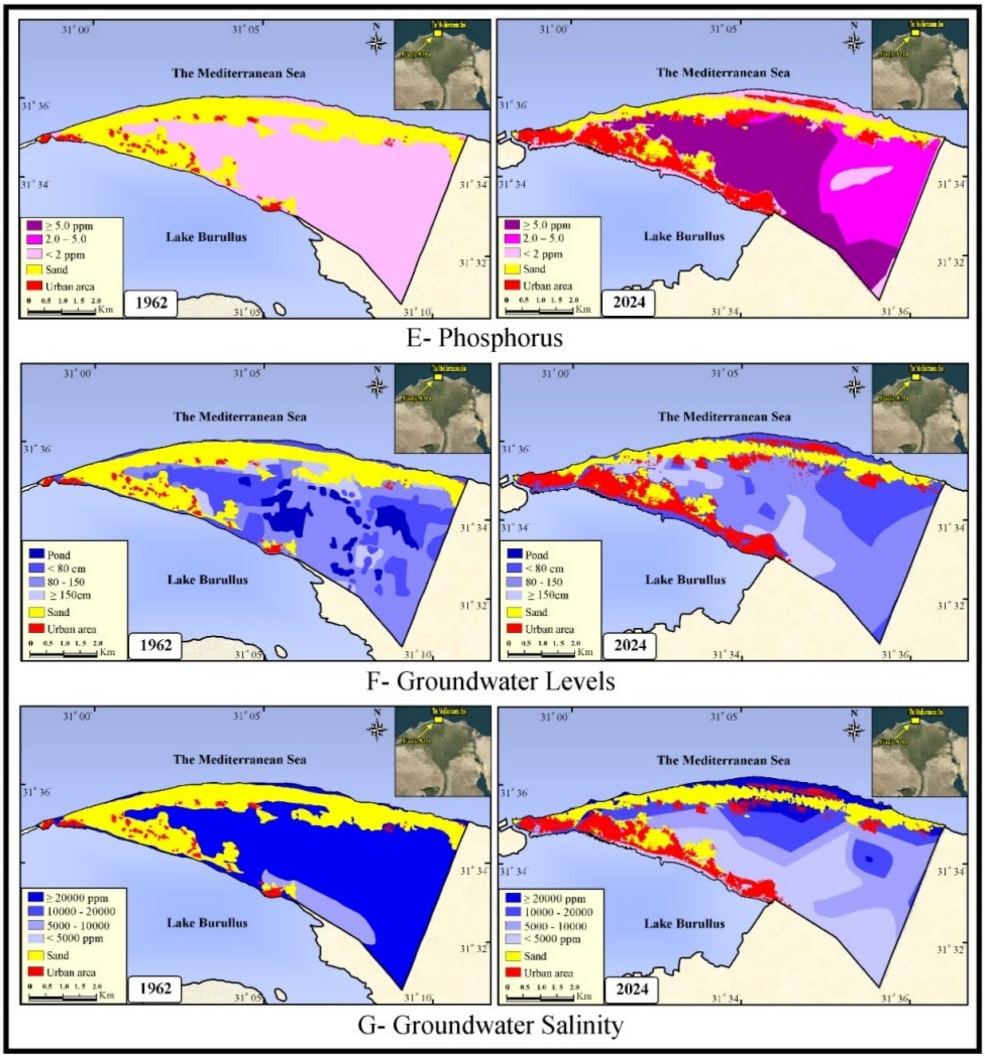
Soil Texture			Soil Salinity			Soil Phosphoric Acid			Soil Organic Matter			Soil Azote			Groundwater Levels			Groundwater Salinity		
Type	1962	2024	Category mmho/cm	1962	2024	Category ppm	1962	2024	Category %	1962	2024	Category ppm	1962	2024	Category cm	1962	2024	Category ppm	1962	2024
First	60.45	8.91	< 4	1.42	32.00	< 2	71.24	16.34	< 1%	71.24	31.50	< 50	30.23	77.33	< 80	21.96	16.24	< 5000	0.00	26.19
Second	10.79	68.42	4-8	3.62	14.94	2.0-5.0	0.00	24.34	1-2%	0.00	16.92	50-75	41.01	-	80-150	35.31	48.00	5000-10000	5.50	18.14
Third	27.32	10.34	8-16	16.42	19.54	> 5.00	0.00	36.61	> 2%	0.00	28.91	-	-	-	> 150	5.32	13.10	10000-20000	0.00	17.58
-	-	-	16-32	11.46	9.70	-	-	-	-	-	-	-	-	-	ponds	8.66	-	> 20000	65.74	15.38
-	-	-	> 32	38.32	1.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	Sand	27.32	10.34	Sand	27.32	10.34	Sand	27.32	10.34	Sand	27.32	10.34	Sand	27.32	10.34	Sand	27.32	10.34
Urban	1.44	12.33	Urban	1.44	12.33	Urban	1.44	12.33	Urban	1.44	12.33	Urban	1.44	12.33	Urban	1.44	12.33	Urban	1.44	12.33
Total	100	100	Total	100	100	Total	100	100	Total	100	100	Total	100	100	Total	100	100	Total	100	100

Source: It is based on Figure 26.



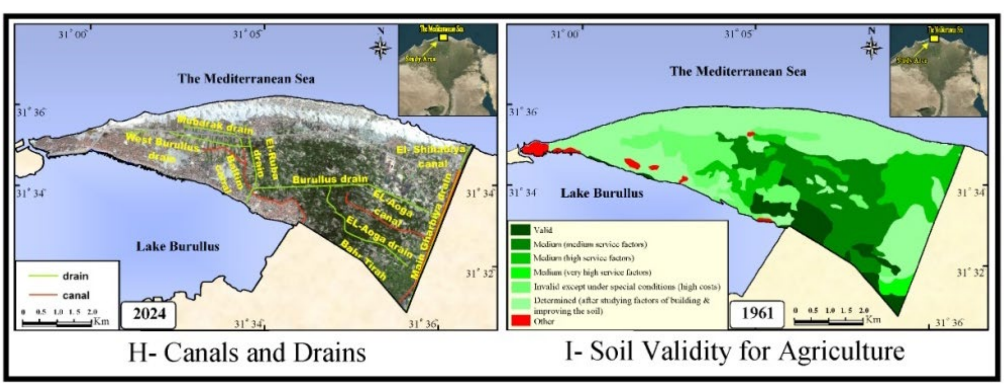
Source: Ministry of Agriculture, General Land Administration, Land Survey and Improvement Control, Land Survey Department, Classification Inventory, Land Division of Baltim Center (1962), and Appendixes 1 to 3.

Figure 26/A. Some Model Inputs (Soil Characteristics) Impacting the Productive Capacity in Baltim Area



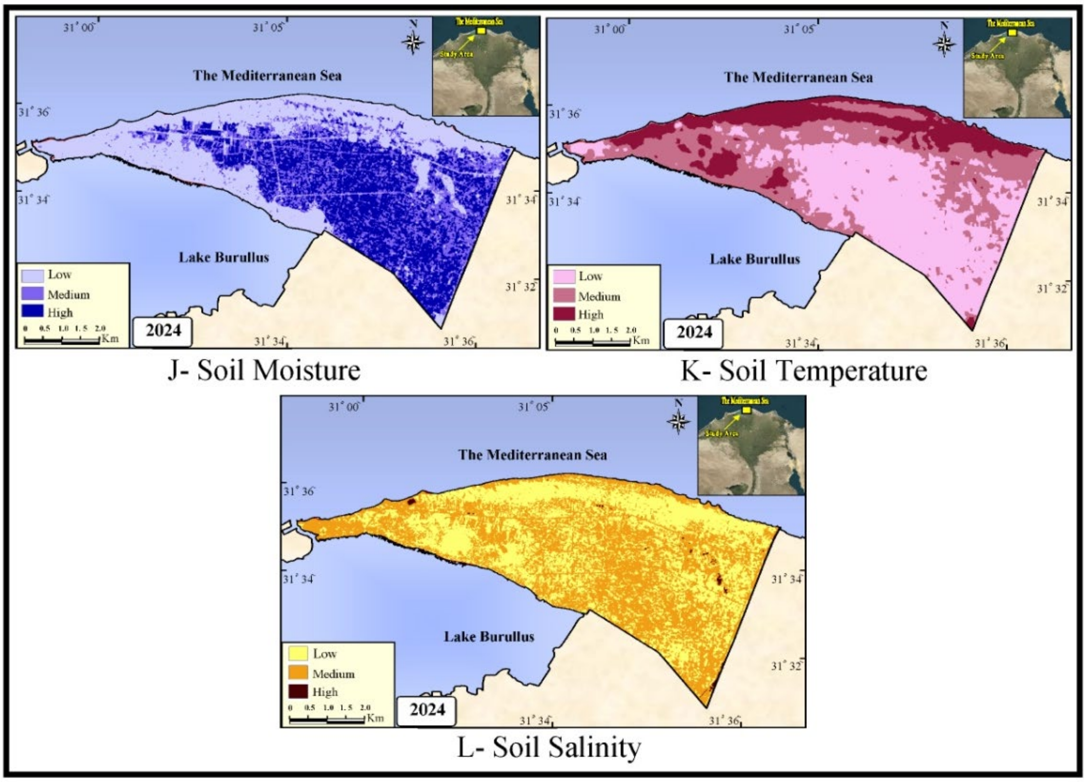
Source: Ministry of Agriculture, General Land Administration, Land Survey and Improvement Control, Land Survey Department, Classification Inventory, Land Division of Baltim Center (1962), and Appendixes 1 to 3.

Figure 26/B. Some Model Inputs (Soil and Groundwater Characteristics) Impacting the Productive Capacity in Baltim Area



Source: Military Survey Authority, Topographic Maps, Scale 1:50000 (2020), Google Earth (2024), and Maps of the High Dam Land Surveying Project (El-Hamoul - Baltim), Scale 1:50000 (1961).

Figure 26/C. Some Model Inputs (Canals, Drains and Soil Validity for Agriculture) Impacting the Productive Capacity in Baltim Area



Source: Satellite images Landsat, 2024.

Figure 26/D. Some Model Inputs (Soil Temperature, Moisture and Salinity) Impacting the Productive Capacity in Baltim Area

6.1. Soil Texture

- **The first type:** In 1962, it includes the majority of the lands, representing 60.45% of the total study area. The soil is characterized by having a very light texture; that is, a mixture of fine and coarse sand, in addition to having a deep profile and being loose and predominated by the yellow colour. Moreover, it is very permeable; that is, the degree of hydraulic conductivity of the soil exceeds 1.0 cm^3/hour. In these lands, it is noted that the percentage of the soil saturation capacity with water is less than 25%, due to the predominance of the percentage of coarse sand ranging between 60% and 75%, the percentage of fine sand ranging between 20% and 35%, and the percentage of clay ranging between 1.0% and 3.5%. As for 2024, the matter has changed significantly: these lands' percentage decreases to 8.91% of the total area of the Baltim area. The reason for this is not due to a decrease in the percentage of coarse sand; on the contrary, its percentage increased to 70%. It is due to an increase in the percentage of clay ranging between 8.59% and 9.68%, which causes an increase in the percentage of saturation capacity to range between 26.52% and 28.59%.
- **The second type:** In 1962, this type of lands includes some areas in the villages of Baltim and El-Shihabiya, and they represent limited areas of the study area, representing 10.79%. The soil of this type is characterized by being of a light texture, i.e. sandy loam, and the soil is somewhat cohesive in the surface layer and loose in the subsurface layer. It has a deep profile and is predominated by the dark yellow colour. The soil is considered very permeable to water; that is, the degree of hydraulic conductivity greatly exceeds 1.0 cm^3/hour. Moreover, the percentage of the soil saturation capacity increases, ranging between 7% and 38%, as a result of the increase in the percentage of clay. It is found that the percentage of clay is about 10%, the percentage of fine sand ranges between 25%

and 35%, and the percentage of coarse sand ranges between 20% and 50%. As for 2024, the percentage of the area of this category increases to 68.42%: the percentage of coarse sand ranges between 39.22% and 68.23%, noting an increase in the percentage of clay between 10.19% and 34.40%, which results in an increase in the percentage of the soil saturation capacity between 31.07% and 63.58%. This change is mainly owing to the continuous backfilling process for low-lying areas by mixing the available sand in the study area with clay soil from areas adjacent to the Baltim area, or by adding clay soil to improve the characteristics of the local soil and increase its productive capacity.

- **The third type:** This type of lands includes the sand dune area, which is characterized by its very light texture; that is, a mixture of fine and coarse sand along the soil profile. In addition, its colour is light yellow, it has a deep profile, and it is and very permeable to water, exceeding 1.0 cm^3/hour. It is noted that the percentage of fine sand increases by 50%, the percentage of coarse sand increases from 50% to 70%, the percentage of silt from 0.5% and 1.0%, and the percentage of clay from 0.5 to 2.5%. Above all, these lands' area decreases from 27.32% in 1962 to 10.34% in 2024.

6.2. Soil Permeability

The majority of the lands of the Baltim area are characterized by being very permeable to water throughout the length of the soil profile, exceeding 1.0 cm^3/hour, whether in 1962 or 2024. This is mainly due to the fact that they are sandy lands with a very light texture in which the percentage of fine and coarse sand prevails over all other physical soil components.

6.3. Soil Salinity

Soil salinity is one of the most significant problems facing agriculture because of its negative impact on agricultural production in the area. Therefore, the lands of the Baltim area are classified according to the degrees of salinity in the soil profile as follows:

- **Highly saline lands:** Soil salinity exceeds 16 mmho/cm. Most of these lands were spread in 1962 in the waste areas east, center, west and south of the study area and included large areas due to the lack of an adequate network of irrigation and drainage projects so that washing operations could be carried out in these lands, with a rise in highly saline groundwater level (less than 80 cm from the surface). The percentage of the area of these lands constituted 49.76% of the total area in 1962, while their percentage decrease in 2024 reaching 10.85%. The reason for this decrease is due to the operations of treating the soil in the area by backfilling it with other clay and sandy soil and raising its level, in addition to operations of flood irrigation in lands near the drains that help wash the soil and reduce its salinity. They currently cover the vast majority of El-Shihabiya village and the border areas between it and the Baltim village, due to the presence of some ponds, swamps and sabkhas that permeate this area, in addition to the northern coastal areas. Above all, the high salinity in the soil had an impact on the decrease of the agricultural productive capacity in those areas.
- **Low saline lands**: The degree of soil salinity is less than 16 mmho/cm. These lands included cultivated lands in the Baltim area in 1962, the majority of which were closer to relatively moderate salinity due to insufficient washing and drainage of these lands, and the high groundwater level that appeared at a depth ranging between 80 and 150 cm. The percentage of the area of these lands reached 21.46% of the total area in 1962, while its percentage reach 66.48% in 2024. The reason for this large increase is due to the continuous improvement of drainage processes and the rise in the levels of the ground's surface through the backfilling process and distancing from groundwater. This is a major reason for the decrease in these lands' salinity and the increase in their agricultural productive capacity.

6.4. Soil Alkalinity

The degree of soil alkalinity increases during the comparison period, as it ranges between 6.7 and 8.1, with an average of 7.4 in 1962. The lowest values are recorded in the villages of El-Sahil El-Bahari, El-Sahil El-Qibli, and El-Rub', while the highest values are recorded in the villages of Baltim and El-Shihabiya. As for the year 2024, the alkalinity values range between 7.88 and 8.67, with an average of 8.3, That is, between a moderately alkaline soil that is valid to some degree for plant growth and a very highly alkaline soil. This percentage negatively affects the fertility of the soil and thus weakens the productive capacity of the agricultural land, which requires adding agricultural gypsum to it and washing it well with water.

6.5. Phosphoric Acid

The soil in the Baltim area is characterized by being very poor in the degree of dissolved phosphorus concentration in 1962, as the percentage was less than 2.0 ppm in all agricultural lands, which are low percentages that are not suitable for the growth of agricultural crops. On the other hand, the degree of concentration increases and exceeds 5.0 ppm in the soil in 2024 in many areas, particularly the southern and western areas, representing 36.61% of the total study area. However, the lands in which the phosphorus concentration is still low, less than 2.0 ppm, records the lowest percentage for the area at 16.34% of the total area, and they are spread in the sabkha area in the village of El-Shihabiya. Accordingly, farmers must add pure dissolved phosphorus to irrigation water to lower the soil's pH and increase its productive capacity.

6.6. Organic Matter

The percentage of organic matter in the soil was very low in all lands of the study area in 1962, as its concentration reached less than 1%, while in 2024 the area of land for this class decreases by almost half (31.5%), and it appears in agricultural lands located north of the villages of El-Shihabiya and Baltim. However, the lands in which the percentage of organic matter exceeds 2.0% appear only in 2024, and cover a large area, representing 28.9% of the total area. These lands are considered rich in organic matter and valid for agriculture. In addition, they are spread across old agricultural lands, particularly those located in the south and some lands located to the west, as a result of adding large amounts of good organic fertilizers to improve the quality of the soil.

6.7. Azote

On the one hand, the amount of dissolved azote in the surface layers of the soil ranged between 50 and 75 ppm, representing 41.04% of the total area in 1962, and appeared in the villages of El-Shihabiya, El-Rub', and El-Sahel El-Qibli. The amount of azote in the surface layer of soil that was less than 50 ppm represented 30.23% in the lands of the villages of Baltim, El-Hammad, El-Sahil El-Bahari, and El-Bana'in. On the other hand, the amount of dissolved azote in the surface layer of the soil reaches less than 50 ppm in 2024, representing 77.33%, and appears in all agricultural lands in the study area.

6.8. Groundwater Salinity

It is noted from the division of the lands of the Baltim area according to the degrees of salinity of the groundwater in 1962 that it was very high in most of the lands, as it exceeded more than 20000 ppm, representing 65.74% of the total area. As for the cultivated areas south of the village of Baltim and those adjacent to the Tira Sea, the degree of salinity of the groundwater ranged between 5000 and 10000 ppm, representing 5.5%, which indicates that groundwater during that period was completely invalid for irrigation in all lands of the study area, according to Appendix 3. However, it is the total opposite in 2024, as the majority of the center's lands have a salinity of less than 5000 ppm, representing 26.19% of the total area, and they appear in the southern areas of the villages of the Baltim area and parts of the center, extending from east to west along the length of the area. This is due to the construction of many canals, in addition to mixing drain water with irrigation water, which has led to a decrease in the salinity of the water seeping under the earth's surface. On the other hand, the degree of salinity of groundwater increases as we head north and approach the Mediterranean coast, where highly salty water spreads north of the region, with a salinity exceeding 20000 ppm, representing 15.83%. This is due to its mixing with highly saline sea water. It is worth noting that although the degree of salinity of groundwater has generally decreased, it still ranges between medium and very high for agricultural crops (Appendix 4).

6.9. Groundwater Levels

Groundwater levels vary as a result of differences in the extent of soil permeability and sources of water recharge from one place to another in the study area. On the one hand, it was found that the area of land in which the groundwater level appears at a depth of less than 80 cm from the soil surface reached 21.96% of the total area in 1962 and is scattered widely in many areas located in the east and center of the area, as well as some flooded ponds. However, the percentage decreases in 2024 to 16.24% due to the spread of backfilling in low-lying areas and ponds, and raising their level to become far from the level of groundwater, and this class was concentrated in the parts located to the northeast of the area, particularly north of the village of El-Shihabiya (Figure 27). In fact, this is due to the absence of any drains, whether exposed or covered, in addition to the spread of low-level sandy lands close to the sea coast.

On the other hand, the percentage of the land area in which the groundwater level appears at a depth ranging between 80 and 150 cm was the highest, reaching 35.31% in 1962 and 48.0% in 2024, and it included all cultivated lands in the middle of the area. As for the lands in which the groundwater level appears at a depth of more than 150 cm from the soil surface, they reach 5.32% in 1962 and 13.10% in 2024, which is the lowest percentage, and they are concentrated in agricultural lands near the city of Baltim in the south. Based on the aforementioned, it is evident that the process of raising the land level during the comparison period is the reason for the distance of groundwater levels from the surface layer of the soil to a large extent. However, in general, the Baltim area suffers from a problem in the agricultural drainage process, particularly in the northern and northeastern parts, which is a major reason for the soil saturation with water, high groundwater levels, and consequently high surface soil salinity as well as a decrease in its productive capacity.

Source: Field Study, 2024.

Figure 27. Variation in Groundwater Levels in Baltim Area

6.10. Validity of Soil and Water for Agricultural Crops according to Chemical Characteristics

The quality of the soil and the quality of water, particularly groundwater, are evaluated to determine their validity for agriculture by analyzing some soil and water samples in different areas, examining them, and then classifying them according to the soluble sodium percentage (SSP), and the degree of concentration of the residual sodium carbonate (RSC) and sodium absorption rate (SAR). The results of the analysis in Tables 10 and 11 indicate the following:

6.10.1. Soil Validity for Agriculture

- The percentages of soluble sodium range between 20.0 and 99.0%, i.e. from soils completely invalid for agriculture in highly saline sabkha areas to soils with good agricultural production in some agriculturally reclaimed areas in the center and west of the area. However, there is a lack of residual sodium carbonate concentration values in all samples.
- The degree of the sodium adsorption rate concentration ranges between 0.94 and 278.6 mEq/L, i.e. between classifications of low to extreme risk in the east of the area in highly saline lands. As for the rest of the samples in the majority of the area's lands, they indicate the validity of the soil for agriculture as a result of the treatment operations they are exposed to by backfilling them with clay soil and washing them with water to reduce salinity.

Table 10. Soil Classification according to Soluble Sodium Percentage, Residual Sodium Carbonate Concentrations, and Sodium Adsorption Rates

No.	SSP %	Degree of Validity	RSC mEq/L	Degree of Validity	SAR mEq/L	Degree of Risk	Degree of General Validity
1	25.0	Good	-	Nothing	0.94	Low	Very valid
3	43.3	Allowed to use	-	Nothing	1.7	Low	Valid
5	47.8	Allowed to use	-	Nothing	2.5	Low	Valid
6	39.3	Good	-	Nothing	1.54	Low	Very valid
7	38.7	Good	-	Nothing	1.7	Low	Very valid
9	41.7	Allowed to use	-	Nothing	1.9	Low	Valid
10	58.9	Allowed to use	-	Nothing	3.0	Low	Valid
11	95.3	Completely Invalid	-	Nothing	112.8	Very high	Invalid
12	45.8	Allowed to use	-	Nothing	1.7	Low	Valid
13	58.6	Allowed to use	-	Nothing	3.5	Low	Valid
14	45.0	Allowed to use	-	Nothing	1.9	Low	Valid
15	88.9	Completely Invalid	-	Nothing	33.4	Very high	Invalid
16	92.3	Completely Invalid	-	Nothing	34.12	Very high	Invalid
17	99.0	Completely Invalid	-	Nothing	278.6	Very high	Invalid

Source: It is based on Appendix 5.

6.10.2. Groundwater Quality for Irrigation

- The percentages of soluble sodium range between 53.4 and 93.2%, i.e. between percentages that are completely invalid for irrigation, particularly in sabkha areas due to their high salinity that represents a risk to the soil and agricultural crops and they are located in the northeast of the study area, to percentages that are allowed to use in some areas in the middle of the area due to their low salinity to some degree.

- There is a lack of residual sodium carbonate concentration values in all samples except for Sample 10 in the north of the area, which reaches 3.1 mEq/L, indicating that it is invalid for irrigation.
- The degree of the sodium adsorption rate concentration ranges between 6.4 and 163.5 mEq/L, i.e. between classifications of very high to medium risk. In fact, this is an evidence of the difference in validity for irrigation from one area to another, even though they may be valid for irrigation to some degree in some areas east and north of the area.

Table 11. Classification of Groundwater Quality according to Soluble Sodium Percentage, Residual Sodium Carbonate Concentrations, and Sodium Adsorption Rates

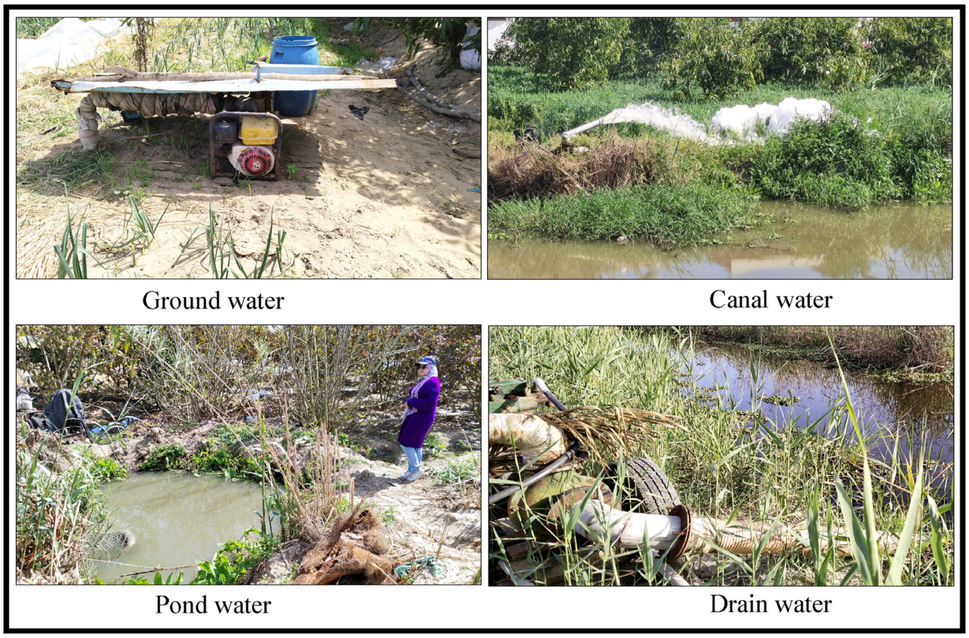
No.	SSP %	Degree of Validity	RSC mEq/L	Degree of Validity	SAR mEq/L	Degree of Risk	Degree of General Validity
7	53.4	Allowed to use	-	Nothing	6.6	Medium	Medium
10	93.2	Completely invalid	3.1	Often invalid for irrigation	39.2	Very high	Completely invalid
11	64.7	Invalid to some degree	-	Nothing	7.2	High	Invalid to some degree
12	72.5	Invalid to some degree	-	Nothing	15.8	Very high	Invalid
13	65.3	Invalid to some degree	-	Nothing	15.0	Very high	Invalid
14	59.9	Allowed to use	-	Nothing	6.4	Medium	Medium
17	71.6	Invalid to some degree	-	Nothing	163.5	Very high	Invalid

Source: It is based on Appendix 5.

6.11. Irrigation and Drainage

The lands located west of the main Gharbia drain were irrigated from the Tira Sea, which extends to Baltim, by means of subsidiary canals. In general, these canals did not have water reaching the northern parts of the study area. As for the lands located in the northern part of the areas of Baltim, Sheikh Mubarak, El-Shihabiya, El-Sahil El-Bahari, and all of the areas of El-Burj, El-Bana'in, and El-Sahil El-Qibli, most of them were sand dunes, and their cultivated areas depended on rainwater in winter and surface groundwater during the summer in 1962. As for the drainage condition during that period, all the lands of the Baltim area were considered deprived of main, subsidiary, and field drains. There is only the main Gharbia drain in the center, and the water level in it is very high, which caused water to leak into the neighboring lands. There was also the Burullus drain, which has not yet been established and the existing part of it is not cleansed. Accordingly, the lands of the study area in 1962 relied on underground drainage and drainage in the low-lying areas interspersed with them, which was the reason for the spread of ponds and swamps over large areas during that period.

However, satellite images and a field study in 2024 show the diversity of sources and methods of irrigation and drainage in the Baltim area (Figures 28 and 29). The construction of a network of main and open field drainage and irrigation channels has begun, represented in the following: El-Awja Drain, Burullus Drain, Mubarak Drain, El-Rub' Drain, Al-Rub' Drain, and West Burullus Drain, in addition to the main Gharbia drain, El-Shihabiya canal, and El-Awja to irrigate the agricultural lands located in the south, center, and west of the area. Despite this change, the field study reveals that there is a shortage in the amount of water needed for irrigation, particularly in the northeast of the area (north of El-Shihabiya village), which is a reason why farmers tend to use agricultural drainage water and water collected in low-lying (industrial) areas, resulting in the deterioration of agricultural lands and a decrease in their productive capacity in those areas.



Source: Field Study, 2024.

Figure 28. Sources of Irrigation Water in Baltim Area

Source: Field Study, 2024.

Figure 29. Types of Irrigation in Baltim Area

6.12. Types of Agricultural Crops and Their Productivity

The classification inventory of the lands in 1962, the reports of the Directorate of Agriculture in Kafr El-Sheikh in 2023, and the field study in 2024 reveal an increase in the area and diversity of agricultural crops in the Baltim area. The most important of these crops are summer vegetable crops (watermelon, tomatoes), the Nile vegetable crops (potatoes), and winter vegetable crops (tomatoes), in addition to some palm trees, figs, grapes, citrus fruits, zucchini, cucumbers, eggplant, peas, alfalfa, lettuce, cabbage, and carrots. As for field crops, the most important of them are wheat, barley, cotton, beans, corn, and sugar beets. The following is a study of the most important agricultural crops, particularly those in common between the years 1962 and 2023/2024:

- **1962:** The average productivity per acre of field crops reached 3.11 ardab/acre of wheat, 6.25 ardab/acre of barley, 2.45

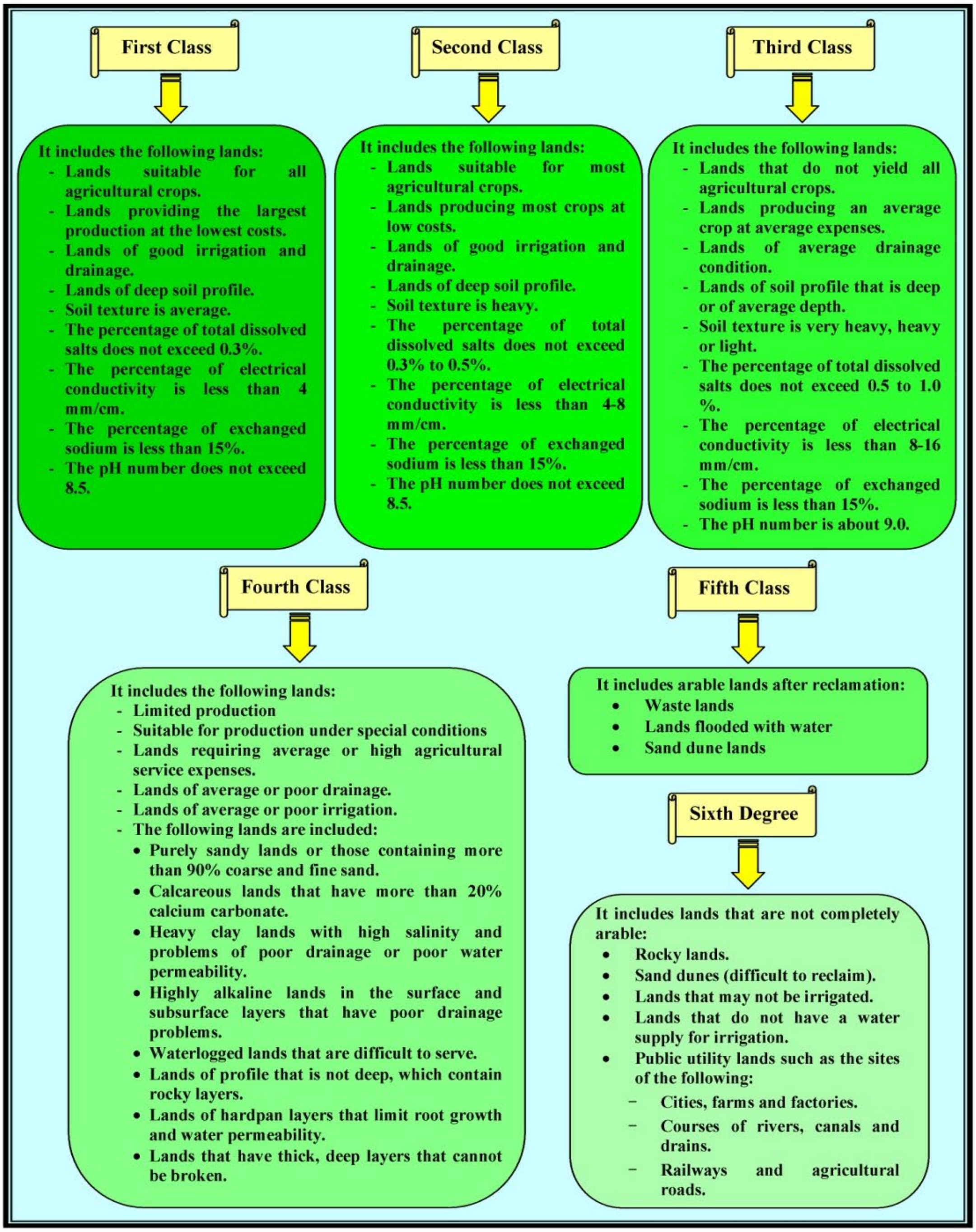
ardab/acre of beans, 3.08 quintals/acre of cotton, and 3.9 ardab/acre of summer maize, while the general average production per acre in the Republic for the same crops reached 6.92, 9.14, 3.16, 3.21, and 9.94 respectively (Ministry of Agriculture, 1962). This, in turn, indicates that the average productivity per acre of field crops in the study area were much lower than the general average production per acre in Egypt during that period. In fact, this is due to the lack of an adequate network of irrigation and drainage channels, high groundwater levels, and the percentage of salts in the soil, which reduced the agricultural production capacity.

- **2023/2024**(1)**:** The productivity per acre of all crops increases significantly during the comparison period, as the average production per acre of wheat reach 17 ardab/acre, the dry bean crop 7.5 ardab/acre, the summer maize 25 ardab/acre, and the cotton crop 4.4 quintals/acre. However, this increase is met by an increase in the average productivity per acre for agricultural crops in Egypt, as it reach 19 ardab/acre, 10 ardab/acre, 30 ardab/acre, and 10 quintals/acre respectively for the previous crops. According to the reports of the Directorate of Agriculture in Kafr El-Sheikh and the 2024 field study, it is found that many types of crops are widespread though they did not exist before (in 1962), or represented very limited areas of the study area, such as the following: rice crop with an average productivity of 3.4 tons/acre, alfalfa 20 tons/acre, sugar beets 2.4 tons/acre, tomatoes 13 tons/acre in winter and 17 tons/acre in summer, potato crop 11 tons/acre in winter and 13 tons/acre in summer, eggplant 10 tons/acre in winter and 11.5 tons/acre in summer, cucumbers 10 tons/acre in winter and 13 tons/acre in summer, peas 5 tons/acre, zucchini 7 tons/acre in winter, cabbage 13 tons/acre in the area, carrot 13 tons/acre, watermelon 18 tons/acre, and watermelon pulp 15 tons/acre. The increase, whether in diversity or in average productivity in the area, is due to the extensive agricultural reclamation operations, as the area includes large areas of waste land that could be reclaimed, in addition to extending a network of irrigation and drainage channels, paying attention to adding organic fertilizers, and the fact that the sandy soil in the area is valid for growing all types of vegetables. The field study and the questioning of many farmers also reveal the spread of many agricultural lands, particularly south of the village of Baltim, where the average productivity per acre is higher than the general average in Egypt, such as some field crops and vegetables. As for the rest of the agricultural lands, they still face several problems, the most important of which are the following: high levels of salinity and alkalinity and poor drainage conditions, particularly in lands located next to some of the main canals and drains, which causes water to leak into them, as is the case in the main Gharbia drain. This is in addition to the growth of weeds in the canals and drains, lack of cleansing, and urban sprawl in its various forms.

7. Building a Digital Model to Evaluate the Productive Capacity of the Baltim Area Soil

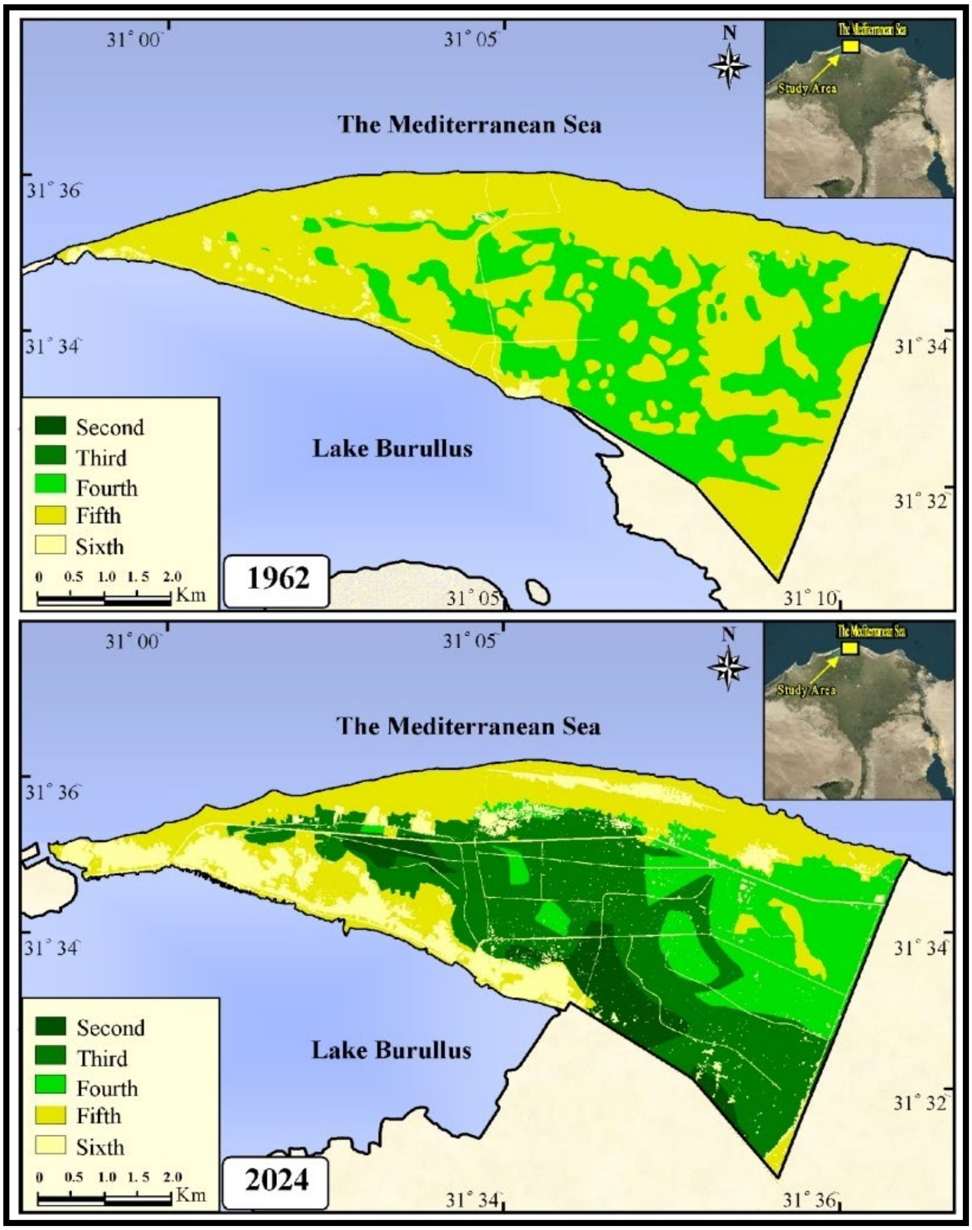
The productive capacity of the soil was evaluated based on the previous inputs, which include the hydropedological and hydrogeological potential, the productive condition of lands, their suitability for producing different agricultural crops (field, fruits and vegetables), and the costs of production and land service. The results of model application (Figures 30 and 31, and Table 12) indicate that the Baltim area falls in the following classes:

(1) The average productivity of the rice crop was 4.6 tons/acre, the wheat crop was 20.5 ardab/acre, and the pea crop was 6.5 tons/acre (Field Study, 2024), while the average productivity of those crops in the Republic reached 4.5 tons/acre and 19 ardab/acre, and 6 tons/acre, respectively (Ministry of Agriculture and Land Reclamation, Separate and Unpublished Reports, 2023).



Source: It is based on the classification inventory and land division of Baltim center, Ministry of Agriculture, the General Land Administration, Land Survey and Improvement Control and Land Survey Department, 1962.

Figure 30. Classification of the Productive Capacity of Soil according to the System followed in Dividing the Egyptian Lands



Source: It is based on the inputs of the productive capacity model.

Figure 31. The Productive Capacity of Soil in Baltim Area in 1962 and 2024

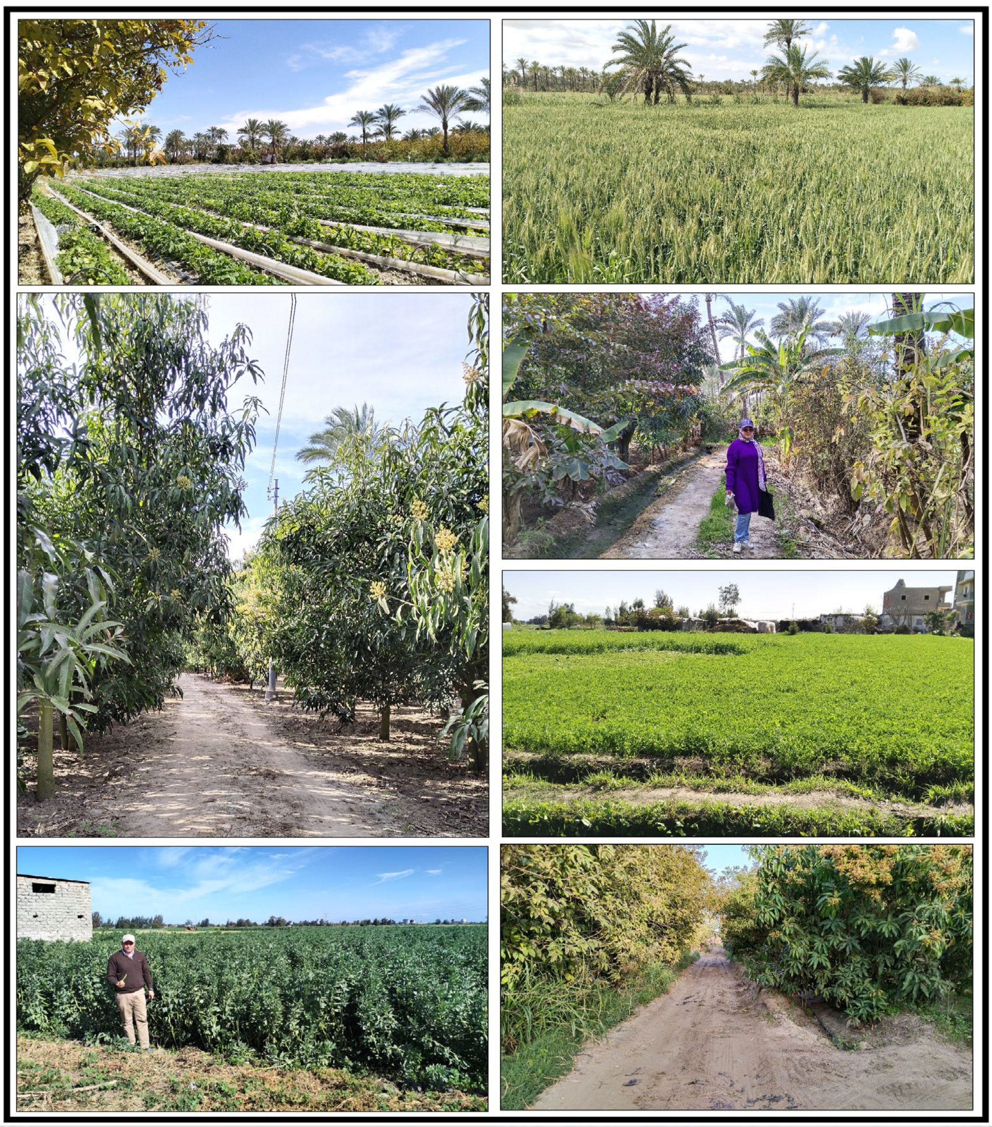
Table 12. Classification of Soil according to the Productive Capacity in Baltim Area in 1962 and 2024

Classification	1962	2024
Second	–	7.19
Third	–	33.67
Fourth	31.87	21.42
Fifth	65.00	21.15
Sixth	3.13	16.57
Total	100.00	100.00

Source: It is based on Figure 31.

The analysis of Figures 30 and 31 and Table 12 indicates the following:

- **Second-class Lands:** These are cultivated lands of good production, whose production exceeds the general average for the production of various crops. Their agricultural service costs are normal, irrigation is available in sufficient quantities, and drainage condition is considered good. In addition, their soil salinity is normal, less than 8.0 mm/cm; the degree of alkalinity is often very low, less than 8.5; the salinity of groundwater is very low; and there is a groundwater level at a depth greater than 150 cm from the soil surface. Above all, this class of soil was not monitored in 1962, while its area reached 7.19% of the total study area in 2024. The lands of this class are spread south of the village of Baltim and north of the village of Al-Rub (Figure 32).



Source: Field Study, 2024.

Figure 32. Second-class and Third-class Lands in Baltim Area

- **Third-class Lands:** These are cultivated lands of average production, and the productivity of an acre of crops is within the general average of an acre's production in the Republic. However, they do not yield all agricultural crops. These lands often have an average percentage of salts, ranging between 8 and 16 mm/cm, and the majority of lands of this class are devoid of alkalinity to some extent. Above all, this class did not exist in 1962, while it appeared in 2024 with an area reaching 33.67% of the total study area. The majority of these lands are spread in areas adjacent to the second class, particularly the southeast of El-Shihabiya, and the vast majority is from the village of Baltim, the southern areas of the villages of Sheikh Mubarak and El-Sahil El-Bahari, and the north of the villages of Al-Rub' and El-Sahil El-Qibli (Figure 32). The reason for the existence of the second and third classes in 2024 is due to solving many problems, the most important of which are the following: reducing the groundwater level and the degree of salinity, due to the high level of that land surface, in addition to establishing an agricultural drainage network on fourth-class lands, which helped improve some of their physical and chemical characteristics and increase their productivity to fall within a better class, which is the third class and the second class.
- **Fourth-class Lands:** They include the remaining part of agricultural lands in the Baltim area. They are considered poorly productive or newly reclaimed, and their production is much lower than the general average of an acre's production in the Republic. The weakness of the lands is due to the fact that they are sandy, most of them are highly or extremely saline, they are alkaline, and there is a groundwater level at a depth of 80 cm from the soil surface or less than this depth. Besides, these lands do not receive sufficient irrigation water to wash these high salts, and they are deprived of the main and field drainage necessary to dispose of the washing water. The area of these lands reached 31.87% in 1962, and the majority of these lands were located in the villages of Baltim, El-Shihabiya, Al-Rub', and El-Sahil El-Qibli, in addition to small areas in the high sand dunes in the villages of Sheikh Mubarak, El-Sahil El-Bahari, El-Bana'in, and El-Burj. As for the year 2024, its area decreased to 21.42%, and this percentage does not indicate a decrease in its area. On the contrary, large areas of the Baltim area have been reclaimed, due primarily to the change in the terrain characteristics. The ponds and swamps that were widespread in 1947 were reclaimed, after backfilling them and raising their level; and parts of the sand dunes were reclaimed. Accordingly, the area of fourth-class lands increased significantly during the comparison period. However, with the continued improvement of soil characteristics during this period, many parts of them turned to the better to be included in the second-class and third-class lands. Above all, fourth-class lands are spread to the north and northeast of the village of El-Shihabiya, and they cover small scattered areas in the rest of the villages (Figure 33).

Source: Field Study, 2024.

Figure 33. Fourth-class Lands in Baltim Area

- **Fifth-class Lands:** This class includes waste lands, lands flooded with water, and sand dunes suitable for agricultural reclamation, and covers large areas of the Baltim area. It is noted that the majority of these lands are extremely saline and have a high groundwater level at a depth of less than 80 cm, particularly in the lands located on the eastern side. This class covered the vast majority of the Baltim are in 1962, reaching 65.0%, while its area decreased significantly in 2024, covering 21.15% of the total study area. The reason for this decrease in area is due to the conversion of large areas of it to fourth-class lands owing to the great interest of the state in reclaiming many waste areas as well as ponds and swamps, and converting them almost completely into agricultural land, in addition to reclaiming many areas of sand dunes, as previously mentioned. The lands of this class currently represent salinas and swamps that are flooded with water in the winter and dry up in the summer. Other lands are also located in the area of sand dunes, particularly the northern ones, and such lands need to be leveled or treated using sprinkler irrigation when cultivating them. The majority of these lands are spread north of the villages of Baltim and El-Shihabiya, and they cover the vast majority of the villages of Sheikh Mubarak, El-Sahil El-Bahari, and El-Bana'in (Figure 34).

- **Sixth-class Lands:** They include lands that do not yield agricultural production, and they are the ones on which public utilities are built, such as facilities, village buildings, farms, canals, drains, and main roads. The area of lands of this class is considered small in comparison to the area in 1962, as it represented only 3.13%, due to the lack of facilities, public utilities, and irrigation and drainage projects. However, their area increased in 2024 to reach 16.57% of the total study area, with the extensive human intervention in the Baltim area, particularly urban development and the associated construction of roads, and agricultural development as well as the associated construction of canals and drains.

Source: Field Study, 2024.

Figure 34. Fifth-class Lands in Baltim Area

8. Conclusion

8.1. Results

- The Baltim area is subjected to extensive human interventions, the most important of which is the process of agricultural reclamation, which is imposed in the presence of a change in the terrain characteristics, particularly the levels and degree of slope of the land's surface. This has led to the removal and change of some physical phenomena such as ponds, sabkhas, and sand dunes.
- The predominant deposits in the Baltim area are sand dune deposits, which are located in areas adjacent to the Mediterranean Sea and Lake Burullus, followed by Nile silt deposits.
- The decrease in temperature and evaporation rates during the winter causes the spread of ponds and swamps in low-lying areas, whether resulting from rainfall or through water leakage from neighboring high-level lands. When the temperature rises during the summer months and evaporation rates increase, salt deposits accumulate and their percentage in the surface layer of the soil increases. With the dominance of northwest and north winds, and the presence of sand dunes that are a source of fine, mobile sand carried by the wind, they throw them on the agricultural areas adjacent to them. This, in turn, causes a change in their mechanical characteristics and a decrease in their agricultural quality.
- The dominant feature of the surface of the Baltim area in 1947 is that of levels ranging between 0 and 1 m, exceeding 57%, which has a negative impact on the productive capacity of the soil due to the high degree of salt concentration in them because of their proximity to the groundwater surface level. However, the terrain characteristics changed in 2020: the first category, which is less than zero, completely disappeared, and there was

a very significant decrease in the second category, which ranges between 0 and 1 m. In essence, this is a reflection of human intervention through agricultural reclamation, which did not succeed except in one case: raising the levels of the surface of low-lying lands by backfilling primarily.

- The convex (low-lying) areas, particularly those located south of the sand dunes north and northeast of the study area, were exploited in digging many artificial ponds to collect water leaking from irrigation water in the concave areas for reuse in irrigation.
- Deposition and backfilling are predominant in the study area, as the areas that are backfilled with a height ranging between 2 and 3 meters occupy the largest area, covering 30.05% of the total area of the Baltim area, while the total volume of backfilling reach 48.98 million m^3, with a percentage of 17.75%.
- The areas that are backfilled to a height of less than 2 meters occupy 18.22% in terms of area, and are spread throughout all the villages. With the large area, a large total volume of backfill results, with a percentage of 51.69%.
- The areas of erosion and removal are spread over very limited areas, as their area does not exceed 5.0% of the total area of the Baltim area, while the volume reaches 4.67 million m^3, with a percentage of 1.69%. They cover the sand dune areas located northwest of the study area.
- Changes in the terrain characteristics are reflected in the physical and chemical characteristics of the soil, particularly its distance from groundwater, the decrease in salinity of the soil and groundwater, and other factors affecting the productive capacity of the soil. This has caused the area of agricultural land to increase from 45.75% in 1947 to 62.73% in 2024, along with improving the characteristics of old lands and increasing their average productivity per acre.
- Due to the change in the physical and chemical characteristics of the soil and other factors, the productive capacity of the soil in the Baltim area changed, and the fourth-class lands improved to include part of them among the second-class and third-class lands, which were not monitored in 1962. In addition, the area of the fourth-class to the second-class lands increased to double in 2024, reaching 62.28% of the total study area. One of the most important reasons for this increase is the change in terrain characteristics, as the ponds and swamps that were widespread in 1947 were reclaimed after backfilling them and increasing their levels.

8.2. Recommendations

- Backfilling the low-lying areas that turn into ponds and swamps during the winter, so that they become at an appropriate height of groundwater (1.5 meters or more), by using sand available in the northern area, mixing it with organic fertilizers, or bringing clay or silt soil from nearby areas, so as to improve its physical and chemical characteristics to increase its fertility and production capacity.
- Leveling the northern sand dunes or using modern irrigation methods, whether drip or spray, when planting them, with attention paid to improving the palm varieties currently grown.
- Delivering fresh irrigation water to all lands of the Baltim area, particularly the northern and northeastern areas, by creating sufficient deep canals, and taking care of cleansing and maintaining the existing canals, as well as expanding their profile until the irrigation water reaches its limits.
- Establishing a sufficient network of public, subsidiary and field drainage projects, so that washing water of excess salts into the soil can be disposed of and the raised groundwater level comes to a depth greater than 150 cm from the surface.
- Adding agricultural gypsum to lands that have shown alkalinity, as well as adding organic fertilizers in sufficient quantities to improve the physical and chemical characteristics of the soil.

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Appendix 1. Mechanical Characteristics of Soil in Baltim Area in 2024

No.	Clay	Silt	Fine Sand	Coarse Sand	No.	Clay	Silt	Fine Sand	Coarse Sand
1	8.59	2.03	16.55	72.83	10	8.64	1.75	10.71	78.90
2	12.41	1.99	15.78	69.82	11	14.65	8.86	27.82	48.67
3	12.58	0.00	20.71	66.71	12	10.48	2.29	28.14	59.09
4	13.18	0.18	17.57	69.07	13	8.64	0.58	19.30	71.48
5	10.19	3.70	18.57	67.54	14	17.22	3.72	10.83	68.23
6	9.85	0.66	15.02	74.47	15	20.33	3.91	14.17	61.59
7	15.60	1.00	14.78	68.62	16	34.40	11.24	15.14	39.22
8	8.45	0.98	15.25	75.32	17	9.68	2.23	17.17	70.92
9	9.21	0.23	12.68	77.88	-	-	-	-	-

Source: The analysis is conducted at the Laboratory of the Faculty of Agriculture, Mansoura University.

Appendix 2. Some Physical and Chemical Characteristics of Soil in Baltim Area in 2024

No.	Salinity (dsm^{-1})	PH	Cations (mEq/L)				Anions (mEq/L)				Phosphorus Mg/kg	Azote Mg/kg	Organic matter %	Saturation capacity %
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Co_3^{2-}	Hco_3^-	Cl^-	So_4^{2-}				
1	1.93	8.41	1.57	0.29	4.02	1.55	0.00	1.72	0.99	0.00	9.20	8.54	5.95	26.52
3	3.65	8.21	2.68	1.18	2.55	2.50	0.00	1.65	2.38	0.62	13.35	10.33	1.04	38.21
5	4.22	8.04	3.60	0.07	2.29	1.72	0.00	1.34	4.36	0.00	6.31	9.20	0.73	36.75
6	2.57	8.16	2.17	0.37	2.29	1.64	0.00	1.30	4.95	0.00	11.69	8.00	2.02	28.44
7	4.80	7.95	2.40	0.13	2.98	1.03	0.00	1.00	2.78	1.10	10.35	23.64	1.44	31.07
9	3.15	7.88	2.68	0.07	3.50	0.34	0.00	1.23	0.99	0.94	13.28	7.19	2.20	44.59
10	6.30	8.67	4.21	1.45	2.47	1.47	0.00	1.53	2.97	2.79	3.53	8.83	0.40	28.59
11	25.1	8.32	313.57	1.61	7.53	7.93	0.00	1.30	100.86	12.94	1.35	7.72	1.60	48.09
12	2.78	8.47	2.35	0.69	2.12	1.47	0.00	1.23	0.59	0.96	5.96	12.00	1.2	32.46
13	5.88	8.46	4.53	0.18	2.47	0.86	0.00	1.03	2.38	3.46	4.89	10.57	0.51	27.56
14	4.50	8.26	2.68	0.40	2.29	1.47	0.00	1.49	2.38	1.62	4.13	11.33	1.22	45.04
15	12.85	8.11	70.52	0.91	5.19	3.71	0.00	0.96	83.95	7.94	5.50	12.58	1.96	45.14
16	10.63	8.45	48.86	0.27	2.29	1.81	0.00	1.92	44.34	4.37	4.43	11.00	2.91	63.85
17	36.16	8.33	421.19	9.68	3.02	1.55	0.00	3.07	292.2	16.33	1.81	12.73	3.35	27.50

Source: The analysis is conducted at the Laboratory of the Faculty of Agriculture, Mansoura University.

Appendix 3. Chemical Characteristics of Water in Baltim Area in 2024

Type	No.	PH	Salinity ppm	Cations (mEq/L)				Anions (mEq/L)			
				Na^+	K^+	Ca^{2+}	Mg^{2+}	Co_3^{2-}	Hco_3^-	Cl^-	So_4^{2-}
Groundwater	7	7.61	2919.0	19.3	0.5	4.6	12.7	0.0	4.5	7.3	4.5
	10	8.12	5014.4	58.1	2.2	1.9	2.5	0.5	7.0	26.6	12.7
	11	7.57	3388.8	14.8	0.8	3.3	5.2	0.0	4.8	12.4	4.4
	12	7.76	5475.2	48.8	1.4	5.3	13.7	0.0	6.2	40.47	7.5
	13	7.68	6441.6	61.6	1.9	9.8	23.9	1.0	12.2	47.3	8.6
	14	7.87	5475.8	14.4	0.7	4.1	6.0	0.4	4.9	9.67	6.11
	17	7.86	50352.2	5310.2	10.9	1300.1	810.2	0.7	490.5	490.2	2600.8
Pond	18	7.76	21312.2	1116.1	34.2	68.9	348.2	0.7	15.8	147.0	1404.3

Source: The analysis is conducted at the Laboratory of Faculty of Agriculture, Mansoura University.

Appendix 4. Classification of Water according to its Validity for Irrigation Based on Its Degree of Salinity in Egypt

Total Dissolved Salts (ppm)	Degree of Electric Conductivity (mmho/cm)	Degree of Risk	Total Dissolved Salts (ppm)	Degree of Electric Conductivity (mmho/cm)	Degree of Risk
< 500	< 0.75	Very low	2000-3200	3.0-5.0	High
500-1100	0.75-1.75	Low	≥ 3200	≥ 5	Very high
1100-2000	1.75-3.0	Medium			

Source: Suliman (1983).

Appendix 5. Classification of Irrigation Water Quality according to the Concentration of Sodium

SSP % (2)	Degree of Risk	RSC mEq/L(3)	Degree of Risk	SAR mEq/L(4)	Degree of Risk
< 20	Excellent	< 1.25	Low	< 4	Low
20-40	Good	1.25-2.5	Medium	4-7	Medium
40-60	Allowed to use	≥ 2.5	Extreme	7-13	High
60-80	Invalid to some degree	—	—	≥ 13	Very high
≥ 80	Completely invalid	—	—	—	—

Source: El-Tahlawi, et al. (2014), Salman and Elnazer (2015), and Suliman (1983).

(2) SSP(Soluble Sodium Percentage) =[Na+K(Meg/L)/Ca+Mg+K+Na(Mg/L)]×100 (Reddy, 2013)
(3) RSC(Residual Sodium Carbonate) = (Co_3^{--}+ Hco_3^{--}) – (Ca^{++} + Mg^{++}) (Ismail et al., 2015)
(4) SAR(Sodium Adsorption Rate) = $Na/[(Ca+Mg)/2]^{1/2}$ (El-Tahlawi et al., 2014)