Geomorphological Assessment of Land Resources in the Wadi Al-Assiuti Alluvial Fan, Egypt, using Geospatial Techniques

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ABSTRACT

The study highlighted the significance of geomorphological assessment in evaluating land resources in dry alluvial fan environments and its crucial role in agricultural development. This is particularly relevant in addressing food security challenges faced by many countries due to rapid population growth and limited agricultural resources. By integrating multiple analytical techniques, the study provided a comprehensive approach for the geomorphological assessment of the land resources of the Wadi Al-Assiuti alluvial fan for agricultural purposes.The methodologies employed included the ALES model, geographic information systems (GIS), and remote sensing software, all of which were instrumental in processing and analyzing spatial data to determine optimal land use. A key focus of the study was evaluating the land's productive capacity and its suitability for 14 different crops, crops were categorized into three suitability levels. Very suitable crops included wheat, tomatoes, and cotton,. Moderately suitable crops, such as beans, grapes, and corn, required some soil modifications to achieve optimal yields. Meanwhile, poorly suitable crops, including bananas and sugarcane, faced significant challenges due to factors like high salinity, To visually represent these findings, the study developed maps illustrating the geographical distribution of each crop, providing a clear spatial perspective on agricultural potential. The results underscore promising opportunities for agricultural reclamation in the study area, with the potential to expand cultivated land for a diverse range of crops, including grains, vegetables, fruits, and industrial crops vital for various industries, the study offers valuable insights for policymakers, agricultural planners, supporting informed decision-making in agricultural expansion and sustainable land-use planning, optimize resource allocation, and contribute to long-term sustainable development in the area.

Keywords: Geomorphological assessment - Land resources - Alluvial fans - Land suitability - ALES model – Wadi Al-Assiuti.

مستخلص البحث:

التقييم الجيوموفولوجي للموارد الأرضية بالمروحة الفيضية لوادي الأسيوطي، مصر، باستخدام التقنيات الجيومكانية

سلطت الدراسة الضوء على أهمية التقييم الجيومورفولوجي في دراسة الموارد الأرضية في بيئات المراوح الفيضية الجافة ودوره الأساسي في تطوير الزراعة، خاصة في ظل التحديات المتعلقة بالأمن الغذائي التي تواجهها العديد من الدول نتيجة النمو السكاني السريع وندرة الموارد الزراعية، ومن خلال دمج تقنيات تحليلية متعددة، قدمت الدراسة نهجًا شاملاً للتقييم الجيومورفولوجى للموارد الأرضية بالمروحة الفيضية لوادى الأسيوطي بهدف الزراعة. وشملت المنهجيات المستخدمة "نموذج ALES

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ونظم المعلومات الجغرافية (GIS) وبرامج الاستشعار من البُعد، حيث لعبت هذه الأدوات دورًا أساسيًا في معالجة وتحليل البيانات المكانية لتحديد أفضل استخدام للأراضي. وركزت الدراسة بشكل أساسي على تقييم القدرة الإنتاجية للأراضي ومدى ملاءمتها لـ 14 محصولًا زراعيًا مختلفًا، وتم تصنيف المحاصيل إلى ثلاث فئات من حيث الملاءمة، المحاصيل شديدة الملاءمة شملت القمح والطماطم والقطن، أما المحاصيل متوسطة الملاءمة، مثل الفول والعنب والذرة، فتتطلب بعض التعديلات في التربة لتحقيق إنتاجية مثلى، في حين أن المحاصيل ضعيفة الملاءمة، مثل الموز وقصب السكر، واجهت تحديات كبيرة بسبب عوامل مثل الملوحة العالية، ولتمثيل هذه النتائج بشكل مرئي، تم إعداد خرائط توضح التوزيع الجغرافي لكل محصول، مما يوفر منظورًا مكانيًا واضحًا حول الإمكانات الزراعية في المنطقة ، وتؤكد النتائج على الفرص الواعدة لاستصلاح الأراضي الزراعية في منطقة الدراسة، مع إمكانية توسيع الرقعة الزراعية لإنتاج مجموعة متنوعة من المحاصيل، بما في ذلك الحبوب والخضروات والفواكه، بالإضافة إلى المحاصيل الصناعية التي تلعب دورًا مهمًا في العديد من الصناعات، وتوفر الدراسة رؤى قيمة لصناع القرار والمخططين الزراعيين، لدعم اتخاذ القرارات المستنيرة في توسيع الرقعة الزراعية والتخطيط المستدام لاستخدام الأراضي وتحسين تخصيص الموارد، والمساهمة في التنمية المستدامة طويلة الأجل في المنطقة.

الكلمات المفتاحية: التقييم الجيومورفولوجى– الموارد الأرضية– المراوح الفيضية– ملاءمة الأرض للزراعة– نموذج ALES – الوادي الأسيوطي.

Introduction

The study area is part of the Wadi Al-Assiuti Basin, which is one of the important basins east of the Nile (Abdel Aziz., 2001,P.12), The geomorphological assessment of land resources in flood-prone areas is essential for identifying suitable agricultural lands and optimizing crop selection, This evaluation not only aids in determining the most appropriate crops for cultivation but also provides valuable insights for effective land management and sustainable agricultural planning, Agricultural land use planning is based on the capacity (Bilas, G., et al.,2022,P4).The study of soil resources is of great importance in food production (Stoyan et al., 2000; Elkateb et al., 2003). The soil is an important economic resource, (Deshmukh، N.D. 2016) as it is considered one of the most important basic elements in agricultural production, especially with the increasing population and pressure on ground resources. Accordingly, FAO (1985) considered land evaluation as one of the important technologies to determine the soil capabilities for certain cultivations or using them for certain purposes, The study used the merge between dimension and GIS, as multi-spectrum satellite images reflecting great analytical potential. GISs have effective tools for determining the land's capacity and suitability for agriculture and natural resource management (AbdelRahman et al., 2016). Moreover, GIS and its integrated functional nature with remote sensing facilitates the databases of establishing and developing land resources.

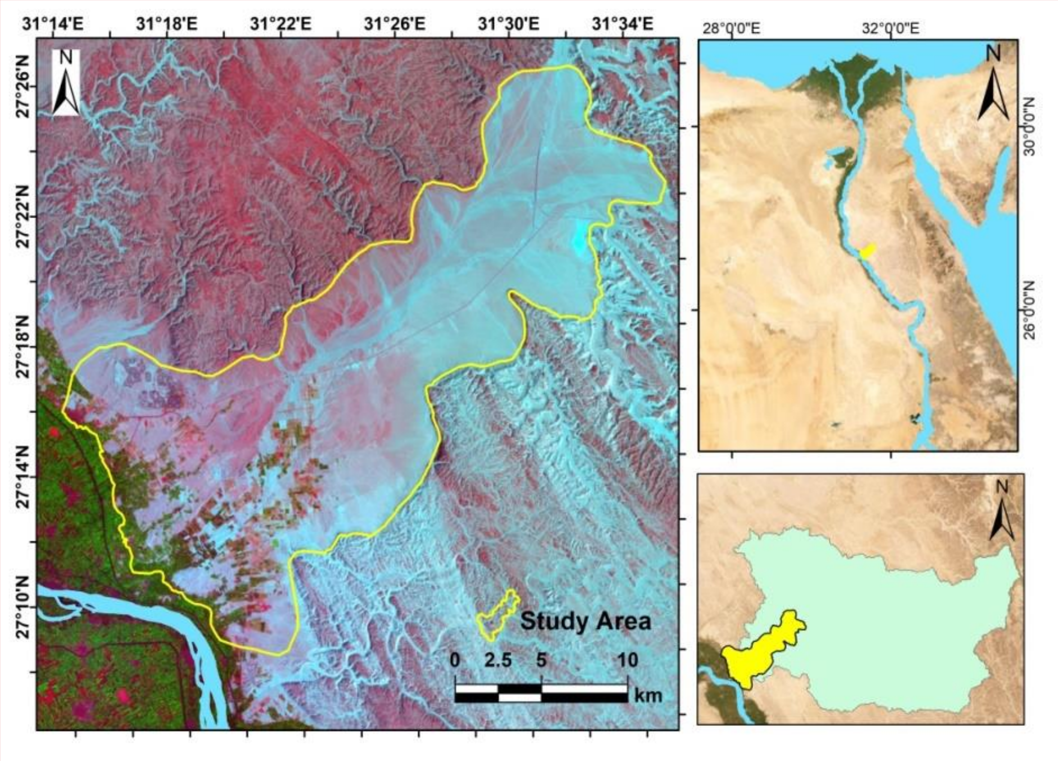
The present study aims to develop a comprehensive database of land resources within the study area, providing a valuable tool for identifying optimal sites for sustainable development projects. This database not only ensures efficient data coordination and maximization of resource value but also facilitates continuous updates, enhances decision-making processes, and supports early warning systems.

A key objective of this research is to characterize the land and water resources of the alluvial fan of Wadi Al-Assiuti. This includes evaluating soil capability and suitability to determine the best land-use practices, conducting a thorough inventory of available land and water resources, and integrating these findings into a decision support system for land evaluation. By doing so, the study aims to propose suitable crops for cultivation, aligning agricultural practices with environmental sustainability and resource availability.

To achieve these objectives, the study employs the Analytical Inductive Method, which emphasizes an in-depth exploration of complex phenomena through systematic data analysis. This method enables the identification of relationships and patterns within the collected data, ensuring a comprehensive and scientifically grounded assessment. The gathered data undergoes rigorous processing to derive meaningful insights that contribute to effective land management strategies.

Location:

Studying the location of any region and its borders has a spatial meaning because it is an essential element in drawing the characteristics of that administrative region and highlighting its geographical characteristics. The study area is located between 27° 05' and 27° 30' N and 31° 00' and 31° 35' E with a total area of about 39035 hectares. The study area includes the desert back of Assiut districts, Assiut governorate, Egypt (Fig. 1).

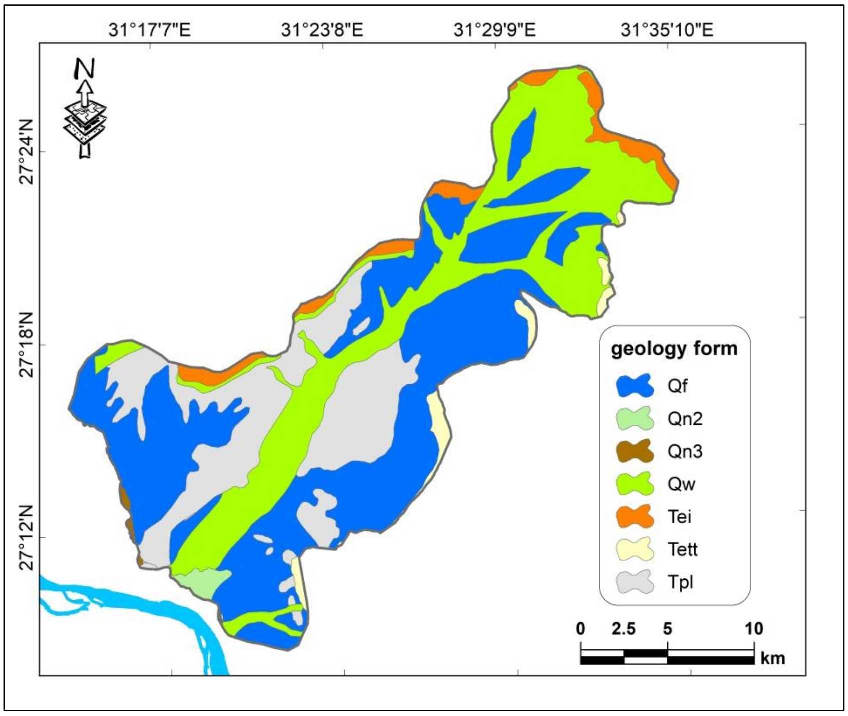


- **Source: after land sat 8 OLI using gis**

Figure (1): Location map for the study area

Geological Aspects

Through Figure (2) and previous studies (Said, 1962; Ashmawy and Nassin, 1999), the following results have been obtained. The geological formations of the study area date back to the Eocene and Pliocene eras of the Tertiary period and the Pleistocene and Holocene eras of the Quaternary period, and all of them are sedimentary rocks. The geology of the study area consists of the following formations: Fanglomerate (Qf), Minia Formation (Tei), Neonile deposits (Qn3), Pliocene deposits, undifferentiated sediments (Tpl), Prenile deposits (Qn2), Thebes Group\ Serai (Thebes) Formation (Tett), and Wadi Deposits (Qw). The Eocene rocks represent the oldest geological formations in the study area. The Serai Formation is the oldest geological formation in the area and dates back to the early Eocene. It is a limestone rock interspersed with some flint formations. The Minia Formation represents the middle Eocene and appears as a pure white limestone that may tend towards brown or gray, While the Pliocene formations are represented by the Tpl Formation, which consists of deposits of sand and clay minerals, this formation is considered rich in clay minerals. As for the Quaternary formations, they are surface deposits consisting of gravel, sand, and pebbles. The Pleistocene includes the Qf and Qn2 deposits, and the Holocene includes the Qw valley-bottom deposits.



Source: Geological map of Egypt, CONOCO, 1987, scale 1:500,000.

Figure (2): Geological formations of the study area .

Climate Aspects

Climate plays a crucial role in shaping the surface characteristics of the study area through its dynamic interaction with geological formations. Various climatic elements, such as temperature, precipitation, wind, and humidity, influence weathering, erosion, and sediment deposition processes. These interactions contribute to the development of distinctive landforms and surface phenomena, ultimately affecting the landscape's evolution over time. Climate is also linked to agricultural and urban expansions and all development patterns in the study area.

The following is a study of the important climatic elements in the study area. Temperature is one of the most important climatic elements affecting the study area. From Table (1), it is clear that the maximum temperatures are characterized by high temperatures, ranging between 48.2 Celsius degrees for June and 32.2 Celsius degrees for January. The temperature range for the maximum temperature reaches 16 Celsius degrees. This is due to the region being located in the desert zone. We also note the average temperatures in the winter, with the lowest minimum temperature of 0.3 Celsius degrees recorded in February, and the highest maximum temperature of 17.4 recorded in August, with the minimum temperature reaching 17.1 Celsius degrees.

Table (1): Maximum and minimum temperature in the study area during the period 1984 to 2020

Month	**Temperature**	
	Max	**Min**
December	35.4	1.6
January	32.2	0.4
February	36.2	0.3
March	41.0	1.8
April	43.3	6.9
May	48.0	10.3
June	48.2	14.4
July	46.6	18.0
August	44.8	17.4
September	43.0	15.6
October	43.6	8.6
November	39.0	3.0

Source: Egyptian Meteorological Authority.

Rain also is an important climatic element that has a mechanical and chemical impact on the region. From Table (2), it is clear that summer is the driest season of the year, and it is also clear that there is little rain falling in the study area during the current drought period, and the highest average was recorded in February of 0.5 mm/year, followed by November with an average of 1.2 mm/year. The region is characterized by drought and scarcity of rain, except for the occurrence of some rainstorms at distant intervals. A rainstorm was recorded on November 2, 1994, with an amount of 37 mm.

Table(2): Average monthly rainfall (mm/day) during the period of 1984 to 2020			
Month	**rain**	**Month**	**rain**
January	0.1	July	0
February	0.5	August	0
March	effect	September	0
April	0.2	October	effect
May	effect	November	1.2
June	0	December	0.1
Total	2.1		
Average	0.2		

Source: Egyptian Meteorological Authority

Materials and Methodology

The current study used multiple techniques in processing and analyzing spatial data such as determining soil capability and land suitability classes using the ALES model. Many land classification systems have been developed in various countries of the world, and they are relative classifications developed to solve the problems of land use planning. Previous land evaluation systems classified lands in a specific order to identify the best uses of the land in general or in the form of areas for specific purposes, such as agriculture, forests, pastures, and urban areas. In the 1980s, SYS proposed a method in which land suitability classes were presented based on the number and intensity of determinants of land characteristics, and properties. This worked on developing a practical computational method that allows for the evaluation of land characteristics and land quality to find the land coefficient and determine land suitability classes. This method was adopted by FAO to apply the agro-environmental evaluation to evaluate land. The ALES model was used to predict soil suitability for some common crops cultivated in the study area (Table 4, Figs. 5, 6, 7). It is a system that is used to assess agricultural land in arid and semi-arid regions (Abd El-Kawy et al., 2010; Ismail et al., 2012) to learn about the ability and suitability of soil for certain crops. In this system, the properties of physical and chemical soil and fertility are combined in addition to the quality of irrigation water, climatic conditions, and surface properties. Through this, the soil capacity is also identified as well as its classification into the classes of suitability for some important crops.

The following is the presentation of the outputs in maps representing the geographical distribution of each crop that corresponds to certain properties of the soil, climate, water, and surface in the study area. The spatial distribution of the studied soil was prepared using the Kriging tool within the GIS program tools. The SYS classification is based on 9 criteria used to classify lands according to their productive capacity. A copy of each criterion is matched with the spatial determinants, and then the value of each criterion is multiplied. After obtaining the result, it is matched with the soil classification criterion based on productive capacity. These suitability criteria for agricultural production are: S1 class for very suitable, S2 for suitable, S3 for medium suitable, S4 for little suitable, and finally N for unsuitable class. The study also used GIS to process spatial data, produce accurate information, model soil maps, and interpret the variation in its physical and chemical properties at the spatial and temporal levels. More details are given in the following paragraphs.

Data collection and processing:

The necessary data and information to conduct the study were obtained from many sources represented by the Earth Explorer (earthexplorer.usgs.gov) website for NASA to obtain the images of the modern European satellite Sentinel-2 with a spatial resolution of 10 m. x 10 m. The Digital Elevation Model (DEM) was obtained from the radar image analysis from the Shuttle Topography Mission (SRTM) mission with a spatial accuracy of 30 m. x 30 m.

Analysis of satellite images:

Images of the European industrial satellite were obtained by Sentinel-2 that covered the study area on 8/28/2023, knowing that these images are registered in place according to the Universal Transverse Mercator (UTM) of Zone N36. This was followed by a clip cut on the part that represents the study area. The subset of the study area process cuts out (clips) the preferred study area from the image scene into a smaller more manageable file. An unsupervised classification routine (Categorize) was used to create clusters of pixels with similar spectral characteristics to recognize the main classes. Twelve spectral classes were created using bands 3, 4, and 8 to be an input to the module.

Building up Digital Spatial Database:

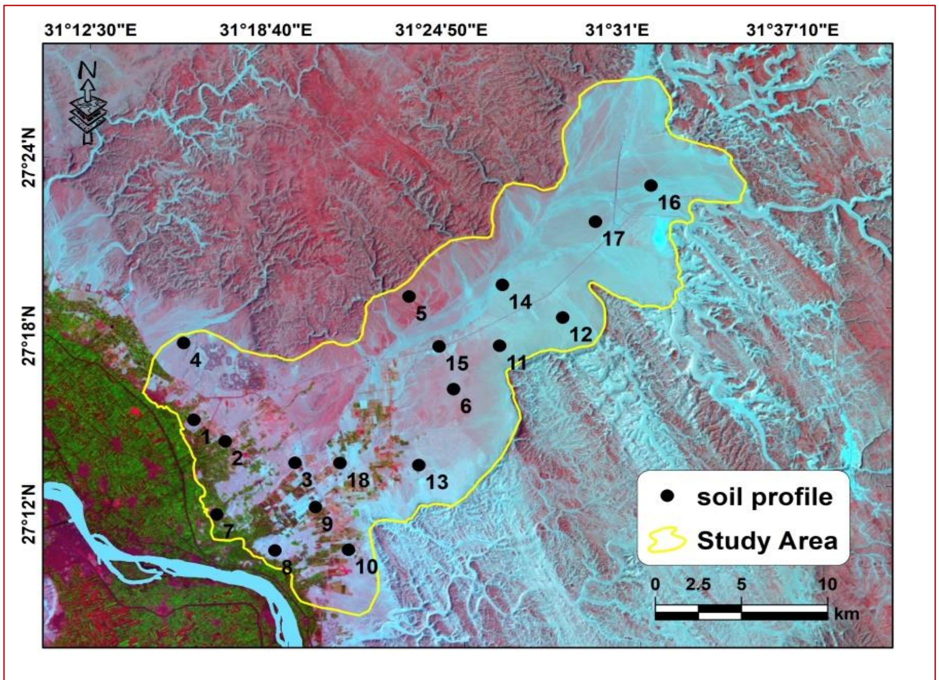
The data input process is the operation of entering the spatial and non-spatial data into GIS using ArcGIS Pro 3.3 software. Each soil observation was geo-referenced using the Global Position Systems (GPS) and digitized. The different soil attributes were coded, and new fields were added to the profile database file in Arc GIS software .

Descriptive statistical parameters:

The study adopted the quantitative method in analyzing the data obtained about the studied phenomena and in various comparisons, whether through percentages, rates, and mathematical equations, in addition to using some programs of the Statistical Portfolio for the Social Sciences 20 Minitab14 and SPSS, represented by the use of the simple correlation coefficient R. Minimum, maximum, mean, standard deviation and coefficient of variance were calculated using SPSS software v. 22 .

Field studies

A reconnaissance soil survey was carried out to obtain the needed information. In the field, 21 soil observations were dug to cover unsupervised classification units and topography of the studied area. Digging soil sections to a depth of 150 cm or until reaching an obstacle that limits the depth of the soil with a physiological description of the area (Fig. 2).



Source: Field work and using ArcGIS10.8.

Figure (3): Soil sites samples of the study area

Laboratory analysis:

Soil samples were prepared to determine some soil chemical properties (Page et al., 1982), including the electric conductivity in dS/m, soluble cations, and anions. The soil reaction (pH) was measured in the suspension (1:2.5), and soil texture by hydrometer (FAO, 1970). Water samples were analyzed to characterize the water quality.

Results and Discussion

1- Surface properties:

The terrain affects the process of soil formation directly and indirectly depending on their sizes. The depth of the land units is determined according to the nature of the slope. Flat or slightly sloping areas help in the accumulation of soil materials, and the depth of their section contains many secondary minerals and resistant minerals. As the slope increases, erosion increases and accumulation decreases. Hence, the soil profile is stony and contains many primary minerals.

a- Elevation aspects

The topography of the area was studied using a DEM obtained from SRTM images with a spatial resolution of 30 m x 30 m. GIS programs were used in DEM analysis to obtain a slope map and aspect directions (Fig. 4). It is clear that the levels of the study area range between 50 to 250 m, and the levels generally decrease from the northeast towards the southwest, and the level decreases from the sides of the fan towards the main channel.

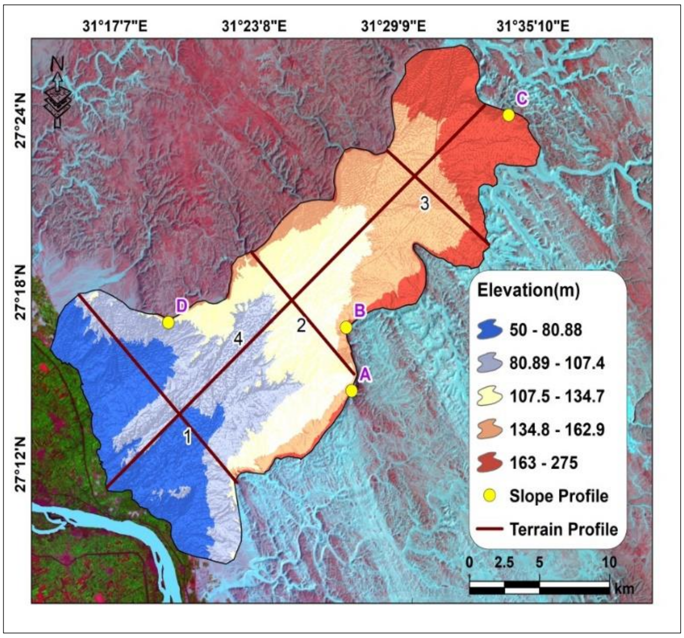
b- Slope:

The slope gradient, along with the elevation and depressions of the terrain, plays a crucial role in the process of soil formation. On sloping terrains, soil tends to be transported downward under the influence of Earth's gravity. Therefore, the soil on the upper slopes becomes thin and cohesive while it collects and increases in thickness and softness on the lower slopes. In addition, the slope of the land is a factor in surface and table erosion. The slope percentage was calculated from the analysis of the DEM, and the study area is characterized by a nearly level (25.99%) to gently sloping (65.74%), with varying degrees of slope and increasing on the sides (Table 3; Fig. 5).

Table (3): Slope classes and their surface areas.

Slope Class	Hectares	(%)
Nearly level	10803	25.99
Gently sloping	27210	65.47
Sloping	3546	8.53

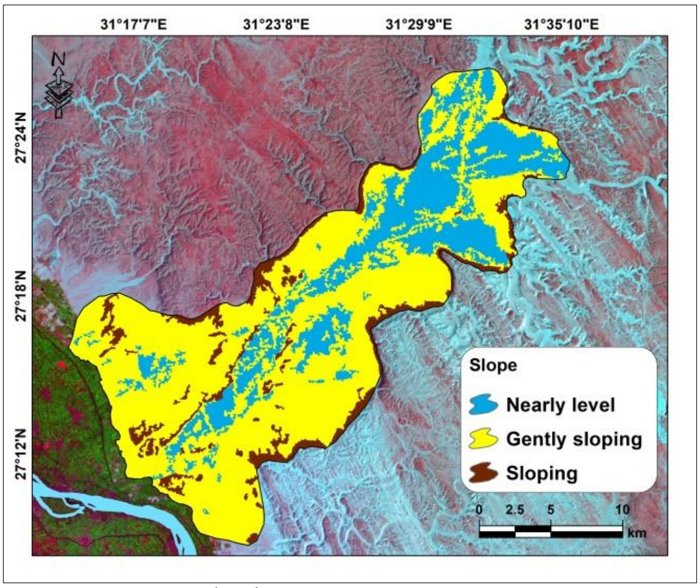
Source: Slope analysis and using ArcGIS10.8.



Source: USGS and using ArcGIS10.8.

Figure (4): DEM and measured profiles of the study area.

Three transverse topographical profiles were prepared to express the characteristics of the area's surface, taking the south-east, and north-west directions (Fig. 4). They showed the relative flatness of the flood fan surface with a slight variation, which gives the area great importance in the reclamation operations. A longitudinal topographical profile was also prepared, extending from west to east (Fig. 6). It was found that the flood alluvial fan is characterized by a slight inclination from the east towards the west, which contributes to the process of planning irrigation methods and infrastructure, and the level is gradually increased in a simple manner, which contributes to planning the study area.



Source: DEM and using ArcGIS10.8.

Figure (5): Slope of the study area.

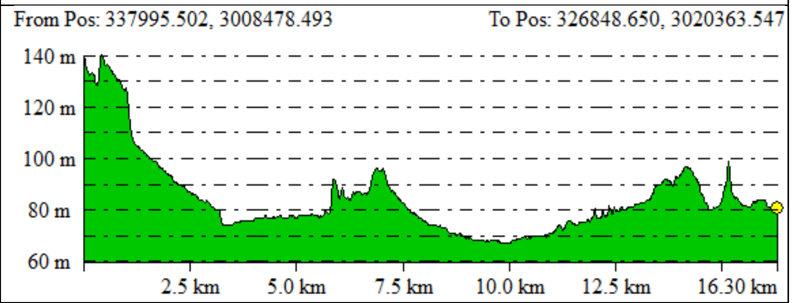
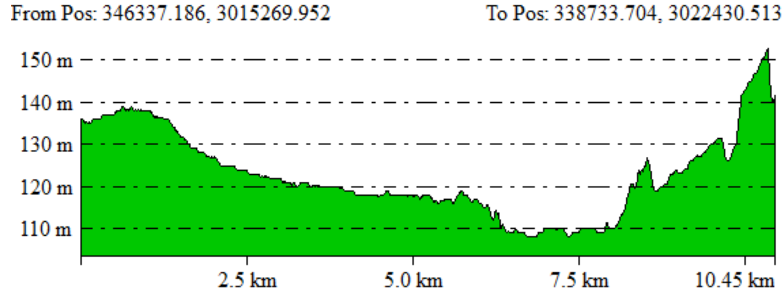
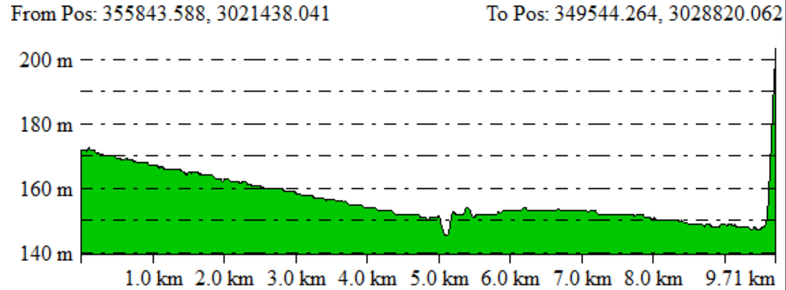
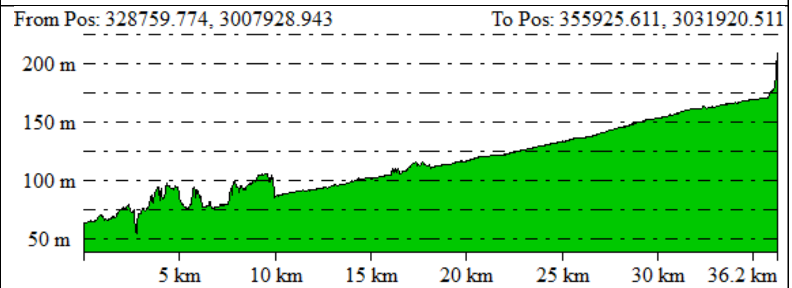
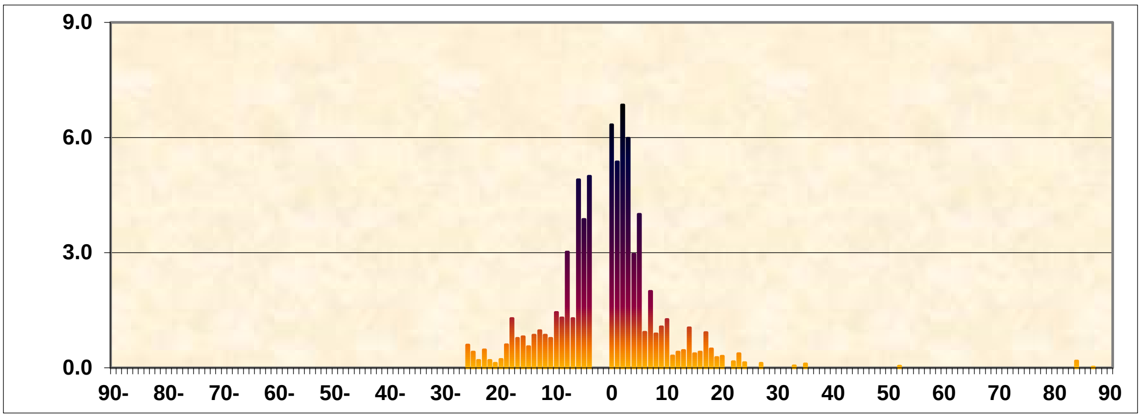
No.	Description	Terrain Profile
1	Length = 16.65 Direction SE/NW Type = Cross section	
2	Length = 10.81 Direction SE/NW Type = Cross section	
3	Length = 9.50 Direction SE/NW Type = Cross section	
4	Length = 36.72 Direction SE/NW Type = Longitudinal section	

Figure (6): Topographic profiles of the study area.

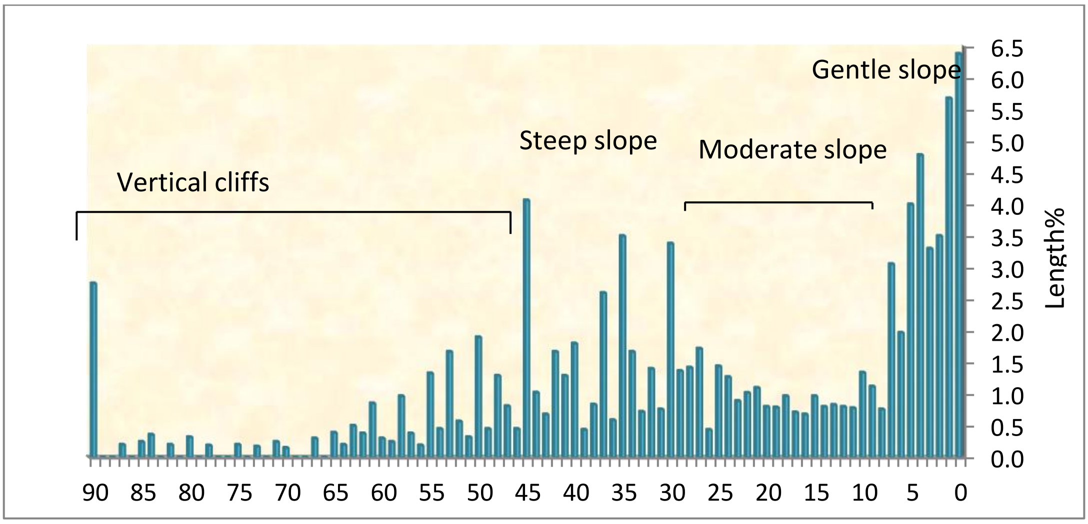
c- Morphometric analysis:

This analysis aims to clarify some geomorphological characteristics, in addition to the characteristics of slopes and curvature rates that are useful in identifying the prevailing slope shapes and the factors that shape them and determine their development stages. We note from Figures (7, 8, 9, 10) that the mountain edges surrounding the alluvial fan are characterized by a steep slope, as their slope angles ranged between 60 and 40 degrees in their upper and middle sectors, respectively. While the angles of its slope ranged between 25 and 40 degrees in its lower sections at the foot of the slope, which is covered with sediments of stubble cones and blocks falling from the tops of the slopes, a group of watercourses descending from the edge are spread throughout it, which are characterized by their narrowness and straightness. It is worth noting that the role played by the valleys in the retreat and formation of the edge is minor in light of the prevailing drought conditions that the region is currently witnessing. Weathering processes are the factors influencing its formation and development with the help of the joints and cracks spread across the edge.



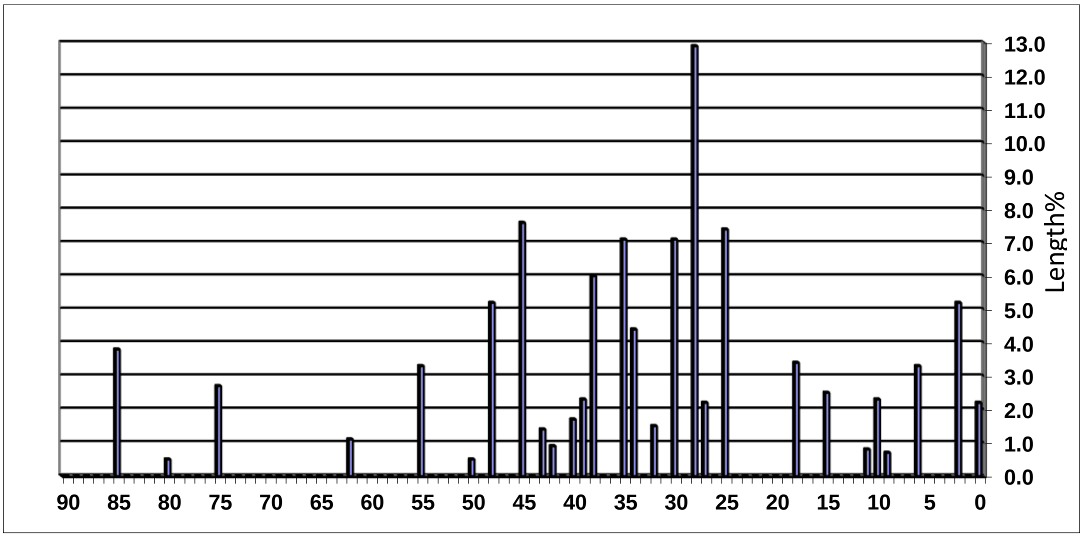
Source: Field work and use Excel.
Figure (7): Sections of the study area.

The slope sections in the study area were analyzed through the distribution of slope angles, and the analysis of the curvature rates, where 5 sections were measured along the edge. The sectors were drawn based on the field study and 2023 satellite images (Landsat OLI/TRIS), in addition to the ArcGIS v.10.8 and Global Mapper v.11 programs with an accuracy of 15 m. with the help of the Google Earth Pro v.7.3 program. The total lengths of the sections measured along the main edge amounted to about 5,700 m., and these lengths ranged between 1,220 m.



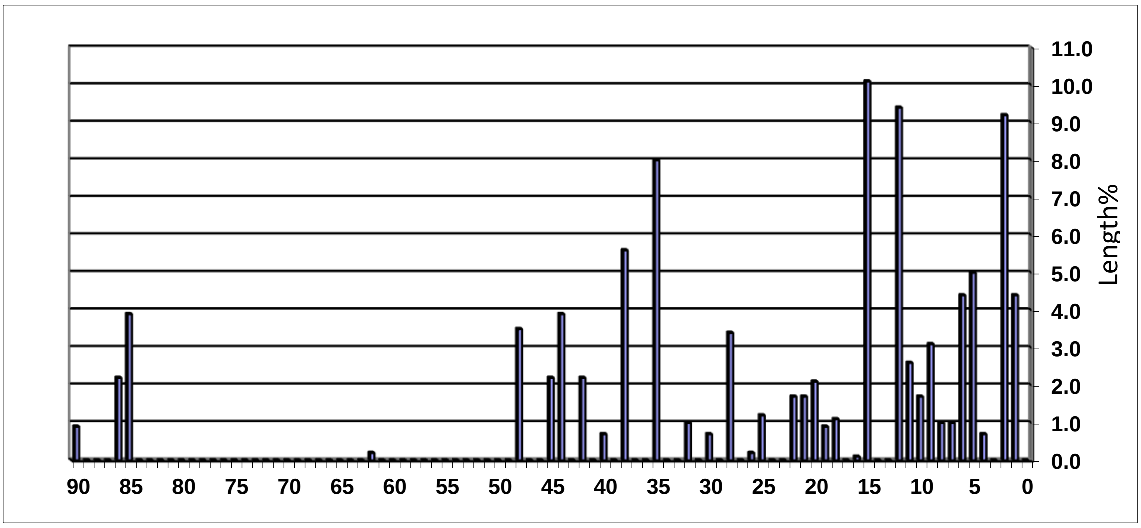
Source: Field work and use Excel.

Figure (8): Curvature analysis of the slopes along the study area.



Source: Field work and use Excel.

Figure (9): Cross sections of valley sides of the study area.



Source: Field work and use Excel.
Figure (10): Longitudinal sections of the study area.

d- Slope direction

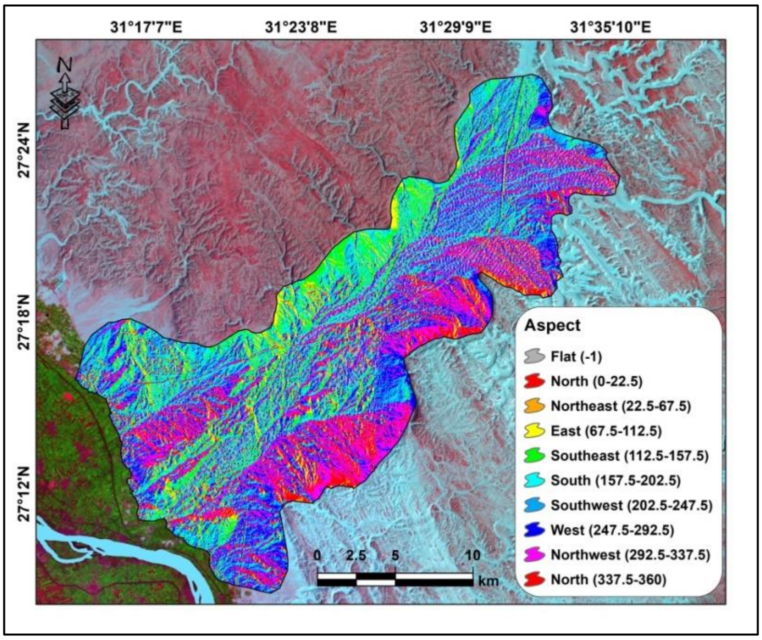
The extraction process is important to identify the direction of the slope and indicates knowledge of the direction of movement of surface materials, which has an impact on investment (Allison & Goudie, 1990).

Table (4): Classification of slope direction for the study area

Degree	Direction	Total Area (km^2)	Area (%)
(-1)	Flat	42.14	10.05
(0-22.5)	North	12.24	2.92
(22.5-67.5)	Northeast	15.18	3.62
(67.5-112.5)	East	33.31	7.94
(112.5-157.5)	Southeast	37.68	8.98
(157.5-202.5)	South	45.48	10.84
(202.5-247.5)	Southwest	60.66	14.46
(247.5-292.5)	West	65.37	15.59
(292.5-337.5)	Northwest	66.43	15.84
(337.5-360)	North	40.87	9.75
SUM	-	419.35	100.00

Source: DEM and Slope Analysis using ArcGIS 10.8.

Studying the slope directions can help identify the movement of materials on slopes. It also helps in planning the axes of the road network and Agricultural planning, given that crops need sunlight at appropriate rates, and the slope direction determines this to a large extent, Table (4) (Fig. 11). It is clear that the prevailing direction of slopes in the study area is the southwest direction at a rate of 16.59%, followed by a slight difference by the west direction 15.59%, and the slopes facing south amounted to 10.84%, while the flat lands represent 10.05% compared to the area of the study area. As a result, it is easy for potential crops in the study area to obtain the appropriate solar radiation for growth and greening processes



Source: DEM and using ArcGIS10.8.

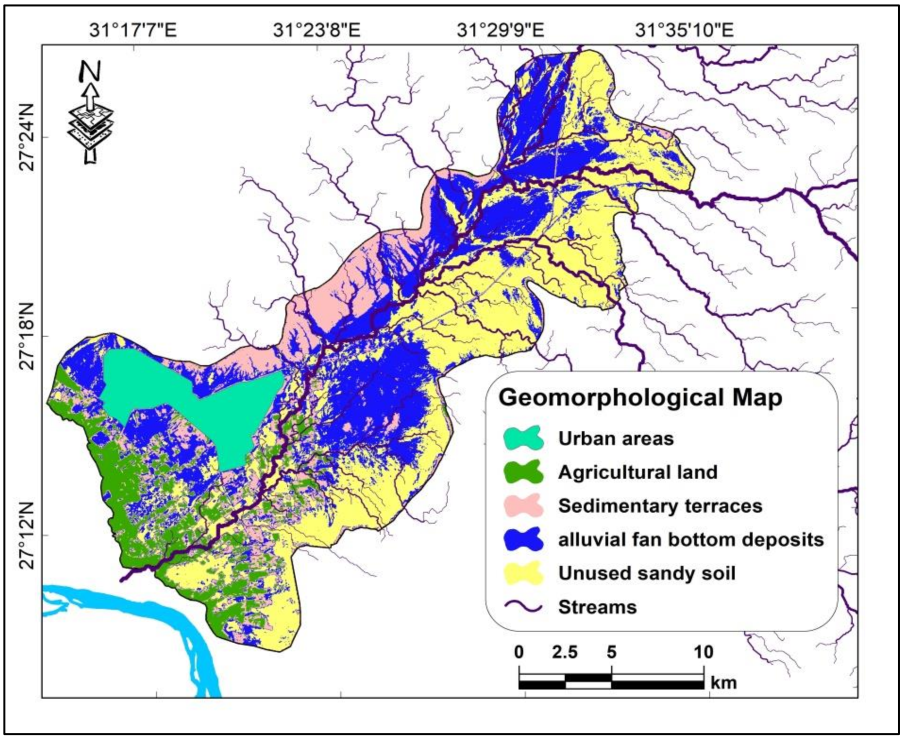
Figure (11): Classification of slope directions of the study area.

2- Geomorphological and hydrological aspects:

The study area is an alluvial fan of the Wadi Assiuti Basin, which has an area of about 6049 km^2. The basin is of the sixth order stream order. According to Table (5) and Figures (12, 13, 14), the elongation coefficient of the alluvial fan reaches 1.82, the roundness coefficient reaches 0.33, and the shape coefficient reaches 0.32. We noted that the study area takes a rectangular shape and is far from a spherical shape.

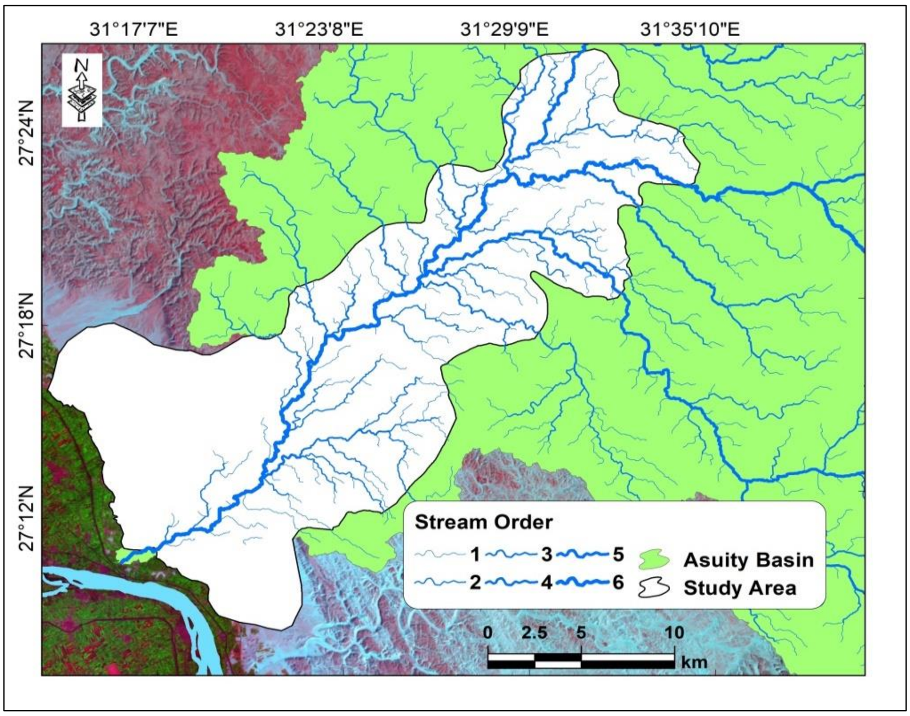
Table (5): Morphometric characteristics of the Wadi Assuti alluvial fan.				
Elongation Ratio (Re)	0.63	$Re = 2\sqrt{A} / L \times \sqrt{\pi}$	A = Area of the basin (km^2) L = length (km) π = 3.14	Gregory,at.el ,1973,pp.39-51
Circulatory Ratio (Rc)	0.33	$Rc = 4 \times Pi \times A/P^2$	Pi = 'Pi' value i.e., 3.14 A = Area of the basin (km^2) P2=Square of the perimeter (km)	Miller (1953)
Form Factor (Rf)	0.32	$Rf = A/Lb^2$	A = Area of the basin (km^2) Lb^2 = Square Basin length (km)	Horton (1932)

Source: morphometric analysis using ArcGIS 10.8.



Source: Land SAT 8 and using ArcGIS10.8.

Figure (12).Geomorphological map of the study area.



Source: Hydrological analysis using ArcGIS).

Figure (13): Stream net of the study area

From Table (6), it is clear that the largest percentage of geomorphic units is represented by unused sandy soil (35.54%), followed by alluvial sediments at the bottom of the valley (31.42%), and river terraces came at about 31.42% of the total study area. The Wadi Assiuti floodplain area is one of the urban and agricultural expansion areas in Assiut Governorate. It includes the cities of New Assiut and Rehab. Their urban area reaches about 28.79 km^2, representing about 6.87% of the total area of the study area, while agricultural lands include about 38.54 km^2, representing 9.19% of the total area of the region.

Table (6): Spatial characteristics of the geomorphic units.

Geomorphic Unit	Min.	Max.	Average	Total area	Area (%)
Agricultural land	0.001	15.91	0.06	38.54	9.19
Sedimentary terraces	0.001	14.15	0.02	71.20	16.98
alluvial fan bottom deposits	0.001	38.82	0.03	131.76	31.42
Unused sandy soil	0.001	44.00	0.08	149.05	35.54
urban Areas	0.024	3.52	0.25	28.79	6.87
-	-	-	-	419.35	100.00

Source: Land SAT 8 and using ArcGIS10.8.

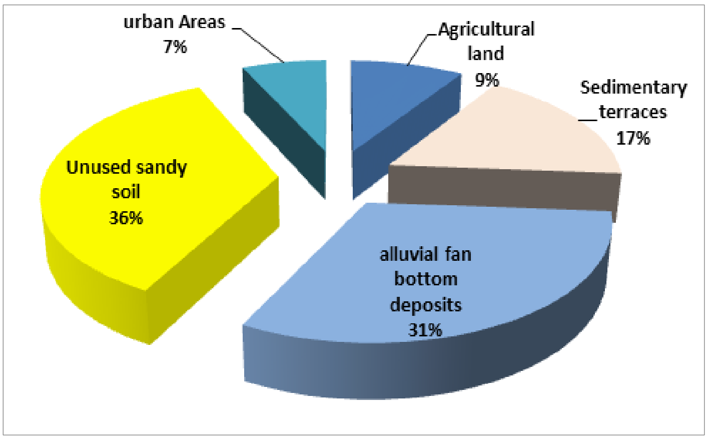


Figure (14): Percentages of the geomorphic units in the study area.

3- Statistical Characterization of Soil:

Table (7) indicates the statistical parameters of the soil profile for the different soil horizons samples. The results show that the soil depth ranged value about 100 cm. pH ranged from 7.95 to 8.48. Soil salinity (EC) ranged from 0.39 to 31.60 dS/m. The highest homogeneity properties were Ec (dS/m), SAR (%), $CaCO_3$ (%), clay content (%), and sand ratio (%) are 0.94, 0.81, 1.73, 0.69, and 0.42, respectively. EC values increase with depth in horizon no. 2 ranging from 0.69 to 21 dS/m.

Table (7): Statistical characterization of the studied soil

Parameter	Min.	Max.	Range	Median	St. dev.	Variance	C.V.
Soil depth (cm)	100.00	180.00	80.00	150.00	29.95	897.06	0.22
PH	7.95	8.48	0.53	8.32	0.17	0.03	0.02
Soil salinity (ds/m)	0.39	31.60	31.21	3.41	8.20	67.19	1.24
K (meq/L)	3.81	8.62	4.81	4.90	1.48	2.18	0.27
N (meq/L)	2.07	9.47	7.40	4.35	2.39	5.71	0.52
Organic matter (%)	0.02	12.00	11.98	0.08	2.81	7.89	3.77
Gypsum (%)	0.00	2.23	2.23	0.65	0.83	0.68	1.03
$CaCO_3$ (%)	4.31	30.43	26.12	16.90	7.48	56.01	0.41
Clay content (%)	1.57	11.85	10.28	4.44	3.15	9.91	0.56

Source: prepared by the researcher based on the fieldwork.

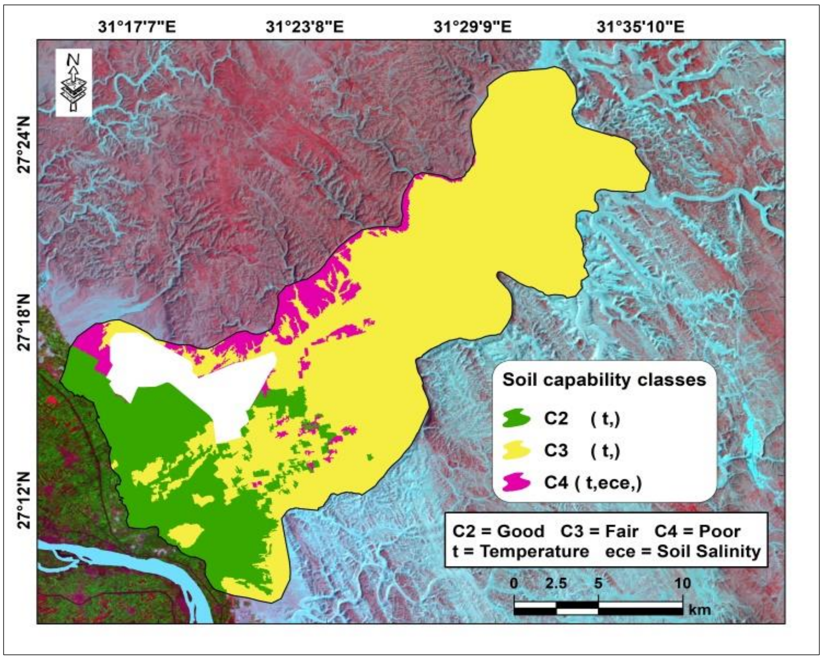
4- Soil capability and land suitability:

Land capability and suitability evaluation have been done using ALES-Arid as shown in Table (8). Figure (15) shows that the study area is characterized by a high production capacity for crops according to the classification S2 (t,) and C3 (t,), representing 93.36%, where the lands with very high capacity include about 21.36% of the total area of the area, and the lands with medium production capacity include about 72.00%. The area with low production capacity represents only about 6.64% of the total area of the study area, and accordingly, about 93.36% of the area of the study area has suitable production capacity under temperature conditions, while the area with low production capacity can be improved according to the ECE factor.

Table (8): Soil capability and land suitability classes and their surface areas.

	Hectare	(%)		Hectare	(%)		Hectare	(%)
Soil classes			**Cotton**			**Sugar beat**		
C2(t,)	8337.35	21.3	S2 (t,)	33433.6	85.6	S2 (ece, t,)	381.13	0.98
C3 (t,)	28105.0	72.0	S3 (ece, t,)	381.13	0.98	S2 (t,)	33433.6	85.6
C4 (t,ece,)	2592.84	6.64	S3 (t,)	5084.16	13.0	S3 (t,)	5084.16	13.0
Wheat			S4 (ece, t,)	136.27	0.35	S4 (ece, t,)	136.27	0.35
S2 (t,)	19485.7	49.9	**Faba bean**			**Sugarcane**		
S3 (t,)	19032.0	48.7	S2 (t,)	6125.55	15.6	S3 (t, temp,)	23563.2	60.3
S4 (ece, t,)	517.40	1.33	S3 (ece, t,)	3516.61	9.01	S4 (ece, t,	3526.11	9.03
Alfalfa			S3 (t,)	11709.3	30.0	S4 (t, temp,)	11945.8	30.6
S2 (t, temp,)	8214.94	21.0	S4 (ece, t,)	17683.7	45.3	**Sunflower**		
S2 (temp,)	6125.55	15.6	**Grape**			S2 (t, temp,)	6125.55	15.6
S3 (ece, t, temp,)	3008.71	7.71	S2 (temp,)	6125.55	15.6	S3 (ece, t,	381.13	0.98
S3 (ece, temp,)	621.74	1.59	S3 (ece, t,	14469.1	37.0	S3 (t, temp,)	32392.2	82.9
S3 (t, temp,)	20546.8	52.6	S3 (ece, temp,	621.74	1.59	S4 (ece, t,	136.27	0.35
S4 (ece, temp,)	517.40	1.33	S3 (t, temp,)	15225.9	39.0	**Tomato**		
Banana			S4 (ece, t,	2075.44	5.32	S2 (t, temp,)	6624.89	16.9
S3 (t, temp,)	6125.55	15.6	S4 (ece, temp,	517.40	1.33	S2 (temp,)	6125.55	15.6
S4 (ece, t, temp,)	12463.2	31.9	**Maize**			S3 (ece, t,	5084.16	13.0
S4 (t, ca, temp,)	9005.04	23.0	S3 (ece, t,	2211.79	5.67	S3 (ece, temp,	621.74	1.59
S4 (t, temp,)	6220.90	15.9	S3 (t, temp,)	21351.4	54.7	S3 (t, temp,)	20061.4	51.3
NS1 (ece, t, ca,	136.27	0.35	S4 (ece, t,	15471.9	39.6	S4 (ece, temp,	517.40	1.33
NS1 (ece, t, temp,)	5084.16	13.0	**Onion**			**Watermelon**		
Cabbage			S2 (t,)	6125.55	15.6	S2 (temp,)	6125.55	15.6
S2 (t,)	11572.4	29.6	S3 (ece, t,)	11048.3	28.3	S3 (ece, t,	13535.8	34.6
S3 (ece, t,)	17166.3	43.9	S3 (t,)	14047.9	35.9	S3 (ece, temp,	621.74	1.59
S3 (t,)	9779.00	25.0	S4 (ece, t,)	7813.35	20.0	S3 (t, temp,)	15225.9	39.0
S4 (ece, t,)	517.40	1.33				S4 (ece, t,	3008.71	7.71
						S4 (ece, temp,	517.40	1.33

Source: Land capability and suitability using ALES-arid modeling in GIS program.



Source: Hydrological analysis using ArcGIS.

Figure (15): Soil capability classes of the study area.

The suitability of the soil in the study area for some field crops, vegetables, and fruit trees was evaluated using the ASL-arid system adopted to evaluate the suitability of the soil for 14 important crops, which were classified into the following categories as follows:

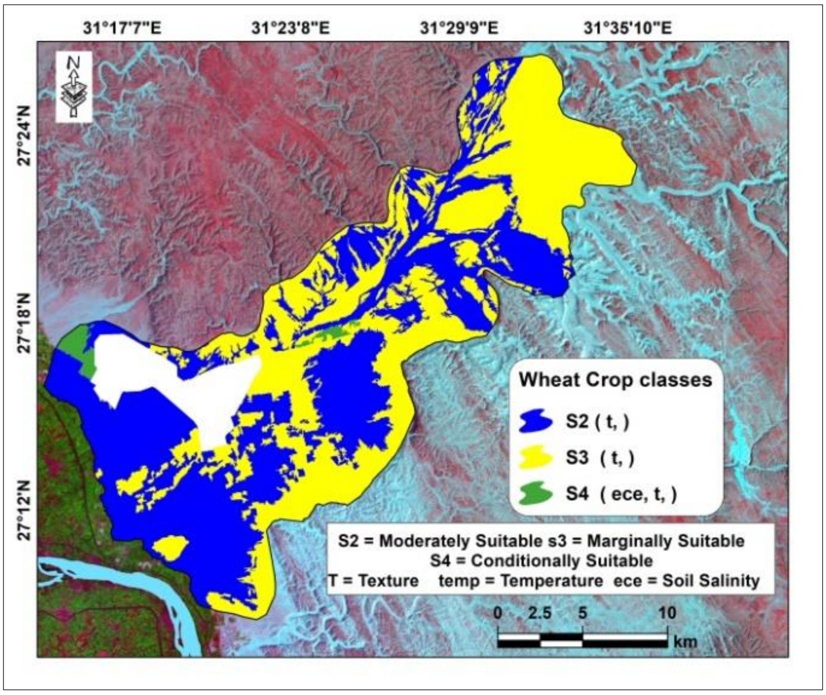
I. Cereal crops: wheat, barley, and maize.
II. Orchard crops: Grapes, and bananas.
III. Vegetable crops: Tomato, cabbage, and watermelon.
IV. Fodder crops: Alfalfa.
V. Industrial crops: Sugar beat, cotton, faba bean, sugarcane, and sunflower.

a- Cereal crops:

These crops rank first in terms of their importance in the study area, as wheat has a special importance among the main food grain crops in Egypt in terms of its nutritional importance for the population. Barley is no different from wheat, while maze is widely cultivated in many parts of the country due to the increased demand for it because it is basic in poultry feed and the manufacture of vegetable oils. By applying the soil suitability model for **wheat and barley** cultivation (Fig. 16), the suitable area (S2, S3) for cultivation with texture as limitations represents 98.68% of the study area. On the other hand, the **maize** (S3), is represented 60.37% with texture, soil salinity, and temperature as limitations (Figs,17).

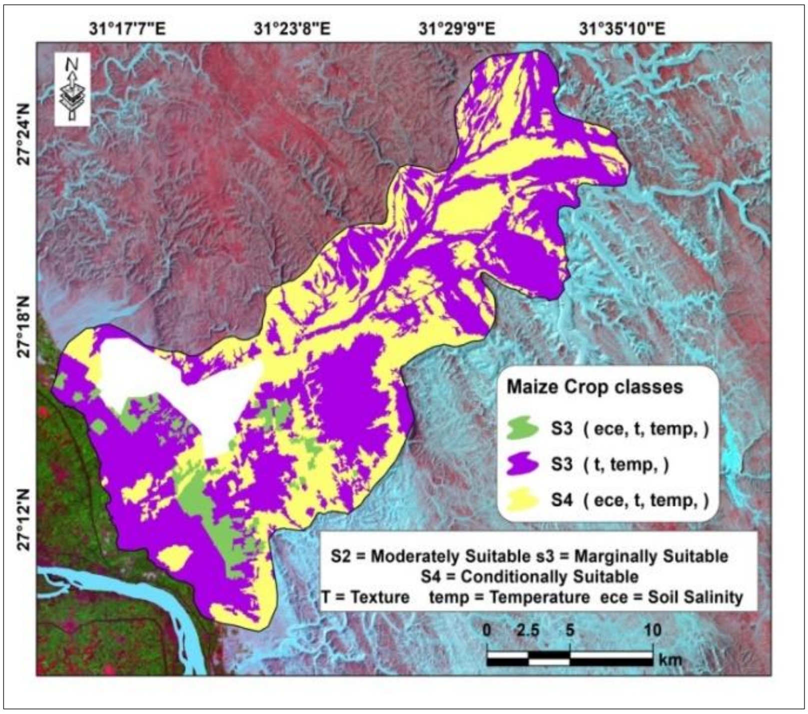
b- Orchard crops:

It is considered a perennial tree crop and its production is repeated throughout its growth period, while the benefit of fruit trees varies according to the type of fruit. The productive capacity of the soil for some of these crops was evaluated in the study area, as follows from Figures (18, 19) Grape, the productive capacity category of type S3 (t, temp,) came in first place with an area of 15225 hectares, representing 39.01% of the total area of the study area, followed by the productive capacity category S3 (ece, t, temp,) with an area of 14469 hectares and representing 37.07%. This shows the suitable area (S2, S3) for cultivation with temperature and texture as limitations represent 93.36% of the study area, For **bananas,** the suitable area is 15%, while 66% conditionally suitable, and 15% are not suitable due to the presence of growth determinates such as temperature, texture, soil salinity, and calcium carbonate.



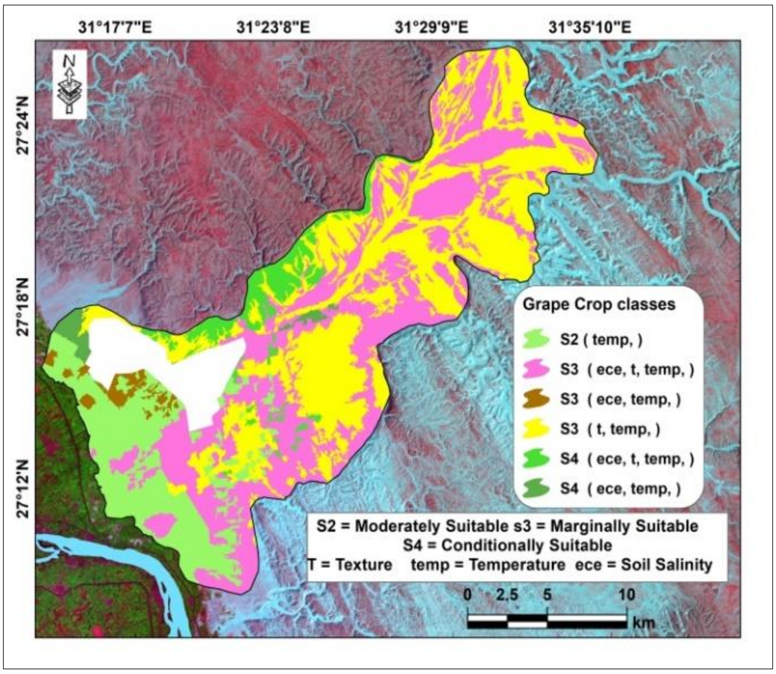
Source: ALES Model using Arc GIS.

Figure (16): Land suitability for wheat and barley of the study



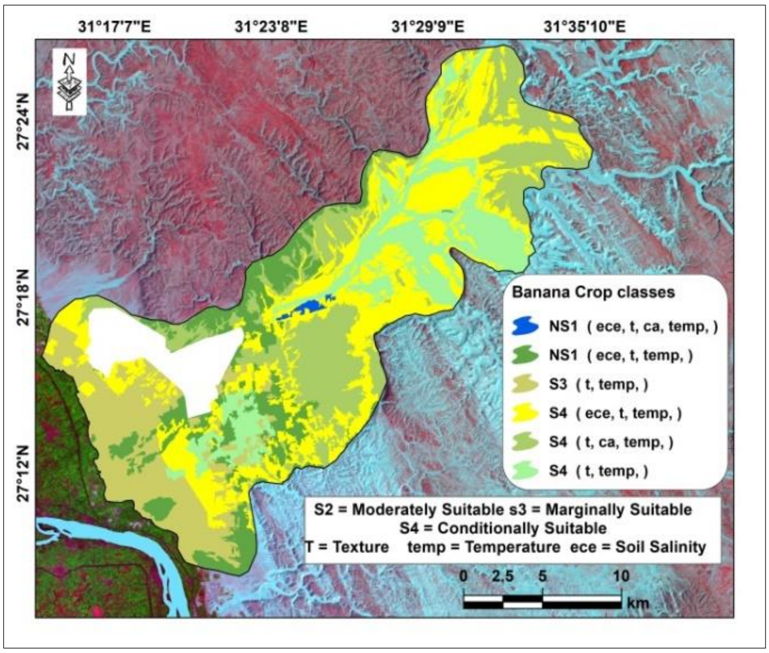
source: ALES model using Arc GIS.

Figure (17) Land suitability for Maize of the study



Source: ALES model using Arc GIS.

Figure (18) Land suitability for Grape of the study

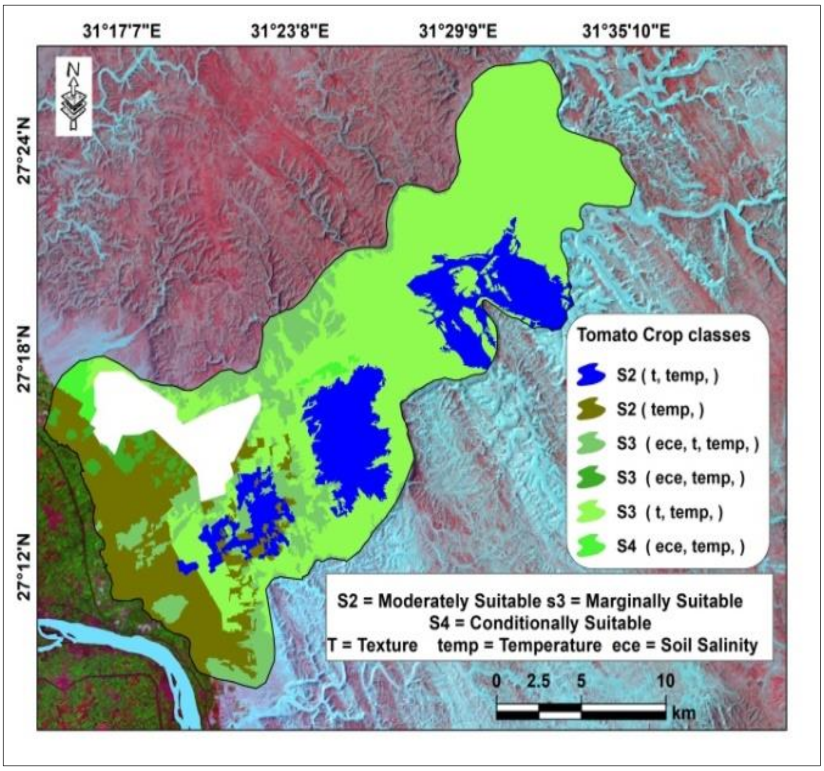


Source: ALES Model using Arc GIS.

Figure (19) Land suitability for Banana of the study

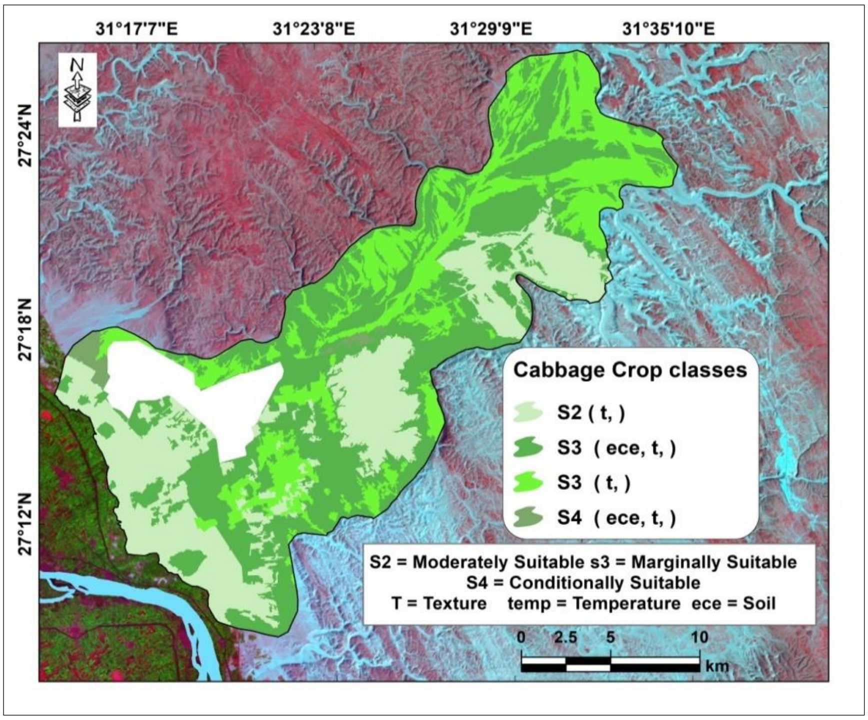
c- *Vegetable crops:*

The demand for it has increased because it contains vitamins and minerals necessary for the human body, in addition to containing carbohydrates, fats, and proteins that help cells grow and perform various life activities, which are as follows from Figures (14, 15, 16, 17). For **Tomatoes,** the productive capacity category of this crop S3 (t, temp,) came in first place with an area of 20061 hectares, representing 51.39% of the total area of the study area, followed by the productive capacity category S2 (t, temp,) with an area of 6624 hectares, representing 16.97%. This shows the suitable area (S2, S3) for cultivation with texture and temperature as limitations represent 98% of the study area (Fig. 20). For **Cabbage,** as for its cultivation, the productive capacity of type S3 (ece, t,) came in first place with an area of 17166 hectares, representing 43.98% of the total area of the study area, followed by the productive capacity category S2 (t,) with an area of 11572 hectares, representing 29.65%. The high capacity of the soil of the study area for growing cabbage is evident, this shows the suitable area (S2, S3) for cultivation with texture and ECE as limitations are represented 98.68% of the study area (Fig. 21). For **Onions,** as for its cultivation, the productive capacity category S3 (t,) came in first place with an area of 14047 hectares, representing 35.99% of the total area of the study area, followed by the S3 (ece, t,) with an area of 11048 hectares, representing 28.30%. The high capacity of the soil in the study area for onion cultivation is evident, this shows the suitable area (S2, S3) for cultivation with texture and ECE as limitations represent 79.98% of the study area (Fig. 22).



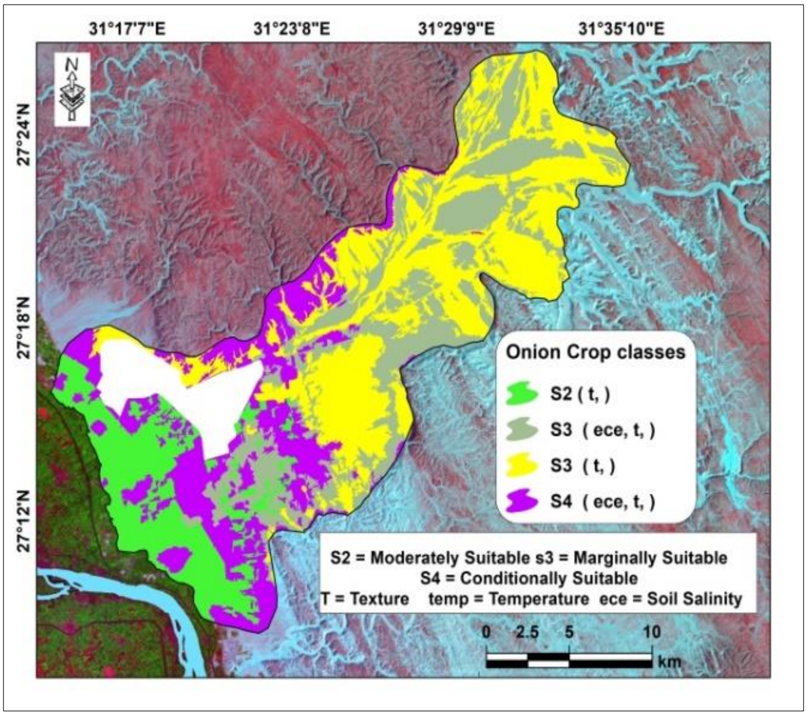
Source: ALES Model using Arc GIS.

Figure (20): Land suitability for tomatoes in the study area.



Source: ALES Model using Arc GIS.

Figure (21): Land suitability for cabbage in the study area.



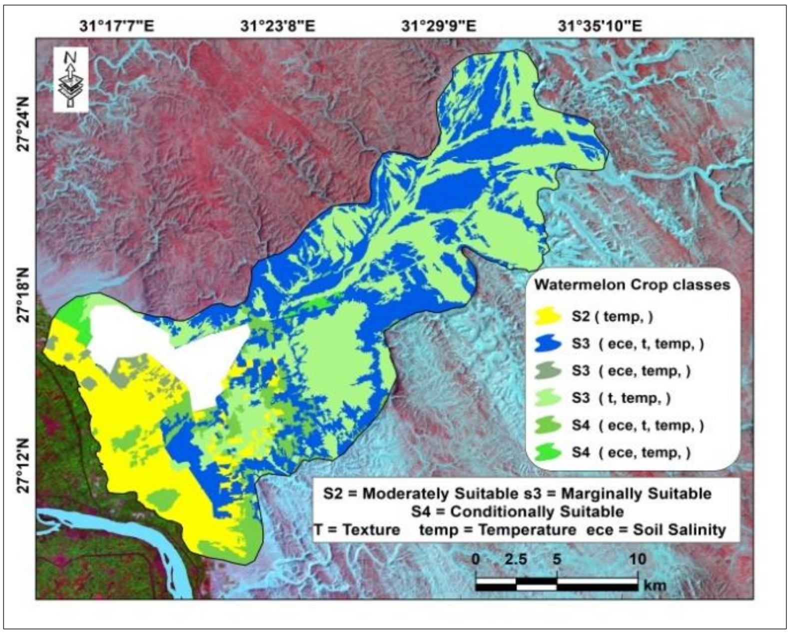
Source: ALES Model using Arc GIS.

Figure (22): Land suitability for onions in the study area.

Watermelon is characterized by its high suitability for cultivation in the study area. The S3 (t, temp,) category came in first place with an area of 15225 hectares, representing 39.01% of the total area of the study area, followed by the S3 (ece, t, temp,) category with an area of 13535 hectares, representing 34.68%, then the S2 (temp,) soil suitability category with an area of 6125 hectares, representing 15.69% of the total study area. As a result, the suitable area (S2, S3) for cultivation with temperature, ECE, and texture as limitations represent 90.97% of the study area (Fig. 23).

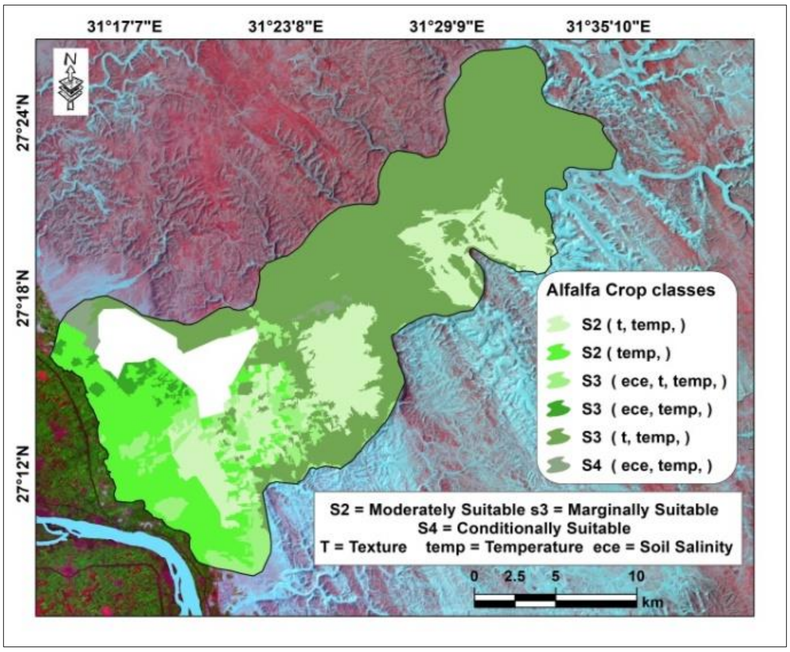
d- **Fodder Crops:**

It is grown to obtain green fodder or seeds or both and is provided as animal feed directly or after processing, as the provision of animal products and their quality is linked to the amount available to the animals because they have good nutritional value, and are characterized by their high ability to produce the largest amount of green matter, and their ability to grow quickly after grazing in addition to improving the chemical and physical properties of the soil. The most important of these is **Alfalfa.** Table (5) and Figure (24) indicate that the productive capacity of crops. We found that the S3 (t, temp,) category came in first place with an area of 20546 hectares and a percentage of 52.64% of the total study area, followed by the productive capacity category S2 (temp,) with an area of 8214 hectares and a percentage of 21.04%, and it is clear that the suitability of increasing the capacity of the soil of the study area for growing alfalfa is suitable. As a result, the suitable area (S2, S3) for cultivation with texture, temperature, and ECE as limitations represents 98.67% of the study area.



Source: ALES model using Arc GIS.

Figure (23) Land suitability for Watermelon of the study area.

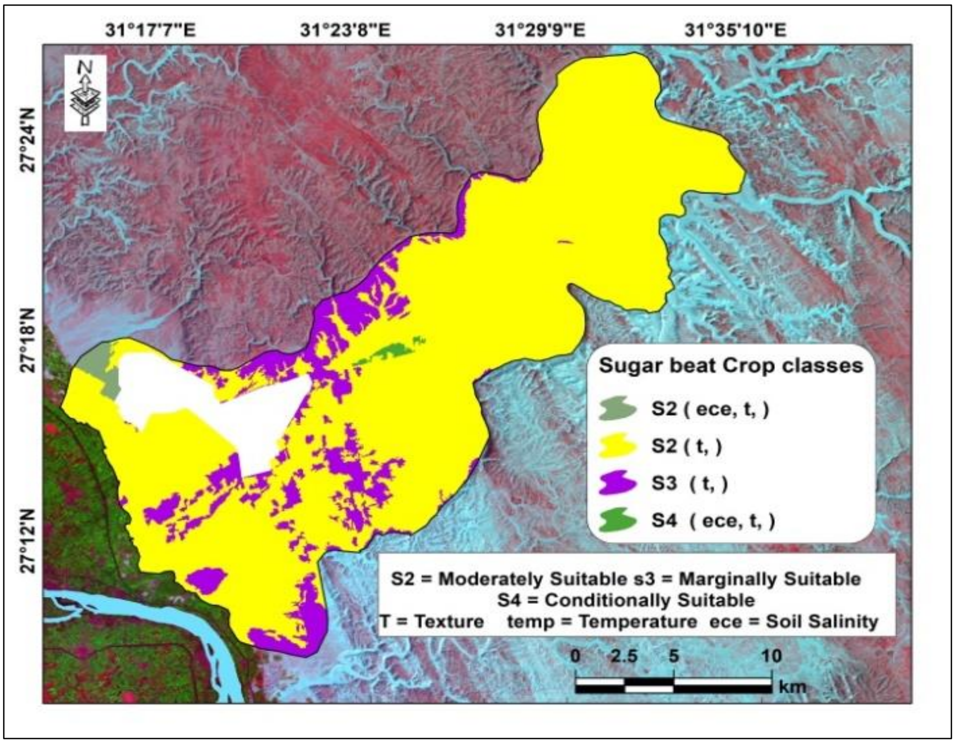


Source: ALES model using Arc GIS.

Figure (24) Land suitability for Alfalfa of The study

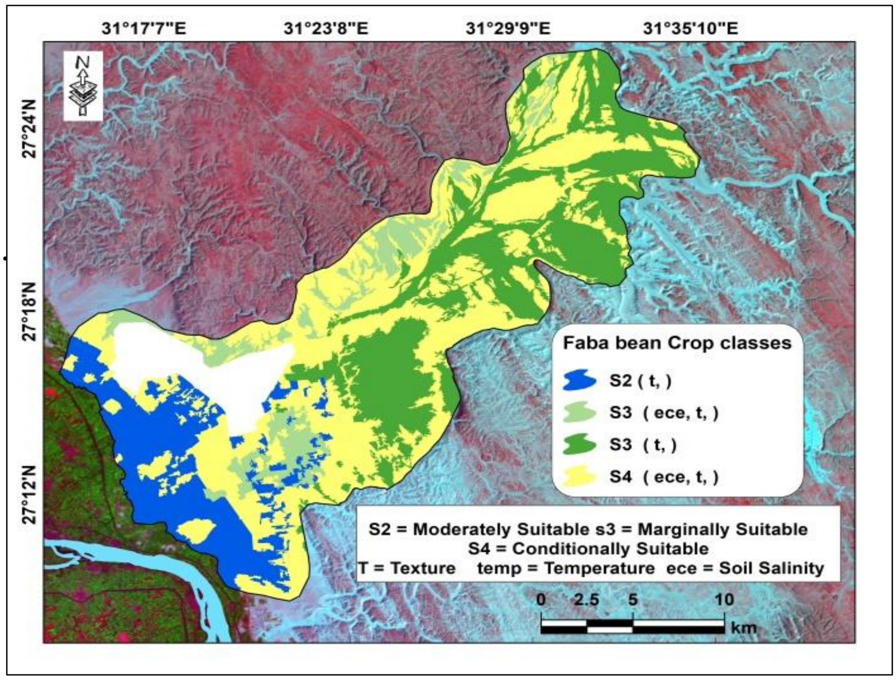
a- *Industrial crops:*

It is considered one of the important crops in the study area. This importance comes from the fact that it is used as a raw material in many industries. These crops are classified according to the type of industry from which the raw material is taken into fiber crops, and it is also used in the manufacture of vegetable oils (Figs. 25, 26, 27, 28, 29). For **Sugar Beat,** by applying the soil suitability model for cultivation, the productive capacity category of type S2 (t,) came in first place with an area of 33433 hectares, representing 85.65% of the total study area, followed by the productive capacity category S3 (t,) with a percentage of 13.02%. As a result, the suitable area (S2, S3) for cultivation with ECE and temperature as limitations represents 99.65% of the study area. For **cotton,** the productive capacity category of this crop, type S2 (t,) came in first place with an area of 33433 hectares, representing 85.65% of the total area of the study area, followed by the productive capacity category S3 (t,) with a percentage of 13.02%. The soil of the study area is highly suitable for cotton cultivation, As a result, the suitable area (S2, S3) for cultivation with temperature and ECE as limitations represents 99.65% of the study area. For **Faba Bean (**Tables 19, 20, 21, 22), we found that the productive capacity category of type S4 (ece, t,) is in first place with an area of 17683 hectares, representing 45.30% of the total area of the study area, followed by the productive capacity category S3 (t,) with an area of 11709 hectares, representing 30.00%, As a result, the suitable area (S2, S3) for cultivation with temperature and ECE as limitations represents 54.7% of the study area. For **Sugarcane,** as for its cultivation potential in the region, category S3 (t, temp,) came in first place with an area of 23563 hectares, representing 60.36% of the total area of the study area, followed by category S4 (t, temp,) with an area of 11945 hectares, representing 30.60%. As a result, the suitable area (S3) for cultivation with texture and ECE as limitations represents 60.36% of the study area. For **Sunflowers**, the productive capacity category S3 (t, temp,) came in first place with an area of 32392 hectares, representing 82.98% of the total area of the study area, followed by the productive capacity category S2 (t, temp,) with an area of 6125 hectares, representing 15.69%. This shows the suitable area (S2, S3) for cultivation with texture, temperature, and ECE as limitations representing 99.65% of the study area.



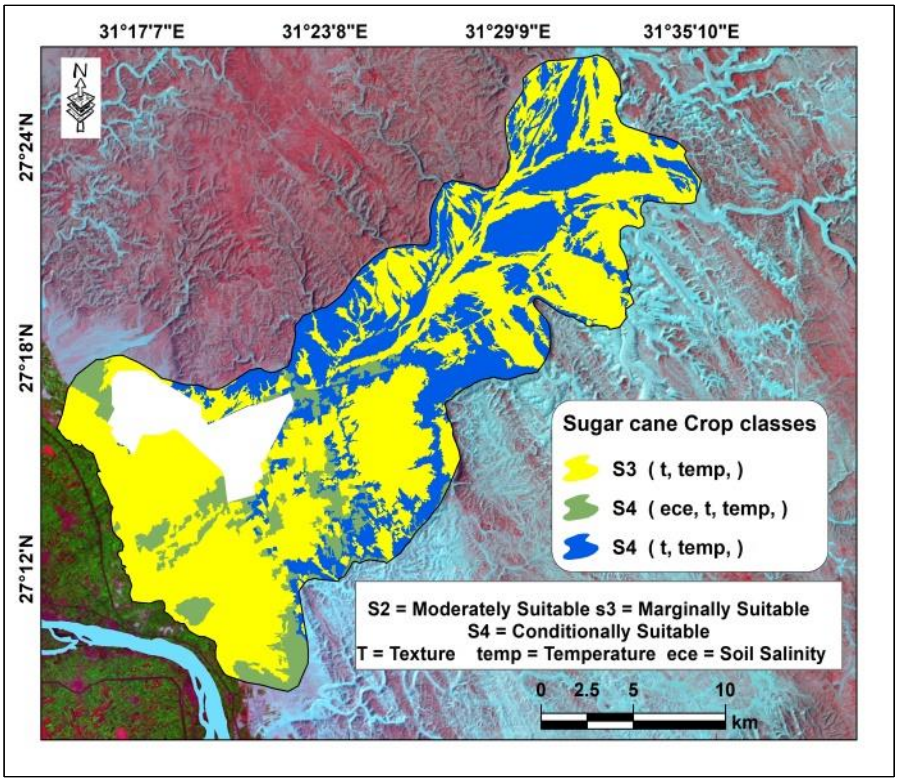
Source: ALES model using Arc GIS.

Figure (25) Land suitability for Sugar beat of the study area.



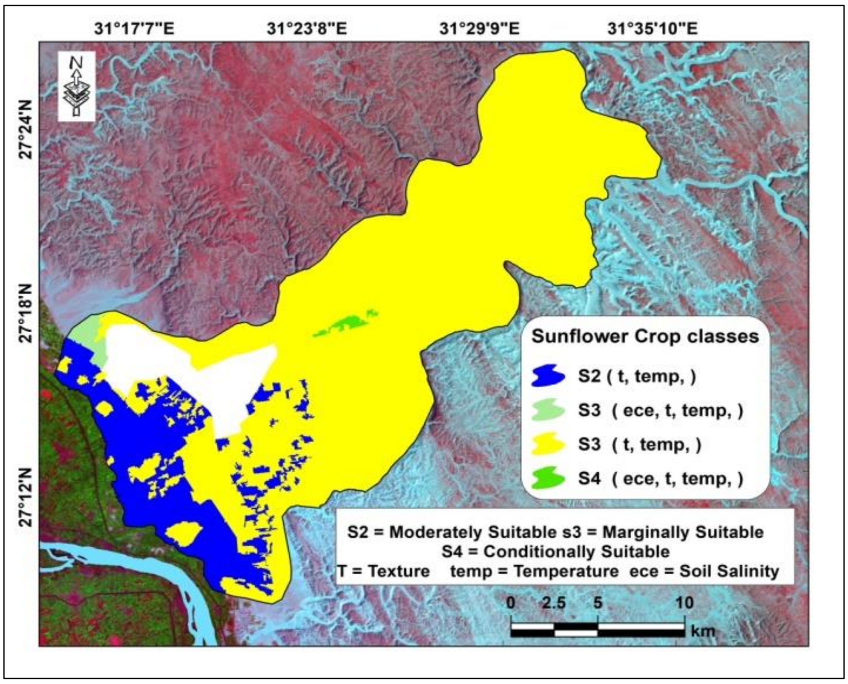
Source: ALES model using Arc GIS.

Figure (26) Land suitability Faba bean of the study area.



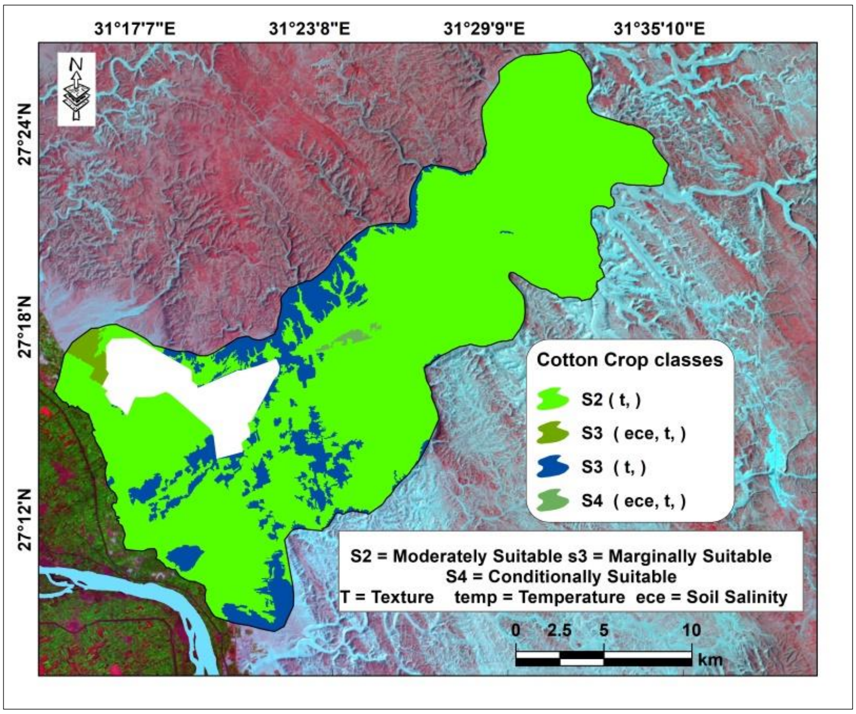
Source: ALES model using Arc GIS.

Figure (27) Land suitability Sugarcane of the study area.



Source: ALES model using Arc GIS.

Figure (28) Land suitability Sunflower of the study



Source: ALES model using Arc GIS.

Figure (29) Land suitability Faba bean of the study area.

CONCLUSIONS

The evaluation of land resources in the alluvial fan of Wadi Al-Assiuti focused on assessing soil capacity and agricultural suitability, providing a foundation for sustainable land use planning and agricultural development. The study adopted a soil evaluation system specifically designed for arid and semi-arid regions, ensuring a comprehensive assessment of soil productivity. By categorizing the land based on its production potential, the study identified key limitations and opportunities for agricultural expansion in the region.

The classification revealed that poor land capacity was primarily linked to high soil salinity, low fertility, and coarse soil texture, all of which contribute to reduced agricultural viability. These limitations affect water retention, nutrient availability, and plant growth, making some areas challenging for cultivation. However, by employing appropriate soil management techniques—such as irrigation improvements, soil amendments, and salinity control—these challenges can be mitigated, enhancing agricultural potential. The study identified variations in soil suitability for different crops, categorizing the land into three levels of suitability. Highly suitable land includes crops that thrive in the soil conditions of the Wadi Assiuti alluvial fan with minimal intervention, such as wheat, tomatoes, sugar beet, cotton, alfalfa, sunflower, onions, cabbage, and watermelon. Moderately suitable land consists of crops that can be cultivated successfully but may require some soil amendments or specific management techniques to optimize yield, including faba beans, grapes, and maize. Poorly suitable land includes crops that face significant challenges due to soil conditions, such as excessive salinity, poor structure, or low fertility. Bananas and sugarcane fall into this category, as their cultivation requires extensive soil improvements, increased water availability, and nutrient management.

The study also found that some areas were unsuitable for fruit trees, mainly due to shallow soil depth and high soil salinity. However, these limitations are not insurmountable. Many of these areas can be reclaimed through land improvement strategies such as deep plowing, organic matter enrichment, and advanced irrigation techniques like drip or subsurface irrigation to control salinity buildup. Additionally, the introduction of salttolerant crops and rotational cropping systems can further enhance soil productivity over time.

Despite the challenges, the study highlights the promising potential for agricultural expansion in the Wadi Al-Assiuti alluvial fan. By implementing integrated land management practices, including precision agriculture, soil conservation techniques, and sustainable irrigation strategies, the region can be transformed into a productive agricultural zone. Moreover, the introduction of climate-resilient crops and innovative farming technologies, such as hydroponics and agroforestry, can further support long-term agricultural sustainability in the region. Given the increasing demand for food security and sustainable land use, this research provides valuable insights for policymakers, land developers, and agricultural planners. The findings can guide strategic decision-making regarding crop selection, land reclamation projects, and investment in agricultural infrastructure, ultimately contributing to economic growth and environmental sustainability in the region.

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