مجلة كلية الآداب بالوادي الجديد- مجلة علمية محكمة- ديسمبر ٢٠٢٢

# Building Spatial Climate Model for Soil Capability Using Geomatics, West of Toshka, Egypt

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## Abstract:

Soil capability always related to soil quality, which directly affect productivity, environmental factors, land use/land cover, and bio-activities. Monitoring of soil capability parameters will help to simplify and explain some impacts of climate effect on hyper arid condition and the responses required for such difficult agricultural adaptation. This paper presented using geographic information system, GNSS and remote sensing techniques “geomatics” to manage and update soil spatial datasets, furthermore, spatial-climate monitoring for soil characteristics and distribution. Assessing land types and identifying degraded spots with soil problems such as salty, alkaline or other productive capability. Adding an interpolation methods for generalizing samples results for study area. In the current research, a spatial-climate model for soil capability was built to evaluate soil capability based on; chemical, physical and biological soil characteristics. The results of the spatial model were correlated with both land capabilities and climate of the study area. Nonetheless, this model proposed for decision-makers tool for soil capability classification under similar conditions.

**Keywords:** Soil Capability, Climate, Toshka, Spatial Model and Geomatics

**الملخص:**

**بناء نموذج مكاني مناخي لقدرة التربة الإنتاجية باستخدام تطبيقات الجيوماتكس، غرب توشكي، مصر**

تصنيف قدرة التربة الإنتاجية يرتبط دائماً بنوعية التربة والتي بدورها تأثر وتتأثر بشكل مباشر في الظروف البيئية وغطاء ولإستخدامات الأرض إلى جانب التأثير على التغيرات العضوية. لذلك يعتمد البحث على متابعة وتصنيف التربة وإظهار أثر المناخ والظروف الجوية والتي تؤدى إلى بيئة شديدة الجفاف، وعلى الرغم من تلك الظروف المحلية القاسية، تظهر مشروعات زراعية متوطنة بالقرب من منطقة الدراسة. تهتم الدراسة المقدمة بإستخدام تقنيات الإستشعار من بعد ونظم المعلومات الجغرافية ونظم تحديد المواقع والتي تعرف إجماعاً "بتطبيقات الجيوماتكس". لذلك تركز الدراسة لتصميم نموذج مكاني مناخي يعتمد على تحليلات التربة المختلفة وتوزيعها، سعياً لمعرفة أماكن تدهور التربة والأماكن التي يمكن تقديمها كمرحلة أولي عند التوسع في أنشطة الزراعة، حيث تلقي الدراسة الضوء مشكلات التربة من ملوحة وقلوية مرتفعة وخصائص التربة المختلفة والتي تتحكم في تصنيف التربة وقدرتها الإنتاجية. النموذج المقترح يمكن إستخدامه كأداه تساعد متخذ القرر في تحديد أماكن أولوية التوسع الزراعي بأسلوب علمي ودقيق.

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## 1. Introduction:-

Spatial datasets are very important for decision-making; it is a critical for solving today's natural and human problems, which require smart and effective decisions regarding spatial data availability. Soil classification according to production capabilities is essential; soil assessed in all its components according to its ability to produce common crops and identifies constraints that reduce its productivity. Characterization of potentially suitable areas needs more quantitative, interdisciplinary approaches. While soil characterization and mapping have strongly and successfully developed during the last decades by geostatistics, remote, proximal and in situ sensors, electromagneticnon-invasive techniques, digital terrain modelling and GIS in general, development of land evaluation has been rather limited (Johan Bouma,2017).

Capability refers to suitability of a given soil to produce crops, besides, current natural biomass content in an ecosystem. In addition to soil chemical-biological physical status, topography and water status condition, the state of soil productivity is influenced by climatic elements such as precipitation, humidity and temperature. If properly managed, soil is one of the most significant natural resources that can abet in bridging the food demand gap to achieve food security (Shokr, M.S et al, 2021). Most of the study area is situated on a silt sand land, which is one of the most suitable types of soil for agriculture. Human interferes are a major influencers for agricultural suitability and sustainability, because of it is major effect neither positive nor negative according to human activities manners.

Despite this contribution, unsustainable agricultural activities are one of the major threats to soil health and associated land productivity. This is due to the intensification of unsustainable agricultural practices, vegetation degradation and mismanagement (Pacheco, F.A.L 2019). Therefore, understanding agricultural soil capability is essential to land use planning and sustainability because maintaining agricultural productivity is essential for ensuring food security and help protection of the environment by stopping land degradation. Agriculture is the primary human use of land. For that, agricultural land capability data is useful for decisions about nature conservation and land use policy (Shokr et al., 2021).

## 2. Methods and Material:

Landscape features and processes and is influenced by terrain, soil and climatic attributes
and their interactions. Failure to manage land in accordance with its capability risks degradation of resources both on- and off-site, leading to a decline in natural ecosystem
values, agricultural productivity and infrastructure functionality. (State of NSW and Office of Environment and Heritage, 2012). Building spatial model requires highly detailed visualization outputs and analytics, these spatial model relies on three main indicators; Surface Characters **(geomorphology units, slope), climatic factors**

**and soil analysis**. As mentioned below after determining study area location, as follow:

## 2.1. Study Area:

The study was conducted in west of Toshka lakes, located in the southern part of Western desert of Egypt, the southern boundary meets the borders of Egypt with Sudan, that's about 365 km south east of the New Valley governorate. The area extends between two longitudes (28° 00' 00" - 31° 00' 00") east and two latitudes longitudes (22° 00' 00" - 25° 00' 00") north, as shown figure 1. The study area covers about 9.5 km$^2$. This area is one of the most promising areas such as the Toshka National Project in southern Egypt and represent a promising agricultural development spot. Besides, from the west side East Owainat project is located, which is one of the largest agricultural projects in Egypt. The study area considers it to be an agricultural safety valve because it relying on huge quantities of under groundwater.

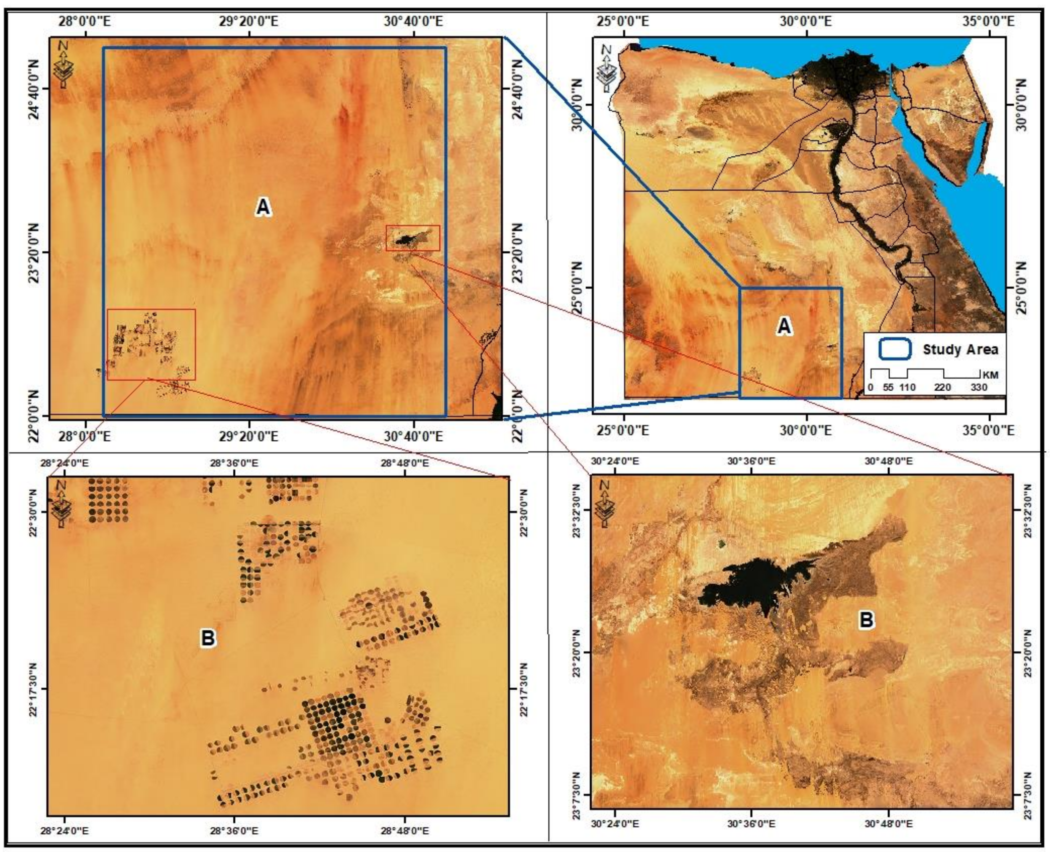



**Figure (1): (A) Location and boundaries of the study area, (B) Agricultural activities around study area.**

## 2.2. Satellite Data

The study relies on multiple satellite data sets, hence, covering many research aspects. Therefore, planet image acquired on December 2021 under clear sky conditions was used to monitor land activities and agricultural progress. The multi-spectral bands of PSScene image have a three-meter spatial resolution for bands 1, 2, 3, and 4, respectively.

Nonetheless, for producing the main geomorphological units of the study area using Landsat 8-OLI-TIRS satellite images acquired as shown by table (1), with 15m spatial resolution, also, used for soil profiles location visualization and display.

**Table (1): Landsat satellite images that were used in the research**

| Acquisition Date | Satellite Number | Sensor Type | WRS | | UTM Zone | Datum | Resolution (M) |
|---|---|---|---|---|---|---|---|
| | | | Path | Row | | | |
| 31/12/2021 | Landsat 8 | OLI-TIRS | 176 | 43 | 35N | WGS 84 | 30 |
| 31/12/2021 | Landsat 8 | OLI-TIRS | 176 | 44 | 35N | WGS 84 | 30 |
| 31/12/2021 | Landsat 8 | OLI-TIRS | 176 | 45 | 35N | WGS 84 | 30 |
| 22/12/2021 | Landsat 8 | OLI-TIRS | 177 | 43 | 35N | WGS 84 | 30 |
| 22/12/2021 | Landsat 8 | OLI-TIRS | 177 | 44 | 35N | WGS 84 | 30 |
| 22/12/2021 | Landsat 8 | OLI-TIRS | 177 | 45 | 35N | WGS 84 | 30 |

Source: http://www.usgs.gov.

## 2.3. Data Inputs for the Model

The input data and analysis outputs were used to construct the spatial model were collected from several sources, the most important of which was the fieldwork that served as the backbone of the study, besides, spatial analysis, interpolation and geo-statistical outputs.

Due to the different ranges between values for each of the inputs layers, therefore, value reclassification processes have changed the actual values of the layers to alternative weight values ranging from (1- 9-10 ) expressing their important and impact. Value or weight (9-10) is the best value or weights and value (1) which is the least important and influential, For example, the salinity category between (0-2) ds/m took the highest weight value of (9) because it is the lowest salinity concentration category and therefore has a good impact on the soil capability, while the salinity category between (8.1-14.8) ds/m took the lowest weight value (1); is recognized as high salinity. Each component of the model that has been reclassified and given relative weights, as presented below:

### 2.3.1. Surface Characters

#### 2.3.1.1. Geomorphological Units

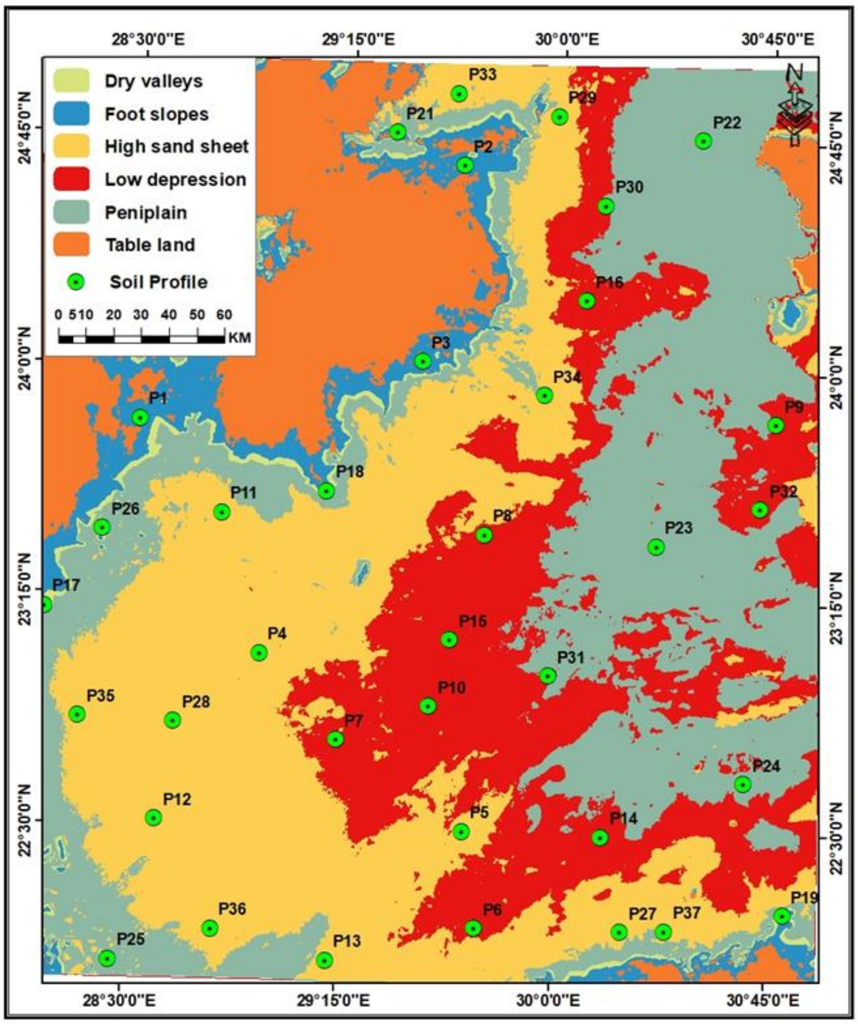
The study area was divided into a number of geomorphological units and the sectors were taken from them according to the unit's area. The samples of these sectors were mechanically and chemically analyzed to identify their characteristics, so that the researcher could measure the relationship between the characteristics of the soil and its environment to assist in the process of assessing the soil of the study area and determining its capability.

**Table (2): Distribution of the geomorphological units of the study Area**

| Geomorphological unit | Count of Profile | Profile Labels | Area ($km^2$) |
|---|---|---|---|
| Low depression | 11 | 31,30,29,27,26,22,18,16,15,9,8 | 17666,6 |
| Peneplain | 5 | 37, 36, 20, 14, 10 | 25921,1 |
| sand sheet | 13 | 35,34,33,28,24,13,12,7,5,4,3,2,1 | 26753,8 |
| Dry valleys | 5 | 32,21,19,17,11 | 1431,4 |
| Table land | - | - | 17551.4 |
| Foot slopes | 3 | 25,23,6 | 5515, 5 |
| **Total** | **37** | **94835** | |

Source: Created by researchers; using ArcGis 10.4 software, based on Landsat8-OLI-TIRS (2021-12) satellite visuals and SRTM 1 Arc-Second digital elevation model.

**Figure (2): Distribution of the geomorphological units of the study area.**



### 2.3.1.2. Topography Data

The Digital Elevation Model 'DEM' provided at 30-m spatial resolution which produced by the NASA Shuttle Radar Topographic Mission (SRTM) known as Raster data, combined with tabular data (elevation values). DEM helps in extract slope value, which is one of the most important surface characteristics for soil capability assessment. Therefore, it was linked to chemical and mechanical soil analyses. Slope analysis determine the appropriate irrigation method, as mentioned at Food and Agriculture Organization of the United Nations (FAO) guide, Sideruis, 1984 and FAO1985.

**Table (3): Distribution of slope classes and its reclassification**

| Classification regression ratio according to (Sideruis,1984 and FAO,1985) | | | In-program classification | |
|---|---|---|---|---|
| **Production Capability Grade** | **Slope %** | **Grade** | **Actual Values** | **Alternative value** |
| **Too high.** | **Too high.** | **0-2** | **I** | **9** |
| **High** | **High** | **2-8** | **II** | **8** |
| **Medium** | **Medium** | **8-16** | **III** | **7** |
| **Low** | **Low** | **16-30** | **IV** | **5** |
| **Very low** | **Very low** | **30 and more** | **V** | **2** |

Slope value classified into five different categories then reclassified, setting the class (0% - 2%) value (9), while setting the category with regression ratio between (2% - 8%) value (8), while class (8% - 16%) Value (7), followed by class (16% - 30%) value (5), the last class with lowest rate from (value 30%) (2), as shown in table (3) and figure (3)

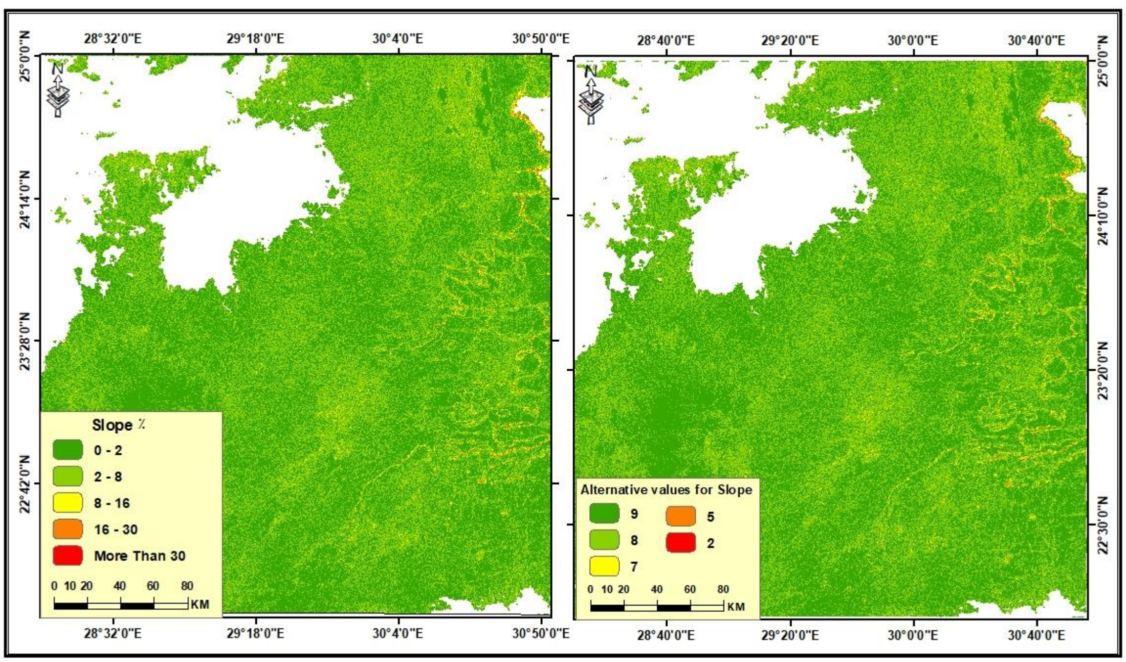



**Figure (3): Slope and reclassification**

### 2.3.2. Climatic Factors

#### 2.3.2.1. Temperature:

Generally, temperatures in the study area characterized by the fact that no value abnormality or significant difference from location to another. Thus, several factors create such a general temperature characteristic, including length of the day, number of sunshine hours, sunrays angle, as well as surfaces receiving sunrays. Therefore, the annual maximum temperature average 31.5 °C, with only 2°C different from lowest and highest degrees. Nonetheless, average annual temperature 15.6°C, which considered low value comparing with maximum temperature especially during summer, however, the reason of this different inland climate, which is usually more extreme. Winters may be very cold, and summers nights tend to decrease temperature. Also, very hot during day and moderate to cold through night, Figure (4-5).

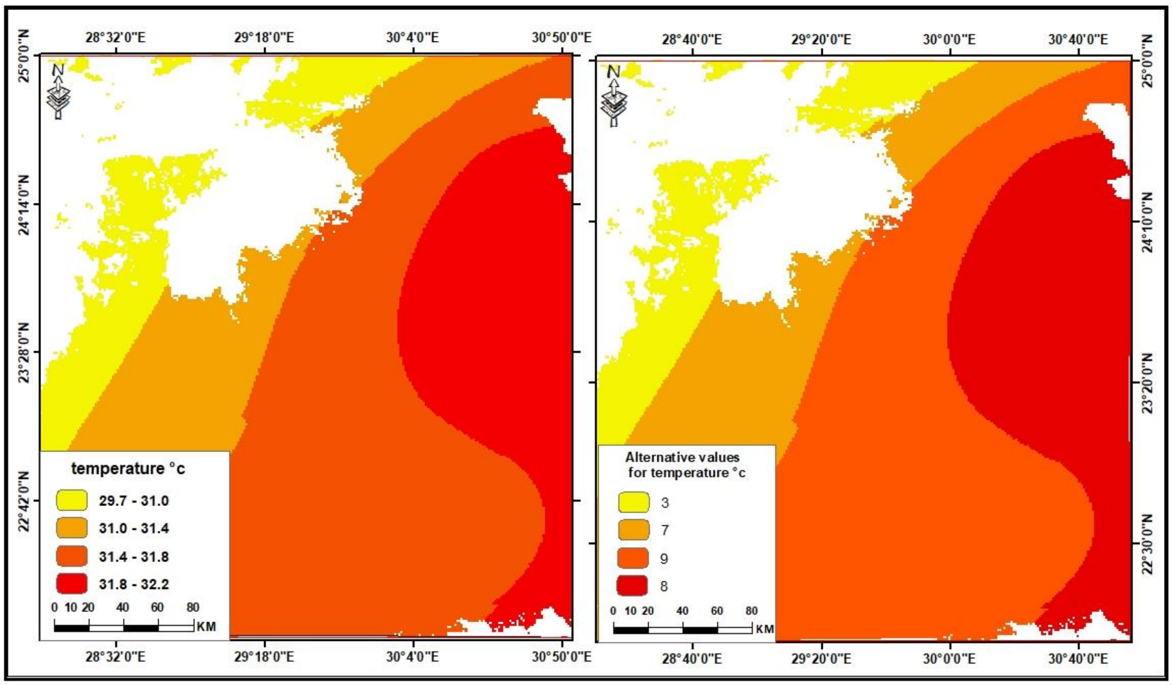



**Figure (4): Average Annual Maximum Temperature, from 1990 to 2020**

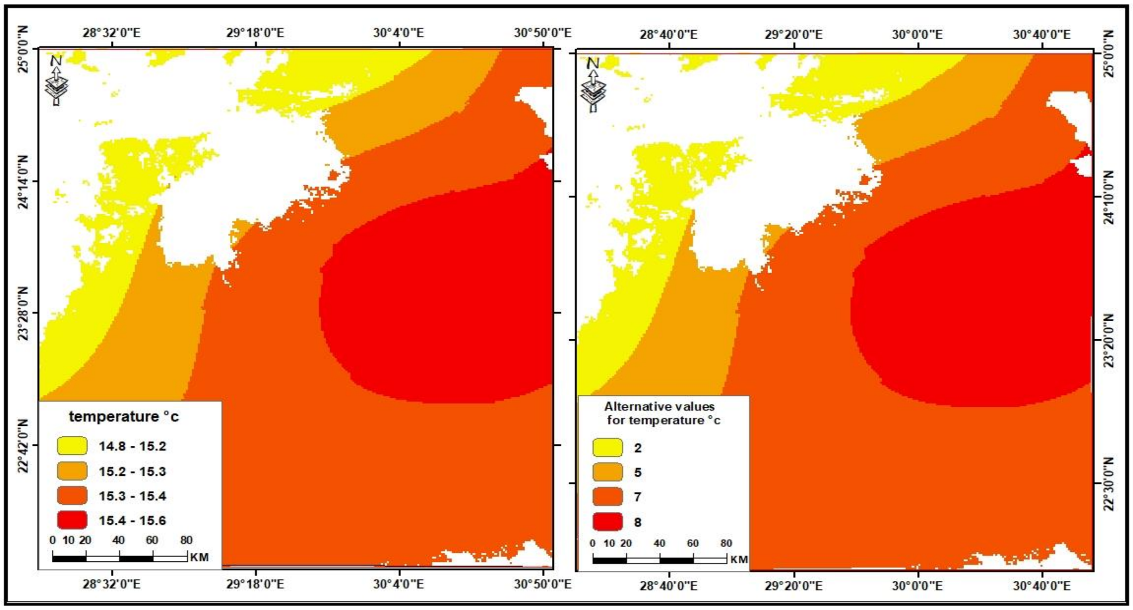



**Figure (5): Average Annual Temperature, from 1990 to 2020**

### 2.3.2.2. Relative Humidity

Relative humidity indicates the amount of water vapor in the atmosphere is inversely proportional to the pressure of water vapor, furthermore, directly affects various precipitation forms. The remarkable recorded months are the winter and summer months, and it rises in the winter months as a result of high air pressure, and decreases during the summer due to the scarcity of the water source in the study area, in addition to low pressure and high temperatures. It reaches its annual maximum in the north, reaching 42%, and decreasing with the direction to the south, to record 24%. Figure (6).

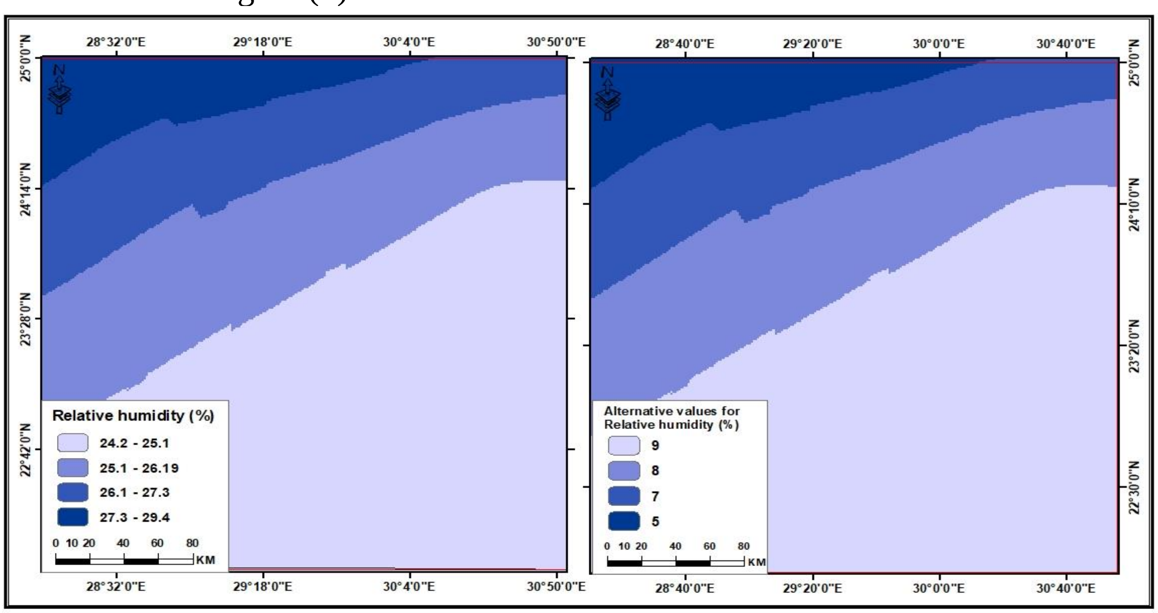



**Figure (6): Average Annual Relative Humidity, from 1990 to 2020**

### 2.3.3. Field Survey and soil Analysis

Field surveys were conducted to 37 soil profiles, one hundred and twenty representative soil samples were taken from all soil profile. The depth of soil profiles ranges through field study from 12/12/2021 to 18/12/2021, moreover, located these profiles with GPS combined data. Soil characteristics were used to support the productive capability of the soil. Therefore, a set of criteria has been used to determine the impact of each individual element. Hence, this elements as follow:

**1- Soil texture** **2- EC** **3- pH** **4- CaCO3**
**5- OM** **6-Gypsum** **7- CEC** **8- Soil Depth**


Source: Field study, December 2021

**Photo (1) Field work, making measurements, excavating Profile and taking soil samples**

The key soil limiting factors in the study area were identified to be high salinity, increased sodium saturation, poor drainage, calcium carbonate, and rough soil texture. (El Behairy et al, 2022).

The represented paper carried out a series of processes representing the different elements of the spatial model's construction. Interpolation process, is one of the mathematical methods by which unknown values that fall between known values are estimated. The basic assumption of spatial fulfilment is that the points close to each other are more similar than those far away; Values are estimated based on the nearest point value, and to extract a set of new layers showing the spatial distribution of soil (Mechanical and Chemical Analyses) such: texture, salinity, pH, calcium carbonate, organic matter, cationic exchange capability, cross-sodium ratio, gypsum ratio and sector depth, requiring conversion of field measurements to a continuous surface.

**2.3.3.1. Salinity (EC):**

Soil salinity is one of the most important determinants of soil capability and production in dry and semi-dry soil. The presence of high concentrations of dissolved salts limits the plant's ability to absorb water from the ground solution. World Food and Agriculture Organization's Salinity index (Sideruis, 1984 and FAO,1985), used to identify different salinity categories. Hence, comparing these classification categories with the average salinity concentration of the soil sectors of the study area, the average concentration was found to be between (0.82 -10.9) ds /m, divided into four categories shown in the table (4), these categories were then reclassified and alternative weight values were taken to reflect their relevance or impact, as reflected in the figure (7)

**Table (4): Distribution of soil categories with different salinity grades and reclassification**

| Salinity classification according to (Sideruis,1984 and FAO,1985) | | | In-program classification | |
|---|---|---|---|---|
| Soil Category | EC(ds/m) | Grade | Actual Values | Alternative value |
| Too high. | 0 – 2 | I | 0 – 2 | 9 |
| High | 2.1 - 4.0 | II | 2 - 4 | 8 |
| Medium | 4.1 - 8.0 | III | 4 - 8 | 7 |
| Low | 8.1 - 16.0 | IV | 8 - 14.8 | 4 |
| Very low | Larger than 16 | V | ------ | ------ |

Source: Researcher's work based on chemical analysis and classification (Sideruis, and FAO).

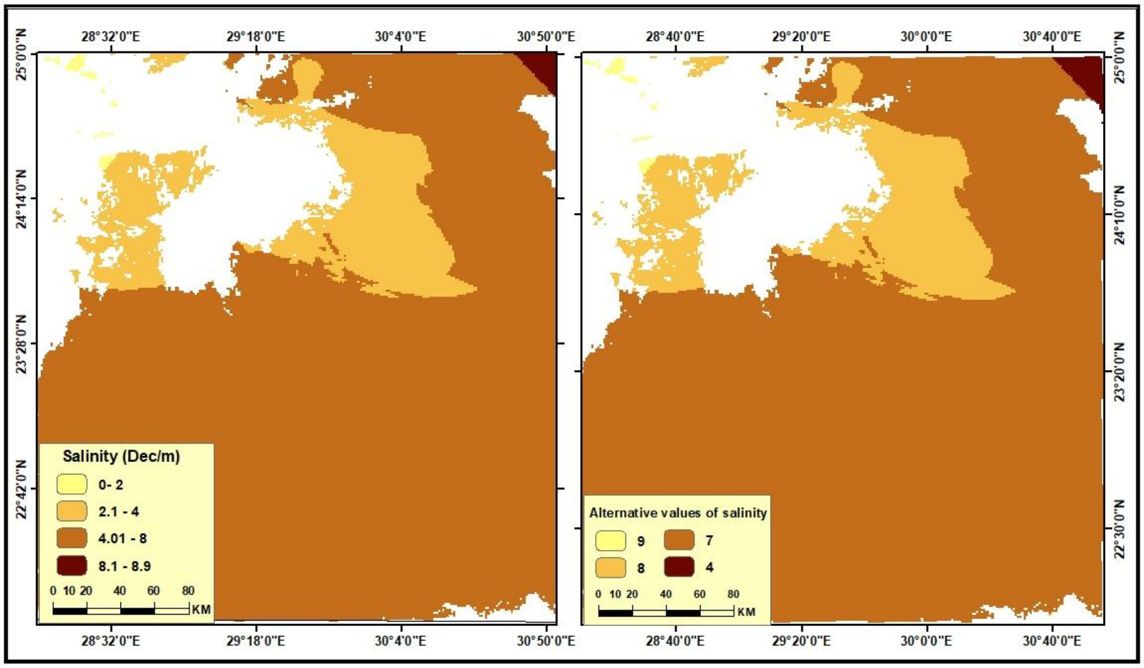



**Figure (7): Salinity distribution and reclassification of the study area's soil**

**2.3.3.2.Soil Depth:**

The effective depth of soil which roots can utilization moisture of soil, therefore, it is important selection for agriculture and the effective depth of the soil sector is determined by the presence of a ground water level or blocked soil that impedes roots growth that also blocks water infiltration through soil structure. Hence, the ideal depth of a well-drained homogenous soil is 120cm or more, where deep-sectoral soil spreads most of the roots of most crops below 60cm, while root spread is significantly lower for depths greater than 120cm. Generally, FAO Sector Depth Guide and CEDRESS (Sideruis, 1984 and FAO,1985), in determining the different depths of the soil sectors, based on the prevailing soil depth, this factor was classified into five categories, as shown in table (5) and figure (8).

**Table (5): Distribution and reclassification of the profiles of the different sectors of the soil**

| Classification of sector depth according to (Sideruis,1984 and FAO,1985) | | | In-program classification | |
|---|---|---|---|---|
| Production Capability Grade | Depth (cm) | Grade | Actual Values | Alternative value |
| Too high. | More than 120 | I | More than 120 | 10 |
| High | 120-80 | II | 120-80 | 9 |
| Medium | 50-80 | III | 50-80 | 8 |
| Low | 25-50 | IV | 25-50 | 6 |
| Very low | Less than 25 | V | Less than 25 | 5 |

Source: Researcher's work using ArcGIS10.4 based on chemical analysis and classification (Sideruis, and FAO)

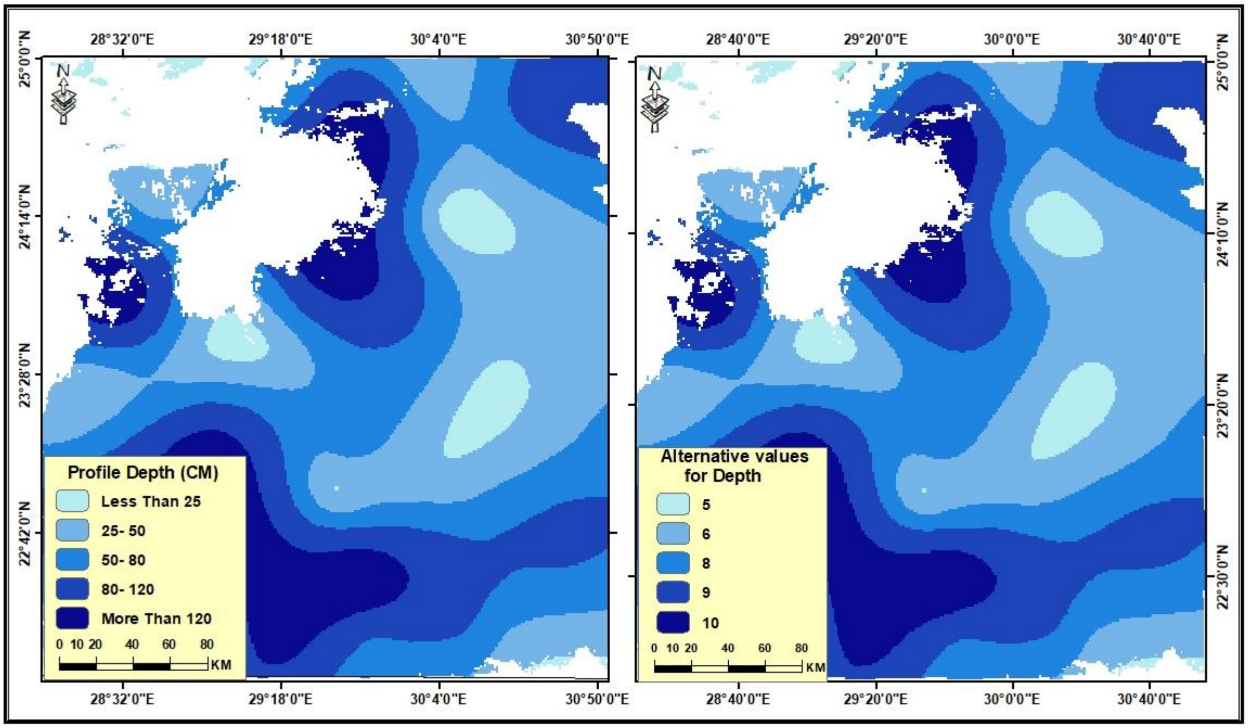



**Figure (8): Soil Depth Distribution and reclassification**

**2.3.3.3. Calcium carbonate (CaCO3):**

Calcium carbonate affects both the natural and chemical properties of the soil, and its effect depends on its concentration, condition and sizes. However, calcium carbonate presence vertically rarely affect the movement of water, but may prevent the roots movement and spread. According to FAO Calcium Carbonate Index (Sideruis, 1984 and FAO,1985) to give relative weights to each category; This factor's values were divided into five different categories and reclassified, as shown in the table (6) and figure (9).

**Table: (6) Distribution and reclassification of categories of $CaCO_3$**

| Classification of $CaCO_3$ according to (Sideruis,1984 and FAO,1985) | | | In-program classification | |
|---|---|---|---|---|
| **Production Capability Grade** | $CaCo_3$٪ | Grade | Actual Values | Alternative value |
| **Too high.** | Less than 8 | I | Less than 8 | 10 |
| **High** | 8-12 | II | 8-12 | 9 |
| **Medium** | 12-16 | III | 12-16 | 8 |
| **Low** | 16-35 | IV | 16-35 | 7 |
| **Very low** | Greater than 35 | V | More than 16 | 6 |

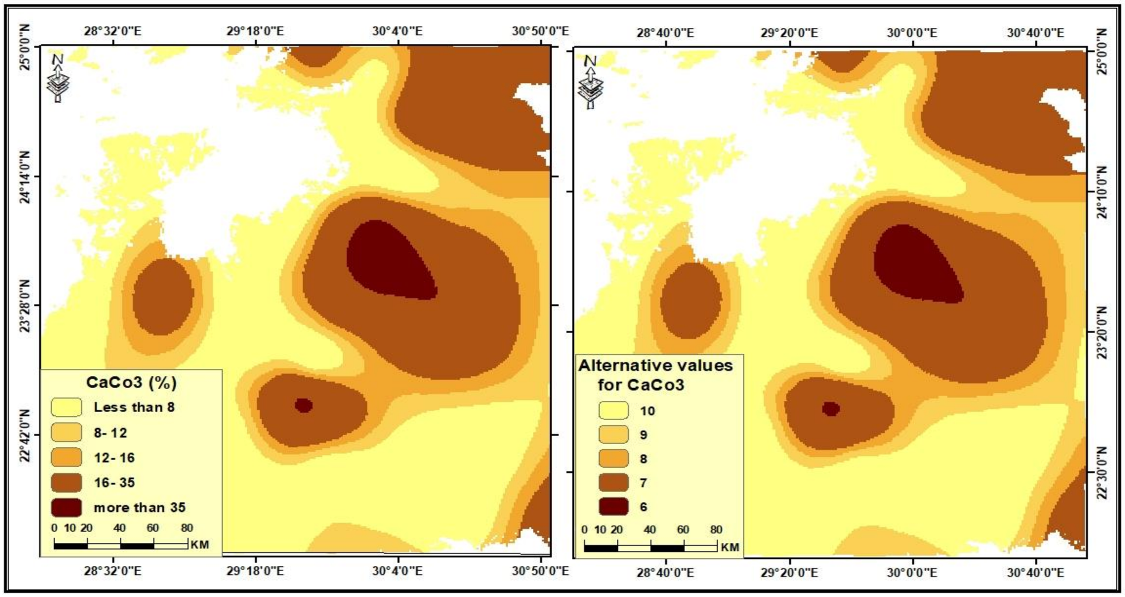



Figure (9): Calcium carbonate ratio Distribution and reclassification

### 2.3.3.4.Gypsum (CaSO4):

Gypsum is agricultural useful; It improves the state of soil construction, as a source of calcium, plant's nutrient and replaces mutual sodium in soils, so, it prevent soil degradation. This factor's values were divided into three different categories and reclassified, as shown in the table (7) and figure (10).

**Table (7): Distribution and reclassification of $CaSO_4$ categories**

| $CaSO_4$ | 0.5-0.8 | 0.8-1.7 | 1.7-3.2 | 3.2-5.1 |
|---|---|---|---|---|
| alternative value | 5 | 6 | 7 | 8 |

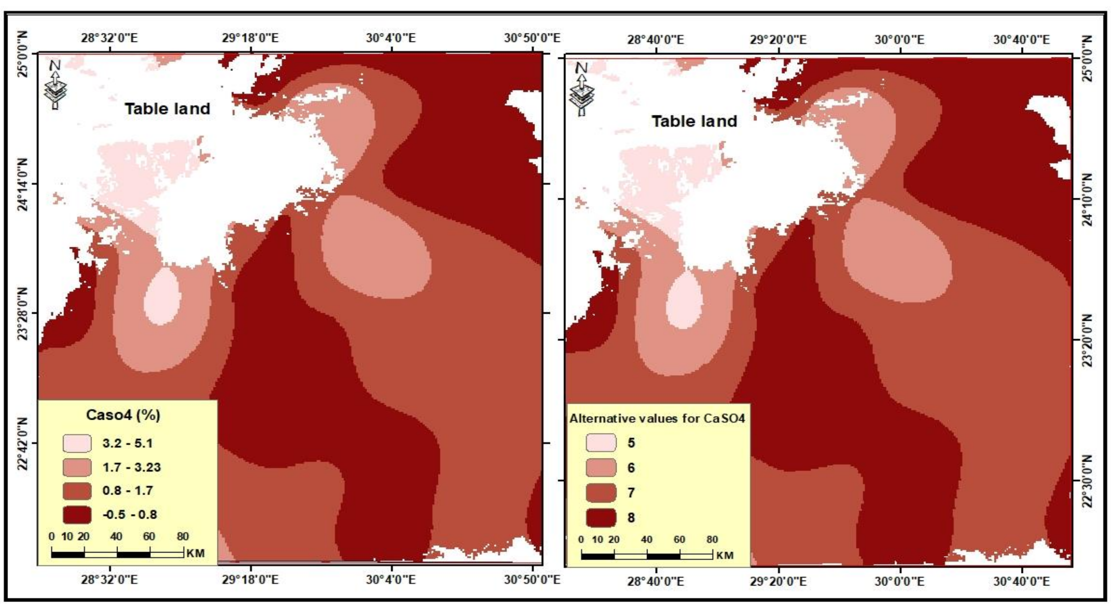



Figure (10): Distribution of $CaSO_4$ and reclassification

**2.3.3.5. The acidity number (pH):**

Acidity number (pH) is an important characteristic of soil; as each type of plant has certain limits of acidity number in order to grow normally, and the activity of micro-organisms is closely related to the acidity number of the soil, in addition to that it directly affects the facilitation of nutrients and thus soil fertility. This number indicates the acidity or basicity of the soil (Abdel-Aal et al., B.T., p. 141). The acidity figure reflects the state of saturation with sodium and the presence of alkaline carbonate in the soil, and it has a significant effect on the viability of nutrients. Usually, a pH number greater than 8.5 indicates an increase in the percentage of saturation with exchanged sodium than 15% and the presence of sodium carbonate, while in the case of a pH number lower than 7.5, the soil does not contains dissolved carbonates and reduces the proportion of exchanged sodium.

Categories of pH relied on Acidity and Alkalinity Index of the United States Department of Agriculture (United States Department of Agriculture, 1998), in determining the different alkalinity categories.This factor was classified into three different categories: neutral lands with a pH concentration less than 7.3, which is the best category of lands, and reclassified (Reclassify) by giving all lands in this category an alternative numerical value (9), and low alkalinity lands reclassified By giving them alternative values (7), and the alkaline medium lands were given the alternative value (6) after their classification, and this is evident from the table (8) and Figure (11).

**Table (8): Distribution and reclassification of acidity and alkaline categories of the soil**

| pH classification according to USDA | | | In-program classification |
|---|---|---|---|
| Classification | Category | Actual Values | Alternative value |
| Very acidic | 3.5-4.4 | - | - |
| Very acidic | 4.5-5.0 | - | - |
| Extremely acidic | 5.1-5.5 | 5.1-5.5 | 5 |
| Average acidity | 5.6-6.0 | 5.6-6.0 | 6 |
| Low acidity | 6.1-6.5 | 6.1-6.5 | 7 |
| Equal | 6.6-7.3 | 6.6-7.3 | 8 |
| Low alkaline | 7.4-7.8 | 7.4-7.8 | 8 |
| Average alkaline | 7.9-8.4 | 7.9-8.4 | 10 |
| Highly Alkaline | 8.5-9 | - | - |

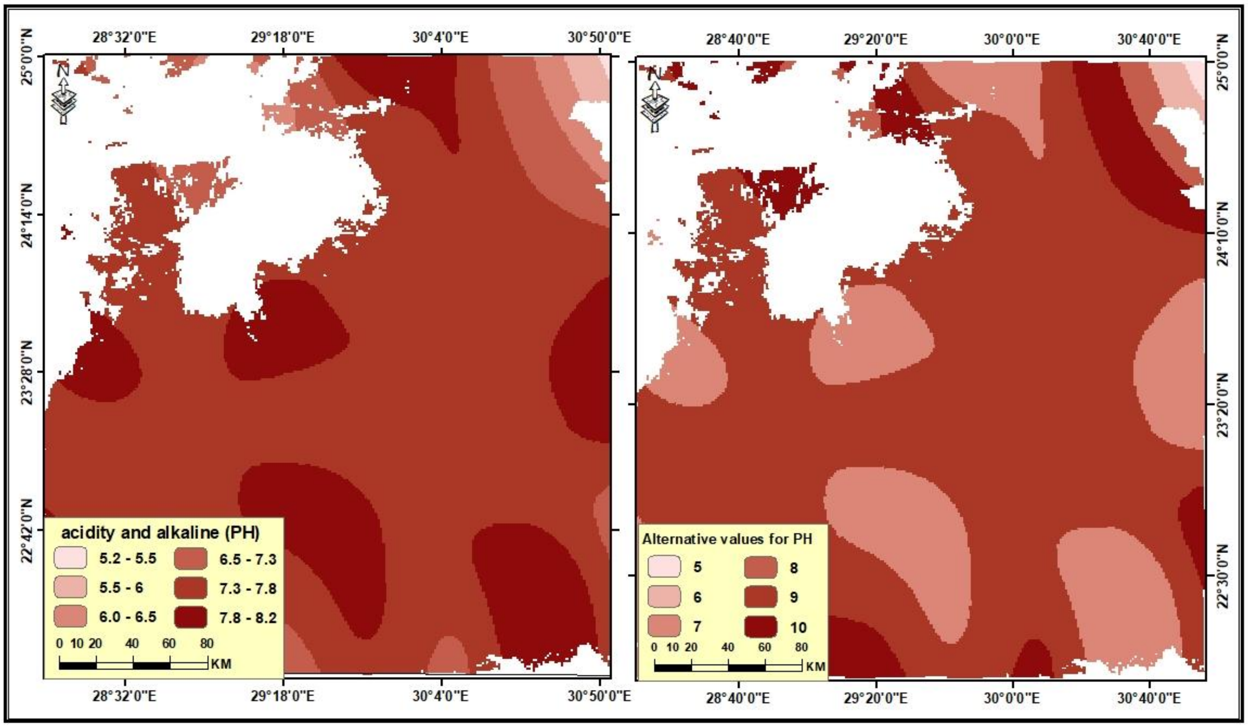



**Figure (11): Distribution and reclassification of acidity and alkalinity of the study area**

### 2.3.3.6.Organic matter (OM) :

In General, overall sample values of the abovementioned micronutrients were in deficiency ranges. However, their contents in desert soils mainly depend on the rock derived from the parent materials and the prevailing weathering processes in the region (Al-Soghir, 2022). Organic content of the soil greatly affects productive capability of the soil, because, it provides many nutrients necessary for plants, as organic matter is the main source of nitrogen in the soil, adding, it was classified into five categories, so the category in which the percentage of organic matter as shown from Table (9) and Figure (12).

**Table (9): Distribution of the categories of (OM%) and its reclassification**

| Actual values | 0.02-0.22 | 0.22-0.45 | 0.45-0.76 | 0.76-1.29 |
|---|---|---|---|---|
| Alternative value | 5 | 8 | 9 | 10 |

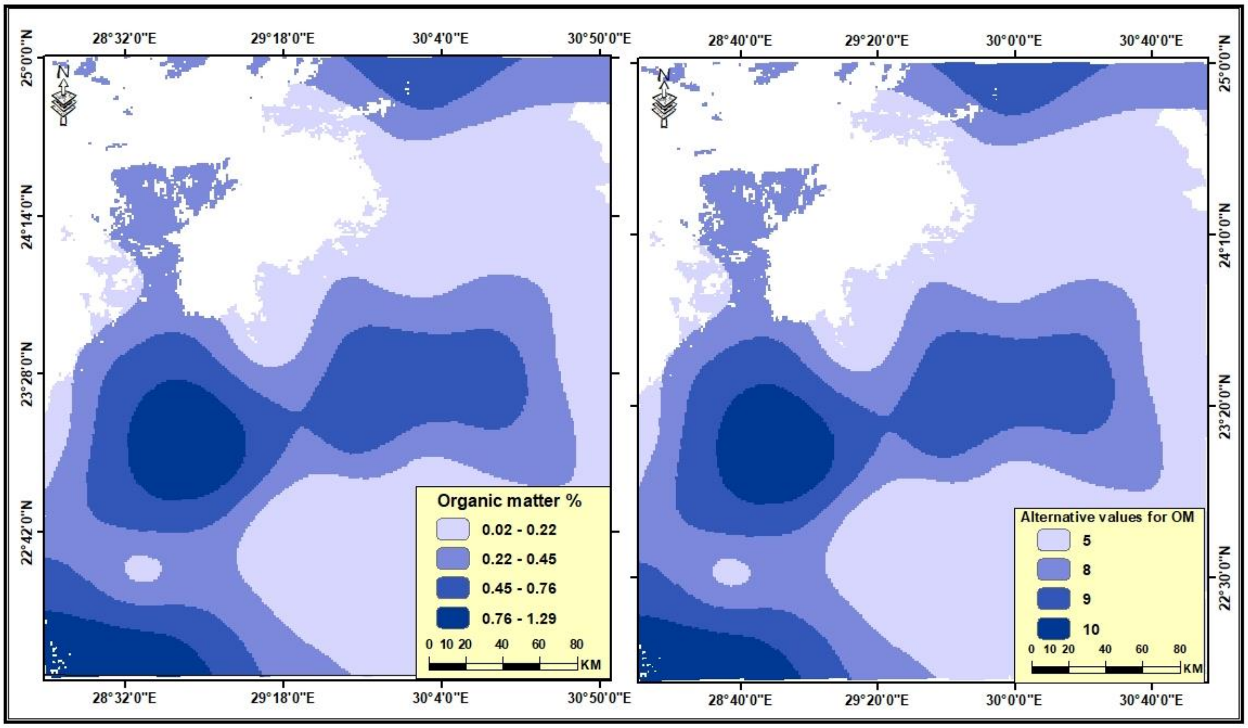


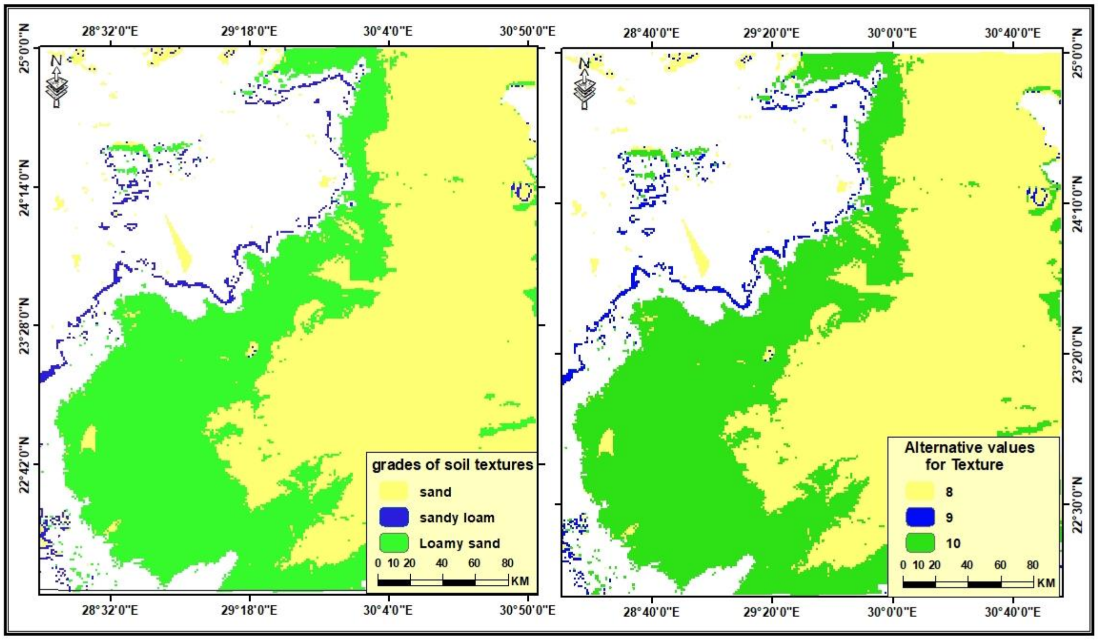

**Figure (12): spatial distribution of the categories of (OM%) and its reclassification**

### 2.3.3.7. Soil Texture

Soil Texture is indicates soil natural quality. It affects many physical properties such as moisture, infiltration, ability to retain nutrients and minerals, also, texture of soil affect organic content and calcium carbonate. The validity index of (Sys, 1979, Sys and Verheye, 1978) was used to determine the relative weights for each grade of texture; As it was divided into three different categories and reclassified, as shown in the table (10) and figure (13),texture degree of sandy loam soil took (9), while loamy sand soil took (10), and sandy soil (8).

**Table (10): Distribution of different grades Texture and its reclassification**

| Actual values | sandy | sandy loam | loamy sand |
|---|---|---|---|
| Alternative value | 8 | 9 | 10 |




**Form (13): Distribution of different grades Texture and its reclassification**

### 2.3.3.8. Cation exchange capacity (CEC):

Cation exchange capacity is important properties in soil from a chemical point of view. The ion exchange process and the exchange capability are due to the clay and the organic matter the soil as it has an amphoteric property and appears from its ability to bind both positive cations and negative anions. CEC have negative charges on their surfaces, with lower effect of positive charge, although, soil carry both types of charges, yet the net charge is negative. As shown (11) and figure (14).

**Table (11): Distribution of soil classes with the ratio of CEC and its reclassification**

| Classification of Cation Exchange Capacity according to (Sideruis,1984 and FAO,1985) | | | In-program classification | |
|---|---|---|---|---|
| **Production Capability Grade** | CEC(meq/100G) | Grade | Actual Values | Alternative value |
| **Too high.** | More than 24 | I | 24-34 | - |
| **High** | 16-24 | II | 16-24 | - |
| **Medium** | 12-16 | III | 12-13.9 | 9 |
| **Low** | 6-12 | IV | 6-12 | 8 |
| **Very low** | Less than 6 | V | 0.7-6 | 6 |

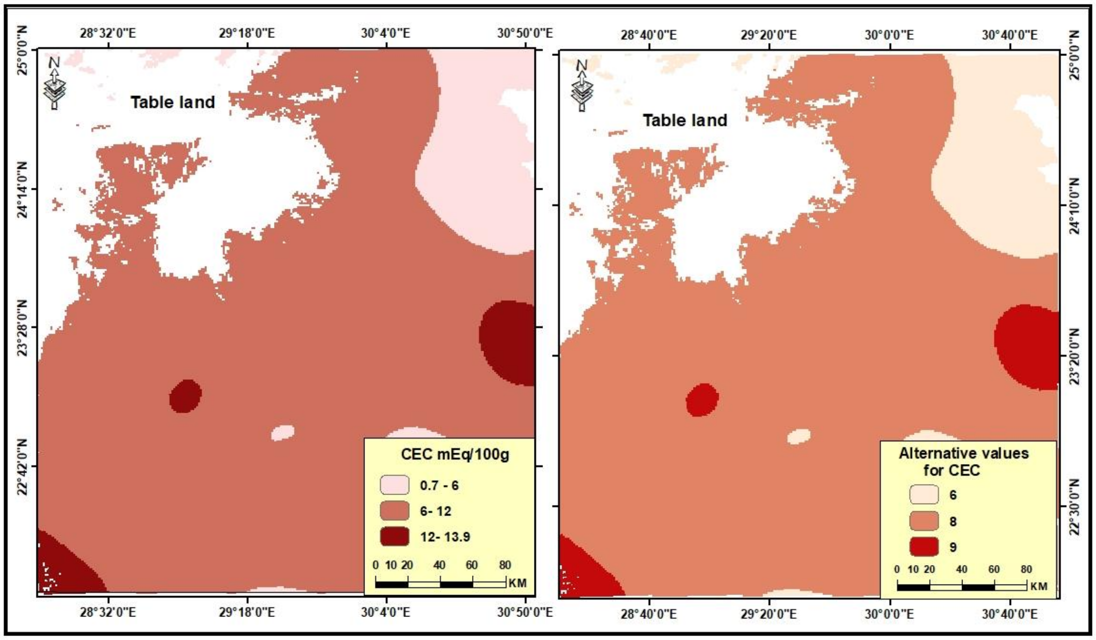



**Figure (14): Spatial distribution of the cation exchange capacity and its reclassification**

## 2.4. Building model Structure:

The spatial analysis model of the productive capability of the soil of the study area went through five basic stages. Data and visualization for the study area data input collected at the initial stage, followed by the second Stage, which was the harmonization of such data within the GIS templates, and then processing. The modelling and data analysis Stage followed, and then ended with a set of outputs representing the capability variables scores of the study area's soil.

Model was processed and built, followed by a series of processes, such as reclassification of all the model inputs, and then these layers were collected through the work (Weighted Overlay) so that the best relative weights of all layers would be discouraged, and this can be explained as follows:

### 2.4.1. Weighted overlay

At this stage, all layers grouped and weighted, in order to collect the best qualities of all layers that were reclassified, and weight was given to each of these layers according to the importance of each element, provided that the sum of the weights of the layers (100% or 1 %), and Table (12) shows the weights of the layers according to their importance, and the process of giving weight here is a relative process that depends on the user's experience and his vision of the importance and effectiveness of one element over another, and the product of this process is a number of layers containing four categories that represent the best lands, representing soil capability.

**Table (12): distribution of percentages for each of the criteria used in building the model**

| m. | Class | Weight% | m. | Class | Weight% |
|---|---|---|---|---|---|
| **1** | EC | 5 | 7 | Organic Mater | 10 |
| **2** | PH | 15 | 8 | Gypsum | 10 |
| **3** | Texture | 10 | 9 | CEC | 5 |
| **4** | Profile Depth | 10 | 10 | Slope | 5 |
| **5** | Calcium carbonate | 10 | 11 | Average Annual Maximum Temperature | 5 |
| **6** | Humidity | 10 | 12 | Average Annual Temperature | 5 |
| **Total** | | 100% | | | |

Source: Researchers work based on ArcGIS 10.4

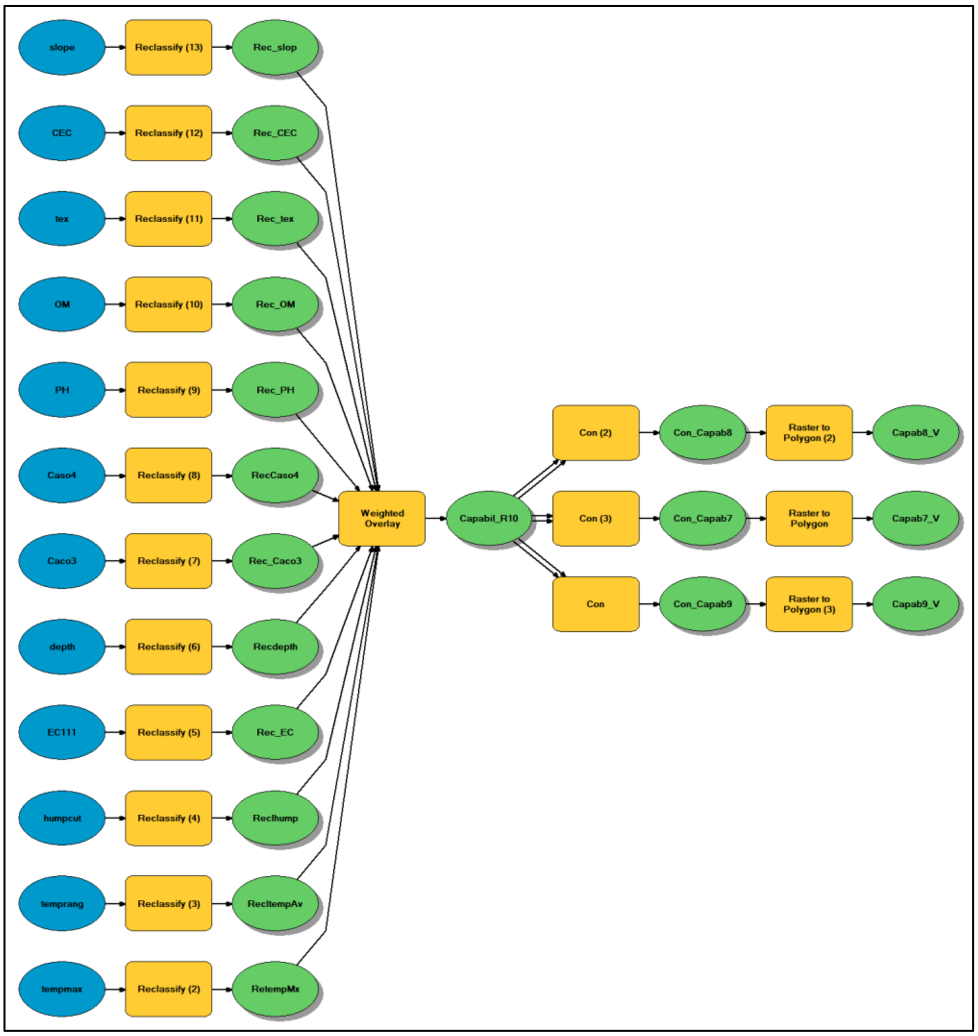



**Figure (15) Spatial- climate Model Structure**

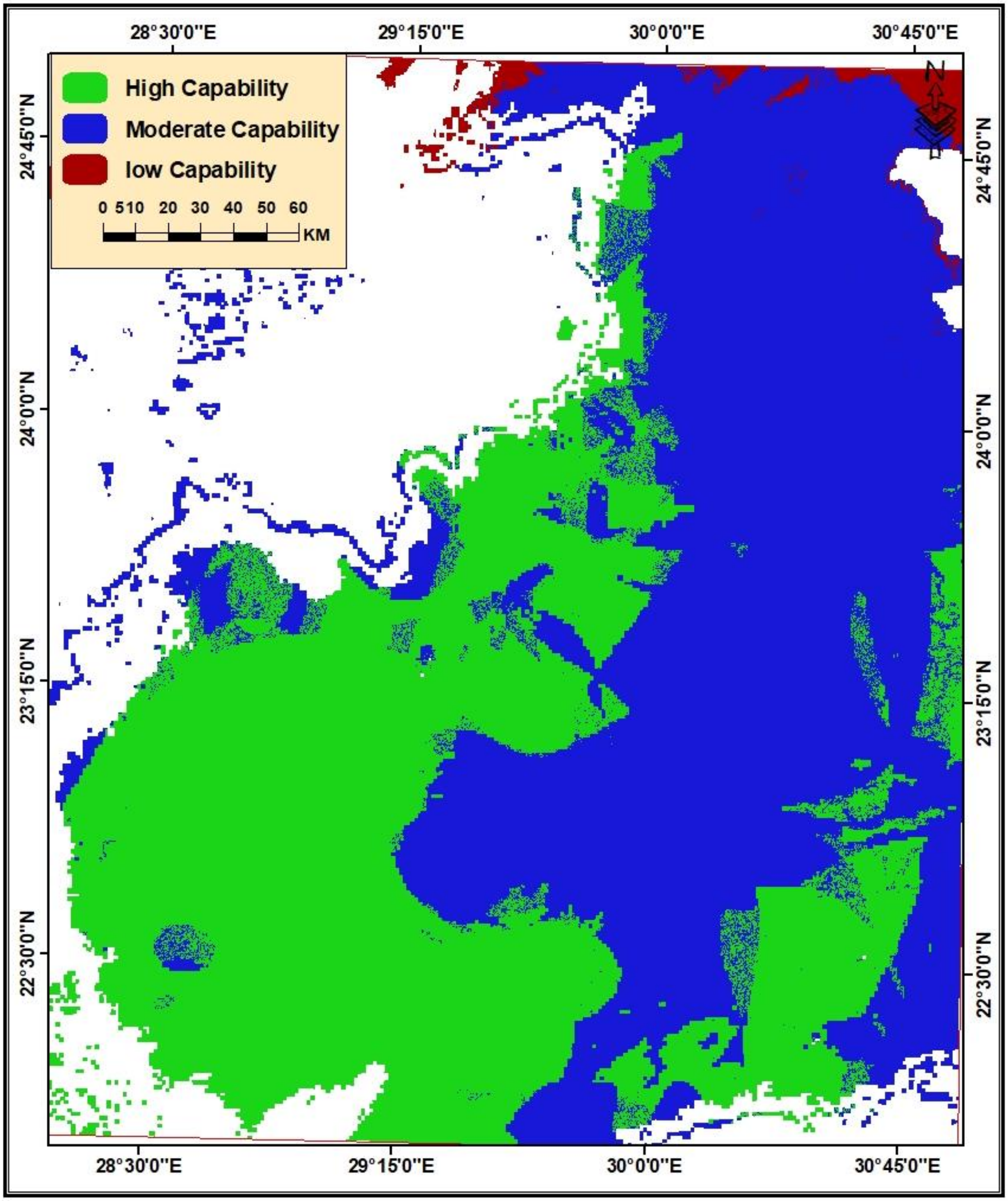



**Figure (16) Soil capability extracted from spatial model**

## 3. Result and Discussions:

Geomatics technique allow various methods of the spatial variability for soil properties include geostatistics approaches based on measurements at adjacent locations with certain weights assigned to each measurement, however, weighted overlay process was the main process that all inputs could be masked according to each layer weight and important. Nonetheless, overlay methodology is a very flexible tool depends on data inputs quality and understanding for each layer important from the model scope perspective.

Physical and chemical conditions of the soil will change due to accumulation of toxic specific ions Na, Mg and Cl in soil solution that will raise the osmotic potential
of the soil solution FAO (1988), the increase in calcium concentration in solution leads usually to a drop in potassium uptake by plants. Similarly, the increase in calcium concentration could lead to a drop in magnesium uptake. In general, relationship between Ca, Mg and K is related to texture, organic matter and the type of clay in the soil (Mohammed M. Sherif, 2016).

Therefore, final output layers represent the soil capabilities for further agricultural development west of Toshka, with consideration to climatic variables, topography characteristics and soil chemical elements. The proposed potential land for high capabilities suitability for agricultural development reaches 28744.2 km2 and 34167.7 km2 for moderate capability then comes low capability class with the lowest area 1059.4 km2, as shown in (table 12) and (figure 16). Nearly half of the study area recognized as moderate soil capability, which known as limitation of agricultural potentiality unless intensive soil conservation and chemical supplementary.

**Table (12):** The spatial distribution of the degrees of capacity of the soil of the study area

| m. | Class | Area ($KM^2$) |
|---|---|---|
| 1 | High Capability | 28744.2 |
| 2 | Moderate Capability | 34167.7 |
| 3 | Low Capability | 1059.4 |
| Grand Total | | 63971.3 |

West Toshka is a hyper arid region due to water absence, nonetheless, these dry condition and soil with low organic matter in general will be a limitation for any agricultural expansion. However, many agricultural activities was established around the study area, which indicate the ability to sustain agricultural process there with supportive tools. Despite, the capability classes are high to low classification, but, high capability classification is relative according to study area local characteristic.

**Appendix (1)**: Chemical properties of the soil profiles of the study area

| N.Profile | Depth (CM) | EC (ds/m) | CaCO3 % | Gypsum % | Texture |
|---|---|---|---|---|---|
| 1 | 0-20 | 8.36 | 3.18 | 0.68 | LS |
| | 20-30 | 7.23 | 3.10 | 1.30 | LS |
| | 30-150 | 6.25 | 3.86 | 1.41 | S |
| 2 | 0-10 | 1.88 | 5.16 | 0.82 | LS |
| | 10-20 | 1.03 | 9.63 | 0.81 | LS |
| | 30-150 | 0.33 | 2.66 | 3.63 | LS |
| 3 | 0-15 | 0.95 | 1.37 | 2.57 | S |
| | 15-25 | 0.73 | 1.12 | 1.96 | S |
| | 25-150 | 0.35 | 1.29 | 0.55 | S |
| 4 | 0-10 | 0.67 | 1.03 | 0.53 | LS |
| | 40106.00 | 0.83 | 6.36 | 0.74 | LS |
| | 20-150 | 1.26 | 8.05 | 0.82 | LS |
| 5 | 0-5 | 0.47 | 5.30 | 1.24 | LS |
| | 5-10 | 0.29 | 1.72 | 0.79 | S |
| | 10-150 | 0.33 | 1.72 | 1.03 | S |
| 6 | 0-15 | 0.33 | 1.72 | 1.23 | S |
| | 15-30 | 0.33 | 1.72 | 1.39 | S |
| | 30-80 | 0.26 | 9.34 | 1.28 | S |
| 7 | 0-21 | 0.17 | 9.34 | 0.73 | S |
| | 21-60 | 0.17 | 9.34 | 1.23 | S |
| | 60-90 | 0.17 | 9.34 | 1.39 | S |
| | 90-120 | 1.8 | 4.30 | 0.44 | S |
| 8 | 0-15 | 0.34 | 16.33 | 0.50 | S |
| | 15-70 | 0.69 | 27.51 | 1.00 | S |
| 9 | 0-40 | 0.43 | 12.30 | 0.83 | S |
| 10 | 0-25 | 0.17 | 36.19 | 0.18 | S |
| 11 | 0-20 | 0.64 | 43.84 | 5.59 | LS |
| | 20-40 | 0.29 | 3.01 | 1.82 | SL |
| 12 | 0-25 | 0.5 | 2.75 | 0.43 | S |
| | 25-65 | 0.63 | 2.58 | 0.34 | S |
| 13 | 0-20 | 4.00 | 1.55 | 1.23 | S |
| | 20-80 | 2.40 | 1.11 | 1.39 | S |
| | 80-120 | 1.42 | 2.14 | 2.29 | S |
| 14 | 0-30 | 1.42 | 0.95 | 0.53 | S |
| | 30-60 | 1.42 | 0.95 | 0.74 | S |
| | 60-80 | 0.17 | 0.95 | 0.82 | S |
| | 80-95 | 0.17 | 5.59 | 0.28 | S |
| 15 | 0-40 | 0.35 | 2.90 | 0.49 | S |
| | 40-60 | 0.43 | 6.02 | 0.97 | S |

| | | | | | |
|---|---|---|---|---|---|
| 16 | 0-20 | 0.23 | 0.43 | 0.48 | S |

Source: The work of researchers based on the results of laboratory analysis of soil profiles

*(SL) sandy loam, (LS) loam sandy, (S) sandy.

**Continued Appendix (1)**: Chemical properties of the soil profiles of the study area

| N.Profile | Depth (CM) | EC (ds/m) | CaCO3 % | Gypsum % | Texture |
|---|---|---|---|---|---|
| 17 | 0-10 | 0.18 | 4.47 | 0.90 | LS |
| | 10-40 | 0.58 | 1.21 | 1.01 | SL |
| 18 | 0-20 | 0.11 | 2.58 | 0.94 | S |
| 19 | 0-40 | 0.21 | 19.51 | 0.81 | LS |
| 20 | 0-12 | 0.1 | 5.90 | 9.10 | S |
| | 12-45 | 0.2 | 2.40 | 3.66 | S |
| 21 | 0-45 | 0.13 | 1.06 | 0.20 | SL |
| | 45-80 | 0.17 | 3.87 | 0.89 | SL |
| 22 | 0-23 | 0.17 | 40.14 | 0.51 | S |
| | 23-30 | 0.15 | 35.42 | 0.28 | S |
| | 30-90 | 0.15 | 35.42 | 1.28 | S |
| 23 | 0-20 | 0.17 | 33.10 | 1.30 | S |
| 24 | 0-40 | 0.6 | 3.86 | 1.41 | S |
| | 40-90 | 0.1 | 5.16 | 0.82 | S |
| 25 | 0-17 | 0.28 | 1.12 | 1.96 | LS |
| 26 | 0-37 | 0.52 | 1.29 | 0.55 | S |
| 27 | 0-20 | 0.46 | 1.03 | 0.53 | S |
| | 20-70 | 0.87 | 6.36 | 0.74 | S |
| 28 | 0-15 | 0.64 | 18.05 | 0.82 | S |
| | 15-50 | 1.88 | 15.30 | 1.24 | S |
| | 50-120 | 2 | 1.72 | 0.79 | S |
| 29 | 0-15 | 0.16 | 6.33 | 1.03 | S |
| | 15-45 | 0.16 | 6.33 | 0.82 | S |
| 30 | 0-20 | 0.39 | 19.34 | 1.28 | S |
| | 20-50 | 1.12 | 29.48 | 0.73 | S |
| 31 | 0-10 | 0.28 | 14.96 | 1.03 | S |
| | 10-30 | 0.28 | 12.30 | 0.83 | S |
| 32 | 0-12 | 0.4 | 11.09 | 1.00 | LS |
| | 12-40 | 2.41 | 17.88 | 1.11 | LS |
| 33 | 0-25 | 0.17 | 50.72 | 1.29 | S |
| | 25-45 | 0.95 | 3.61 | 1.06 | S |
| | 45-90 | 3.7 | 5.85 | 0.16 | S |
| 34 | 0-25 | 0.17 | 36.10 | 0.82 | S |
| | 25-45 | 0.95 | 36.19 | 0.18 | LS |
| | 45-90 | 3.7 | 43.84 | 5.59 | LS |
| 35 | 0-25 | 0.53 | 3.01 | 1.82 | LS |
| | 25-70 | 1.73 | 2.75 | 0.43 | LS |
| | 70-110 | 0.57 | 2.58 | 0.34 | S |
| 36 | 0-40 | 0.45 | 1.55 | 2.23 | S |
| | 0-10 | 0.19 | 1.11 | 5.33 | S |

| | | | | | |
|---|---|---|---|---|---|
| 37 | 10-45 | 0.26 | 2.14 | 0.29 | S |

Source: The work of researchers based on the results of laboratory analysis of soil profiles

*(SL) sandy loam, (LS) loam sandy, (S) sandy.

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