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Evaluation of Land Capability Index for Some Soils in South El-Hussinia Plain Region, Egypt, by Integrated Use of Gis and Remote Sensing Techniques.

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Abstract

The area includes the South El-Hussinia Plain of Egypt between latitudes 30° 55' – 31° 05' N and longitudes 31° 55' - 32° 10' E, 13 soil profiles were dug. The study area is about 34684 ha., Supervised and unsupervised classification in the current study, it was applied on corrected images to identify main units, results showed 5 classes: arable lands, bare lands, urban, fish ponds and roads. The main goal of this study is to assess the land capability and evaluate soils for irrigated agriculture. Field survey was carried out to characterize each land unit. Thirteen soil profiles were dug in the field, morphologically described and sampled for laboratory analyses. The capability index was done using ALES program and GIS modeling. The utilized evaluation system was developed based on the mathematical modeling of different land evaluation parameters (soil physical and chemical). Interpolation of different soil characteristics was done to create different soil maps. The final capability index map was created through the overlaying process using the interpolated maps. The study area was classified as 22.60 % belongs to C2 (Good Soils) class, 14.91% fits in C3 class (Fair Soils) class, 11.92% belongs to C4 (Poor soils) class and 23.61% belongs to C5 class (Very Poor Soils) class. The study of the factors affecting the crop composition showed that the natural and human factors had a clear effect on the crop complex in the study area.

Keywords: Land capability, Land evaluation, El-Hussinia Plain, GIS and remote sensing.

Introduction

Increasing population pressure and changing human needs play a critical role in the competition for different uses for the same tract of land. Systematic land use planning is therefore needed to assure not only the improvement of the social conditions of the present but also the conservation of the environment for future generation. Moreover, land evaluation using a scientific process is important to assess the potential and constraints of a given land parcel for agricultural purposes **(Rossiter, 1996).** Land assessment is seen as a set of methodological guidelines rather than a land classification system, such as land capacity and land irrigation suitability **(FAO, 1976 and Van Lanen *et. al.*, 1992)**. Land evaluation is a utilization mapping to give the information for the sustainable agricultural production, managing land recourses, land capability and land suitability are various kinds of identifying land for specific land uses (**FAO, 2008; Tadesse and Negese, 2020 and Debesa et al., 2020).** There for, land evaluation is a tool for strategic land use planning. Building agricultural use and management system based on agro-ecological potential and restriction is the best way to achieve sustainability **(FAO, 1978).** The specific evaluation expresses the suitability of the specific ecosystem or crop and depends on land characteristics, rationalization of land use and planting patterns, and farming techniques **(Várallyay, 2011)**. Recently, the cruel-effects of land use on the environment and environmental sustainability of agricultural production systems have become a subject of concern. The problems of declining soil fertility, overexploitation of natural resources and unrestricted soil erosion are associated with intensive agriculture in developing countries **Lanen Van et al. (1992).** Land evaluation analysis would resolve these issues while providing better land-use options to the farmers. Successful development soil evaluation program requires a comprehensive inventory of chemical and physical resources and environment. These are the basic elements of a land evaluation for regional land use planning. The aim of land evaluation is to provide land management with information, which will improve the quality of land use decisions. Several systems for land evaluation in Egypt have been introduced.. However, the involved calculation methods were tedious and could subject results for errors. **Ismail et al. (2005)** suggested The Applied System for Land Evaluation (ASLE) in arid and semi-arid regions. They listed four major factors to define the land capability classification, which were: soil chemical and physical properties, environmental status, irrigation system and water qualities and soil fertility.

Remote sensing technology provides a viable alternative to traditional field work because of its large area coverage, multi-spectral information and almost continuous observations. Some of the important applications of remote sensing technology are agriculture, geology and hydrology **(KarlsonandOstwald, 2016).** Remote sensing products play an indispensable role in many applications, such as: carbon emission monitoring, forest monitoring, medical science and epidemiological research, land change detection, natural disaster assessment, agriculture and water/wetland monitoring, climate dynamics and biology Diversity research **(Khatami et al., 2016).** Process the data layer in the multi-standard evaluation to achieve suitability, which can be conveniently realized by using GIS. Remote sensing and GIS are used in many studies of land resource mapping and management in Egypt **(Mohamed et al., 2014 and Saleh and Belal, 2014). Ismail et al. (2005)** proved the usefulness of GIS in terrain parameter analysis, and the effectiveness of GIS and remote sensing integration in monitoring soil characteristics of land reclamation and mapping of potential soil units. Remote sensing (RS) data is not only used to estimate cropping system analysis and land use and land cover estimation in different seasons, but also to estimate biophysical parameters and indices **(Rao et al., 1996 and Panigrahy et al., 2006).** In addition, in the past four years, remote sensing and GIS have been increasingly used in multiple application areas, including land suitability assessment **(Hamzeh et al., 2014; El-Baroudy and Moghanm, 2014)**. The interpretation of soil quality and site information for agricultural use and management practices is integrated using geographic information systems **(FAO, 1991, 2007).**

The main purpose of this research is to (1) evaluate the land resources the south El-Hussinia Plain, Egypt, (2) evaluate the main land use restrictions and (3) prepare land capability map using GIS technology and ASEL. The study will help establish the decision-making framework and future planning of the study area.

Materials and Methods.

Description of the study area

The study area is located in the south El-Hussinia Plain of Egypt between latitudes 30° 55' – 31° 05' N and longitudes 31° 55' - 32° 10' E (fig. 1). It covers about 34684 ha (346.48 km2) and is located within El-Hussinia district and extended North up till Lake Manzala, East till Bahr El-Bakar drainage line and West towards El-Dakahlia Governorate (Mataria and Manzala). Huge areas of Lake Manzala bottom have been artificially dried to expose the fluvio-marine deposits. Such deposits have a heavy clay texture with young sediment origin. These young deposits resulted from the deposition of the suspended matter by the Nile into the foreshore lakes that are directly in connection with the sea. The young fluvio-marine deposits are covered with aeolian sand and loose-like deposits in stratified layers **(Said, 1993).** Topographically, the elevation of the area around 13 m above the mean sea level (a.m.s.l.). Figure 1 shows a map of the Nile Delta topography.

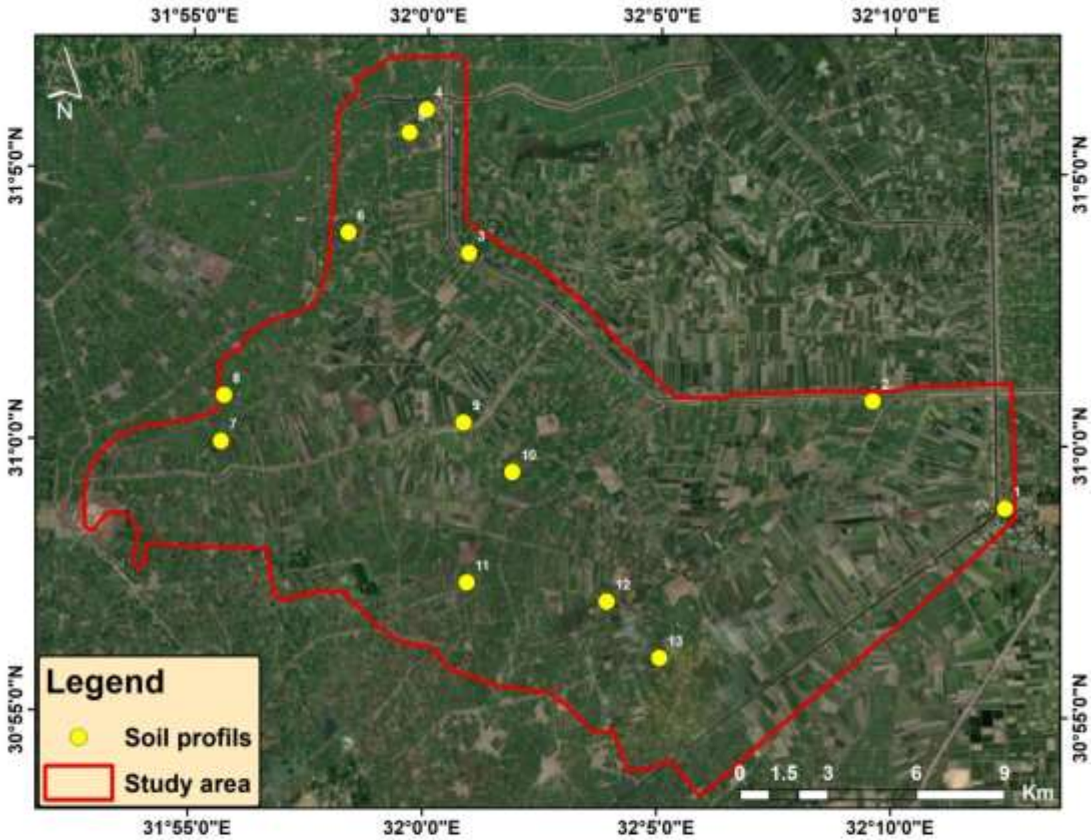

Fig.1. Location map of the study area.

Climate

According to the **Egyptian Meteorological Authority (2009),** The area is characterized by a climate of Mediterranean Sea with hot arid summer and little rain winter, the average temperature range is 13.8 °C to 28.8 °C. The highest monthly average temperature is 36.6 °C in July, while the lowest monthly average low temperature is 8.4 °C in January. Mean annual soil temperature is less than 22 ºC and difference between mean summer and mean winter temperatures is more than 5.0 ºC. Based on the nomenclature of the USDA Soil Taxonomy system **(USDA, 1975 and USDA, 2014)** the soil temperature regime is thermic and soil moisture regime is torric, except for soils of high-water table when the moisture regime is aquic. Precipitation is very low; the maximum monthly is 7 mm in January and February, and the period from May to September is the dry season. Water vapor in the atmosphere is generally related to air temperature and is called "the humidity". The relative measure of moisture in the air to the amount needed to saturate the air is known as relative humidity. The humidity varies from 42% in May to 56 % in January and December. Sun hours range between 14.3 h in January and 11.2 h in August. Meteorological data averages for 1999 to 2019 are given in Table 1 and Figure 2.

Table 1: Climatological data of El-Hussinia plain (1999- 2019).

Month	Temperature (°C)			Mean humidity (%)	Mean Rainfall(mm)	Sun hours(hours)
	Max.	Min.	Mean			
January	19.7	8.4	13.8	56.0	7.0	14.3
February	21.3	9.0	14.9	51.0	7.0	12.2
March	25.0	10.8	17.6	47.0	4.0	12.8
April	29.0	13.3	20.9	44.0	2.0	12.9
May	33.2	16.8	24.7	42.0	0.0	12.7
June	36.0	19.8	27.6	45.0	0.0	12.4
July	36.6	21.6	28.7	51.0	0.0	11.5
August	36.3	22.1	28.8	54.0	0.0	11.2
September	34.7	20.8	27.3	52.0	0.0	12.9
October	31.0	18.1	24.1	54.0	2.0	12.1

November	26.1	14.3	19.8	56.0	4.0	11.4
December	21.5	10.5	15.6	56.0	4.0	13.6
Mean	29.2	15.5	22.0	50.7	2.5	12.5

Data: (1999-2019) https://en.climate-data.org/africa/egypt/al-sharqia-governorate-2580/r/september-9/

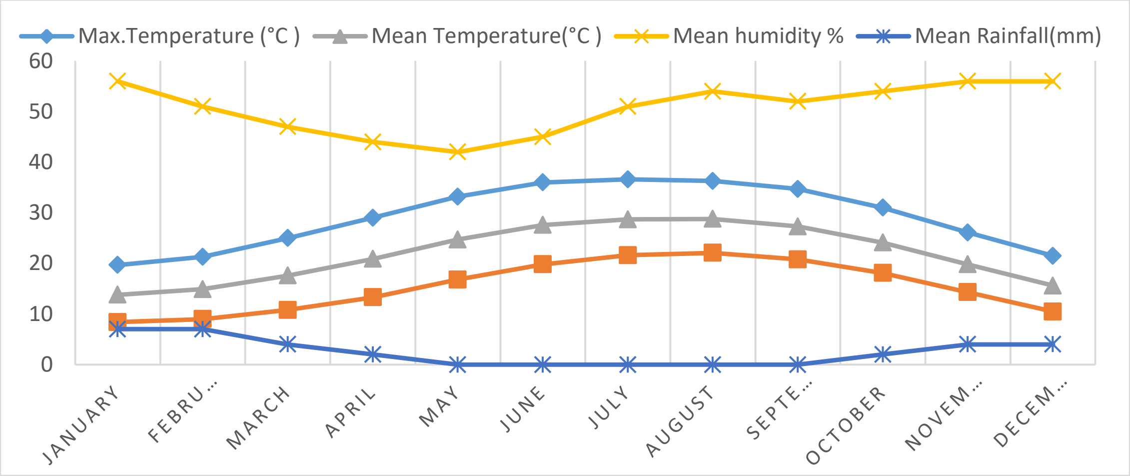

Figure 2: Climatological data of the studied area.

Geology.

Land of El-Hussinia plain belongs to the late Pleistocene which is represented by the deposits of the Neonile which lowering its course at a rate of 1m/1000 years **(Said, 1993).** The soils of El-Hussinia plain are characterized by the following geological units according to **(EGPA, 1987)** as shown in Figure 3: 1) Nile silt, 2) stabilized sand dunes and 3) sabkha deposits and marshes.

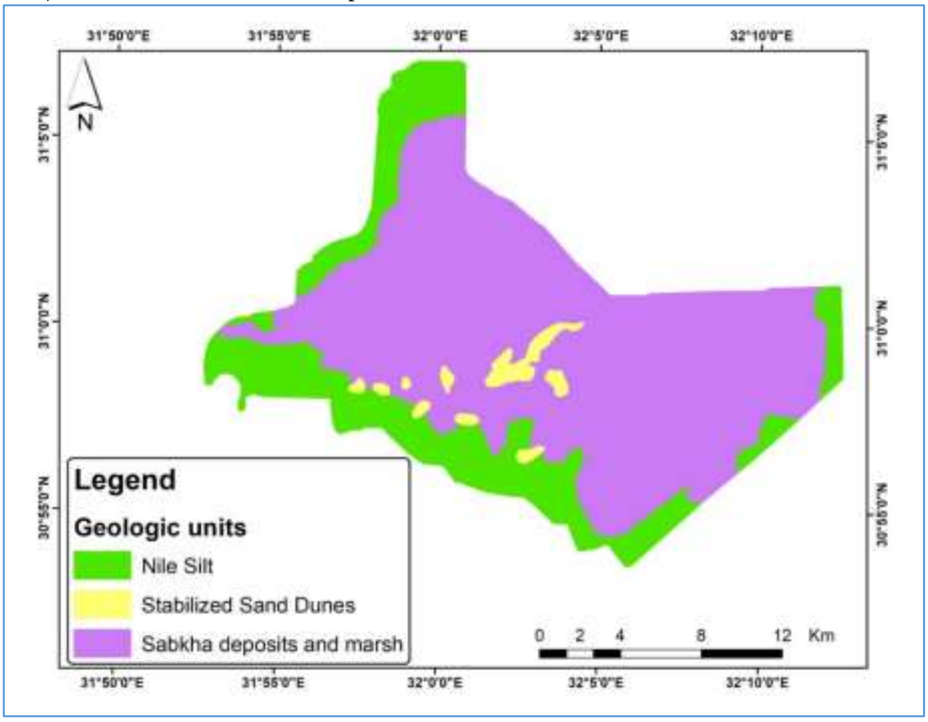

Figure 3: Geological map of south El-Hussinia Plain (After EGPA, 1987).

Geomorphology.

According to **Darwish et al. (2014),** El-Hussinia plain area was geomorphologically categorized into river terraces, clay flat and dried lake bed. These geomorphic units followed the high, moderate and low situated topography of the area, respectively. In addition, there were basin, depression and aeolian deposits whereas basin consisted of overflow basin and decantation one.

Digital image processing.

The remote sensing analyses used data from Landsat Data Continuity Mission (LDCM) sensor (Landsat 8) covering the study area acquired under clear sky conditions dated to the year 2023. All further digital image processing and analyses were executed using the standard approaches provided by the software ENVI 5.3 and Arc-GIS 10.3 software's **(ITT, 2009).** The digital image processing included bad lines manipulation by filling gaps module designed using IDL language, data calibration to radiance according to **Lillesand and Kiefer (2007).**

Soil survey and field work

A rapid reconnaissance survey was conducted throughout the investigated area in order to gain an appreciation of the broad soil patterns and landscape characteristics. Based on the pre-field interpretation and the information gained during the reconnaissance survey, thirteen soil profiles were dug for morphological description and soil analyses according to **FAO (1990 and 2006).** The soil profiles represent the area under study were chosen on the basis of available geomorphologic information. These profiles were dug wide open to a depth of 150 cm unless opposed by bedrock, extremely hard layer and water table. Soil profiles were expected to reflect the wide variations in both geomorphology and soil in the study area. Then, transect sampling methods are applied to cross the different mapping units in the area. The primary mapping units were verified resulting from analysis of the DEM and interpretation information gained during supervised and unsupervised classification Landsat-8 data. Morphological description of the soil was undertaken according to the criteria established by field book for describing sampling soils **(FAO Guidelines for soil description 1990 and 2006),** which include surface characteristics, i.e., coordinates, elevation, slope, topography, land form, vegetation, parent material, land use, drainage, and different soil layers. Description of soil profile layers was carried out in the field included: soil color, soil texture, soil structure, consistency, cementation and compaction, roots and all other features recognized in each layer. Soil classification was carried out according to the Soil Taxonomy System **(USDA, 2014).** The collected soil samples, amounted 39, represented the consequent morphological variations throughout the entire depths of the soil profiles. Water samples, two surface and ground water samples, were collected for laboratory analyses. The soil profiles and water samples were located using GPS.

Soil laboratory analyses

The collected soil samples were air dried, crushed and prepared for laboratory analyses. Laboratory analyses were carried out for particle size distribution using the pipette method **(Piper, 1950),** calcium carbonate content using Collin's calcimeter **(Black, 1982),** Electric conductivity (EC), soluble cations and anions, organic matter, pH, gypsum and CEC were determined according to **Jackson (1976).**

Building up Digital Georeference Database

The spatial data include vector data (shape files) use points and polygons to represent map features, while non-spatial data include attributes information. The different soil attributes were coded and new fields were added and linked to the profile database file in Arc GIS 10.3 software. Each soil profile was geo-referenced using the Global Position Systems (GPS). The following is an example of database of soil profiles and main chemical and physical properties as shown by Arc GIS 10.3 software.

Land capability ASLE model.

FAO framework (FAO, 1976). Was used to assess and characteristics soil of the investigated area by using Applied System for Land Evaluation (ASLE) program (Figure 4). The aim of this system was to provide a method forecast the general land use capability for a broad series of possible agricultural uses. Where it works interactively, comparing the values of the characteristics of the land-unit to be evaluated with the generalization levels established for each capability class. The factors influencing the soil suitability were used according to the ASLE framework for land evaluation which include the following: Soil properties: Physical properties that determine the soil-water relationship in the soil (e.g. clay content, number of layers, soil depth, land form, level of surface and slope), chemical properties (e.g. salinity, alkalinity, $CaCO_3$ content and gypsum content. The capability evaluation includes six capability orders for agriculture and reclamation land capability which are excellent (C1), good (C2), Fair (C3), poor (C4), very poor (C5) and Non-agriculture (C6) (Table 3).

Table 2: Land capability index and ratings for ASLE program.

Class	Description	Rating (%)
C1	Excellent	> 80
C2	Good	< 80 - > 60
C3	Fair	< 60 - > 40
C4	Poor	< 40 - > 20
C5	Very poor	< 20 - >10
C6	Non-agriculture	< 10

The capability index (Ci) is calculated, and this value is also integrated in the definition where:

Capability index (Ci) = [t * (w/100) * (S1/100) *(S 2/100)* (S 3/100) *(S 4/100) * (S n/100)* (n/100)………………………..Equation (1)

In light of the calculated Ci values, the orders and classes of lands can be distinguished as follows: Class C1: land units without limitations (Ci > 80). Class C2: land units with one slight limitation (Ci 60 to 80). Class C3: land units with more than slight limitations and more than moderate limitations (Ci 40 to 60). Class C4: land units with more than moderate limitations and /or one severe limitation that do not exclude the use of the land (Ci 20 to 40). Class C5: land units with one or more severe limitation that excludes the use of the land, or with one or more severe limitation (Ci 10 to 20). Class C6: land units with severe or very severe limitations that cannot be corrected (Ci < 10).

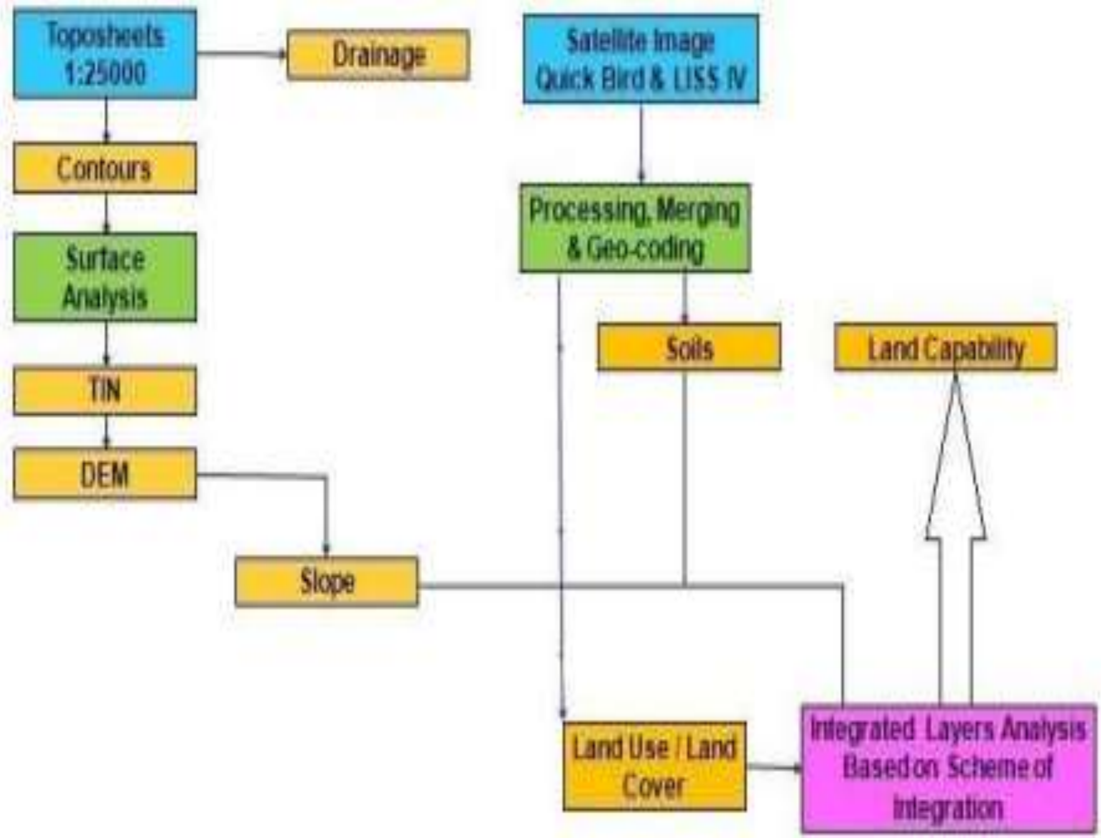

Figure 4: Chart of ASLE model.

Results and Discussion

Geomorphologic features.

The geomorphological features (Figure 5) comprised flood plain, aeolian deposits and lacustrine deposits. The flood plains include: 1- decantation basins (DB), 2- overflow basins (OB), 3- river terraces (RT), 4- turtle backs (TB). The lacustrine deposits include: 1- clay flats (CF), 2- dried lake beds (DLB) and 3- depressions (Dp). Areas and their percentage of total area: Decantation basins: 812 ha, 2.34% of the total area., Overflow basins: 3290 ha, 9.49 % of the total area, River terraces: 6421 ha, 18.50% of the total area, Turtle backs: 75 ha, 0.22% of the total area, Clay flats: 11689 ha, 33.70 % of the total area, Dried lakebed: 2504 ha, 7.22% of the total area, Depressions: 356 ha, 1.03% of the total area, Fish ponds: 9273 ha, 26.74% of the total area and Aeolian deposits: 264 ha, 0.76% of the total area.

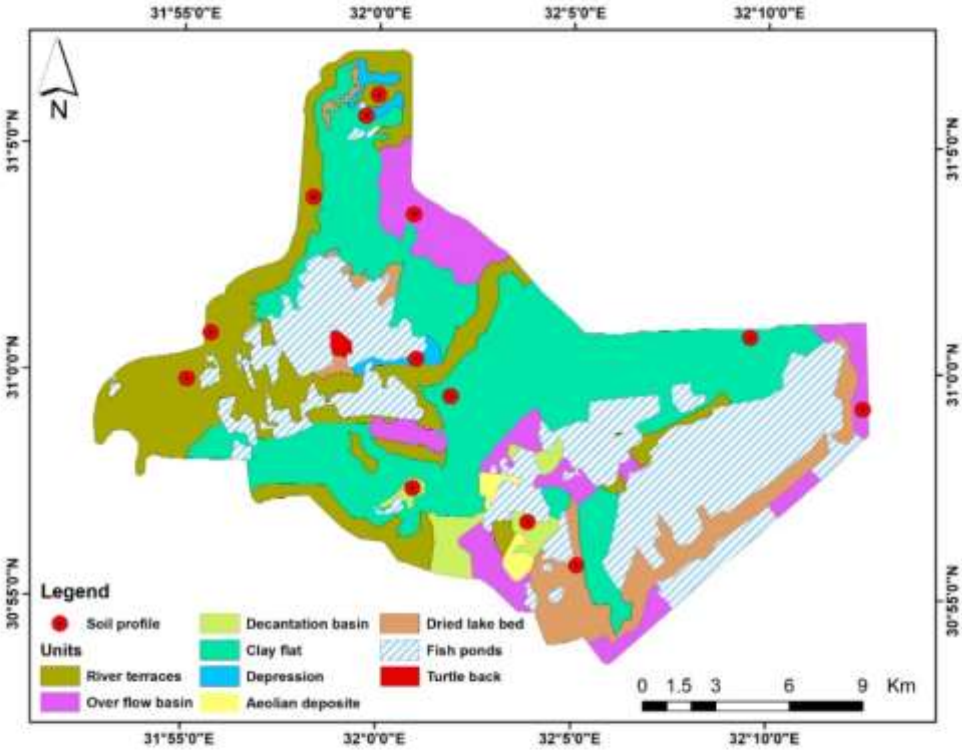

Figure 5: Geomorphological map of the study area.

Image classification: -

Image classifications include two types, depending on the method used; unsupervised and supervised. Supervised classification was used supported by Supervised Vector Machines 'SVM' approach after field verification. Systems of SVM are used in many remote sensing-based applications since they are effective in handling complex distributions of heterogeneous land cover classes. The system is derived from statistical theory that provides reliable classification results **(Chen et al 2004 and Hsu et al., 2010).**

Land use/cover classification:

Land use/cover classification is a basic step for understanding the environmental parameters and their relationships with development. Unsupervised classification was performed on landsat 8 imagery in the current study.

Supervised classification

Supervised classification groups pixels that represent areas for which the analyst already knows the information class **(Richards, 1999).** This classification is based on the "brightness" or strength of reflection in specific spectral bands. Supervised is a process which identifies pixels of unknown identity. Supervised classification has a great potential in improving classification accuracy **(Sun et al., 2016).** It indicated 4 classes: agriculture, urban, fish ponds and roads (Figure 6).

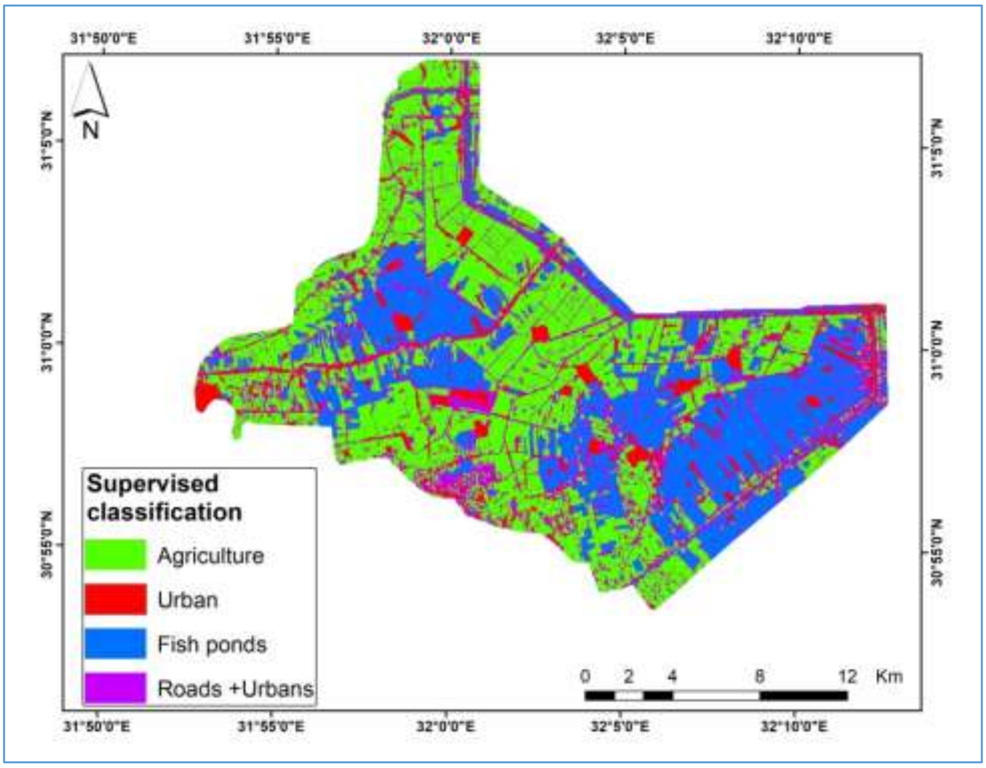

Figure 6: Supervised classification of the study area.

4.3.2. Unsupervised classification:

The advantage of this method is that the analyst can specify the number of preferred categories that the software should identify within the image, without providing detailed information about the study area **(Campbell, 1987).** It is a technique by which pixels can be assigned to similar spectral classes without prior knowledge of these classes. Unsupervised classification is marginally used in large-areas **(Gomize et al., 2016).** In the current study, it was applied on corrected images to identify main units, results showed 5 classes (Figure 7): arable lands, bare lands, urban, fish ponds and roads.

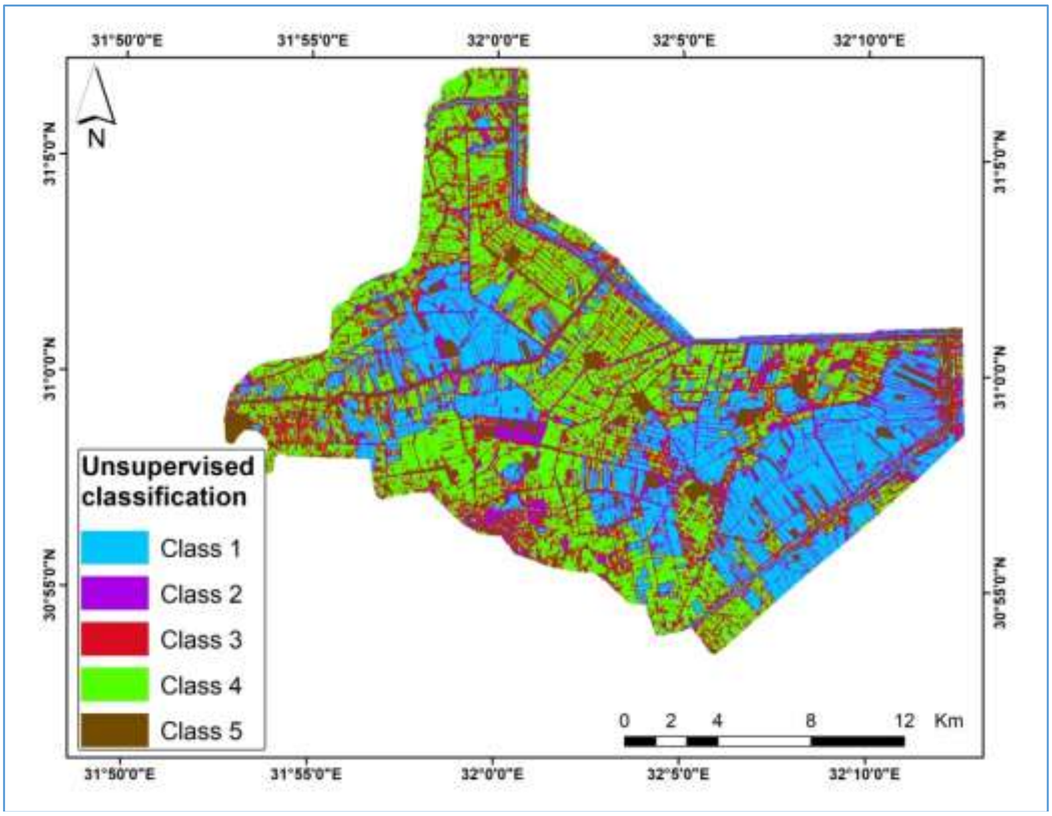

Figure 7: Unsupervised classification of the study area.

Land evaluation assessment using ALES program.

Classification of LSI for some crops using ALES program. Classification of agriculture suitability for some crops production by using the ALES program was according to **Ismail et al. (2005).** The ALES model is a type of soil suitability evaluation that indicates the degree of suitability for a specific land use. The soil parameters used for estimating the suitability index for the wheat crop were, climate, slope, drainage, texture, soil profile depth, calcium carbonate, pH, salinity and sodicity.

Land capability classification

Evaluation of land capability classification using ALES program. Estimation of soil characteristics such as slope, drainage conditions, soil depth, texture, calcium carbonate content, salinity and sodicity were used in the land evaluation. The rating of capability classes of South El-Hussinia Plain area is present in Table 4 and illustrated in Figure 8. Accordingly, the studied area could be classified into four capability classes as follow:

a- Lands of capability class (C2): This class includes the soils which are good capability and a little limitation with capability index (Ci) that is varies between 60 and 80 %. The soils occupy 22.60 % of the total area. The soils of this class are lowly affected by some limitations such as erosion risks, and bioclimatic deficiency. These soils have good productivity for various crops, can be feasible improvement practices and require proper management.

b- Lands of capability class (C3): This class includes the soils which are moderate capability and a moderate severe limitation with capability index (Ci) that is varies between 40 and 60 %. The soils there are and occupy 14.91 % of the total area. The soils of this class are moderately affected by some limitations such as soil, erosion risks, and bioclimatic deficiency. These soils have moderate productivity for various crops, can be feasible improvement practices and require proper management.

c- Lands of capability class (C4): This class comprises the soils that are poor capability and have high limitations with capability index (Ci) that is varies between 20 and 40%. This class there is employs an area of 11.92% of the total area. The soils of this class are highly affected by some limitations such as texture, salinity and bioclimatic deficiency. These soils have poor productivity but can be feasible improvement practices and recommended for producing forage crops.

d- Lands of capability class (C5): This class includes the soils which are very poor capability and have very high limitations with capability index (Ci) that varies between 10 and 20 %. The soils of this class occupy 23.61% of the studied area. The soils of this class are very highly affected by some limitations such as texture, salinity and bioclimatic deficiency. These soils have very poor productivity and recommended for producing forage crops and agroforestry systems.

Table 4. Land capability classification for South El-Hussinia Plain using ALES program

Class	Description	Area (ha)	% of the total area
C2	Good	7838	**22.60**
C3	Fair	5170.7	**14.91**
C4	Poor	4139.3	**11.92**
C5	Very poor	8188	**23.61**
	Fish ponds	9273	**26.74**
	Turtle back	75	**0.22**

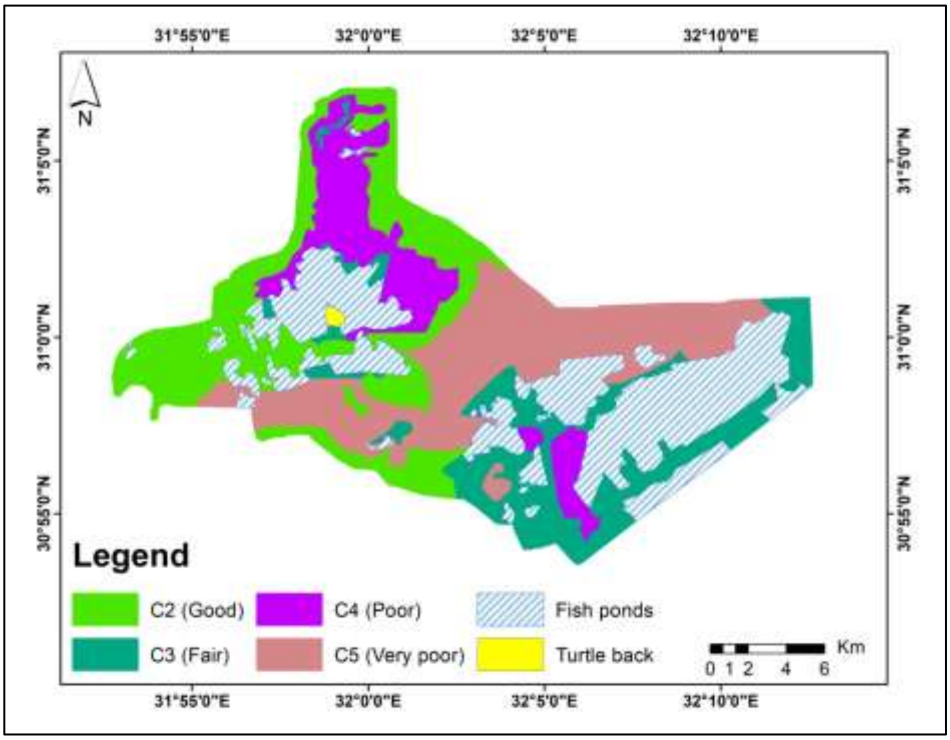

Figure 8: Land Capability map.

Conclusion

Analysis of land capability can help to achieve sustainable crop production for agriculture development in El-Hussinia plain area. The ALES program was more effective in assessing the land capability of arid and semi-arid regions. The purpose of this research is to use GIS and ALES program to assess land capability for various soils conditions. According to ALES, the soils of the studied area varied in the capability classification, ranged from good capability (C2) to very poor capability (C5) for agriculture. Moderate and poor land capabilities were found some limitations; these limitations can be improved through proper management practices. Most of the studied area 73.04% are suitable for agricultural use. Based on the analysis of the soil and the study of the capability of the land, it is preferable to use an agricultural cycle to obtain the highest yield of the crop of the soil. Prefer farming with the appropriate types of agricultural crops proposed for the area in order to maximize agricultural production and economic return from them. Agricultural holding affects agriculture and agricultural production, and it is closely related to the prevailing type of soil and its degree of production, as well as to the state of irrigation and drainage, and the human factor is the most important control affecting the average agricultural holding. The study recommends that agricultural mechanization has a role in horizontal and vertical agricultural development processes, a new agricultural speed, while increasing production costs, reducing its costs, and starting agricultural operations.

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تقييم دليل قدرة الأراضي لبعض اراضى منطقة جنوب سهل الحسينية، مصر، بالاستخدام المتكامل بين تقنيات نظم المعلومات الجغرافية والاستشعار من بعد

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تبلغ مساحة منطقة الدراسةحوالى 34684 هكتارا،وتشمل منطقة الدراسة منطقة جنوب سهل الحسينية بمصر بين خطى عرض 30 55 – 31 05 شمالا وخطى طول 31 55 – 32 10 شرقا. وقد تم حفر 13 قطاعا للتربة. , وتم عمل التصنيف المحكوم والغير محكوم لمنطقة الدراسة وأظهرت الدراسة خمسة أصناف: الأراضى الصالحة للزراعة والأراضى البور والمبانى الحضرية ومزارع الأسماك والطرق. والهدف الرئيسى من هذه الدراسةهو تقييم التربة الزراعية المروية. تم اجراء مؤشر القدرة للاراضى باستخدام برنامج ال ASEL ونظم المعلومات الجغرافية GIS وتم تطوير نظام التقييم المستخدم بناء على النمذجة الرياضية لمختلف معايير تقييم الاراضى (الخصائص الفيزيائية والكيميائية). وتم عمل استيفاء لخصائص التربة المختلفة لانشاء خرائط التربةالمختلفة. تم تصنيف منطقة الدراسة على انها 22.60% وتنتمى الى فسم (C2) تربة جيدة، و 14.91% تنتمى الى قسم C3 (تربة متوسطة)، و11.92% تنتمى الى قسم C4 (تربة فقيرة)، و 23.61% تنتمى الى قسم C5 (تربة فقيرة جدا). أظهرت الدراسة ان العوامل المؤثرة على تركيب المحصول ان العوامل الطبيعية والبشرية كان لها تاثير واضح على مقدرة الأرض على انتاج المحاصيل في منطقة الدراسة.