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Demand-Driven Land Suitability Assessment – A Case Study in Fayoum Depression, Egypt– Using RS and GIS

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ABSTRACT

The present study aims at performing current and potential suitability assessment for land use types at Itsa District, Fayoum Depression, Egypt. The geopedological approach of Zinck was utilized to generate the physiographic soil map of the study area. Remote sensing techniques by means of satellite image of the study area, was visually interpreted, then with the aid of digital elevation model, geological map, and geographic information systems (GIS), the base soil map was generated. Where two landscapes, Hilland and Depression, including eleven landforms were identified in the study area. Field work was conducted to check and confirm the boundaries of soil map units. Twelve soil profiles, and auger hole observations were examined to represent each map unit. The United States Department of Agriculture soil classification system, Soil Taxonomy, was used to classify the soil up to family level. The land suitability was carried out for twelve crops representing field crops, vegetables, orchards, and aromatic plants. Where land use requirements were matched with the land characteristics for each map unit producing the suitability class of corresponding unit. The results showed variation in land suitability for different crops, varies from high suitability (S1) to not suitable (N). In general, wheat, barley, clover, sorghum, and chamomile showed high suitability in the different map units. The map unit (Hi211) has a low suitability with classes of marginal suitable (S3) and not suitable (N). In general, limiting factors varies from correctable and non-correctable factors, thus, applying the proper management can improve the suitability for most of the map units.

KEYWORDS: Land suitability, remote sensing, geographic information systems, Itsa, Fayoum, Egypt.

1. INTRODUCTION

Increasing human demand, in addition to land degradation process threaten the limited natural resources. Agriculture represents an important source to meet the human needs, therefore, sustainable land use needs to be planned taking into consideration the maintenance of land and water quality (Dumanski, 1997). In arid and semi-arid regions, existence of irrigation water shortage, soil salinity and alkalinity, and improper management increase the vulnerability of such regions (Farshad, 1997). On the other hand, urban sprawl over the agricultural areas reduces the land resources (Dengiz et al., 2003). Such processes can be effectively assessed using Remote Sensing (RS) data which also provide vital data for agricultural planning (Lenney et al., 1996). In addition, RS has been proven to be a valuable tool for land use/cover monitoring (Matinfar et al., 2007), especially with the availability of free RS data, i.e., Landsat data. Hence, soil mapping and land suitability assessment require various spatial data and field survey, Geographic Information Systems (GIS) capabilities help to intigrate such data in order to derive the required data and thematic maps (Reddy et al., 2018). Various studies have demonistrated the intigration potentiality of RS and GIS in land suitability assessment (El Baroudy et al., 2020, Mohamed et al., 2019). Land suitability assessment concerned with land performance assessment when utilized for particular purposes (FAO, 1976), therefore, it is important for sustainability of natural resources (Rossiter, 1996). To evaluate the land for agricultural use, relative factors such as soil characteristics, water availability and quality, and climate are to be evaluated as an essential step for agricultural development (Kumar et al., 2021).

In general, Fayoum soils have different suitability classes because of natural variation in land qualities as a result of variation in parent material, topography, in addition to the variation due to the mismanagement of soil and water resources. Abdelfattah (1998) investigated the land use planning for the NE part of Fayoum Depression and noted various suitability classes, where the limiting factors were soil salinity and alkalinity, moisture availability and nutrient availability. Another study of the soil physical suitability of the north Bahr Wahby and west Kom Oshim areas by Alam (2009) concluded that the main soil constrains for land capability are salinity and cementation problems. Similar findings in some cultivated lands in Fayoum were observed by EL Ghonamey et al. (2018) where the main limiting factors were soil depth, texture, and salinity. According to the above-mentioned conditions in Fayoum, this enforces the decision makers to establish a proper soil and water management strategy to overcome the correctable soil limiting factors. In addition, the land suitability assessment is crucial to define the optimum land use types in order to achieve sustainable agriculture system in the entire area. The main objective of the present study is to perform current and potential suitability assessment for the selected land use types.

2. MATERIALS AND METHODS

2.1.Description of the study area

The study area is located in Itsa District, South-East of Fayoum Depression, Egypt, and extends from 29° 00′ 50″ to 29° 19′ 00″ N and 30° 30′ 30″ to 30° 56′ 15″ E (Figure 1), with a total area of 81969 hectares (ha). Generally, the study area has some natural characteristics in its location and topographical form. Itsa district is a part of Fayoum oasis which is fed by Nile water through Bahr Yousef and Hassan Wassef Canals. There is a potentiality for vast reclaimable areas in case that water resources are available.

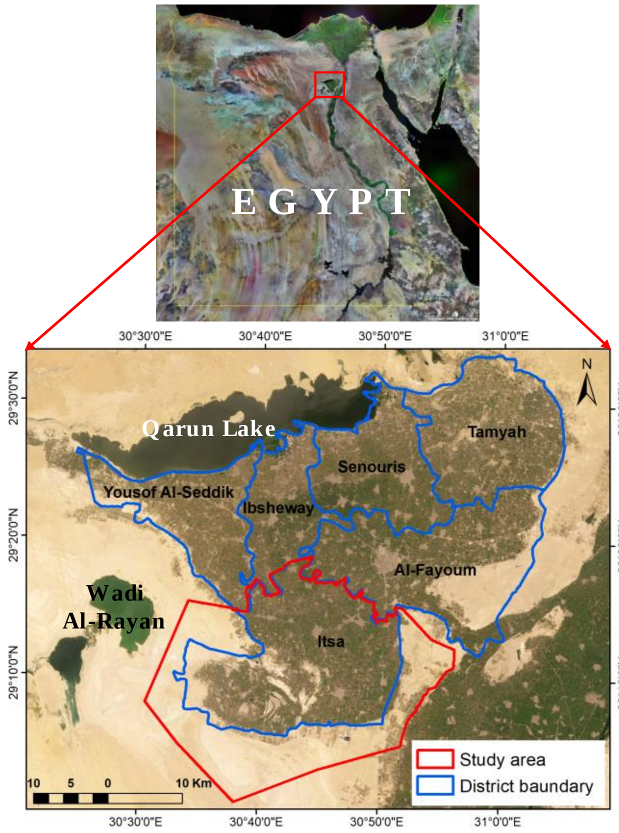
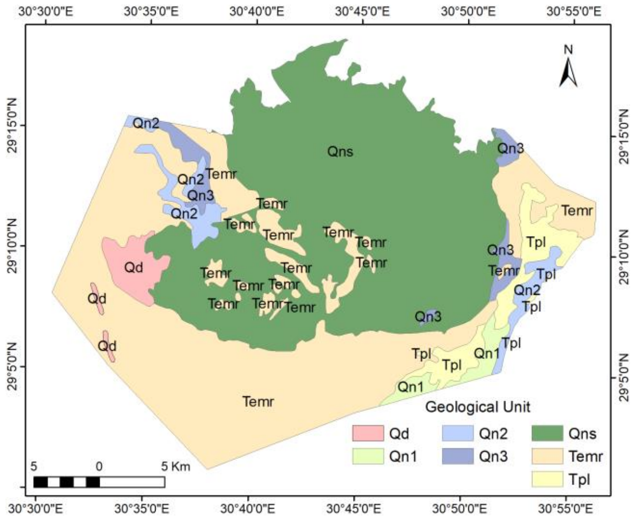


Figure 1. Location of the study area

The study area is characterized by arid climate, long hot summer, short and rare rainfall winter, high evaporation rate and moderate relative humidity. The temperature ranges from 8.1 °C in January to 23.5 °C in August as a minimum temperature, while the maximum varies from 21.1 °C in January to 38.1 °C in July. The mean temperature ranges from 14.6 °C in January to 31.0°C in August. The annual rainfall is 8 mm/year, and average daily evaporation varies from 1.7 to 7.7 mm/day in January and June, respectively, with an annual average value of 4.7 mm/day. The monthly average relative humidity ranges from 43.5 % in May to 53.1 % in January, with an average value of 48.4 %. The maximum wind speed value reaches 5.20 m/s in April and the minimum speed value is 3.76 m/s in December, with an average of 4.45 m/s.

The study area includes mainly two geological formations; Quaternary Nile deposits from which the old agriculture land is formed, and Wadi Rayan formation (Figure 2).



Abbreviations:

Qns:	Nile silt	Qd:	Sand dunes
Qn3:	Neonile deposits	Qn2:	Prenile deposits
Qn1:	Protonile deposits	Tpl:	Pliocene deposits
Temr:	Mokattam Group, Wadi Rayan Formation		

Figure 2. The Geological map of the study area (Conoco, 1987)

The main source of irrigation water in the study area is the fresh Nile water, which is distributed via irrigation canals. The main canals are Arous and Al-Gharaq Canals. Recently, there is a project (Qouta project) to extend a new canal in the southern part of the study area. It is planned to irrigate 16000 Feddans divided as 26 plots on the left and 30 plots right to Wadi Al-Rayan Road, with an average of 800-900 Feddans for each irrigated plot. This canal is about 28 km long and starts from a station located on Bahr Yousef. The project is planned to be completed in 2021. On the other hand, the ground water resource is limited in the study area.

2.2.Geographical data processing

As the objectives of the current study deal with soil mapping, different data sources were utilized accordingly. Remotely sensed data of Landsat 8 Operational Land Imager (OLI) with spatial resolution 30 m was downloaded from The United States Geological Survey (USGS) (http://glovis.usgs.gov). In addition to the topographic maps 1:50.000 (Egyptian General Survey Authority, 1991) and geological map 1:500000 (CONOCO, 1987). Digital Elevation Model (DEM) was created using the extracted contour lines from the topographic maps.

Digital image pre-processing procedures are basically the ways to change and enhance original raw spatial data to increase the information availability and to provide the best possible product for analysis and interpretation (Abdelfattah and Shahid, 2007; King et al., 2013). The geographical data sets were clipped to the boundary of the study area. With the aid of 3D capabilities, the study area was investigated in 3D visualization, where DEM and Landsat data were presented in 3D environment (Figure 3). This approach enabled studying the geomorphological units and defining the landscape and other topographic features required to produce the physiographic map.

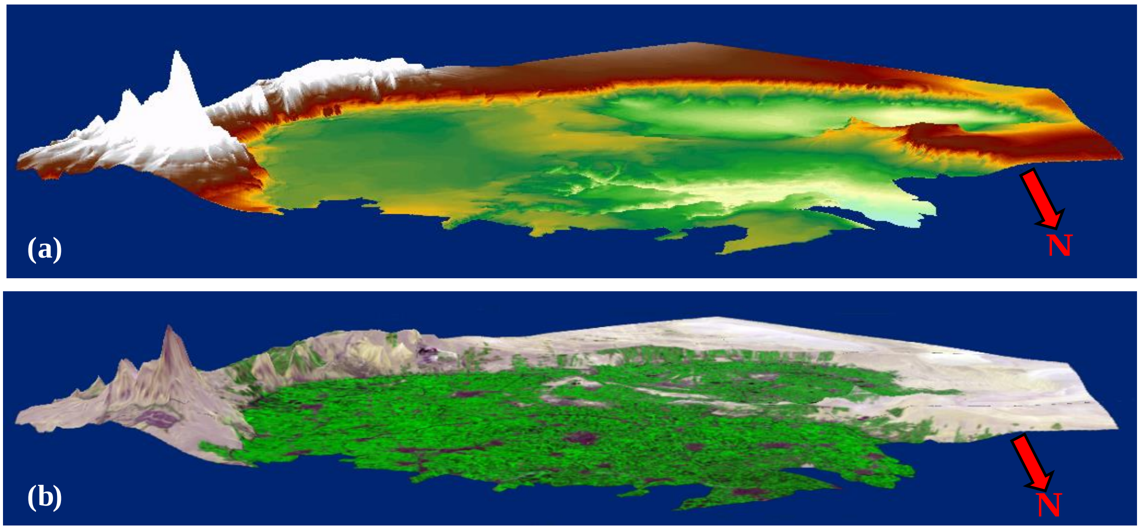


Figure 3. 3D view of (a) digital elevation model, and (b) Landsat 8 image of the study area

2.3.Field work

The field work was carried-out during the winter season of 2016/17 according to the created base map from the geopedological approach. The transect sampling method was applied to cross the different mapping units in the area, where two transects have been defined. In addition, check points were done to validate different mapping boundaries. During the fieldwork, 12 profiles were dug, described, and sampled. The profiles were described morphologically following the FAO (2006). A total of 52 samples were collected for physical and chemical analysis, where all sampling locations were recorded using GPS to create a geodatabase for profiles' location (Figure 4) with various soil attributes for further analysis.

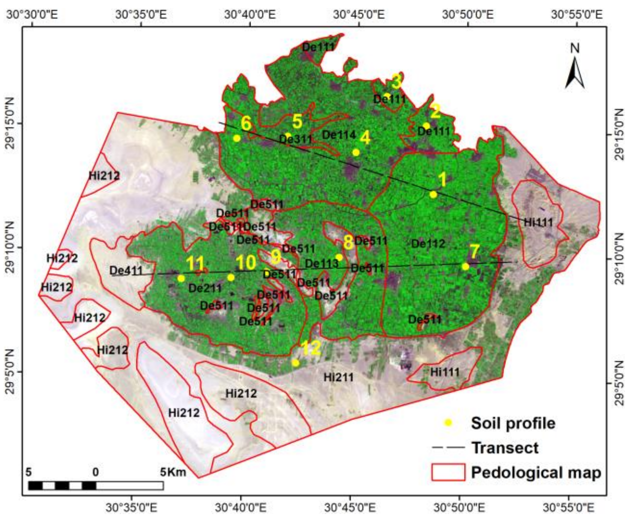


Figure 4. Location of the investigated soil profiles

2.4.Laboratory analysis

The collected samples were prepared for physical and chemical analysis. The disturbed samples were air dried, ground gently, then the fine earth was obtained using 2 mm sieve to be used for measuring various soil characteristics.

Both disturbed and non-disturbed samples (soil cores) were subjected to the laboratory analyses of physical properties (soil texture, hydraulic conductivity, field capacity, welting point, bulk density), and chemical properties (electrical conductivity, soil pH, total calcium carbonate, soluble cations and anions, cation exchange capacity, organic matter (Jackson, 1967), gypsum content, and exchangeable sodium present according to Page (1982), Richards (1954), Black et al. (1965), Klute (1986), and Allison et al. (1969). Soil color was described according to Munsell Color chart (1954).

2.5.Soil map

Physiographic soil map resulted from a series of steps, where the base map was verified and represented by soil profiles in the field. The laboratory analysis results were utilized with the help of the morphological description to classify the soils according to the American system of soil taxonomy (USDA, 2014). The geopedological approach (Zinck, 2013) was adapted to generate the soil map, where one ideal soil profile was selected to represent soil characteristics of each soil map unit.

2.6.Land suitability assessment

In the current study, the physical (soil) suitability was applied, where Microsoft Excel was utilized to apply the concept of FAO land evaluation framework (FAO, 1976) in order to assess the suitability of Land Mapping Units (LMUs) for the selected Land Utilization Types (LUTs).

According to the existing conditions in the study area, such as climate, soil characteristics, and existing cropping system, 12 LUTs were chosen as follows: field crops (wheat, barley, clover, maize, sorghum, sugar beet, cotton), vegetables (tomato and onion), orchards (olive and citrus), medicinal and aromatic plants (chamomile). Finally, a suitability map for each LUT (crop) was produced.

Each LUT needs specific land use requirements (LURs) which represent the conditions of the land necessary for successful and sustained implementation of that LUT. The LURs are derived from different references, namely, Siderius (1989); Sys et al. (1993); Mahmoud (2002) and Abdelfattah et al. (2004) and adapted to fulfil the local condition of the study area. The land use requirements are expressed in terms of land qualities (LQs) and their corresponding land characteristics (LCs) which are selected according to the suggested land use types and their requirements (Table 1). The requirements of each LUT are compared or matched with the qualities of each map unit, to give an overall land suitability class for each relevant land utilization type on each land unit. For each land characteristics there are four limitation levels with corresponding land classes and rating values as follow:

S1 = highly suitable. S2 = moderately suitable.
S3 = marginally suitable. N= not suitable.

Table 1. Land qualities (LQs) and land characteristics (LCs)

Land quality	Symbol	Land characteristics	Unit
Moisture Availability	m	Available Water Soil Texture	% class
Oxygen Availability	o	Soil Drainage	class
Rooting Condition	r	Soil Depth Soil Texture	cm class
Nutrient Availability	na	Soil Reaction Organic Carbon $CaCO_3$	pH % %
Nutrient Retention capacity	nr	CEC	meq/100g
Topography	t	Slope	%
Salinity and Alkalinity	sk	EC ESP	dS m^{-1} %

3. RESULTS AND DISCUSSION

The study area is characterized by elevation ranges from -3m to 161m m.s.l. (mean sea level) as indicated by the digital elevation model (DEM) (Figure 5). The lowest elevation values are located in the northern part of the study area. The depression landscape is surrounded by elevations higher than 20m m.s.l., and the maximum elevation of 161m m.s.l. is observed in the eastern part as a hilly area. Thus, in general, the elevation decreases from south towards the north. The slope values range from 0.0 to 31.4 %, where most of the study area is flat (slope < 2%), while the slopes characterize the edges of the terraces, valley sides and hilly areas.

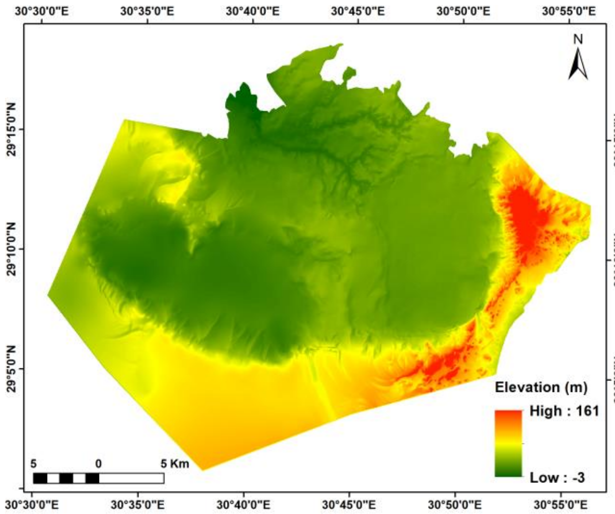


Figure 5. Digital Elevation Model (DEM) of the study area

3.1.Description of the physiographic units

Physiographic soil map of the study area represents two main landscapes; Depression and Hilland (Table 2), with a total area of 81969 hectares (ha), about 195164 Feddans (1 Feddans is equivalent to 0.42 ha). The depression landscape represents an area of 43077 ha (52.6% of the study area), and mainly includes the Nile deposits forming the more fertile soils. While the Hilland landscape represents an area of 38892 ha (47.5% of the study area) and includes the desertic land, which are currently under reclamation and the main crops are vegetables. These two landscapes were finally divided into eleven landforms as shown in the physiographic soil map (Figure 6) and the legend presented in Table (2).

3.1.1. Depression landscape

The depression landscape occupies the north and central parts of the study area and surrounded by the Hillock landscape on the southern sides. Within this landscape, eight landforms were distinguished, namely, 4 terraces with different levels, rock outcrop, sand dunes, swales, and bottom of the basin.

3.1.1.1. Higher terrace (De111)

Soils of higher terrace are represented by profile 2 and characterized by clayey texture; organic matter (0.51 to 2.03%); pH values (7.60 to 8.19); EC values (1.68 to 11.90 dS m^{-1}); ESP values (4.57 to 10.54%); and SAR values (4.10 to 8.84); and cation exchange capacity (CEC) ranges between 20.5 to 40.0 meq/100g soil. The soils of this map unit are mainly Typic Haplotorrerts.

3.1.1.2. Relatively higher terrace (De112)

Soils of relatively higher terrace are represented by profile 1 and characterized by clayey texture; low contents of organic matter (0.44 to 1.22%); pH values (7.94 to 8.51); EC values (3.00 to 11.50 dS m^{-1}); ESP values (11.38 to 20.87%); SAR values (9.56 to 18.73); and CEC ranges between 23.6 to 35.2 meq/100g soil. The soils of this map unit are mainly Sodic Haplotorrerts.

3.1.1.3. Moderately higher terrace (De113)

Soils of moderately higher terrace are represented by profile 8 with sandy clay loam texture in the top 50 cm and clayey texture in the next layers; low contents of organic matter (0.82 to 2.85 %); pH values (7.62 to 8.61); EC values (1.52 to 4.50 dS m^{-1}); ESP values (5.78 to 30.56%); SAR values (5.01 to 30.69); and CEC ranges between 9.5 to 40.6 meq/100g soil. The soils of this map unit are mainly Typic Calcitorrerts.

3.1.1.4. Lower terrace (De114)

Soils of lower terrace are represented by profile number 4 and characterized by clayey texture; low contents of organic matter (0.76 to 3.01 %); pH values (8.14 and 8.57); EC values (3.24 and 4.70 dS m^{-1}); ESP values (19.92 to 26.87%); and SAR values (17.72 to 25.76); and CEC ranges between 23.5 to 40.2 meq/100g soil. The soils of this map unit are mainly Sodic Haplotorrerts.

3.1.1.5. Bottom (De211)

Soils of this map unit are represented by profile 11 and characterized by clayey texture; low contents of organic matter (0.96 to 2.63%); pH values (7.82 to 8.36); EC values (1.76 to 3.16 dS m^{-1}); ESP values (10.08 to 17.44 %); SAR values (8.45 to 15.18); and CEC ranges between 15.8 to 36.5 meq/100g soil. The soils of this map unit are mainly Typic Calcitorrerts.

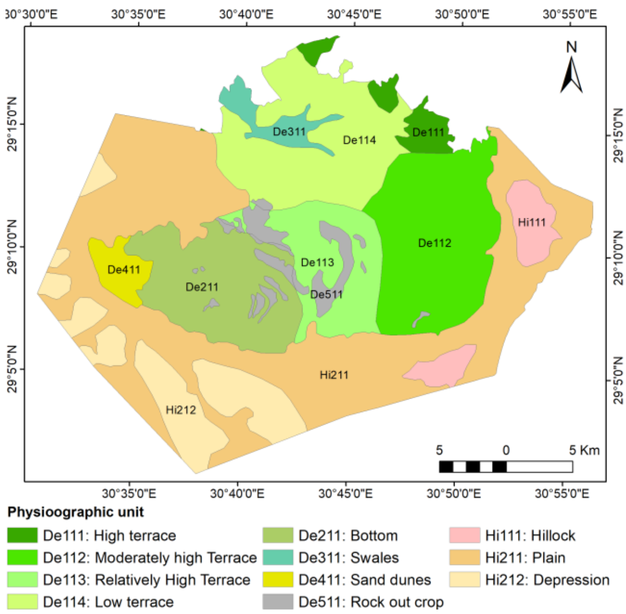


Figure 6. Physiographic soil map of the study area

Table 2. Legend of the physiographic soil map

Landscape	Relief	Lithology	Landform		Area (ha)	Taxonomy
			Name	Code		
Depression	De1: Terraces	Qns	Higher terrace	De111	1837	Typic Haplotorrerts
			Relatively high terrace	De112	5587	Sodic Haplotorrerts
			Moderately high terrace	De113	11258	Typic Calcitorrerts
			Lower terrace	De114	10480	Sodic Haplotorrerts
	De2: Basin	Qns	Bottom	De211	8314	Typic Calcitorrerts
	De3: Swales	Qns	Swales	De311	1561	Sodic Haplotorrerts
	De4: Sand dunes	Qd	Sand dunes	De411	1498	-
	De5: Rock out crop	Temr	Rock outcrop	De511	2541	-
Hilland	Hi1: Hill	Tpl	Hillock	Hi111	2639	-
	Hi2: plain	Temr	Plain	Hi211	28507	Typic Torriorthents
			Depression	Hi212	7746	-

3.1.1.6. Swales (De311)

Soils of swales are represented by profile number 5 and characterized by clayey texture; low contents of organic matter (0.88 to 2.09 %); pH values (8.38 to 8.44); EC values (29.80 to 50.60 dS m^{-1}); ESP values (17.97 to 24.27%); and SAR values (15.70 to 22.59); and CEC ranges between 29.8 to 50.6 meq/100g soil. The soils of this map unit are mainly Sodic Haplotorrerts.

3.1.1.7. Sand dunes (De411)

This map unit represents an area of 1498 ha and needs to be managed properly to reduce the sand dunes movement or erosion which affects the surrounding areas. This map unit is not evaluated.

3.1.1.8. Rock outcrop (De511)

This unit includes the rock outcrop areas that formed from shallow marine limestone with nummulites gizehensis repeatedly intercalated by shale and sandy shale. this map unit is not evaluated.

3.1.2. Hilland landscape

The hilland landscape includes the following landform units, Hillock, Plain and Depression. The hillock map unit is mostly rock outcrop, and the depression unit representing some parts within the hilland landscape where the elevation is lower than the surrounding area. These two map units were not evaluated. While the most widespread landform within this landscape is the plain map unit.

3.1.2.1. Plain (Hi211)

The plain map unit includes the reclaimed soils and other areas under reclamation for agriculture use as there is a new irrigation canal that will enable more agriculture expansion. The soils of this unit are represented by profile 12 and characterized by loamy sand texture; low contents of organic matter (0.22 % to 1.91 %); pH values (7.60 and 7.89); EC values (5.90 and 13.50 dS m^{-1}); ESP values (1.16 to 2.33 %); SAR values between 1.65 and 2.47; and CEC ranges between 2.9 to 8.9 meq/100g soil. The soils of this map unit are mainly Typic Torriorthents.

3.2.Physical suitability assessment

In the FAO framework for land evaluation, land utilization types (LUTs) have one or more land use requirements (LURs), which are matched with the corresponding land qualities (Rossiter and Wambeke, 1997). The most relevant LURs were selected for each LUT, on the basis of the available bibliography and the information collected during the fieldwork. The requirement tables were prepared, for which some reference books and publications were used such as, Siderius (1989) and Sys et al. (1993). There is no doubt that LURs tables have to be adapted and adjusted for the studied area. Seven relevant land qualities (LQs) and their diagnostic factors were selected, namely moisture availability, oxygen availability, rooting condition, nutrient availability, nutrient retention capacity, topography and salinity and alkalinity. Each soil map unit (SMU) is represented by one modal profile that correspond to the main soils. The SMUs and their characteristics required for land suitability assessment are presented in Table (3).

The results of matching LURs with LQs show the physical suitability at four suitability classes corresponding to the FAO classes of S1, S2, S3 and N (Table 4). While suitability subclasses show the type(s) of limitation by sub-class suffixes (codes). After obtaining the land suitability assessment results for each LUT, the results were transferred into ArcGIS to produce suitability maps as presented in Figure (7).

Table 3. Soil mapping units and their characteristics

Mapping unit	Representative soil Profile	Depth (cm)	Soil Texture	Available Water (%)	Soil Drainage	pH	Organic Carbon	CaCO3 (%)	CEC Cmole kg^{-1}	EC dS m^{-1}	ESP	Slope (%)
De111	2	120	C	21.32	Poor	7.97	1.12	11.50	28.98	5.52	6.67	0.25
De112	1	110	C	21.29	Mod. Well	8.21	0.82	5.24	29.27	6.34	18.18	0.20
De113	8	120	SCL	18.11	Well	7.95	1.59	17.62	18.95	2.33	10.72	0.29
De114	4	130	C	18.00	Mod. Well	8.48	1.63	6.71	32.32	3.97	22.27	0.45
De211	11	120	C	20.07	Well	7.92	1.60	16.33	27.03	3.52	11.52	0.28
De311	5	120	C	19.51	Well	8.41	1.54	6.60	36.20	2.64	22.01	0.72
Hi211	12	140	LS	10.36	Well	7.79	0.83	11.14	5.04	8.93	1.76	1.10

3.2.1. Description of SMUs suitability

The land suitability assessment results presented in Tables (4) show a clear variation in the suitability from highly suitable (S1) to not suitable (N) due to different limiting factors.

The mapping unit "De111" is marginally suitable for wheat, barley, clover, olive, cotton, onion, and sugar beet, while it is not suitable for maize, sorghum, citrus, tomato, and chamomile. The limiting factor in this unit is the oxygen availability which is raised from poor drainage conditions of this map unit. As noted during the field work, this area has a problem in the subsurface drainage system, therefore, applying the required maintenance could improve the drainage conditions and, accordingly, the suitability for the studied crops.

The mapping unit "De112" has a moderate suitability class for 5 crops: wheat, sorghum, cotton, sugar beet, and chamomile. While it is not suitable for citrus and tomato where the limiting soil qualities are nutrient availability, and salinity and alkalinity because of land characteristics of pH value, soil salinity and ESP values. These factors can be improved by applying the proper land management practices. Also, improving these limiting factors will improve the moderately and marginal suitable classes as well.

The mapping unit "De113" has high suitability class for clover, sorghum, and chamomile; however, it varies from moderately to marginally suitable for other crops, where the limiting soil qualities are nutrient availability, moisture availability and rooting conditions.

Table 4. Physical land suitability and the limiting factors

LUT	Soil mapping unit						
	De111	**De112**	**De113**	**De114**	**De211**	**De311**	**Hi211**
Wheat	S3;o	S2;na,sk	S2;m,r	S3;na	S1	S3;na	S3;m,nr,sk
Barley	S3;o	S3;na	S2;m,r	S3;na	S1	S3;na	S3;m,nr
Clover	S3;o	S3;na	S1	S3;na	S1	S3;na	S3;m,nr
Maize	N;o	S3;na,sk	S2;na	S3;na,sk	S2;na	S3;na,sk	N;sk
Sorghum	N;o	S2;na	S1	S3;na	S1	S3;na	S3;m,nr
Olive	S3;o	S3;na	S2;m,r	S3;na	S1	S3;na	S3;nr
Citrus	N;o	N;na,sk	S3;na	N;na,sk	S3;na	N;na,sk	N;sk
Cotton	S3;o	S2;na	S2;na	S2;na,sk	S2;na	S2;na,sk	S3;m,r,nr
Onion	S3;o	S3;na,sk	S3;na	S3;na	S3;na	S3;na	S3;m,nr,sk
Sugar beet	S3;o	S2;na	S2;na	S2;na,sk	S2;na	S2;na,sk	S3;m,nr
Tomato	N;o	N;na	S3;na	N;na	S3;na	N;na	S3;m,na,nr,sk
Chamomile	N;o	S2;na,sk	S1	S2;na,sk	S1	S2;na,sk	S3;m,r,nr,sk

***Limitations*:** sk: salinity and alkalinity; m: moisture availability; r: rooting conditions; na: nutrient availability; o: oxygen availability; nr: nutrient retention capacity.

The mapping unit "De114" has suitability classes varies from moderate to not suitable, where the main limiting soil qualities are nutrient availability, and salinity and alkalinity. These land qualities can be improved by applying the proper soil management practices, which could improve the suitability classes.

The mapping units "De211" has high suitability class for wheat, barley, clover, sorghum, olive, and chamomile. While it is moderately suitable for maize, cotton, and sugar beet. For other crops, citrus, onion, and tomato, it is marginally suitable. The limiting soil quality is nutrient availability.

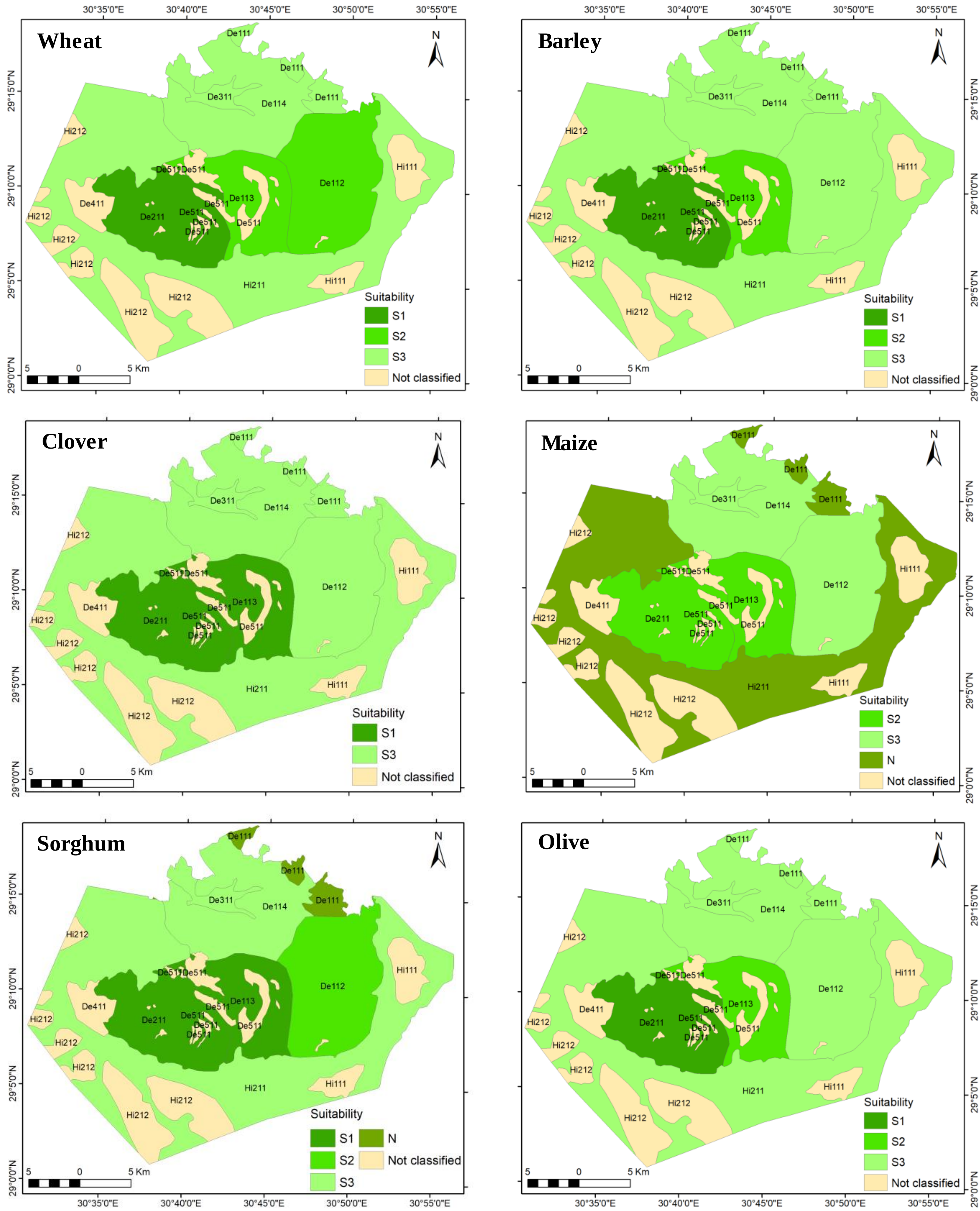


Figure 7. Soil physical suitability for the studied crops

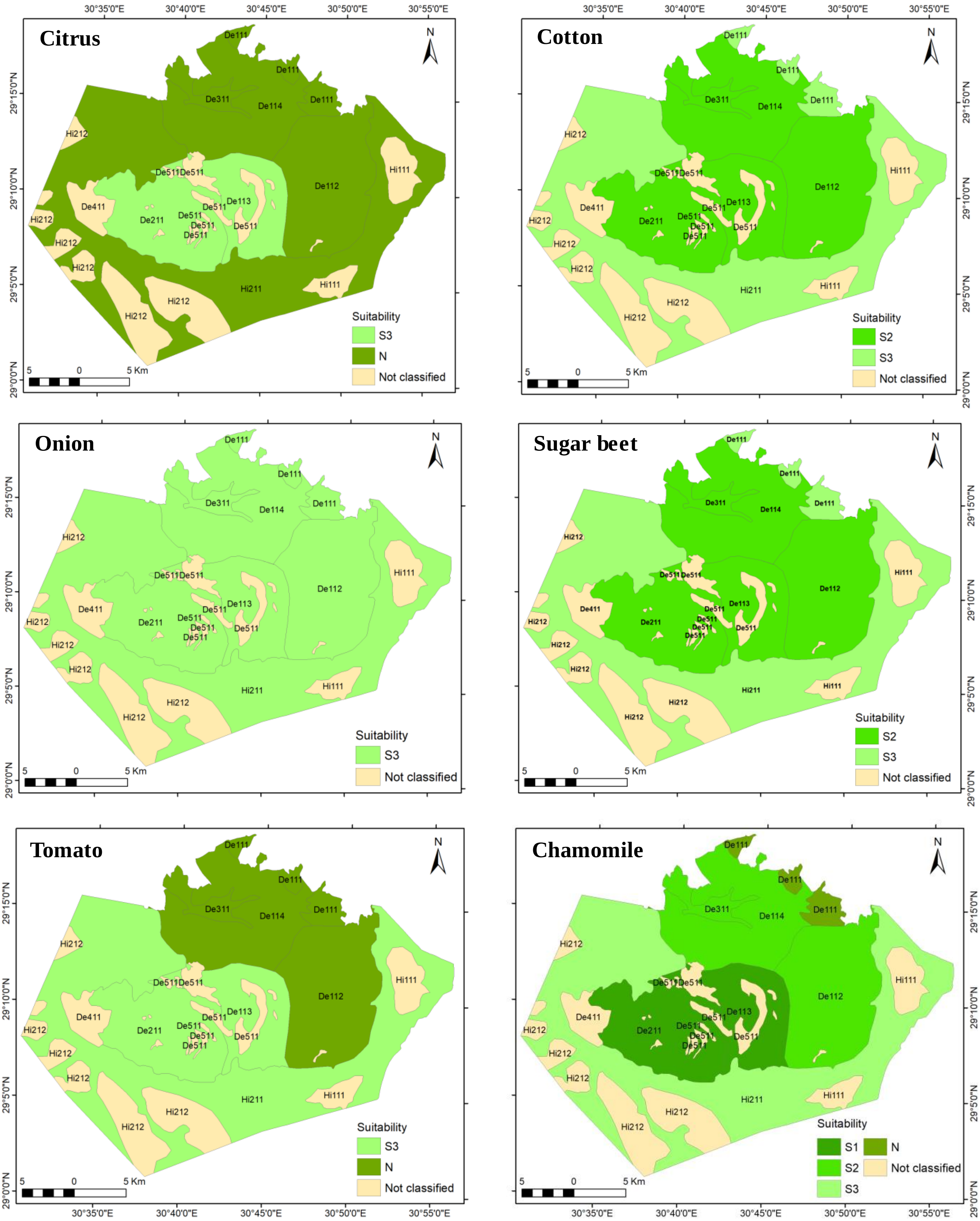


Figure 7. Continued

The mapping units "De311" has moderate suitability class for cotton, sugar beet and chamomile. While it is not suitable for citrus and tomato. But it is marginally suitable for other crops. The limiting soil qualities are nutrient availability, and salinity and alkalinity.

The map unit "Hi211" has low suitability where the suitability classes are marginal suitable (S3) for all crops, except for maize and citrus it is not suitable (N). Generally, suitability for each class has different limiting factors (as shown in Table 4). The common limiting factors are salinity and alkalinity, moisture availability, nutrient availability, and nutrient retention capacity. Which means, more attention should be paid to this map unit to provide different management practices required to overcome correctable limiting factors. This map units represents the current and potential expansion area in Itsa. Despite the mentioned problems in physical and chemical properties of this map unit, most of the farmers in this unit are following the drip irrigation method and agricultural management practices that overcome such constraints. In addition, the main cultivated crops are tomato and vegetables resulting in a good yield. Finally, this issue requires further studies to establish the proper land suitability assessment approach under such conditions of agricultural systems.

3.2.2. Potential land suitability

As discussed in the land suitability of different mapping units, the suitability for studied crops ranges from highly suitable (S1) to not suitable (N). The limiting factors that decrease the suitability varies from factors that are not correctable and others that can be corrected or improved by applying the proper land management programs. The obtained results could help the decision maker to design and establish such programs to improve the suitability classes and consequently increasing the land productivity. The land characteristics that can be improved i.e., soil drainage, soil reaction, salinity and alkalinity will improve the relative land qualities. Such improvement could be through the following soil management practices:

1. Lowering the ground water table through drainage improvement.
2. Deep plowing or sub-soiling to improve soil permeability and moisture availability.
3. Organic fertilization to improve permeability, CEC, and nutrient availability.
4. Scheduling the irrigation periods to avoid the soil crust formation which is related to calcareous soil.

In the potential land suitability, it is proposed that each of those land characteristics could be improved just one level to the higher class, then the potential land suitability was produced (Table 5). The obtained results showed that, in general, most of the suitability classes have been improved. Moreover, all "not-suitable" classes have been improved to the marginal suitability.

Table 5. Potential physical land suitability and the limiting factors

LUT	Mapping unit						
	De111	**De112**	**De113**	**De114**	**De211**	**De311**	**Hi211**
Wheat	S2;o	S1	S2;m,r	S2;na	S1	S2;na	S3;m,nr
Barley	S2;o	S2;na	S2;m,r	S2;na	S1	S2;na	S3;m,nr
Clover	S2;o,na	S2;na	S1	S2;na	S1	S2;na	S3;m,nr
Maize	S3;o	S2;na,sk	S2;na	S2;na,sk	S2;na	S2;na,sk	S3;m,nr,sk
Sorghum	S3;o	S1	S1	S2;na	S1	S2;na	S3;m,nr
Olive	S2;o	S2;r,na	S2;m,r	S2;na	S1	S2;na	S3;nr
Citrus	S3;o,na	S3;na,sk	S3;na	S3;na,sk	S3;na	S3;na,sk	S3;na,nr,sk
Cotton	S2;o	S2;na	S2;na	S1	S2;na	S1	S3;m,r,nr
Onion	S2;o,na	S2;na,sk	S3;na	S2;na	S3;na	S2;na	S3;m,nr
Sugar beet	S2;o	S2;na	S2;na	S1	S2;na	S1	S3;m,nr
Tomato	S3;o,na	S3;na	S3;na	S3;na	S3;na	S3;na	S3;m,na,nr
Chamomile	S3;o	S2;na	S1	S1	S1	S1	S3;m,r,nr

Limitations: sk: salinity and alkalinity; m: moisture availability; r: rooting conditions; na: nutrient availability; o: oxygen availability; nr: nutrient retention capacity.

4. CONCLUSION

Selecting the appropriate land use is one of the most important steps toward sustainable development. The current study aims at evaluating the land suitability of different mapping units to some selected crops, thus, the optimum land use for each unit can be planned. The study area, Itsa District, located in the South-East of Fayoum Depression, Egypt, and covering an area of about 81969 ha.

The first step towards achieving that target was producing the soil base-map applying the geopedological approach of Zinck (2013). In this regard, the visual interpretation for the 3D view of satellite image (overlayed on the DEM) was applied to identify the physiographic map units. Then locations of the soil profiles to be studied were identified to represent soils of the study area during field survey. The field work was carried out during the Winter of 2016/17, where 12 representative soil profiles were dug and morphologically described according to FAO (2006). Fifty-two soil samples were collected for physical and chemical analysis. The physiographic soil map showed two landscape types dominated in the study area namely, Depression and Hilland. In addition, two soil orders were identified: Vertisols and Entisols. After all, a geographic data base including all required soil-attributes was built to be utilized in land suitability assessment for specific crops.

The digital elevation model (DEM) expressed considerable variation in the topography, where the elevation ranges from -3 m to 161 m m.s.l., the lowest elevation values recorded on the north whereas the highest values recorded in the south-east area. According to the slope map, most of the study area has a slope < 2%, while the slopes characterize the edges of the terraces, valley sides and hilly areas.

The land suitability assessment for twelve crops was carried out according to the FAO framework for land evaluation. The results showed a clear variation in suitability from highly suitable (S1) to not suitable (N) due to different limiting factors. In general, wheat, barley, clover, sorghum, and chamomile showed high suitability in different map units. On the other hand, the map unit "Hi211" has low suitability where the suitability classes are marginal suitable (S3) and not suitable (N). Overall, the limiting factors varies from the correctable and non-correctable factors, thus applying the proper management can improve the suitability of the study area.

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الملخص العربي

الحاجة الي تقييم الصلاحية للأراضي – دراسة حالة في منخفض الفيوم، مصر – باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية

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يمثل الاستخدام المناسب للأراضي أحد أهم الخطوات نحو تحقيق التنمية المستدامة، وتهدف الدراسة الحالية إلى تقييم الموارد الأرضية بمركز اطسا، محافظة الفيوم، مصر. وتقع منطقة الدراسة بين دائرتي عرض "٥٠ '٠٠ °٢٩ و "٠٠ '١٩ °٢٩ شمالا وخطى طول "٣٠ '٣٠ °٣٠ و "١٥ '٥٦ °٣٠ شرقا، حيث تشغل مساحة حوالي ٨١٩٦٩ هكتار.

تم تحديد وحدات الخريطة الفيزيوجرافية لمنطقة الدراسة عن طريق التفسير البصري لمرئيات الأقمار الاصطناعية وبالاستعانة بنموذج الارتفاعات الرقمي وتم إنتاج الوحدات الخريطية باستخدام التكامل بين تلك البيانات والدراسة الحقلية (خلال شتاء ٢٠١٧/٢٠١٦) التي شملت ١٢ قطاعًا والتي تم وصفها مورفولوجيا وفقا لدليل منظمة الأغذية والزراعة (FAO, 2006)، وتم جمع ٥٢ عينة من التربة للتحليل الفيزيائي والكيميائي. وتم الدمج بين نتائج تقسيم التربة والبيانات الحقلية والتحليلات المعملية والوحدات الفيزيوجرافية لإنتاج خريطة التربة باستخدام نظم المعلومات الجغرافية. حيث أوضحت خريطة التربة أن منطقة الدراسة تتكون من ٢ وحدة فيزيوجرافية رئيسة "Landscape" هما Depression and Hilland، وتنقسم الى ٧ وحدات فيزيوجرافية فرعية.

وقد أظهر نموذج الارتفاع الرقمي في منطقة الدراسة تباينًا كبيرا في الطبوغرافيا حيث يتراوح الارتفاع من ٣ م تحت مستوى سطح البحر إلى ١٦١ م فوق مستوى سطح البحر، وأدنى قيم الارتفاع كانت في الجزء الشمالي من المنطقة المدروسة في حين أن أعلى القيم المسجلة كانت في الجانب الجنوبي الغربي والتي تمثل منطقة التلال. ويمكن ملاحظة أن قيم الارتفاع تنخفض من الجنوب باتجاه الشمال. وقد اشتقت قيم الميول من نموذج الارتفاعات الرقمي، حيث تتراوح قيم الميول من صفر إلى ٣١.٤٪ وتشير البيانات أن معظم قيم الميول في منطقة الدراسة تقل عن ٢٪.

تم تقييم الصلاحية للأراضي land suitability بمنطقة الدراسة لعدد ١٢ محصول (حقلي، خضر، فاكهة، ونباتات طبية وعطرية) بالاعتماد على الإطار العام لمنظمة الأغذية والزراعة FAO Land Evaluation Framework, 1976 لتقييم الأراضي. حيث تم عمل مقارنة بين كل من احتياجات المحاصيل وبين خصائص التربة المعنية، ونتج عن ذلك درجة صلاحية كل وحدة أرضية لكل محصول محل الدراسة.

أظهرت النتائج أن هناك تباين في درجات الصلاحية حيث ان هناك وحدات أظهرت صلاحية عالية أو متوسطة لمعظم المحاصيل، بينما هناك وحدات أظهرت صلاحية حدية أو عدم صلاحية لبعض المحاصيل. ويمكن القول ان محاصيل القمح والشعير والبرسيم والذرة الرفيعة والكاموميل قد أظهرت درجات صلاحية عالية في بعض الوحدات الأرضية. ومن ناحية اخري فان المنطقة الجنوبية بمنطقة الدراسة والتي تمثل الأراضي المستصلحة حديثًا قد أظهرت صلاحية حدية وعدم صلاحية لبعض المحاصيل. وبشكل عام فان هناك عوامل محددة للصلاحية يمكن علاجها من خلال تطبيق برامج الخدمة المناسبة مما يؤدي الى تحسين صلاحية تلك الوحدات ورفع درجة الصلاحية لها وبالتالي انتاجيتها.

الكلمات المفتاحية: تقييم الأراضي، نظم المعلومات الجغرافية، اطسا، الفيوم، مصر