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Integration of GIS and ALES Techniques for Modeling Physical and Economic Land Suitability Evaluation

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ABSTRACT

Arid and semi-arid regions are quite vulnerable to land degradation because of water shortage and miss-utilization. Miss- management of the existing soil and water resources are the main causes of land degradation and subsequently low agricultural productivity in the study area. The present study aimed to model and assesses the physical and economic land suitability evaluation for arable land use, with the help of Geographic Information Systems (GIS) and the Automated Land Evaluation System (ALES). Further objective of the present study is to establish a geographical soil database for the study area which can be utilized for future studies. A pilot study area at El Fayoum depression, Egypt, was selected to carry out the current study. Aerial photointerpretation was first undertaken for the preparation of geopedological map using stereoscopic analysis. The soils were classified up to the family level according to the standards of the United States Department of Agriculture (USDA). The Integrated Land and Water Information System (ILWIS) GIS software package was applied and ALES software was used to implement the FAO land evaluation framework 1976. Ten land use types LUTs were investigated: cotton, wheat, maize, sorghum, rice, sugar beet, onion, olive, mango and citrus. Net Present Value and Benefit Cost Ratio were applied to overview the economic situation of the current land use types. The physical evaluation results indicate that, the southern and middle parts of the study area are moderately to highly suitable for the selected LUTs, whereas the northern parts are marginally or not suitable. The economic evaluation results indicate that mango, onion and olive are the highest profitable land use types. Matching both physical and economic evaluation results showed that onion, sugar beet and (cotton, mango, olive & wheat) are the most suitable and promising land use types in the study area.

Key-words*:* GIS, ALES, modeling, land suitability evaluation, El Fayoum.

INTRODUCTION

In most developing countries agriculture remains the important engine for the economic development. A more sustainable agriculture is more likely to provide the long-term benefits required to achieve sustainable development and poverty alleviation. In Egypt only 4% of the country's surface area is under use, which concentrates mainly around the Nile River, the delta area and the Fayoum depression, whereas the remaining 96% are unused desert. Vast regions of the Western and Eastern deserts could become as productive as the present Nile valley and Delta, with the concomitance risk of causing salinization, alkalinization and waterlogging problems. With appropriate management practices the extent of the agricultural lands could spread into the present desert interior. In the arid environment of El Fayoum, land degradation is a severely limiting phenomenon. Therefore, the Fayoum area always requires a higher level of centralized management than the rest of Egypt because of its particular reliance on gravity-fed irrigation system in a closed depression, generating degradation phenomena which ultimately lead to desertification. Miss- management of the existing soil and water resources are the main causes of land degradation and subsequently low agricultural productivity in the study area. Therefore it is important to assess the suitability of different tracts of land for specific alternative forms of land use. The main aim of the present study is to identify the best land use type to be used for different lands, taking into consideration the quality of the land, the requirements of the land use, the social behavior and the economical situation. Geographic Information Systems (GIS) and the Automated Land Evaluation System (ALES) techniques have been used to model and assess the physical and economic land suitability evaluation. Further objective of the present study is to establish a geographical soil database for the study area which can be utilized for future studies. Geographic Information Systems (GIS) and ALES software have proved to be effective, and successful tools in studying, mapping, processing and presenting certain problem (Abdel-Motaleb, 1997). These techniques can be used for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986).

MATERIALS AND METHODS

To execute the present study, a methodological approach has been broadly arranged under two main stages: 1) Data collection and processing stage. 2) Data interpretation and assessment stage. The data collection and processing stage comprises interpretation of aerial photographs, fieldwork, laboratory analyses, re-interpretation of mapping units and digitizing of different maps using ILWIS GIS software. The data interpretation and assessment stage comprises: land suitability evaluation (physical and economic) using ALES software and presentation of final maps and results. The methodological approach used in the present study can be described as follows:

Field survey and production of Geopedological Map

The fieldwork has been divided into three phases: pre- fieldwork, fieldwork and post field work with different activities in each. Pre-fieldwork activities include collection of existing data and maps and preliminary interpretation of aerial photographs using the geopedological approach (Zinck, 1989). Fieldwork activities include verifying the boundaries of the preliminary soil map, description and measurements of soil-related properties (slope, depth, gravel, stoniness, groundwater depth, salinity, drainage, etc), classifying soils according to USDA standards (USDA, 1998 & 1999) and defining of land use types. Four transect sample areas including 11 soil profiles were selected. Besides, soil observations (profiles, minipits, pits and augur holes) were intensively made throughout the study area. The soil observations were carefully described in situ (FAO, 1977 and Farshad 1984& 1985);Post- fieldwork activities include analyzing soil samples, re- interpretation of aerial photographs based on field observations and laboratory analyses and preparing final soil map with legend. To increase the accuracy and purity of the soil map units, slope and texture maps were considered. Figure (1) and Table (1) shows the final soil map and legend.

Geographical soil database

To establish a geographical database for the study area, the main physical and chemical characteristics of each mapping units were determined and stored as attributes in the geographical soil database of ILWIS-GIS (Table 2). Then, the soil database has been exported from ILWIS database to ALES database to allow building up an evaluation model for the selected land use types. The established geographical soil database covers all soil related properties (EC, pH, ESP, SAR, organic matter, $CaCO_3$ equivalent, available water, land use, etc) which can be utilized for further studies.

Physical evaluation

To perform land suitability evaluation according to FAO land evaluation framework (FAO, 1976), the following operations were applied: (1) Selecting and describing land use types. The selection of the suitable land use types depends on their situations in the area, e.g. local needs, area coverage, social acceptability and economical profitability. Based on the existing cropping systems, ten land use types were selected (Table 3); (2) Adapting land use requirements and factor ratings. Land use requirements were selected on the basis of the available bibliography and the information collected during the fieldwork. The requirement tables were prepared and adapted for the study area, for which some references were used such as Siderius (1989) and Sys et al. (1993). Factor ratings were done in terms of four suitability classes: S1, S2, S3 and N; (3) Preparing the relevant land qualities and land characteristic. Five land qualities were considered based on the requirements of the selected LUTs, i.e. salinity & alkalinity, nutrient availability, moisture availability, oxygen availability & rooting conditions; and (4) Matching land use requirements with land qualities. The requirements of each land use type were matched with the qualities of each map unit to obtain an overall suitability class. This matching procedure was done automatically using the Automated Land Evaluation System (ALES). More details are indicated in Abdelfattah (2002).

Economical evaluation

General economic land evaluation was performed to assess the economic feasibility of the selected land use types. It is highly desirable in land evaluation to include information on costs and returns (FAO, 1984b). In ALES evaluation model, it is possible to perform two kinds of economic evaluations: (a) gross margin analysis and (b) discount cash flow analysis. The gross margin is defined as variable costs and returns, in units per currency per hectare per year (Rossiter and Van Wambeke, 1997) whereas the discount cash flow analysis considers the time value of money. According to FAO land evaluation framework, the results of the discounted cash flow can be expressed in the following terms: (1) Net Present Value (NPV), the present value of benefits minus the present value of costs, (2) Benefits/Cost Ratio (BCR), the present value of benefits divided by the present value of costs and (3) Internal Rate of Return (IRR), the rate of discounting at which the present value of benefits becomes equal to the present value of costs. In the present study, NPV and BCR were used to give a general overview of the economic situation of the current land use types (Tables 4 and 5). Details of inputs and outputs for different LUTs are indicated in Abdelfattah (2002).

Application of GIS and ALES techniques

The Integrated Land and Water Information System (ILWIS, 2002) was applied as GIS software package to cover the following operations: digitizing of maps, creation of igital Terrain Model (DTM) using interpolation from the digitized contour lines, creation of slope map from DTM, creation of new soil map by means of crossing with slope and exture maps, maps calculation and their statistics, input attribute and spatial data into geographical soil database, creation of attribute maps (salinity, alkalinity, land suitability etc) and presentation of final maps layouts. ALES was used to implement the FAO land evaluation framework 1976. ALES is a computer program that guides land evaluators in building expert system (Rossiter and Van Wambeke, 1997). Building models for land evaluation using ALES includes two stages: (1) Pre- modeling stage consisting of defining Land Utilization Types (LUTs), selecting and adapting the most important land use requirements of the current LUTs, selecting of the number of severity levels, listing land characteristics and expressing each of the selected land use requirements in terms of its diagnostic land characteristics; (2) Modeling stage includes defining and specifying LUTs, constructing decision trees and inferring land suitabilities. Evaluation, matching between land use requirements and land map units takes place automatically.

RESULTS AND DISCUSSIONS

Physiography and soils

According to the geopedological approach (Zinck, 1989), one landscape was identified in the stud y area which is the plain landscape that contains 5 relief types, 12 landforms and 34 mapping units (Table 1). The soils were classified up to the family level according to the protocol of the United States Department of Agriculture. The main soils identified in the study area as shown in Table (6) are Vertisols (Haplotorrerts), Entisols (Torrifluvents and Torripsamments) and Aridisols (Haplosalids, Aquisalids, Haplocambids and Haploargids). Figure (1) shows soil map of the study area.

Physical evaluation

Land evaluation is the assessment of land use performance when used for specific purposes (FAO, 1976). The main objective of land evaluation is to assess the suitability of different tracts of land for specific alternative forms of land use (Huizing et al., 1995). Land map units are used as a basis for land evaluation and are described in terms of land qualities and characteristics. The land physical suitability evaluation was done following the FAO land evaluation framework, by means of ALES software. The physical suitability results are shown in Table (7). The physical evaluation results indicate that the southern and middle parts of the study area (high and moderately high terraces) are moderately to highly suitable, whereas the northern parts (low terraces) are marginally or not suitable due to salinity and alkalinity constraints. The most suitable LUTs from physical point of view were sugar beet, sorghum, wheat, onion, olive, and cotton. More details are presented in Abdelfattah (2002).

Economical evaluation

The results of the economic evaluation are shown in Table (8). The results indicate that: (1) Mango, onion and olive are the highest profitable land use types concerning both NPV and BCR. (2) Sugar beet, although, it is a newly introduced land use type in the studied area, its economic situation is acceptable and promising. (3) Rice, wheat, sorghum and maize, the main essential cereal crops for domestic consumption, are economically fall in the middle rating. The overall economical evaluation results indicate that mango, onion, olive and cotton are the highest profitable land use types. Sugar beet in winter followed by onion in summer is considered the highest profitable crop rotation. Sugar beet followed by cotton intercalated with onion should be considered also, whereas, mango recorded the highest profitable orchard cultivation.

CONCLUSIONS

The most suitable land use types from physical point of view are sugar beet, sorghum, wheat, onion, olive and cotton. The highest profitable land use types from economic point of view are mango, onion and olive. Sugar beet, although it is a newly introduced land use type in the study area, its economic situation is acceptable and promising. Matching both physical and economic evaluation results showed that onion, sugar beet and (cotton, mango, olive & wheat) are the most suitable and promising land use types in the area.

REFERENCES

Abdelfattah, M.A., 1998. Land evaluation for sustainable land use planning in the NE part of the Fayoum depression, Egypt. M.Sc. Thesis, ITC, Enschede, The Netherlands, pp198.

Abdelfattah M.A., 2002. A GIS evaluation for soil and water management for sustainable agriculture in El Fayoum Governorate, Egypt. Ph.D. dissertation, Faculty of Agriculture, El Fayoum, Cairo University, Egypt, pp160.

Abdel-Motaleb, M.H., 1997. Studies on monitoring desertification and land degradation processes at El Fayoum depression, Egypt. M.Sc. Thesis, Faculty of Agriculture, El Fayoum, Cairo University, Egypt.

Burrough, B.A., 1986. Principles of Geographic Information Systems for Land Resources Assessment. Clarendon Press, Oxford, UK.

FAO, 1976. A Framework for Land Evaluation. FAO Soils Bulletin, 32, Rome, Italy. pp 72.

FAO, 1977. Guidelines for Soil Profile Description, (Second edition), Rome, Italy.

FAO, 1984b. Guidelines: Land Evaluation for Rainfed Agriculture. FAO Soils Bulletin 52, Rome, Italy. pp237.

Huizing, H.A., Farshad, A., Debies, K., 1995. Land evaluation (land use system evaluation). Lecture notes for LELUP module. ITC, Enschede, the Netherlands.

ILWIS, 2002. Integrated Land and Water Information System. Version 3.1, ITC, Enschede, The Netherlands.

Rossiter, D.G., Van Wambeke, A.R., 1997. Automated Land Evaluation System (ALES), Version 4:65 - User's Manual, lthaca: Cornell University, pp 279.

Siderius, W., 1989. Tables of Crop Requirements and Factor Ratings. DLD, Bangkok, Thailand. ITC Internal publication. Code No. SOL 49, Enschede, The Netherlands.

Sys, C.; Van Ranst, E.; Debaveye, J. and Beernaert, F., 1993. Land Evaluation, Part III: Crop Requirements. General Administration for Development Cooperation, Brussels, Belgium, Agricultural publication No. 7, pp 199.

USDA, 1998. Keys to Soil Taxonomy. United States Department of Agriculture, Natural Resources Conservation Center. Eighth edition.

USDA, 1999. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. USDA Agriculture Handbook No. 436. U. S. Government Printing Office: Washington, D.C.

Zinck, J.A., 1989. Physiography and Soils. Soil Survey Course, ITC Lecture Note, K6 (SOL 41), Enschede, The Netherlands.

Table 1 - Legend of the geopedological units

Landscape	Relief	Lithology	Landform	Mapping Unit	***Symbol***	Area/fed.	Percentage
Plain (P1)	Higher terraces (P1 1)	Nile alluvial deposits (P1 11)	Nearly level terrace tread (P1 111)	Slope <0.5% & Tex. Clayey	P1 1111	4453.29	8.5
				Slope <0.5% & Tex. Loamy	P1 1112	2079.00	4.0
				Slope 0.5-2% & Tex. Clayey	P1 1113	2385.86	4.5
				Slope 0.5-2% & Tex. Loamy	P1 1114	1549.07	2.95
				Slope 2-8% & Tex. Clayey	P1 1115	397.29	**0.75**
				Slope 2-8% & Tex. Loamy	P1 1116	308.14	0.6
		Fluvio-lacustrine deposits (P1 12)	Gently sloping terrace tread (P1 121)	Slope <0.5% & Tex. Clayey	P1 1211	5037.86	9.5
				Slope <0.5% & Tex. Loamy	P1 1212	562.93	1.1
				Slope 0.5-2% & Tex. Clayey	P1 1213	1191.43	2.3
			Basin (P1 122)	Slope <0.5% & Tex. Clayey	P1 1221	772.07	1.5
				Slope <0.5% & Tex. Loamy	P1 1222	490.29	1.0
	Moderately high terraces (P1 2)	Alluvial deposits (P1 21)	Nearly level terrace tread (P1 211)	Slope <0.5% & Tex. Clayey	P1 2111	405.64	0.75
				Slope 0.5-2% & Tex. Clayey	P1 2112	565.50	1.1
			Sloping terrace tread (P1 212)	Slope <0.5% & Tex. Clayey	P1 2121	1802.79	3.4
				Slope 0.5-2% & Tex. Clayey	P1 2122	3666.64	7.0
				Slope 0.5-2% & Tex. Loamy	P1 2123	657.21	1.25
				Slope 2-8% & Tex. Clayey	P1 2124	422.14	0.8
			Basin (P1 213)	Slope 0.5-2% & Tex. Clayey	P1 2131	127.07	0.25
	Moderately low terraces (P1 3)	Fluvio-lacustrine deposits (P1 31)	Gently sloping terrace tread (P1 311)	Slope <0.5% & Tex. Sandy	P1 3111	563.57	1.10
				Slope 0.5-2% & Tex. Loamy	P1 3112	384.21	0.75
				Slope 0.5-2% & Tex. Clayey	P1 3113	3663.21	7.00
				Slope <0.5% & Tex. Clayey	P1 3114	6830.57	13.00
				Slope <0.5% & Tex. Loamy	P1 3115	535.50	1.00
	Low terraces (P1 4)	Fluvio-lacustrine (P1 41)	Nearly level to gently sloping terrace tread (P1 411)	Slope 0.5-2% & Tex. Clayey	P1 4111	901.07	1.70
				Slope <0.5% & Tex. Clayey	P1 4112	5251.50	10.00
				Slope <0.5% & Tex. Sandy	P1 4113	460.29	0.90
			Basin covered with sand sheet (P1 412)	Slope <0.5% & Tex. Sandy	P1 4121	264.21	0.50
				Slope <0.5% & Tex. Clayey	P1 4122	1491.00	2.80
			Marshes (P1 413)	Slope <0.5% & Tex. Sandy	P1 4131	613.71	1.20
				Slope <0.5% & Tex. Clayey	P1 4132	1248.64	2.40
	Incisions (P1 5)	Alluvial deposits (P1 51)	Vales (P1 511)	Slope 0.5-2% & Tex. Clayey	P1 5111	1333.50	2.60
				Slope <0.5% & Tex. Clayey	P1 5112	839.36	1.60
				Slope <0.5% & Tex. Loamy	P1 5113	530.36	1.00
			Overflow-mantle (P1 512)	Slope 0.5-2% & Tex. Clayey	P1 5121	633.64	1.20

Table 2 - Land map units characteristics

Diagnostic factors/ LMU#	Symbol	Available water (%)	CEC (cmole/kg)	$CaCO_3$ (%)	Drainage condition[1]	EC (top)[2] dS/m	EC (sub)[2] dS/m Crops	EC (sub)[2] dS/m Fruits	ESP (top)[2]	ESP (sub)[2] Crops	ESP (sub)[2] Fruits	Depth (cm)	Texture[3]	pH	Organic matter (%)
1	PI111 1	34.11	42.33	4.59	W	1.52	1.32	1.39	13.85	14.77	14.92	150	C	7.98	1.46
2	PI111 2	20.71	29.74	1.64	W	2.77	1.50	1.17	13.96	14.06	13.6	150	SCL	7.47	1.44
3	PI111 3	24.69	21.79	1.52	W	1.43	1.85	1.85	10.38	9.71	9.71	80	SCL	7.77	0.80
4	PI111 4	18.82	35.12	2.62	W	1.29	1.17	1.24	6.44	6.31	6.58	150	SCL	8.1	-
5	PI111 5	18	29.60	2.58	MW	1.17	5.05	5.61	13.72	13.72	13.72	150	CL	8.31	1.05
6	PI111 6	19.5	29.48	2.89	W	0.76	0.74	0.73	11.02	11.02	11.02	150	SCL	8	1.36
7	PI121 1	17.69	40.59	4.02	W	4.02	4.89	4.55	13.74	14.34	14.29	150	C	7.81	1.04
8	PI121 2	20	25.85	5.69	W	1.12	1.62	1.73	19.34	19.34	19.34	150	SCL	8.2	1.31
9	PI121 3	9.02	12	1.76	W	1.16	0.88	0.85	2.92	3.33	3.85	150	SCL	8.19	-
10	PI122 1	20.12	16.45	5.47	W	1.75	1.7	1.7	6.62	6.17	6.17	100	SCL	7.44	0.82
11	PI122 2	20.5	29.02	4.65	MW	1.76	3.3	3.16	17.12	17.12	17.12	150	SL	8.4	0.95
12	PI211 1	19.5	38.32	5.39	W	1.66	2.27	2.29	12.53	12.53	12.53	150	C	8.06	1.23
13	PI211 2	20	38.97	10.62	MW	1.69	3.08	3.34	29.47	29.47	29.47	150	C	8.38	1.25
14	PI212 1	22.9	40.31	10.34	MW	11.67	8.16	7.20	14.58	14.58	14.63	110	C	7.70	1.12
15	PI212 2	24.13	32.79	4.46	W	1.72	1.5	1.49	11.6	12.68	13.16	110	C	7.75	1.3
16	PI212 3	16.75	33.31	3.26	W	1.17	1.23	1.26	7.66	9.25	9.68	150	C	7.73	1.17
17	PI212 4	18.5	33.59	3.07	W	1.04	1.52	1.43	11.02	11.02	11.02	120	CL	8.06	1.42
18	PI213 1	19	37.85	9.57	MW	1.61	2.23	2.85	14.93	14.93	14.93	150	C	8.39	1.41
19	PI311 1	18.5	6.42	1.4	EW	3.5	4.39	6.07	11.99	13.15	15.28	205	S	7.8	0.03
20	PI311 2	18.5	33.71	6.15	MW	1.45	1.31	1.25	28.39	28.39	28.39	120	SCL	8.46	1.25
21	PI311 3	19.5	38.13	6	MW	6.68	3.23	3.44	12.18	17.16	16.18	130	C	7.92	1.53
22	PI311 4	20.65	26.34	10.84	W	9.09	8.16	8.5	14.19	16.19	16.46	100	C	7.71	1.02
23	PI311 5	18.5	35.25	4.95	MW	1.74	4.13	4.29	14.14	14.06	13.95	110	CL	7.99	1.32
24	PI411 1	23.95	25.78	11.20	P	22.93	19.08	19.8	31.8	31.26	31.26	80	C	8.55	0.91
25	PI411 2	21	50.66	5.28	MW	2.18	2.28	2.19	23.54	38.7	37.89	170	C	8	1.17
26	PI411 3	17	13.07	5.09	W	4.98	7.58	8.03	31.83	54.51	51.83	125	LS	8.26	2.48
27	PI412 1	17	16.75	4.68	SWE	4.93	8.73	9.64	19.39	19.39	19.39	120	LS	8	0.66
28	PI412 2	21	33.03	7.63	P	80.98	29.03	22.17	13.57	13.47	12.58	120	C	7.73	0.84
29	PI413 1	20	22.13	7.6	P	145.93	31.33	31.33	21.01	26.25	26.25	50	L	7.59	1.27
30	PI413 2	16.8	47.46	9.8	P	37.48	40.91	40.77	33.88	32.62	32.05	115	C	7.9	1.1
31	PI511 1	28.1	26.99	1.53	SWE	1.25	1.35	1.26	6.28	9.69	10.24	135	SCL	7.63	0.95
32	PI511 2	19	32.21	3.97	W	0.81	0.86	0.85	9.47	9.47	9.47	140	SCL	8.08	0.74
33	PI511 3	26.34	26.05	1.53	W	1.38	1.31	1.38	8.29	8.07	7.96	110	SC	7.5	1.49
34	PI512 1	20.37	26.99	3.34	W	2	1.4	1.4	9.1	8.15	7.95	110	CL	7.74	1.15

[1] Drainage condition abbreviations are: W = well, MW = moderately well, EW = excessively well drain, SWE = somewhat excessive and P = poorly drained. [2] topsoil is the average of the first 30 cm, subsoil is the average of 30 to 90 cm in field crops and 30 to 125 cm in fruit crops, other diagnostic factors are the averages of zero to 50 cm. [3] textural classes abbreviations are: C= Clay, CL= Clay Loam, SCL= Sandy Clay Loam, SiL = Silty Loam, GS= Gravely Sand, SL= Sandy Loam L= Loam, SC = Sandy Clay, LS= Loamy Sand, HC= Heavy Clay.

Table 3 - Selected land use types

LUTs	Season	Descriptive name
LUT1	Summer	Semi mechanized cotton followed by clover
LUT2	Winter	Semi-mechanized wheat / barley followed by summer crop
LUT3	Summer	Semi-mechanized maize followed by wheat, clover or vegetables
LUT4	Summer	Semi-mechanized sorghum followed by wheat, clover or vegetables
LUT5	Summer	Semi-mechanized rice followed by beans or vegetables
LUT6	Winter	Semi-mechanized sugar beet follower by summer crop
LUT7	Summer	Semi-mechanized onion follower by winter crop
LUT8	Permanent	Semi-mechanized olive intercropped with date palm
LUT9	Permanent	Semi-mechanized mango intercropped with grape or date palm
LUT10	Permanent	Semi-mechanized citrus intercropped with grape or date palm

Table 4 - Output parameters (mean, optimum, prices and total) for the selected LUTs

Land use types		**Outputs**	**Output unit**	**Average yield** (unit/feddan)	**Optimum yield** (unit/ fed.)	**Prices** (LE/unit)	**Total output** (LE/fed.)(1)
LUT1	Main product	Cotton tissues	Kentar	7.5	10	450	3505
	Other products	Branches	Bundle	200	250	0.65	
LUT2	Main product	Grains	Ardab	17	22	120	
	Other products	Hay	Bale	14	17	20	2320
LUT3	Main product	Grains	Ardab	18	22.5	85	
	Other products	Fodder	Ton	17	23	15	1785
	Other products	Hay	Bale	17	20	17	
LUT4	Main product	Grains	Ardab	16	25	85	
	Other products	Fodder	Ton	19	25	15	1645
LUT5	Main product	Rice grains	Ton	3.200	5000	750	2689
LUT6		Daranat	Ton	16	20	160	2560
LUT7		Onion	Ton	15	19	350	5250
LUT8		Olive fruits	Ton	4.5	5	1100	4950
LUT9		Fruits	Ton	4.8	5.5	2750	13200
LUT10		Fruits	Ton	4.5	6.0	650	2925

(1) LE = Egyptian pound (1 US$ equal to 4 LE). Source: Fayoum Agricultural Directorate and interviews.

Table 5 - Net Present Values and Benefit/Cost Ratio for the selected LUTs

LUTs	Inputs (LE/fed.)	Outputs (LE/fed.)	NPV[1] (LE/fed.) Per season	NPV[1] (LE/fed.) Per month	BCR[2] (LE/fed.)
1- Cotton	1018	3505	2487	355	3.44
2- Wheat	539	2320	1781	274	4.30
3- Maize	692	1785	1093	188	2.58
4- Sorghum	631	1645	1014	184	2.61
5- Rice	905	2689	1784	297	2.97
6- Sugar beet	746	2560	1814	259	3.43
7- Onion	1420.5	5250	3829.5	766	3.70
8- Olive	1100	4950	3850	320	4.5
9- Mango	2570	13200	10630	885	5.14
10- Citrus	1200	2925	1725	143	2.44

1 NPV (Net present value) = Benefits – costs ; 2 BCR (Benefit cost ratio) = Benefits / costs.
*- Inputs-outputs were calculated according to the year 2002 prices, where 1 Egyptian pound LE = 0.25 US$.
*- Details of inputs and outputs of each LUT are indicated in Abdelfattah (2002).

Table 6 - Main soil types identified in each mapping unit of the study area.

MU #	Mapping unit	Main soil	Type of mapping unit
1	Pl 1111	Typic Haplotorrerts	Association
2	Pl 1112	Typic Torrifluvents	Consociation
3	Pl 1113	Vertic Torrifluvents	Consociation
4	Pl 1114	Typic Torrifluvents	Association
5	Pl 1115	Typic Haplotorrerts	Consociation
6	Pl 1116	Typic Torrifluvents	Consociation
7	Pl 1211	Typic Haplotorrerts	Consociation
8	Pl 1212	Typic Haplotorrerts	Consociation
9	Pl 1213	Typic Torrifluvents	Consociation
10	Pl 1221	Typic Torrifluvents	Consociation
11	Pl 1222	Typic Torrifluvents	Consociation
12	Pl 2111	Typic Haplotorrerts	Consociation
13	Pl 2112	Typic Haplotorrerts	Consociation
14	Pl 2121	Typic Haplotorrerts	Association
15	Pl 2122	Vertic Torrifluvents	Consociation
16	Pl 2123	Chromic Haplotorrerts	Consociation
17	Pl 2124	Vertic Torrifluvents	Consociation
18	Pl 2131	Typic Haplotorrerts	Consociation
19	Pl 3111	Typic Haplocambids	Consociation
20	Pl 3112	Typic Haplotorrerts	Consociation
21	Pl 3113	Typic Haplotorrerts	Association
22	Pl 3114	Vertic Torrifluvents	Consociation
23	Pl 3115	Xeric Haplargids	Consociation
24	Pl 4111	Calcic Aquisalids	Consociation
25	Pl 4112	Typic Haplotorrerts	Association
26	Pl 4113	Xeric Torripsamments	Consociation
27	Pl 4121	Typic Torripsamments	Consociation
28	Pl 4122	Typic Haplosalids	Consociation
29	Pl 4131	Typic Aquisalids	Consociation
30	Pl 4132	Typic Haplosalids	Consociation
31	Pl 5111	Typic Torrifluvents	Association
32	Pl 5112	Typic Torrifluvents	Consociation
33	Pl 5113	Vertic Torrifluvents	Consociation
34	Pl 5121	Vertic Torrifluvents	Consociation

Table 7 - Physical suitability subclasses results

LUTs		LUT 1 Cotton	LUT 2 Wheat	LUT 3 Maize	LUT 4 Sorghum	LUT 5 Rice	LUT 6 Sugar beet	LUT 7 Onion	LUT 8 Olive	LUT 9 Mango	LUT 10 Citrus
LMU#	Symbol										
1	P1111 1	3 n	2 n	2 n	2 n	2 n	2 n	2 n/r	1	2 m/r	2 m/r/s
2	P1111 2	1	1	1	1	3 m	1	1	1	1	2 s
3	P1111 3	2 n	2 n	1	2 n	3 m	2 n	2 n	3 r	2 n/r	3 r
4	P1111 4	2 n	2 n	2 n	1	3 m	1	2 n	2 n	2 n	2 n
5	P1111 5	2 n/o	2 n/o	2 n/o/s	2 o	2 n/s	2 o	2 n/o	2 n/o	3 o	2 n/o/s
6	P1111 6	1	1	1	1	3 m	1	1	1	1	2 s
7	P1121 1	2 m/n	2 s	2 m/n/s	2 m	2 m/n/s	2 m	2 m/n/r/s	2 m	2 m/n/r/s	2 m/n/r/s
8	P1121 2	2 n	2 s	2 n/s	1	3 m	1	1	1	2 s	3 s
9	P1121 3	3 m/n	3 m	3 m	3 m	3 m	3 m	3 m	2 m/n	3 m/n	3 m
10	P1122 1	2 n	2 n	1	2n	3 m	2 n	2 n	2 n	2 n	1
11	P1122 2	2 m/n	2 m/n/r/s	3 n	2 m/n	4 m	2 m/n	3 n	2 m/n	3 n	3 n/s
12	P1211 1	1	1	1	1	1	1	2 r	1	2 n/r	2 m/r/s
13	P1211 2	2 n/s	2 n/s	4 s	2s	2 n/s	2 s	2 n/r/s	2 n/s	3 s	4 s
14	P1212 1	2 s	3 s	3 s	2 s	4 s	2 s	4 s	1	3 s	3 s
15	P1212 2	1	1	1	1	1	1	2 r	2 r	2 m/r	2 m/r/s
16	P1212 3	2 m	1	2 m	2 m	2 m/n	2 m	2 m/r	2 m	2 m/r	2 m/r
17	P1212 4	1	1	1	1	1	1	1	2 n	2 n	2 n
18	P1213 1	2 n	2 n	2 n	1	1	2 n	2 n/r	2 n	2 m/n/r	2 m/n/r/s
19	P1311 1	3 m/n/o	3 m/n/o	3 m/n/o	3 m/n/o	4 m/o/r	3 m/n/o	3 n/o	3 m/n/o	3 m/n/o	3 n/o/s
20	P1311 2	2 n/s	2 n/s	4 s	2 s	3 m	2 s	2 n/s	2 n/s	3 s	4 s
21	P1311 3	2 n	2 s	2 n/s	1	3 s	1	2 r/s	1	2 m/r/s	3 s
22	P1311 4	2 s	2 s	3 s	1	3 s	1	2 n/r/s	2 r	3 s	3 s
23	P1311 5	2 n	1	2 n/s	1	2 s	1	1	2 r	2 s	2 r/s
24	P1411 1	4 s	4 s	4 n/s	4 s	4 s	4 s	4 n/s	3 n/o/r/s	4 n/s	4 n/s
25	P1411 2	3 s	2 s	4 s	2 s	3 s	2 s	2 r/s	3 s	4 s	4 s
26	P1411 3	4 s	3 m	4 s	3 m/s	4 m/s	3 s	3 n	4 s	4 s	4 s
27	P1412 1	3 m	3 m	3 m/s	3 m	4 m	2 m/n/o	2 m/n/o/s	3 o	3 n/s	3 s
28	P1412 2	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 s
29	P1413 1	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 r/s	4 s	4 r/s
30	P1413 2	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 s	4 s
31	P1511 1	2 n/o	2 n/o	2 n/o	2 n/o	3 m	2 n/o	2 n/o	3 o	2 n/o	2 n/o/s
32	P1511 2	2 n	2 n	2 n	2 n	3 m/n	2 n	2 n	2 n	3 n	2 n
33	P1511 3	2 n	2 n	1	2 n	2 m/n	2 n	2 n/r	2 n	2 n/r	2 m/r
34	P1512 1	1	1	1	1	2 n	1	1	1	1	1

Note: Number 1 = highly suitable, 2 = moderately suitable, 3 = marginally suitable and 4 = not suitable. The small suffix letters with 2, 3 and 4 indicate limitations with the following abbreviations: s=salinity and sodicity; n=nutrient availability; m=moisture availability; r=rooting conditions; o=oxygen availability

Table 8 - Rating of the most profitable land use types concerning NPV and BCR

Rating position	The best land use Concerning NPV[1]	The best land use Concerning BCR[2]
1	LUT 9- Mango	LUT 9- Mango
2	LUT 7- Onion	LUT 8- Olive
3	LUT 1- Cotton	LUT 2- Wheat
4	LUT 8- Olive	LUT 7- Onion
5	LUT 5- Rice	LUT 1- Cotton
6	LUT 2- Wheat	LUT 6- Sugar beet
7	LUT 6- Sugar beet	LUT 5- Rice
8	LUT 3- Maize	LUT 4- Sorghum
9	LUT 4- Sorghum	LUT 3- Maize
10	LUT 10- Citrus	LUT 10- Citrus

(1) NPV (Net present value) = Benefits – costs, (2) BCR (Benefit cost ratio) = Benefits / costs.

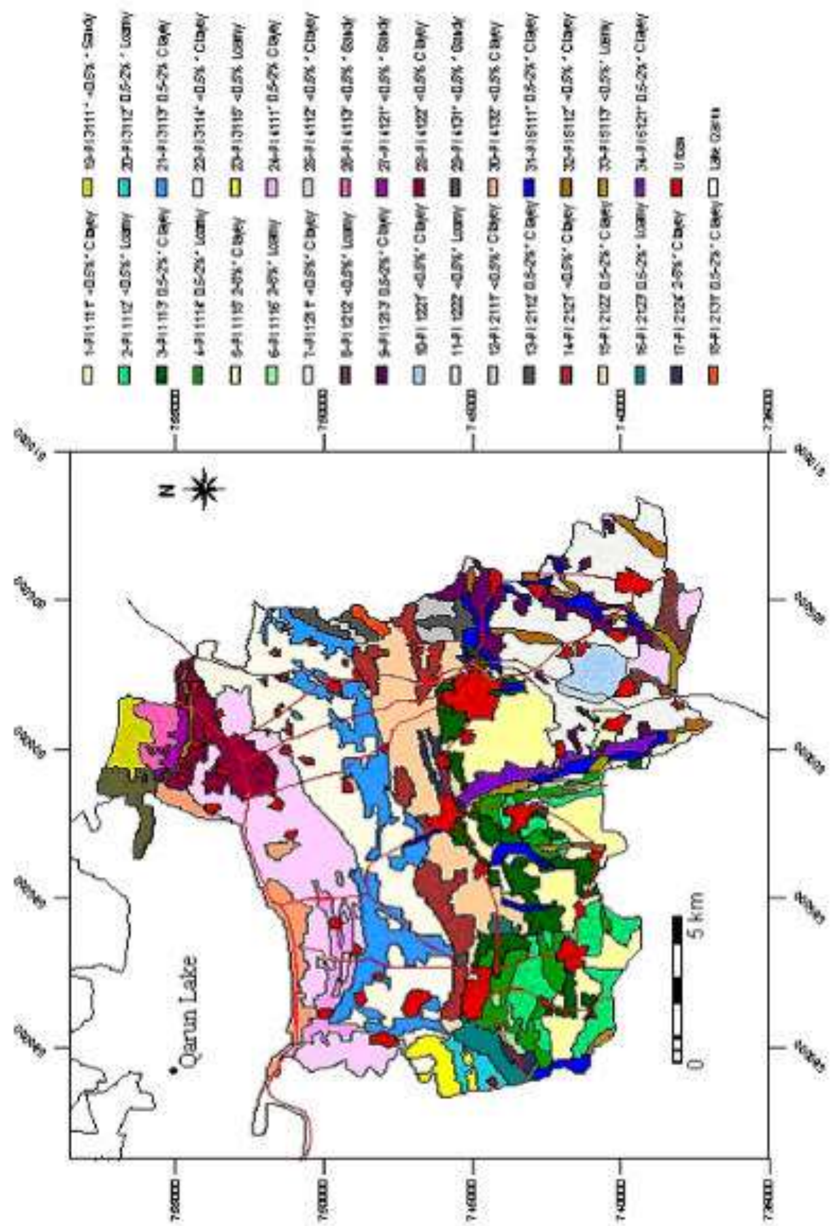

Figure 1 - Geopedological map "soil map" of the studied area.