LAND SUITABILITY ASSESSMENT FOR DATE PALM CULTIVATION IN THE EASTERN NILE DELTA, EGYPT USING AN AUTOMATED LAND EVALUATION SYSTEM AND GIS

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ABSTRACT

A physical land suitability assessment for irrigated date palm in the Eastern Nile Delta was performed using the DATE PALM-EGYPT model built in the Automated Land Evaluation System (ALES) computer program. Selection of the best land for irrigated date palm cultivation and determination of the production limiting factors are done through matching land characteristics with the date palm requirements using decision trees that were build in ALES. Climatic, soil and landform requirements for date palm cultivation are provided. Expert knowledge was captured in ALES and successfully linked to a geographical information system (GIS) in which soil and climatic maps were stored. The GIS procedure applied allowed the distribution pattern of land suitability to be displayed and to calculate the surface area suitable for the date palm within each land unit and for the whole study area. About 73% of the area was found to be suitable and 14% has limitations of some kind. About 13% of the land could not evaluated based on available soil information. Land with very severe limitations owing to soil wetness and salinity and alkalinity hazards. The small-scale maps and the land attributes used render DATE PALM-EGYPT useful to land use planners and researchers at the national level. The results obtained can be employed by land use planners to select areas suitable for irrigated date palm production.

Additional Index Words: date palm, physical land suitability, ALES, GIS, Egypt

INTRODUCTION

Egypt is a rapidly developing nation with population of more than 66 million, which, at the current growth rate of about 1% per year, will exceed the 100 million inhabitants in the coming decade. The agriculture sector employs directly about 60% of the population, but the country is still importing large quantities of basic food commodities. Agricultural production satisfies nearly 70% of the domestic food requirement, including crops and livestock products. Due to the expanding land reclamation in the surroundings of existing arable land, the use of fresh irrigation water is becoming more and more restricted. Irrigation is also more often applied, resulting in some places in water logging and soil salinity. Today, most of the irrigated areas in Egypt are potentially salt affected.

Population pressure on the limited areas with high productivity and national concern about the security of food supply have called the attention on the need for appropriate agricultural management. Egyptian government is aware of the need to expand cultivated areas to meet the requirements of its over-growing population. Attempts are made to increase the cultivation production, in many cases by cultivating date palms *(Phoenix dactylifera L.*) in the new reclaimed and saline-affected areas. Date palm makes a significant contribution towards the creation of equable microclimates within oasis ecosystems, thus enable agricultural development to be sustained in many drought-and saline affected regions. Date palm trees are essential components of farming system equally well in small farm units or as larger scale commercial plantation units. The tremendous advantage of the tree is its resilience, its requirement for limited inputs, its long-term productivity and its multiple purpose attributes (Wagner, 1982; Bircher, 1990; Annual reports, 1992).

To achieve this goal, it is necessary to have comprehensive information on the physical resource and to identify the major limitations to cultivate date palms in order to optimise land use and increase production. Land evaluation deals with two major aspects of land: physical and socio-economic resources (Sys et al., 1991a). Several procedures have been used for physical land evaluation (Sys et al., 1991b; Van Diepen et al., 1991; Van Lanen, 1991, Salah 1998, 1999), ranging from expert knowledge based on farmers’ experience to process-oriented simulation models, based on generally applicable physical and biological laws, which are derived from extensive laboratory and field experiments (Bouma, 1989). The physical land evaluation are particularly attractive when quick results are required or when the data available are not sufficient for quantitative methods based on computer simulation models.

A widely used physical land evaluation method on expert knowledge is the land suitability method developed by FAO (1976) for assessing suitability of land for a specific use. Suitability is expressed in descriptive terms: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), unsuitable with (N1) or without (N2) possibilities for land improvement. The Automated Land Evaluation System (ALES) developed by Rossiter (1995) is based on this framework (FAO, 1976) for land evaluation and offers the possibility of capturing local expert knowledge in decision trees (DTs). ALES can be used to construct models for a wide range of applications in any environment.

The objectives of this study were to present climatic, soil and landform requirements for generative date palm cultivation and demonstrate their potential in physical land evaluation through the combined use of ALES, IDRISI and ILWIS (the Integrated Land and Water Information System). The final objective of this research was to identify major limitations for irrigated date palm cultivation in the investigated area. Subsequently, selecting the most valuable management options in order to alleviate those constraints and improve the yields.

MATERIALS AND METHODS

The study area is situated in the Eastern Nile Delta of Egypt between latitudes 31° 40' and 32° 20' N, and longitudes 30° 25 and 31° 00' E. It includes Ismailia Province and part of El-Sharkyia Province and covers approximately 16,000 km^2 (Fig. 1). It can be divided into two main types of landscape. The first comprises most of the cultivated land in the Eastern Nile Delta region. The topography of this part is level to very gently sloping towards the north and north east from 75 m above sea level in the south, to 0.5-1.0 m close to Manzala Lake in the north west of the study area. The second part, representing the eastern part of the area, which extends to the Suez Canal, includes most of the uncultivated land. The climate is characterised by a hot summer and a mild winter with somewhat cold nights.

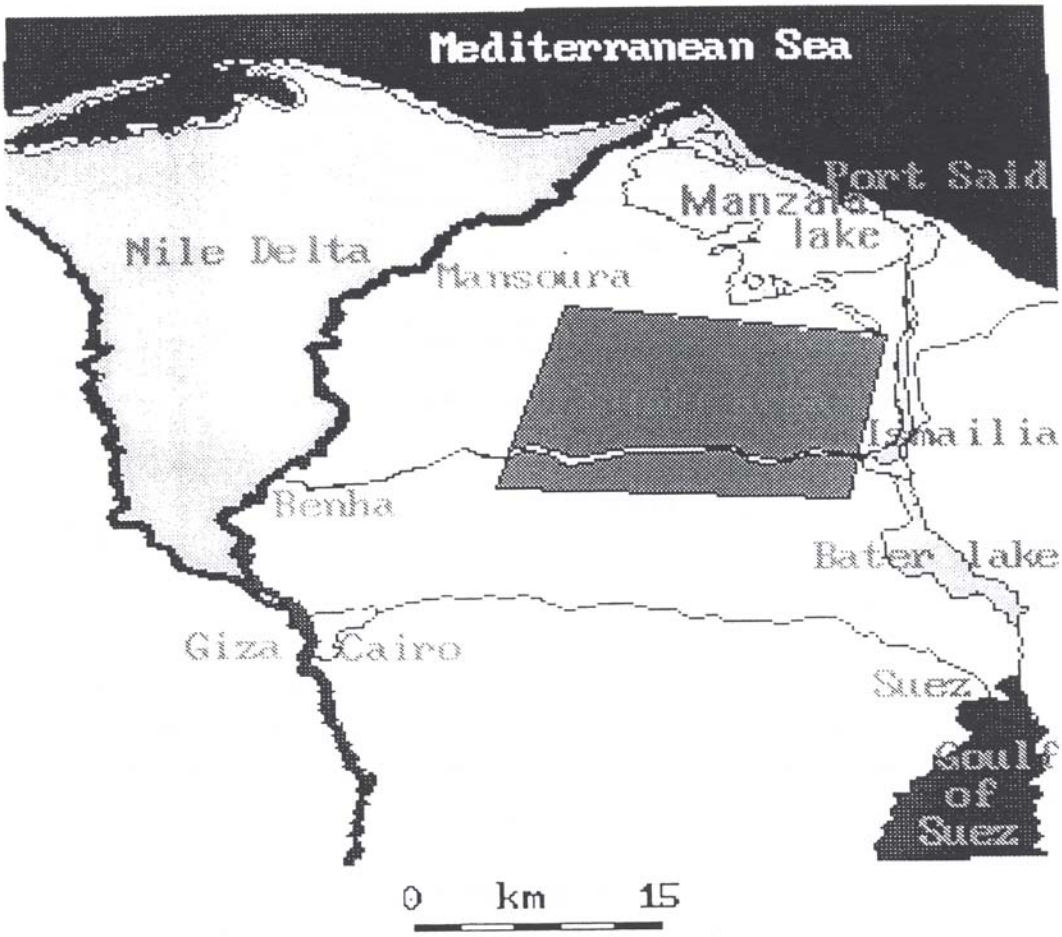

Fig. 1. Location of the study area.

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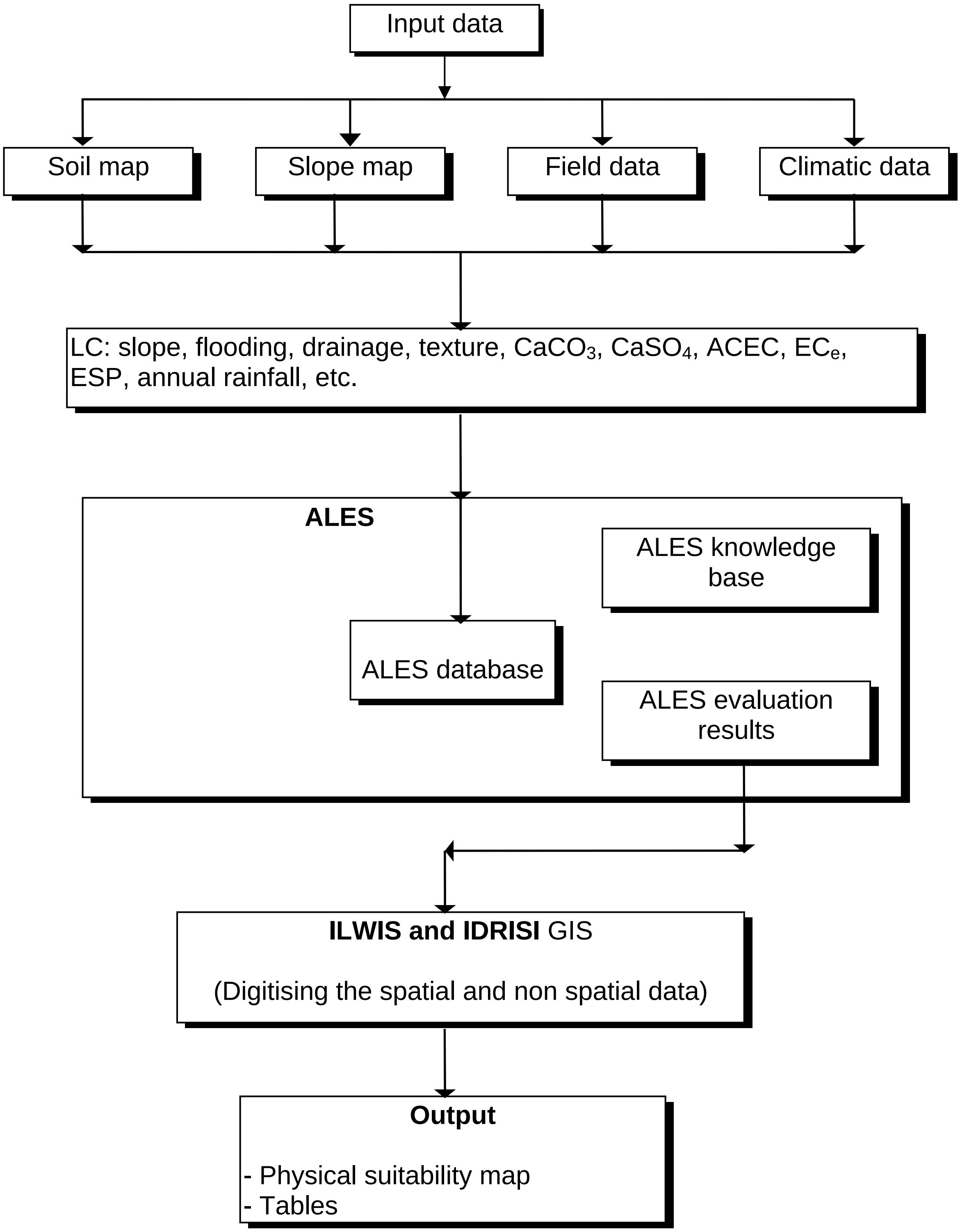

Fig. 2. Linkage of the computer programs used in this study.

Fig. 2. is schematic presentation of the research approach, integrating IDRISI, ILWIS and ALES and expert knowledge in the land suitability. ILWIS (ITC, 1993) and IDRISI (Eastman, 1995) were used to transform the analogue data into raster data. ILWIS was also used to make an overlay of the relevant maps (soil, slope, vegetation, and land use, etc.). The land characteristics (LCs) needed for the automated land evaluation were stored into the ALES database. Subsequently the knowledge base was used to evaluate the suitability of each Land Mapping Unit (LMU). The knowledge base describes the proposed land use, in physical terms. After ALES performed the land evaluation, the results were transferred to ILWIS in order to get a geographical reference for the results. Maps and tables were produced using ILWIS.

2.1. Climatic and soil data

Climatic data used to evaluate the climatic characteristics of the study area were obtained for the Ismailia meteorological station (FAO, 1984). The data set comprises minimum and maximum temperature, global radiation, wind speed, vapour pressure, rainfall, relative humidity, and reference evapotranspiration (ETo). The ETo was calculated using the Penman-Monteith formula (Smith, 1991).

Twenty-nine characteristic soil profiles, representing eight different soil series were used for this research. Information on slope was derived from topographical maps and remote sensing data. Information on drainage, flooding and soil depth was derived from the field descriptions. The other characteristics (Table 1) were calculated either over the upper 25 cm or the depth of the rooting system (100 cm), by using separate weighting factors for each profile section (Sys et al., 1991b). Values of the land characteristics used are given in Table 1 for some of the soil series.

Soil texture and structure, coarse fragments (vol. %), calcium carbonate (%) and gypsum content (%) were recalculated over the depth of the rooting system (100-cm). Apparent cation exchange capacity (ACEC) expressed in (cmol (+) kg^{-1} clay) of the B-horizon or at a depth of 50 cm was calculated without correction for organic matter. Weighted average organic carbon content (%), soil reaction (pH-H_2O), and sum of basic cations (Ca+Mg+K) expressed in (cmol (+) kg^{-1} soil) were calculated for the upper 25 cm. These land characteristics were used to evaluate the soil fertility status.

Soil salinity, expressed by electric conductivity (EC_e, dS/m) was calculated using weighting factors for each profile section. Soil alkalinity, expressed by exchangeable sodium percentage (ESP, %) is represented by the highest horizon value within a depth of 100-cm (Table 1).

Table 1. Values of the land characteristics used for some of the soil series.

Land characteristics*	**Soil series name**		
	deltaic	Fluvial-marine	Salhyia
Slope (%)	0-1	0-1	0-1
Flooding (class)	None	occasional	None
Drainage (class)	Well	Moderate	Well
Texture/structure (class)	C<60s	C<60s	S
Coarse fragments (vol.%)	0	0	0
Soil depth (cm)	150	100	120
$CaCO_3$ content (%)	2.19	2.9	0.88
Gypsum content (%)	0	0	0.17
Apparent CEC (cmol(+)kg^{-1} clay)	129.2	107.4	110.3
Sum of basic cations (cmol(+)kg^{-1} soil)	41.6	29.4	9.17
pH in water (1:2.5)	7.8	7.6	8.6
Organic carbon (%)	0.94	0.7	0.40
EC_e (dS/m)	0.66	58.6	2.40
ESP (%)	8.8	26.1	3.92

* S is sand; LS is loamy sand and C<60s is clay (less than 60% clay) with blocky structure;

EC_e is electric conductivity of saturation extract; ESP is exchangeable sodium percentage.

2.2. Automated land evaluation system (ALES)

ALES is not by itself an 'expert system' and does not include any knowledge about land and land use. ALES can be seen as an empty *"shell"* which provides the tools for the user to build his own expert land evaluation model. These tools are the same as those used in manual land evaluation. The tools used by ALES are on one hand the Land Use Requirements (LURs) of the selected Land Utilisation Types (LUTs) and on the other hand the land characteristics (LCs) of the Land Units (LUs) or Land Mapping Units (LMUs).

In this research, the expert knowledge for date palm was established following the FAO-framework (FAO, 1976; 1983) and resulted in the construction of climatic and landscape and soil requirements for date palm cultivation. This was followed by a review of experimental research findings and literature on parameters such as, phenology and morphology of the date palm, length of the growing cycle, and soil physical and chemical requirements. The expert knowledge was used to compute the physical suitability for growing irrigated date palm.

2.3. Elaborating DATEPALM-EGYPT

2.3.1. Land-utilisation type (LUT)

Cultivation of date palm under low management (capital intensity) by small-scale farmers producing dates for commercial purposes is the land utilisation type (LUT) considered in this research. About 66% of the farmers have less than 1 Feddan (4200 m^2). They use local varieties and are self-supporting. Cultivated date palms undergo a process of artificial fertilisation. The male flowers are cut off and tied to the trees above the female flowers. Seeds or offshoots sprouting from the base of the trunk are used in tree propagation. These reproduce the sex and nature of the parent tree and can therefore be used for commercial planting (Taekhom et al., 1973; annual report, 1992). Fertilisers, pesticides and insecticides are applied. Manure is also applied, if available. The palms are pruned twice a year, dry fronds being removed in the spring in order to that their fibre may be used as a substitute for coir. Yields depend entirely on natural soil fertility and environmental conditions. Farm labour is provided by the farmers and his family and is not costed (Amer, 1994).

2.3.2. Land-use requirements (LURs)

Land utilisation types (LUTs) are defined within ALES by their land-use requirements, i.e. conditions that make land more or less suitable for the land uses (Rossiter, 1995). Six LURs considered for the LUT are: (1) climate (cli), (2) topography conditions (top), (3) wetness conditions (wet), (4) rooting conditions (rot), (5) fertility status (fer), and (6) salinity and alkalinity hazards (salt) (Table 2).

Except for soil fertility status, LURs were selected that make the land either physically unsuitable and/or reduce the suitability. Poor soil fertility status only reduces the suitability but does not make the land physically unsuitable for date palm cultivation. Land improvement was not considered for this LUT. The corresponding land qualities (LQs) were put into one of five limitation classes as follows: (1) none, (2) slight, (3) moderate, (4) severe, and (5) very severe. Land presenting a very severe limitation is physically unsuitable for date palm cultivation. Land presenting slight, moderate, or severe limitation reduces suitability in that order.

Each LQ was defined by a specific combination of selected land characteristics (LCs) (Table 2). The LQs were matched with the LCs to determine the suitability levels of each quality using decision trees (DTs). For each LQ, one severity level decision tree was built. The severity level decision trees were used to determine values of land qualities from values of land characteristics, and physical suitability subclasses from values of land qualities (Table 2).

2.3.3. Decision trees

Severity level decision trees were constructed so that the program could infer land quality ratings from subsets of a list of land characteristics (Table 2). A decision tree can be a severity level or a subclass decision tree. The severity level decision trees allow to place each mapping unit into one of the defined suitability classes, based on how well the corresponding land quality (LQs) of the LUT are met by the prevailing LCs. The subclass decision tree assigns a specific subclass as a final output of the decision procedure, indicating the major limitation. Fig. 3 shows a decision tree followed by rating the LQ soil wetness (wet). The requirement for wetness conditions was determined by the LCs flooding (flo), drainage (dra), water table depth (WT), and soil texture (text). Severity classes of each attribute are expressed by a user-defined number of classes (1, 2, ...5). A final decision is reached when a severity level (1, 2, 3, 4, and 5) is preceded by an asterisk (*). An equality sign (=) indicates that the branch or the severity level takes the decision of the one to which it is equated (Fig. 3). The greater-than sign (>>) shows that the attached branch (sub-tree) should be followed. For instance, when flooding (flo) of the given area is Fo, drainage class is then called from the list of LCs and when the drainage class is WD and the water table depth is greater than 150 cm, the texture class is then called from LCs and twelve possible branches of decisions can be followed (Fig. 3).

The major factors affecting the date palm production and responsible for site-to-site variations in yield in Nile Delta refer to climatic characteristics, including: (1)annual precipitation, (2) irrigation supply, (3) insulation, (4) length of dry season, (5) number of days or precipitation index when it is greater than 5 mm/day during ripening period, (6) average daily temperature for vegetative cycle, flowering and ripening period, respectively, (7) thermal index during the flowering, fruit formation, and ripening period, respectively, (8) mean relative humidity during the vegetative cycle and fruit formation period, respectively, and (9) number of months where the wind speed is > 5 m/s (Table 3). The specific land use requirements, including: (1) topography, (2) wetness, (3) rooting conditions, (4) fertility status, and/or (5) salinity and alkalinity hazards (Table 2).

Table 2. Land use requirements (LURs) in terms of land qualities (LQs) with their severity levels and relations used to build the land evaluation decision trees.

Land quality (LQ) or (LUR)	No. of severity levels for each LQ	To which LC(s) the (LQ) is matched *	No. of classes
Climate (cli)	5	Annual precipitation (P) (mm)	5
		Irrigation water supply	1
		Insulation (mean n (hrs))	5
		Length of dry season: (month: P<0.5 ETo)	5
		Number of days or precipitation index > 5 mm/day: repining period (August- October)	5
		Average daily temperature (°C) for vegetative cycle	10
		Average daily temperature (°C) during the flowering period (February-March)	5
		Average daily temperature (°C) at repining stage (August-October)	5
		Thermal index: heat during the period of flowering, fruit formation and repining period (February-October)	10
		Mean RH (%) during the vegetative cycle	9
		Mean RH (%) during the fruit formation period (April-Augusts)	5
		Number of months where the wind speed is > 5 m/s (February-September)	5
Topography conditions (top)	5	Slope of the land (%)	5
Wetness conditions (wet)	5	Drainage (classes)	7
		Flooding (classes)	6
		Water table depth (cm)	5
		Soil texture (classes)	12
Rooting conditions (rot)	5	Volume of coarse fragment (%)	5
		Effective soil depth (cm)	5
		Calcium carbonate (%)	5
		Gypsum content (%)	5
Fertility status (fer)	5	Apparent CEC (cmol(+)/kg clay)	4
		Sum of basic cations (cmol(+)/kg soil)	5
		Soil reaction (pH)	10
		Organic carbon (%)	5
Salinity & alkalinity hazards (salt)	5	Salinity (EC, dS/m)	5
		Alkalinity (ESP, %)	5

* LC(S) is land characteristic(s); LQ is land quality.

>> Flo (Flooding)
-1. [Fo] >> Dra [drainage]
- - -1 [EXD] >> WT [Water table depth]
- - - - -1. [>150 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............*1 (none)
- - - - - -2. [SiL, CL, SC, Si, SiCL, SiC & C].....*2
- - - - -2. [150-125 cm] = 1
- - - - -3. [125-100 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............*1 (none)
- - - - - -2. [SiL, CL, SC].....................*2 (slight)
- - - - - -3. [Si, SiCL, SiC & C]...........*3 (moderate)
- - - - -4. [100-75 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............*1 (none)
- - - - - -2. [SiL, CL, SC].....................*2 (slight)
- - - - - -3. [Si, SiCL, SiC]...................*3 (moderate)
- - - - - -4. [C]....................................*4 (severe)
- - - - -5. [<75 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............ *2 (slight)
- - - - - -2. [SiL, CL, SC]..................... *3 (moderate)
- - - - - -3. [Si, SiCL]...........................*4 (severe)
- - - - - -4. [SiC & C] = 3
- - -2 [MWD] = 1
- - -3 [SED] >> WT [Water table depth]
- - - - -1. [>150 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............*1 (none)
- - - - - -2. [SiL, CL, SC] = 1
- - - - - -3. [Si, SiCL] .... *2 (slight)
- - - - - -4. [SiC & C]...........................*3 (moderate)
- - - - -2. [150-125 cm] = 1
- - - - -3. [125-100 cm] = 1
- - - - -4. [100-75 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............*1 (none)
- - - - - -2. [SiL, CL, SC].....................*2 (slight)
- - - - - -3. [Si, SiCL]...........................*3 (moderate)
- - - - - -4. [SiC & C]...........................*4 (severe)
- - - - -5. [<75 cm]>>Text [soil texture]
- - - - - -1. [SL, LS, L, SCL, S]............ *2 (slight)
- - - - - -2. [SiL, CL, SC]..................... *3 (moderate)
- - - - - -3. [Si]....................................*4 (severe)
- - - - - -4. [SiCL, SiC & C]..................*5 (v. severe)
??
-2. [F1] = 1
??
-4. [F3].....*5 (very severe)
-5. [F4] = 4

Discriminating entities are introduced by ‘ >> ‘ and underlined.
Values of the entities are [boxed].
The level in the tree is indicated by the leader characteristics, ‘ - ’.
The level in the branch is indicated by a numeric value.
Result values are introduced by ‘ ......* ’.
At the same level, ‘ = ‘ indicate the same result as the branch with the numeric value that follows.
The cut part of the tree is indicated by ‘??’
Abbreviations: F0 = none, F1 = occasional, F2 = seasonal, F3 = often, and F4 = flooded; WD = well-drained, MWD = moderate, SED = somewhat excessively, ED = excessively, ID = imperfectly, PD = poorly, and VPD = very poorly.

Fig. 3. Decision tree to determine land quality ratings of soil wetness.

So when the flooding (flo) is Fo (non), drainage (dra) is WD (well drained), (WT) (water table depth) is greater than 150 cm, and texture (text) is C or SiC (clay or silty clay) there is a slight limitation (a rating of 2 is awarded) (Fig. 3). But when the text is S (sand) the area will be rated as no limitation (a rating of 1 is awarded). The double question mark sign (??) indicates that either decision has not yet been made or that alternative criteria can be inserted in case of incomplete data. In this research the decision trees were constructed and traversed during the computation of an evaluation result in order to provide suitability outputs.

```
>>cli (climatic characteristics)
1. [no limitation] >> top (topographical conditions)
-    -    1. [no limitation] >> wet (wetness and flooding conditions)
-    -    -    -    1. [no limitation] >> rot (rooting conditions)
-    -    -    -    -    1. [no limitation] >> salt (salinity & alkalinity)
-    -    -    -    -    -    1. [no limitation] >> fer (fertility status)
-    -    -    -    -    -    -    -    1. [ no limitation]......*S1
-    -    -    -    -    -    -    -    2. [slight limitation]   = 1
-    -    -    -    -    -    -    -    3. [moderate limit.]...*S2fer
-    -    -    -    -    -    -    -    4. [severe limit.].......*S3fer
-    -    -    -    -    -    2. [slight limitation] = 1
-    -    -    -    -    -    3. [moderate limit.] >> fer (fertility status)
-    -    -    -    -    -    -    -    1. [ no limit.......]......*S2salt
-    -    -    -    -    -    -    -    2. [slight limit.]        = 1
-    -    -    -    -    -    -    -    3. [moderate limit]*S3salt/fer
-    -    -    -    -    -    -    -    4. [severe limit.].......*S3fer
-    -    -    -    -    -    4. [severe limit.] >> fer (fertility status)
-    -    -    -    -    -    -    -    1. [ no limit.......]......*S3salt
-    -    -    -    -    -    -    -    2. [slight limit.] = 1
-    -    -    -    -    -    -    -    3. [moderate limit] = 1
-    -    -    -    -    -    -    -    4. [severe limit.].. *S3salt/fer
-    -    -    -    -    -    5. [very severe limitation]..............*Nsalt
-    -    -    -    -    2. [slight limitation]= 1
??
-    -    -    -    -    5. [very severe limitation]..........*Nrot
-    -    -    -    2. [slight limitation] = 1
??
-    -    -    -    5. [very severe limitation]..........*Nwet
-    -    2. [slight limitation] = 1
??
-    -    5. [very severe limitation]..........*Ntop
2. [slight limitation] = 1
??
Discriminating entities are introduced by ‘ >> ‘ and underlined.
Values of the entities are [boxed].
The level in the tree is indicated by the leader characteristics, ‘ - ’.
The level in the branch is indicated by a numeric value.
Result values are introduced by ‘ ......* ’.
At the same level, ‘ = ‘ indicate the same result as the branch with the numeric value that follows.
The cut part of the tree is indicated by ‘??’.
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Fig. 4. Extract of the physical suitability subclass decision tree.

A physical suitability subclasses decision tree was constructed to determine the physical suitability of the land from the LQ ratings. Land suitable to grow date palm is indicated by the letter S, where as unsuitable land is indicated by the letter N. Arabic numbers are used to show the sequence of decreasing suitability: class S1 land is highly suitable, S2 is moderately suitable, and S3 is marginally suitable, and N is unsuitable. Lower-case letters suffixing the class symbol denote the kind(s) of limitation(s) (Fig. 4). There are six levels of discrimination in the physical suitability subclass decision tree with a number of decision branches at each level. The next discriminating entity is introduced when no severe limitation is encountered. The final land suitability subclass is based on the highest LQ rating (maximum limitation) found along the path of decision (Fig. 4).

Fig. 4 shows paths of the physical suitability decision tree. The program considers the LQ climate (cli) as the first discriminating entity. Depending on the rating, there are five branches to follow. The first branch is followed when there is no limitation. When the next LQs have no or slight limitations, a physical suitability (S1) is awarded. There are no subclasses for class (S1). Moderate and marginal limitations for fertility status (fer) results in subclass S2fer and S3fer, respectively. A Slight, limitations for salinity and alkalinity hazard (salt) result in the same decisions as those for the first branch (=1) at the same level of discrimination. Moderate and marginal limitations for salinity and alkalinity hazards mean that fertility status will be considered. There is no need to consider fertility status when salinity and alkalinity hazards present a very severe limitation in which case Nsalt is awarded.

2.3.4. ALES database and evaluation

Data entry templates were used to specify the LCs for which data were entered. Templates are groupings of different sorts of data, e.g. climatic variables and soil variables. More important templates are used to specify the order in which data are read into ALES from an external source like GIS. Two templates were defined, one for climate and another for soil and landform conditions. Data files for each LMU were read into ALES for evaluation. The “WHY” screen were used to fine-tune DATE PALM-EGYPT to reflect the “real” situation.

3. Results and discussion

Table 3 shows the climatic requirements, limits and the respective ratings used for climatic suitability assessment to identify potentially suitable land for date palm production. Date palm grows well in areas with annual rainfall between 100-200 mm (Morton, 1987; Wrigley, 1995). Date palm is reported to tolerate annual precipitation of 0.5 cm, whereas, annual rainfall greater than 2.25 cm during repining period can reduce the yield. Commercial fruit production is possible only where is a long, hot growing season with daily maximum temperatures of 32.2 °C. The date can tolerate long periods of drought though, for heavy bearing it has a high water requirement. A dry period of less than 6 months results in low yield (Morton, 1987). However, a dry period of at least 7 months is necessary to have good yields. Date palm must have full sun (Wrigley, 1995).

Table 3. A summary of agro-climatic requirements of irrigated date palm in Egypt.

Climatic characteristics	**Rating and limits**				
	1	2	3	4	5
Annual precipitation (P) (mm)	100-150	150-200	200-250	250-300	>300
Irrigation water supply	irrigated				
<u>Insulation</u> Mean n (hrs)	>8.1	8.1-7.3	7.3-5.2	5.2-3.5	<3.5
Length of dry season (month: P<0.5 ETo)	9-8	8-7	7-6	6-5	<5
Number of days or precipitation index > 5 mm/day: repining period (August-October)	5-10	10-15	15-20	20-25	>25
<u>Temperature (°C)</u> Average daily temperature (°C) for vegetative cycle Average daily temperature (°C) during the flowering period (February-March) Average daily temperature (°C) at repining stage (August-October)	22-24 22-19 25-22 32-30	24-27 19-16 22-18 30-27	27-30 16-13 18-14 27-24	30-35 13-7 14-10 24-21	>35 <7 <10 <21
<u>Thermal index:</u> Heat during the period of flowering, fruit formation and repining period (February-October)	2000-2300 1800-1600	2300-2500 1600-1400	2500-2800 1400-1200	2800-3100 1200-1000	>3100 <1000
Mean RH (%) during the vegetative cycle	50-60	60-70 45-40	70-80 40-35	80-90 35-25	>90 <25
Mean RH (%) during the fruit formation period (April-Augusts)	45-55	55-60	60-65	65-75	>75
Number of months where the wind speed is > 5 m/s (February-September)	0-1	2-3	4-5	6-7	>7

Temperature is the most critical climatic factor affecting the generative development of date palm (FAO, 1978). In order to initiate flowering, a temperature above 10 °C is required, but an average temperature less than 10 °C could inhibit flowering production. For proper ripening of fruit, the mean temperature between the period of flowering and ripening should be above 21 °C rising to 27 °C, for at least a month. An average temperature for of 30°C is good for proper ripening. Winter temperatures below –8°C are harmful (Annual report, 1992). The agro-climatic suitability assessment of Ismailia climatic station shows that the study area is highly suitable for growing date palm. In this research, the maximum limitation method was used to assess the suitability.

Table 4 shows the soil landscape requirements, limits and the respective ratings used to identify potentially suitable land for date palm cultivation. The date palm thrives in sand, sandy loamy, clay and other heavy soils. It needs good drainage and aeration. Although the date palm requires a well-aerated soil for maximum yields, the roots will survive submergence in water considerable periods, possibly due to the root structure that may enable them to conduct air downwards to the absorbing rootlets. It grown ideally where the permanent water table is within of the soil surface. These were considered in rating the LCs soil depth (depth) and depth of the water table (WT).

Table 4. A summary of soil landscape requirements of irrigated date palm in Egypt.

Landscape and soil characteristics *	Rating and limits				
	1	2	3	4	5
Slope (%) (for irrigated date palm)	0-5	5-10	10-15	15-30	>30
Flooding [a]	F0	F0	-	F1	F2, F3, F4
Drainage [b]	WD	MWD	SED (fine)	ED ID,	PD, VPD
Texture	SL, LS	L, SCL, S	SiL, CL, SC	Si, SiCL,	SiC, C
Soil depth (cm)	>150	150-120	120-75	75-35	<35
Coarse fragments (Vol. %)	0-5	5-15	15-35	35-55	>55
$CaCO_3$ (%)	0-10	10-15	15-25	25-35	>35
Gypsum (%)	0-15	15-25	25-35	35-45	>45
ACEC (cmol (+) kg^{-1} clay) [d]	>24	24-16	<16(-)	<16(+)	-
SBC (cmol (+) kg^{-1} soil) [e]	>8	8-5	5-3.5	3.5-2	<2
pH (H_2O)	6.5-6.2 6.5-7.2	6.2-5.6 7.2-7.8	5.6-5.3 7.8-8.2	5.3-5.0 8.2-8.5	<5 >8.5
Organic carbon (%)	>2.5	2.5-1.5	1.5-0.7	<0.7	-
EC_e (dS/m) [f]	<6	6-10	10-15	15-20	>20
ESP (%) [g]	<8	8-15	15-25	25-30	>30
Depth of water table (cm)	>150	150-125	125-100	100-75	<75

Full names for land characteristics are given in Table 2. [a] F0, F1, F2, F3 and F4 indicate none, occasional, often and flooded, respectively. [b] WD, MWD, SED, ED, ID, PD, and VPD indicate well, moderate well, somewhat excessively, excessively, imperfectly, poorly and very poorly drained, respectively. [c] S is sand; LS is loamy sand; SL is sandy loam; L is loam; SiL is silt loam; Si is silt; SCL is sandy clay loam; CL is clay loam; SiCL is silty clay loam; SC is sandy clay; SiC is silty clay and C is fine clay, blocky structure. [d] ACEC is apparent CEC. [e] SBC is sum of basic cations. [f] EC_e is electric conductivity of saturation extract. [g] ESP is exchangeable sodium percentage.

The water requirements for date palm are very high, 20,000-30,000 m^3/ha, or even more on very sandy soils. In general date palms are planted, therefore, where enough irrigation water is available or where the trees can reach the groundwater level at maximum depth of 6 m. But even where the trees are largely dependent upon the groundwater, 4-6 irrigations per year is needed.

With regard to rating of the soil fertility status, available information on the soil pH range and other fertility characteristics (Bircher, 1990; Sawan, 1993) was used. Date palm is reported to tolerate a pH of 5.0 to 8.5. Date palm is remarkably tolerant of alkali. It is very tolerant of alkali soils and can grow in soils containing 3-4% white alkali, but to bear well, the palm's roots must be in a stratum with less than 1% of alkali silts. Date palms are also very salt-tolerant, it can tolerate a high salinity level of up to 22,000 parts per million (ppm), but excessive salinity will reduce growth and will result in fruits of inferior quality (Zohary and Hopf, 1993).

There is a scarcity of information on the amounts of gravel and calcium carbonate in the soil, and the effects on date palm. Guidelines used elsewhere for other crops (Sys et al., 1993) were followed in ratings these land characteristics.

Application of the physical land suitability method showed that about 73% of the study area is potentially suitable to cultivate date palm, whereas 14% is not. The potentially suitable land is distributed as follows: 39% is highly suitable (S1), 23% is moderately suitable (S2) and 11% is marginally suitable (S3). An overlay of the climatic suitability map and the soil and landform maps revealed that about 13% of the study area could not evaluated (nr) based on available soil information (Table 5).

Table 5. Percent distribution of the land potentially suitable for date palm cultivation.

Land suitability-subclass	Potentially suitable land					
	High (S1)	Moderate (S2)	Marginal (S3)	Not suitable (N)	not rated (nr)	Total
S1	39.0	-	-	-	-	39
S2fer	-	19.0	-	-	-	19.0
S2wet	-	4.0	-	-	-	4.0
S3fer	-	-	10.0	-	-	10.0
S3salt	-	-	1.0	-	-	1.0
Nsalt	-	-	-	13.0	-	13.0
Nwet	-	-	-	1.0	-	1.0
not rated (nr)	-	-	-	-	13.0	13.0
Total	39.0	23.0	11.0	14.0	13.0	100

Highly suitable land comprises the deltaic and Salhyia soil series. This Land is mainly situated in the Northwest part of the study area and represents the recent Nile alluvial soils. Very severe limitations due to soil wetness (Nwet) and/or salinity and alkalinity hazards (Nsalt) prevail on 1% and 13% of the land, respectively. These limitations preclude the land from the LUT. Wetness limitations caused by poor drainage and heavy clay texture can be alleviated by installing new drainage systems, whereas the problems of excessive drainage can be improved through soil and conservation practices, such as water harvesting. Constraints related to salinity and alkalinity hazards (Nsalt) refer to high salinity of the soils. Most of these soils are situated in the northern part of the study area and represent the fluvial-marine soils. These limitations can be removed by reclaiming these soils through leaching, application of gypsum and proper crop choice (tolerant crops).

Moderate limitations due to fertility status (S2fer) and soil wetness (S2wet) prevail on 19% and 4% of the land, respectively. The limitations to fertility status are mainly associated with high soil pH or low organic matter content. In the study area, most of the farmers have a capacity to improve the fertility status through the application of fertilisers such as gypsum and by adding organic matter.

About 10%and 1% of the land presenting severe limitations due to fertility status conditions (S3fer) and/or salinity and alkalinity hazards (S3salt), respectively. Rooting and topographic conditions, mainly related to volume of coarse fragment, effective rooting depth, calcium and gypsum contents and slope of the land do not represent any kind of limitations.

4. Validation of the model

The accuracy of model built in ALES can be tested when quantitative land evaluation is performed**,** as in this study. However, the predicted yields in ALES require knowledge about the optimum yield and the effect (proportional yield factors) of each LQ severity level. In ALES the predicted yield is obtained by multiplying the optimum yield with the product of the proportional yield factors. The optimum yield is not meant to be a biological maximum (FAO, 1978), but rather a realistically attainable yield in the context of the LUT assuming no limitation (Rossiter and Van Wambeke, 1994). The choice of the optimum yield and the proportional yield factors is normally quite subjective.

The reliability of the model built in ALES for date palm cultivation is based on a comparison between average district farmers' (actual) yields and predicted yields obtained by ALES. Farmers' yields (ton/ha) per district for the years 1985-1995 were available from the Ministry of Agriculture (1996). The Farmers' (actual) yields were found useful as a fast means towards validation of the procedure in this study. In order to calculate the predicted yields in ALES, the optimum yield was set at 2.5 ton/feddan, (2) the LQs: climate, topography, wetness, rooting, fertility, and/or salinity and alkalinity conditions, are chosen as proportional yield factors, and (3) the LQ severity levels none, slight, moderate, and severe, were assigned proportional yield factors of 1.0, 0.95, 0.85 and 0.60, respectively. No proportional yield factor was attributed to a very severe limitation level, as such land would already be physically unsuitable. In order to verify the results obtained by ALES, a regression analysis between the actual yields and the predicted yields obtained by ALES was performed and a high correlation between them was obtained ($r^2 = 0.86$) (Fig. 5).

Fig. 5. The relation between the actual (farmer) yields and predicted yields by ALES.

Conclusions

Land evaluation results are considered valid if they reflect the land evaluator ’s best judgement. Owing to the small-scale maps and the land characteristics selected, DATE PALM-EGYPT can be used for decision making at national level. The results obtained can be employed by land use planners to select areas suitable for date palm production. Outputs of DATE PALM-EGYPT enable the user to select management options to alleviate identified limitations. Investigation of the reasoning process provides the opportunity of assessing the possibility of improving suitability by specific management option(s). Researchers can also use this information to focus on more detailed and meaningful research options in plant breeding, nutrition, water requirements and soil management within the different suitability area.

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