Evaluating Soil Degradation under Different Scenarios of Agricultural Land Management in Mediterranean Region

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Abstract: In this research work the Agro-Ecological Decision Support System MicroLEIS DSS, was applied to evaluate land degradation under different scenarios of land management. El-Fayoum depression was selected as a pilot area, this is one of the western desert depressions in the Arab Republic of Egypt. The area offers a great potential for agriculture using water from the river Nile. The main objective is to investigate and predict the risk of soil contamination for phosphorus, nitrogen, heavy metals and pesticides under traditional and recommended management scenarios of maize cultivation. The following components of MicroLEIS DSS have been used: 1) soil database (SDBm), 2) agro-climate database (CDBm), 3) agricultural management database (MDBm), and 4) the specific assessment model for the vulnerability of soil contamination called “Pantanal”. Then, a recommended scenario based on different land management has been produced for maize crop, which aimed to reduce soil contamination vulnerability of phosphorus, nitrogen, heavy metals and pesticides. The model application results are grouped in five vulnerability classes: V1 (none), V2 (low), V3 (moderate), V4 (high) and V5 (extreme) for each specific contaminant. Results obtained for El-Fayoum area showed that 47.8% and 52.2% of total studied area were classified as V3 and V4 vulnerable land due to phosphorus contamination under the traditional management scenario, but 41.9%5.9% and 52% of total area were classified as V2, V3 and V4 because of the same contaminate under recommended management scenario. On the other hand, 98.7% and 1.3% of the total area were classified as V3 and V4 vulnerable land due to nitrogen and heavy metals under the traditional management scenario, however in the other recommended scenario 94.0% and 5.6% were classified as V1 and V2 classes due to nitrogen contaminate and 79.0%, 19.1% and 1.7% were classified as V1, V2 and V4 for heavy metals contaminates. In the same trend 2.6%, 8.1%, 17.4% and 91.7% were classified as V1, V3, V4 and V5 due to pesticides contamination in the actual management scenario, however 24.0% and 76.0% were classified as V1 and V2 respectively due to the same contaminant under the recommended management scenario. In summary, we can ensure that these innovative agro-ecological studies such as those developed by MicroLEIS DSS can be applied and adapted in the agricultural provinces of Egypt in order to achieve a national sustainable rural management.

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1. Introduction

The area of agricultural land in Egypt is estimated to be about 3.5 million hectare, i.e., 3.45% of the state total area; hence, the agricultural land per capita is about, 0.05 hectares. The disintegration of agricultural ownership and the limited farms sizes are reasons why new technology has not been much adopted in sustainable agriculture management and maintenance (CAPMAS, 2006). El Fayoum depression is one of the most desert regions, which represents one of the promising areas for agricultural utilization in Egypt. It is a natural closed depression excavated in the Eocene limestone plateau without an external drainage. Degradation processes is serious in El Fayoum depression especially the low lying areas under a prevailing landform of depressed terraces varied in their elevation from 25 masl at the southern-east to 45 mbsl at the northern-west directions (El Naggar, 2004). The land and water resources of the depression has been subjected for contamination problems that may be originated from atmospheric depositions, applied commercial fertilizers, pesticides, manures, waste disposals and may be discharge of untreated domestic sewage (Abd

Elgawad et al. 2007). Heavy metals have long been a component of some agricultural pesticides that are sprayed on croplands and eventually end up in rivers, lakes and coastal waters. Also sewage sludge, some fertilizers and industrial waste have a high concentrations of heavy metals. Due to limitations in the allowed amounts of water from the Nile, vast areas of agricultural lands in El Fayoum Province are irrigated with water from mixing stations that mix fresh Nile water and drainage water which lead to increase the concentration of heavy metals in the soils. Regarding to the water pollutants including some plant nutrients in the agricultural drainage water at El-Fayoum depression, the concentrations of the N, P, K, Fe, Mn, Zn, Cu, Cd, Ni, Pb and Co in the irrigation water were still within the permissible limits (Farrag, 2000). Soil protection from heavy metal contamination requires scientific assessment on the relation between site-specific pollutant discharge and environmental effects (Dong et al., 2010). Recent approaches for contaminated land focus on sustainable management solution considering the environmental and spatial planning problems (Vegter, 2001). Land degradation involves two interlocking, complex systems i.e. the natural ecosystem and the human social system. Natural forces, through periodic stresses of extreme and persistent climatic events, and human use and abuse of sensitive and vulnerable dry land ecosystems, often act in unison, creating feedback processes, which are not fully understood. Interactions between the two systems determine the success or failure of resource management programmes (WMO, 2009). Agricultural lands identification, according to its own ecological potentialities and limitations, is the first major objective of land use planning. At the same time, the second major objective is to predict the inherent suitability of each soil unit for supporting a specific crop over a long period of time (Shahbazi et al., 2008). Quantification of agricultural sustainability by means of indicators presents operational problems. The difficulty involves interpreting the combination of required indicators which is a difficulty to use these as a practical decision-support tool (Gomez-Limon et al., 2010). Sustainable development and the definition of indicators to assess progress towards sustainability have become a high priority in scientific research and on policy agendas (Van Cauwenbergh et al., 2007). Different studies have been made to deal with this obstacle by using various methods of aggregating these combinations of multidimensional indicators into indices (e.g. Tellarini, 2000; Rigby et al., 2001; Hajkowicz, 2006 and Qiu et al., 2007). The MicroLEIS DSS system has been widely used over the last 20 years for many different purposes as a land evaluation focuses on global change, the methodology proposed by Micro Land Evaluation Information System DSS can be used to investigate the impact of new scenarios, like climate change, on potentialities and vulnerabilities of the land (Shahbazi et al., 2010). The current study objectified to predict the risk of soil contamination with phosphorus, nitrogen, heavy metals and pesticides under traditional and controlled management scenarios of maize cultivation using the Agro-Ecological Decision Support System MicroLEIS DSS.

2. Materials and methods

2.1. The study area

El Fayoum province is occupies a depression west of the Nile at 90 kilometers southwest of Cairo, between latitudes 29° 02´ and 29° 35´ N and longitudes 30° 23´ and 31° 05´ E (Figure 1). The climatic data of El Fayoum districts indicate that the total rainfalls does not exceed 7.5 mm/year and the mean minimum and maximum annual temperatures are 14.5 (in January) and 31.0 C° (in June) respectively. The evaporation rates coincide with temperatures where the lowest evaporation rate (1.9 mm/day) was recorded in January while the highest value (7.3 mm/day) was recorded in June (CLAC, 2010). According to the aridity index (Ponce et al., 2000) the area is located under hyperarid climatic condition. El-Fayoum depression is a portion of the Eocene limestone plateau at the northern part of the western desert and the subsurface lithology consists of marine sedimentary strata, which has undergone alternating periods of erosion and deposition. The present depression has been formed when the basin was subsided relative to the Nile River, allowing it to break through and to flood the area. This led to the formation of a thick fertile alluvium (Said, 1993). The main identified landforms in El Fayoum depression are fans, resent and old lake terraces, depression, plain, and basins. These landforms are characterized by less than 3.5% surface slopes with an elevation vary from 49 m below sea level to 26 m above sea level.

2.2 Soil mapping

The soil map of the study area was extracted from the soil map of Egypt produced by the Academy of Scientific Research and Technology in 1982, this map was originally classified using the American Soil Taxonomy of 1975. The produced map has been updated according to the latest edition of 2010 since some of the used nomenclature and parameters in the old versions of the USDA keys to soil taxonomy are no longer used. Then, the transformation of the soil map (produced in 1982) into a digital format was done, the study area is covered by two soil map sheets. Theses sheets were scanned and geometrically corrected using UTM projection and WGS-84 datum.

On screen digitizing was used to convert the map sheets into vector formats, and then edge matching was performed using Arc-GIS 9.3 software. Morphological description and laboratory analyses of 46 soil profiles scattered on El-Fayoum districts, were collected from the previous works of Haroun (2004), Ali (2005), and Hamdi (2007). According to the American Soil Taxonomy basics (USDA, 2010), these data were integrated for updating the soil map of El-Fayoum depression.

2.3. MicroLEIS DSS Technology

The MicroLEIS DSS system was developed to assist specific types of decision makers faced with specific agroecological problems. According to De la Rosa et al., (2004) The evolution of MicroLEIS (Mediterranean Land Evaluation Information System) follows the three eras of growth in the computer industry: i) the data processing era, ii) the microcomputer era, and iii) the network era. MicroLEIS is based on over 30 years dedicated research in land suitability evolution. The evaluation process entails dynamic interactions between soil, climate and management variables. MicroLEIS also include 12 modules that allow for the assessment of soil capability and vulnerability and the consequences of future global change scenarios. Input data warehousing, land evaluation modeling, model application software and output result presentation are the main development modules of this system. It has been designed as knowledge based approach which incorporates a set of information tools. Each of these tools is directly linked to another, and custom applications can be carried out on a wide range of problems related to land productivity, land degradation and recently land capacity for carbon sequestration.

2.3.1. Data warehousing

Data warehousing has been designed as a knowledgebase approach which incorporates a set of information tools as follow:

- *Soil database (SDBm):* The multilingual soil database SDBm Plus is a geo-referenced soil attributes database management system for storage of an exceptionally large number of morphological, physical, and chemical properties of 46 soil profiles.
- *Climate database (CDBm):* The climate database integrated in MicroLEIS DSS is a computer-based tool for the organization, storage, and manipulation of agro-climatic data for land evaluation. These georeferenced climate observations, from a particular meteorological station, correspond to the mean values of such records for a determinate period. It is precisely by a period of time that meteorology is distinguished from climate. The basic data of CDBm are the mean values of the daily dataset for a particular month. The stored mean monthly values correspond to a set of temperature and precipitation variables (maximum temperature, minimum temperature, accumulative precipitation, maximum precipitation per day, and days of precipitation for 44 years.
- *Management database (MDBm):* The farming management database is knowledge-based software to capture, store, process, and transfer the agricultural management information obtained through interviews with farmers. Each MDBm dataset consists of georeferenced agricultural information on a particular land use system.

2.3.2. Pantanal model: Specific soil contamination risks

Within the MicroLEIS framework, the Pantanal model was developed as a qualitative evaluative approach for assessing limitations to the use of land, or the vulnerability of the land, in respect to specified agricultural degradation risks. Pantanal model focuses on diffuse ‘soil agro-contamination’ from agricultural substances, i.e. phosphorus, nitrogen, heavy metals, and Pesticides. The model has been developed for spatially distributed systems and uses easily available parameters, being applicable to large geographic regions, also the model can be use at different scales. The biophysical variables or land-related characteristics were used to calculate the attainable or potential contamination risk, and the agricultural practices or management-related characteristics were used to calculate the management contamination risk. The characteristic values, classes for the qualitative variables and ranges for the quantitative variables, were grouped into generalization levels to continue the evaluation procedure the Table 1 shows the list of land and management characteristics selected as input variables of the Pantanal model. . For each vulnerability type, the land evaluation procedure that follows is based on decision trees rather than on matching tables. Through a total of 29 decision trees the qualities (severity levels) are related to the characteristics (generalization levels), and the final decision or vulnerability classes are derived from the qualities. This empirically based model also includes a simple precipitation partitioning sub-model to calculate surface runoff and leaching degree, by using the humidity index as the relation between yearly amounts of precipitation and potential evapotranspiration. Information about the soil and water contamination processes was also obtained from questionnaires, interviews and discussions with a range of specialists, experts and land users as shown in table 2.

Table 1. Summary of environmental Land/management Qualities (11) and associated Land Characteristics (27), for each vulnerability type, considered in Pantanal model.

Land/management quality	Vulnerability type	Land/management characteristic (input variables)
		Attainable contamination risks
Surface run-off, r	P, N, H, X	Relief; soil erodibility; rainfall erosivity.
Leaching degree, l	P, N, H, X	Monthly precipitation; monthly temperature; groundwater table depth; drainage; particle size distribution.
Phosphate fixation, f	P	pH; particle size distribution; organic matter.
Cation retention, c	N, H	pH; particle size distribution; CEC; organic matter.
Denitrification, d	N	Monthly temperature; groundwater table depth; organic matter; pH.
Pesticide sorption, o	X	Organic matter; pH; particle size distribution; CEC.
Pesticide degradation, g	X	Monthly temperature; monthly precipitation; pH; organic matter.
		Management contamination risks
Phosphate incidence, i	P	Landuse type; use of P-fertilizer; artificial drainage.
Nitrogen incidence, j	N	Landuse type; use of N-fertilizer; crop rotation; soil ploughing; time of fertilization; straw incorporation.
Heavy metals incidence, q	H	Landuse type; crop rotation; use of pesticides; use of fertilizers; use of waste.
Pesticides incidence,t	X	Landuse type; persistence in soil; toxicity of pesticides; application methods; artificial groundwater level.

Vulnerability type: P = phosphorus, N = nitrogen, H = heavy metals, and X = pesticides.
Source: From De la Rosa et al. (1998).

Table 2. Pathway of the decision tree branch constructed to relate the Land Quality "Leaching degree" with the associated Land Characteristics in Pantanal model.

Evaluation step	**Land characteristics**	**Severity level**			
		1	**2**	**3**	**4**
A	Humidity index	> B	> C	> D	> E
B	Groundwater table depth	*Low*	> F	> G	
C	Groundwater table depth	*Low*	> H	> I	
D	Groundwater table depth	> J	> K	> L	
E	Groundwater table depth	> M	*Extreme*	*Extreme*	
F	Drainage	Low	Low	> N	
G	Drainage	*Moderate*	*Moderate*	*High*	
H	Drainage	*Low*	> N	*Moderate*	
I	Drainage	*High*	*High*	> O	
J	Drainage	> N	*Moderate*	> P	
K	Drainage	> Q	*High*	> R	
L	Drainage	> O	*Extreme*	*Extreme*	
M	Drainage	*High*	*High*	*Extreme*	
N	Particle size distribution	*Low*	*Moderate*	*Moderate*	
O	Particle size distribution	*High*	*Extreme*	*Extreme*	
P	Particle size distribution	*Moderate*	*Moderate*	*High*	
Q	Particle size distribution	*Moderate*	*High*	*High*	
R	Particle size distribution	*High*	*High*	*Extreme*	

Note: Under each class the symbol > followed by a letter (B to R) is used to direct to the next step of the decision tree. The path is followed until a severity level (Low, Moderate, High or Extreme) of the Land Quality is encountered. **Source**: From De la Rosa et al. (1998).

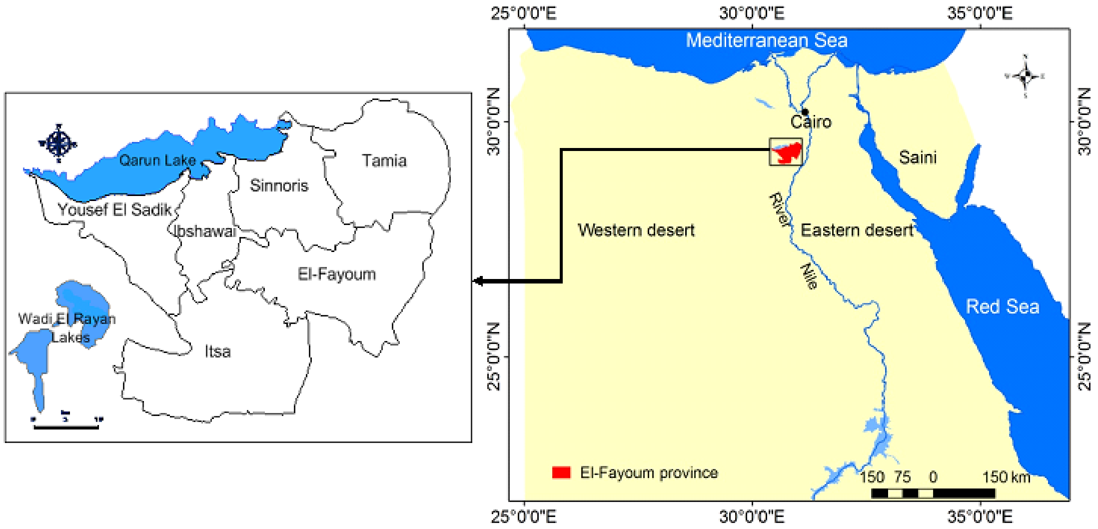


Figure 1. Location of El Fayoum Province in Egypt map (right), the administrative boundaries of El Fayoum Province (left).

Following this expert system or decision trees approach, the agrochemical vulnerability classes established by Pantanal for each type of contamination: Phosphorus, Nitrogen, Heavy metals and Pesticides, for the Land, Management, and Field vulnerability are defined as Class V1 (None), Class V2 (Low), Class V3 (Moderate) and Class V4 (High). The physically-related contamination risk (land vulnerability classes, are calculated separately from the management-related contamination risk (management vulnerability classes), and then both are combined to produce the actual contamination risk (field vulnerability classes). So, the actual vulnerability is grouped in five classes as follows:

Class V1 (None). Field units of this actual class are almost invulnerable to agrochemical contamination because of their biophysical condition and management system. The actual vulnerability to soil, surface and groundwater diffuse pollution are very low. This management system is not considered to be a controlling factor and almost any other farming system could be implemented.

Class V2 (Low). Field units of this actual class are slightly vulnerable to agrochemical contamination because the combination of the management system with the biophysical conditions of the classified field unit does almost no harm to the soil, surface and groundwater quality.

Class V3 (Moderate). Fields units of this actual class are moderately vulnerable to agrochemical contamination; the combination of the management system and biophysical characteristics of the field unit harms the quality of soil, surface and groundwater. The effect on the intensity of the management system to actual vulnerability class can change considerably.

Class V4 (High). Field units of this actual class are highly vulnerable to agrochemical contamination, because the simultaneous impact of the management system and the biophysical characteristics damages the quality of the soil, surface and groundwater of the field unit on a high scale. More-intensive farming systems have negative effects on the environment.

Class V5 (Extreme). Field units of this actual class are extremely vulnerable to agrochemical contamination, because the intensity of the agricultural activities on the field unit and the high biophysical vulnerability of the field unit itself harm the soil, surface and groundwater quality on an extremely high scale. The water management and the quantity and toxicity of the pollutants have to be carefully applied to the field unit.

3. Results and discussion

3.1. Databases of El Fayoum depression

3.1.1. Soil database (SDBm)

As illustrated in Table 3 and Figure 2, the soil data indicate that the *Vertic Torrifluvents* is the dominant soil sub-great group; it covers an area of 76,000 ha representing 42.79% of the mapped soils. Also, the sub-great group of *Typic Haplocalcids* covers an area of 42,100 ha representing 23.70% of total soil area. Its geographic distribution is located on the edges of the depression exhibiting the old river terraces. Additionally *Typic Torrifluvents* occurs within the depression, covering an area of 14,100 ha representing 7.94% of the mapped soils. These soils are associated with the recent terraces of the flood plain. The Gypsic soils i.e. *Typic Haplogypsids* exist on the eastern borders of the El Fayoum depression covering areas of 8,700 ha representing 4.90% respectively. The geographic location of these soil units can be explained by the transgression of the Qarun Lake to the northwest. In the north of depression a small area of the sub-great group *Typic Haplosalids* exist, exhibiting an area of 5,800 ha representing 3.27% of the mapped area. Finally, *Typic Torripsamments* cover small spots in the south of El Fayoum depression, occupying an extension of 2,600 ha representing 1.36% of the whole study area. It should be noticed that such variability of sub-great groups is unique for El Fayoum province due to its location, altitude, formation processes and patterns of agricultural practices. De la Rosa et al. (2009) stated that using soil type information in decision-making is at the heart for sustainable use and management of agricultural land. This agroecological approach can be especially useful when formulating soil-specific agricultural practices to reverse environmental degradation, based on the spatial variability of soils and related resources. The main soil properties of the different soils stored in the SDBm and used for evaluating the soil contamination risk are represented in Table 4.

3.1.2. Climate database (CDBm)

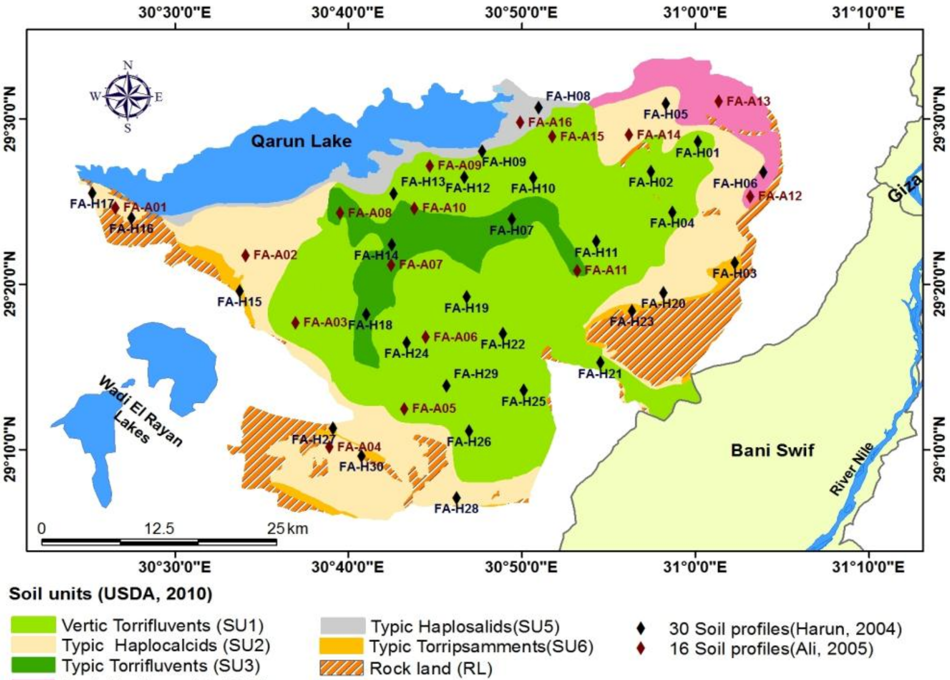
Climatic data for the last 44 consecutive years (1962-2006) were collected from El- Fayoum meteorological station (Table, 5). According to the current precipitation and temperature data of the study area it can be considered as hyper-arid. Adaptation was carried out for the precipitation factor therefore; monthly irrigation water is currently converted to mm, after this adaptation the modeled values of Arkley index are high and the aridity index is minimal. Also, the input climate parameters of Pantanal model are illustrated in Table 6.

Table 3. Soil taxonomic units (USDA, 2010) of the studied soil profiles.

Order	**Sub-order**	**Great group**	**Sub-group**	**Family**	**Representative soil profile***	**Soil unit**	**Area (ha)**
Entisols	Fluvents	Torrifluvents	Vertic Torrifluvents	Fine clayey, smectitic, hyperthermic	FA-H02, FA-H04, FA-H10, FA-H11, FA-H12, **FA-H19**, FA-H22, FA-H24, FA-H25,FA-H26, FA-H29, FA-A03, FA-A05, FA-A06, FA-A09, FA-A15	SU1	76000
			Typic Torrifluvents	Fine loamy, mixed, hyperthermic	**FA-H07**, FA-H14, FA-H18, FA-A07, FA-A08, FA-A10, FA-A11	SU3	14100
	Psamments	Torri-psamments	Typic Torri-psamments	Sand, siliceous, hyperthermic	FA-H03, **FA-H15**, FA-H23,	SU6	2600
Aridisols	Calcids	Haplocalcids	Typic Haplocalcids	Sandy, mixed, hyperthermic	FA-H28, FA-H27, FA-H21, FA-H16	SU2	42100
				Coarse loamy, mixed, hyperthermic	FA-H20, FA-A01, FA-A04		
				Fine loamy, mixed, hyperthermic	FA-H17,FA-H01		
				Clay loam	FA-A02, FA-A14, **FA-H05** FA-H30		
	Gypsids	Haplo-gypsids	Typic Haplo-gypsids	Fine loamy, carbonatic, hyperthermic	FA-A12, FA-A13	SU4	8700
				Fine loamy, mixed, hyperthermic	**FA-H06**		
	Salids	Haplosalids	Typic Haplosalids	Coarse loamy, mixed, hyperthermic	FA-A16 , **FA-H08**, FA-H09, FA-H13	SU5	5800

(*) In bold are the dominate soil profile of each soil unit.

Source: Integrated from Harun, (2004); Ali, (2005) and Hamdi, (2007).



Source: modified after ASRT, 1982

Figure 2. Updated soil map of El Fayoum province overlaid by the sites of the soil profiles.

3.1.3. Management database (MDBm)

Currently, land management in developing countries have a wide range of difficulties such as (1) inefficient and poorly organized governmental institutions, (2) the scarcity of data which are also highly varying in quality and quantity, (3) a difficult economic situation excluding high capital expenditures for land management, and (4) a low interest and knowledge in the society about land management (Alcantara-Ayala, 2002). The farming management database (MDBm) of El-Fayoum, contains information on agricultural use and management of maize crop obtained from scientific publications of the Ministry of Agriculture, in addition more information has been collected during the field work. Table 6 illustrates the traditional management practices. The obtained data represent high similarity of the agricultural operations conducted on maize crop in the different soils units. Cultivation practices, as well as the use of technology, have been cited in all definitions as a major causes of and contributors to, the degradation process in arid, semi-arid and sub humid areas. Cultivation practices that can lead to degradation include land clearing practices, cultivation of marginal climatic regions, cultivation of poor soils, and inappropriate cultivation tactics such as reduced fallow time, improper tillage, drainage, and water use.

3.2. Pantanal model application results

In order to achieve the study object, the model scenario recommends the controlled use of fertilizers, pesticides and prevents the usage of industrial waste and sewage sludge in the agricultural land. This scenario does not seek organic agriculture, therefore the farmer will still use fertilizers and pesticides, but under controlled system. The outputs of Pantanal model include vulnerability classes for phosphorus, nitrogen, heavy metals and pesticides of land, management and field types under the management of maize in the different soils of the study area. The obtained data for maize crops indicates that the land vulnerability of phosphorus, nitrogen, heavy metals and pesticides, in general, is V1 except small patches scattered in the different soil types. While, the management vulnerability is V4 for all contaminants, except for the pesticides which have V2 class. The field vulnerability is high (V4) to moderate (V3) for phosphorus and low (V2) to moderate (V3) for the rest of contaminants.

Field vulnerability represent the interaction between land and management practices, the output results of Pantanal model for predicting contamination risk related to the field vulnerability are illustrated in Table 7. The relation between the vulnerability risk of different contaminants and the soil types under maize cultivation in El-Fayoum districts is shown in Figures 3 to 8. The field vulnerability under traditional and recommended scenario of the different soils in the depression can be explained as follows:

Table 4. Evaluation model application: Input soil parameters of Pantanal model.

SDBm Profile Code	Slope gradient, %	Water table depth, cm	Drainage	Particle size distribution %			USDA Texture class	Organic matter, %	pH	EC, dS /m	ESP, %	CEC, meq/100g	Ca O$_3$, %
				Sand	Silt	Clay							
SU1: Vertic Torrifluvents													
FA-H02	<0.55	150	Moderately Well	47.1	24.2	28.6	SCL	1.9	7.6	2.41	7.7	23.8	6.3
FA-H04	1.5 - 2.0	110	Very Poor	18.1	27.2	54.6	C	0.7	8.5	20.2	16.7	43.9	6.9
FA-H10	0.55 - 1.0	105	Moderately Well	38.9	26.0	35.7	CL	0.3	7.9	8.6	13.6	27.4	8.9
FA-H11	<0.55	150	Moderately Well	59.7	18.0	22.2	SCL	1.9	7.5	1.7	5.92	16.9	1.9
FA-H12	1.0 - 1.5	125	Imperfect	58.4	19.9	21.6	SCL	0.9	8.0	7.2	10.5	15.1	10.9
FA-H13	0.55 - 1.0	110	Very Poor	30.9	14.3	54.7	C	0.8	8.7	8.8	25.7	38.9	15.4
FA-H19	0.55 - 1.0	150	Poor	13.4	29.8	56.6	C	1.7	7.8	2.7	9.6	42.6	5.1
FA-H21	1.0 - 1.5	150	Imperfect	43.7	24.0	31.7	CL	2.0	7.5	2.5	8.7	24.9	3.7
FA-H22	0.55 - 1.0	95	Poor	19.5	32.8	47.5	C	0.9	8.8	10.4	20.8	40.2	5.9
FA-H24	0.55 - 1.0	125	Imperfect	54.9	16.7	28.3	SCL	2.2	7.8	3.5	6.6	21.1	4.3
FA-H25	1.0 - 1.5	150	Poor	11.1	31.9	56.9	C	0.8	8.7	8.6	18.0	42.1	4.9
FA-H26	<0.55	150	Moderately Well	60.9	12.4	26.6	SCL	1.9	7.7	5.2	7.2	18.8	5.4
FA-H29	<0.55	150	Imperfect	42.9	26.9	30.9	CL	2.3	7.6	2.2	6.4	22.3	3.6
FA-A03	1.0 - 1.5	110	Poor	33.3	33.5	33.8	CL	1.1	8.9	1.6	13.9	31.3	10.7
FA-A05	0.55 - 1.0	120	Poor	40.8	18.9	40.2	C	1.2	7.9	3.0	14.6	44.3	13.1
FA-A06	0.55-1.0	120	Poor	28.3	29.8	41.8	C	1.7	7.9	2.9	17.9	45.3	5.9
FA-A09	1.0-1.5	90	Poor	35.5	22.4	42.1	C	1.4	8.1	21.4	11.2	36.4	22.1
FA-A15	1.0 - 1.5	65	Very Poor	25.5	23.0	51.4	C	1.4	8.3	22.4	11.1	36.9	6.9
SU2: Typic Haplocalcids													
FA-H01	2.0 - 2.5	150	Moderately Well	51.4	23.4	25.1	SCL	1.4	8.3	4.9	14.3	12.3	15.6
FA-H05	1.0 - 1.5	120	Very Poor	12.4	23.2	64.3	C	0.8	7.8	6.7	8.5	25.6	39.2
FA-H16	0.55 - 1.0	125	Moderately Well	67.9	14.9	21.7	L	0.9	8.2	9.8	5.8	10.3	45.8
FA-H17	0.55 - 1.0	150	Well	59.0	21.7	19.2	SL	0.7	8.0	7.3	13.2	10.6	18.1
FA-H20	0.55 - 1.0	85	Well	72.0	15.9	14.7	SL	0.8	8.6	15.2	17.3	7.5	19.8
FA-H28	0.55 - 1.0	85	Well	74.9	13.3	11.6	SL	0.5	8.3	12.2	10.9	8.1	30.9
FA-H30*	0.55 - 1.0	70	Excessively	95.0	2.2	2.6	S	0.2	7.7	14.1	7.7	2.0	57.6
FA-A01	0.55 - 1.0	100	Poor	31.0	32.8	36.1	CL	1.6	7.8	3.4	16.9	35.5	18.6
FA-A02	1.0 - 1.5	80	Poor	25.2	41.8	32.9	CL	1.1	8.1	3.1	16.5	27.9	15.8
FA-A04	1.5 - 2.0	100	Well	51.3	26.5	22.1	SCL	1.3	8.0	3.9	23.5	29.9	13.9
FA-A14	1.0 - 1.5	110	Moderately Well	43.4	20.1	36.4	CL	1.3	8.1	1.7	18.1	32.6	16.1
SU3: Typic Torrifluvents													
FA-H07	2.0 - 2.5	150	Poor	25.6	30.7	43.6	C	2.1	7.8	3.0	10.1	35.0	2.6
FA-H14	0.55 - 1.0	150	Poor	11.3	23.7	64.9	C	2.2	7.9	3.8	13.4	45.8	3.7
FA-H18	2.0 - 2.5	150	Poor	22.2	29.9	47.8	C	0.8	8.7	3.4	21.1	38.9	5.8
FA-A07	1.0 - 1.5	125	Moderately Well	59.7	15.8	24.4	SCL	1.4	8.3	1.9	15.7	25.1	4.8
FA-A08	1.0-1.5	100	Moderately Well	51.5	21.1	27.3	SCL	1.4	8.1	2.1	29.4	36.1	19.2
FA-A10	1.5 - 2.0	100	Moderately Well	38.3	24.1	37.5	CL	1.2	8.3	2.3	14.6	43.7	23.6
FA-A11	0.55 - 1.0	125	Poor	27.9	24.4	47.6	C	1.8	7.7	2.9	10.3	42.5	7.1
SU4: Typic Haplogypsids													
FA-H06	1.0 - 1.5	115	Imperfect	46.9	21.4	31.6	SCL	0.8	8.1	10.2	9.9	14.7	32.1
FA-A12	1.0 - 1.5	80	Very Poor	18.9	40.9	40.1	SIC	1.3	7.7	1.7	23.1	36.1	17.6
FA-A13	1.0 - 1.5	120	Moderately Well	51.5	19.3	29.1	SCL	1.4	7.8	2.6	16.5	29.4	21.8
SU5: Typic Haplosalids													
FA-H08	1.0 - 1.5	85	Very Poor	23.1	25.7	51.2	C	3.0	8.0	54.1	17.9	40.4	11.6
FA-H09	1.0 - 1.5	70	0-50	90.8	3.6	5.5	S	3.4	8.5	42.1	24.5	4.5	11.5
FA-A16	<0.55	50	0-50	27.0	28.1	44.9	C	1.1	8.3	22.4	14.8	37.2	18.2
SU6: Typic Torripsamments													
FA-H03	1.0 - 1.5	150	0-50	84.5	6.2	9.1	LS	0.4	7.8	1.6	6.0	5.5	3.1
FA-H15	0.55 - 1.0	150	0-50	91.5	3.2	5.2	S	0.5	7.5	2.5	5.3	4.1	1.6
FA-H23	0.55 - 1.0	150	0-50	88.2	5.3	6.4	LS	0.6	7.6	2.6	5.7	5.6	1.2
FA-H27	<0.55	150	0-50	83	6.0	10.9	LS	0.5	7.6	2.9	7.5	14.2	2.1

Soil texture: C=Clay, CL=Clay Loam, SCL=Sandy Clay Loam, SL=Sandy Loam, LS=Loamy Sand, S=Sand, Si=Silt.
EC= Electric conductivity (dS/m), ESP=Exchangeable Sodium Percent (%) , CEC= Cation Exchange Capacity,
* Rock fragments = > 35 %. **Source**: (Harun, 2004 and Ali, 2005).

Table 5. Summary of agro-meteorological data from El-Fayoum station, during the (1962-2006) period.

Months	Tm, °C	Tmax, °C	Tmin, °C	P , mm	Pmax, mm	Pd	ETo(T), mm	ETo(H)	HUi	ARi	GS	PCi	MFi	AKi
Jan	12.7	20.3	6.1	1.5	1.2	1	19.2	70.3	---	---	---	---	---	---
Feb	14.2	22.3	6.9	1.6	1.4	1	24.6	89.1	---	---	---	---	---	---
Mar	17.2	25.4	9.6	2.6	2.0	1	46.9	113.5	---	---	---	---	---	---
Apr	21.4	30.2	13.2	0.4	0.4	1	84.3	140.3	---	---	---	---	---	---
May	25.2	33.7	16.9	0.1	0.1	1	139.7	159.5	---	---	---	---	---	---
Jun	28.3	36.8	20.0	0.0	0.0	0	143.7	172.0	---	---	---	---	---	---
Jul	28.9	37.2	21.3	0.0	0.0	0	147.8	168.3	---	---	---	---	---	---
Aug	28.6	36.9	21.5	0.0	0.0	0	147.8	159.9	---	---	---	---	---	---
Sep	26.8	34.7	19.9	0.0	0.0	0	135.0	138.6	---	---	---	---	---	---
Oct	23.8	31.6	17.2	0.2	0.2	1	101.5	116.6	---	---	---	---	---	---
Nov	18.8	26.2	12.6	0.9	0.6	1	51.3	86.2	---	---	---	---	---	---
Dec	14.0	21.8	7.7	1.2	0.9	1	24.3	70.3	---	---	---	---	---	---
Annual	21.7	29.8	14.4	8.5	--	8	1066.1	1484.5	0.01	12	12	19	2	2.6

Tm – mean temperature, *Tmax* – maximum temperature, *Tmin* – minimum temperature, *P*–precipitation, ETo(T) – Evapotranspiration calculated by Thornthwaite method, Hui – Humidity index, Ari – Aridity index, GS– growing season, Mfi – Modified Fournier index, Aki – Arkley index.

Table 6. Input of climate parameters that used for the evaluation by Pantanal model.

Parameters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Actual climate												
P. mean, mm	1.7	2.0	4.0	0.3	0.1	0.0	0.0	0.0	0.0	0.4	1.2	1.6
T. mean, °C	12.8	14.3	17.1	21.4	25.3	28.5	29.0	28.9	26.9	23.9	18.9	14.2
P. max, mm	1.2	2.0	3.1	0.3	0.1	0.0	0.0	0.0	0.0	0.4	0.8	1.1
Irrigation water												
Quantity (mm)	42.6	95.4	116.4	114.4	124.5	148.2	161	157.7	134.7	121.9	113.5	98.1

P: precipitation, **T**: temperature

Table 7. Traditional management practices of maize crop in El Fayoum Province.

Variable: number/amount; type; timing
Crop properties
Main varieties of *Zea mays* L.: single cross 9,10, double cross 204, 215 Triple cross 310, 320. **Plant height**, max: 1.8 - 2.5 m **Rooting depth,** max: 0.7 - 1.5 m **Leaf area, SLA (LAI)max**: 35 (5-7) **Growing season length:** 90- 130 days **Duration development stages:** 10, 40, 25, 60, 35 **Crop coefficients, Kc /stage:** 0.40, 0.80, 1.12, 0.87, 0.57 **Harvest index:** 0.35
Cultivation practices
Primary tillage: 1-2, mouldboard ploughing, ll April ; 2-3, disk cultivator **Secondary tillage:** nill **Sowing:** 25-50kg/ha , ploughing and harrowing 70 cm spacing, holl 25-30cm ll April **Plant density:** 70 - 100 thousand plant/ha **Fertilizers:** 40 – 60 m^3 organic fertilizer, 90 kg N, 200 kg Urea (46 % N) in twice of plantation, II June , 200-100 P_2O_5 **Fertilizer requirements:** 300-400 N, 30-40 P, 60-100 K kg/ha **Herbicides**: 1 before the agriculture and after irrigation , 2.4 D , etrazen ¾ kg for 40-600 litter water 1-2, llApr **Plaguicides:** 1, fungicide, Mar. **Harvesting:** combine, ll Aug- **Residues:** stem and leaf cutting/ploughed-in, lll/Sep-l/Oct **Irrigation:** 5-7, 400-500 m3/ha, one irrigation every 2-3 week **Artificial drainage:** nill **Conservation:** nill **Rotation:** maize-(rice - sorghum - and after winter crop like alfalfa and bean) **Production, yield/quality:** 8-12 t/ha; 77% starch, 6-15% protein **Environmental impact, erosion/contamination risk:** high / high

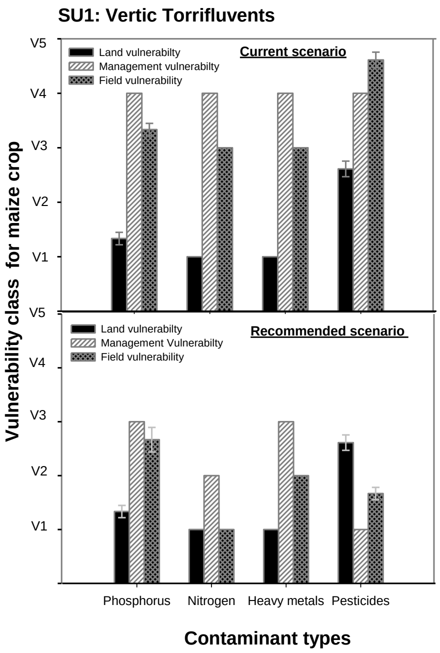


Figure 3. Vulnerability classes for current scenario and hypothetically recommended scenario for Vertic Torrifluvents (SU1).

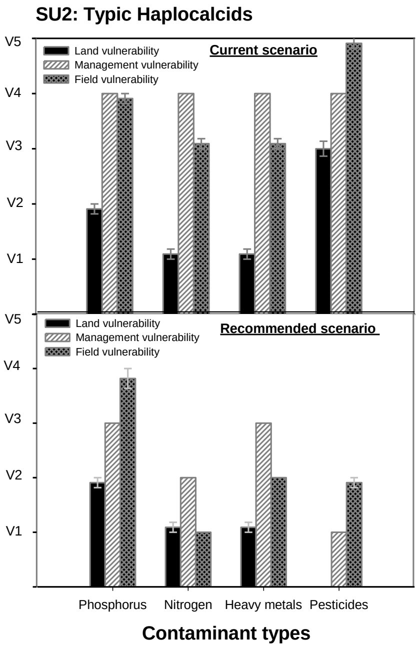


Figure 4. Vulnerability classes for current scenario and hypothetically recommended scenario for Typic Haplocalcids (SU2)

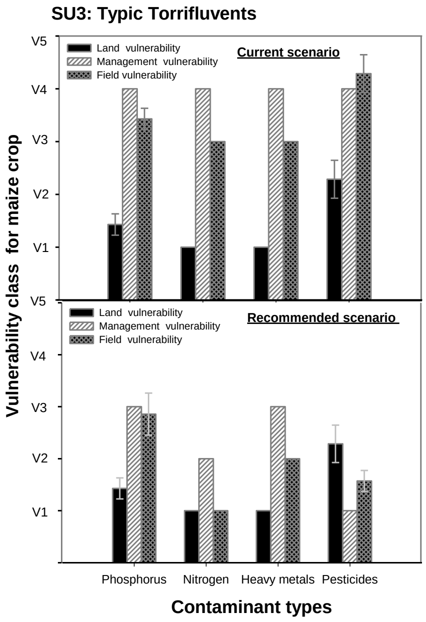


Figure 5. Vulnerability classes for current scenario and hypothetically rerifluvents (SU3). commended scenario for Typic T

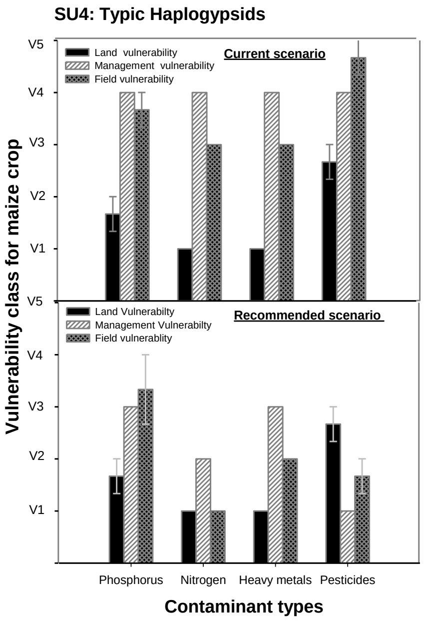


Figure 6. Vulnerability classes for current scenario and hypothetically recommended scenario for Typic Haplogypsids (SU4).

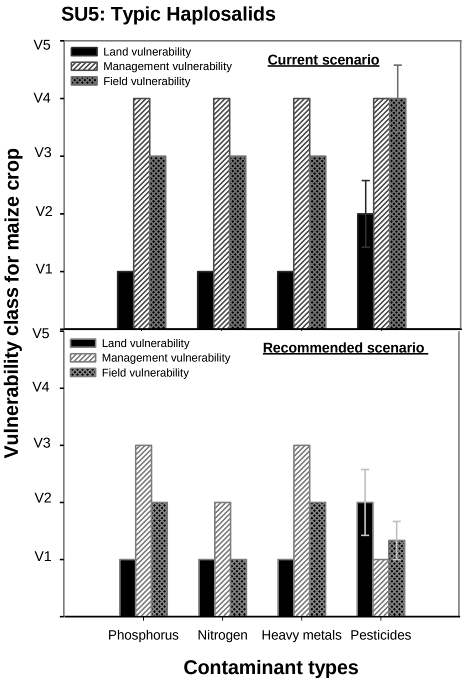


Figure 7. Vulnerability classes for current scenario and hypothetically recommended scenario for Typic Haplosalids (SU5).

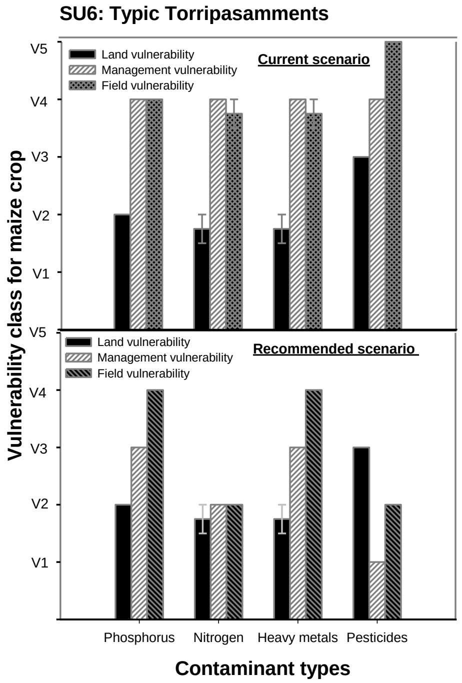


Figure 8. Vulnerability classes for current scenario and hypothetically recommended scenario for Typic Torripsamments (SU6).

-*Vertic Torrifluvents (SU1)*

The obtained data under the traditional management scenario indicate that in *Vertic Torrifluvents* has a moderate vulnerability class (V3) along an extension of 506.7 km^2 (i.e. 66.67 % of the total unit area), while the rest of the area (253.3 km^2), falls within the V4 class due to phosphorus contamination. For nitrogen and heavy metal, it was found that almost all of the area has V3 class. According to vulnerability of pesticides contamination, it was found that 506.7 km^2 has V5 class, while, the rest of the area falls in class V4 (211.1 km^2) and class V3 (42.2 km^2). On the other hand, under the recommended management scenario results indicated that in this soil an area of 506.7 km^2, has a low vulnerability class (V2) while the rest of the area (253.3 km^2) is classified within the V4 class due to phosphorus contamination. For nitrogen and heavy metal, it was found that almost all of the area has V1 class. According vulnerability of pesticides contamination, it was found that 506.7 km^2 has V2 class, while the rest of the area is located within class V1.

- **Typic Haplocalcids (SU2)**

Considering the current management scenario, in *Typic Haplocalcids,* an extension 382.7km^2 (i.e. 90%) of the total unit area has high vulnerability (V4) for phosphorus, while the rest of the area 38.3 km^2 (i.e. 10%) falls into class (V3). For the vulnerability of nitrogen and heavy metals it is found that all SU2 (421 km^2) present moderate vulnerability class (V3). A total amount of 382.7 km^2 present V5 class for pesticides, the rest of the area was evaluated as V1 class with an area of 38.3 km^2. Under the recommended management scenario an extension about 90% of the total unit area has high vulnerability (V4) for phosphorus, while the rest of the area falls into class (V2). The vulnerability of nitrogen and heavy metals was classified as V1 for the whole area. Finally, regarding contamination due to pesticides, an area of 382.7 km^2 present V2 class, the rest of the area was evaluated as V1.

- **Typic Torrifluvents (SU3)**

The *Typic Torrifluvents* soils occupies an area of 141 km^2, about 42.9% of this unit falls within the class V4 for phosphorus vulnerability, while the rest of the area has a moderate vulnerability class (V3). For nitrogen and heavy metals, results showed that the whole area has a moderate vulnerability class (V3). Additionally, the pesticides vulnerability class V5 dominates 57.2% in this unit, while the rest of the area has V4 class (14.22%) and V3 class (28.58%) under the traditional management practices. On the other hand, under the recommended scenario about 42.9% of this unit falls within the class V4 for phosphorus vulnerability, and the rest of the area have a low vulnerability class (V2). For nitrogen and heavy metals, results showed that the total area has a vulnerability class V1. Finally, the pesticides vulnerability class V2 dominates this unit.

- ***Typic Haplogypsid (SU4)***

In *Typic Haplogypsid* the result indicate that about 58 km^2 (i.e. 66.6%) of this unit has a vulnerability class of V4 for phosphorus, while the rest of the area was classified as the vulnerability class of V3. For nitrogen and heavy metals it is found that the whole area, (87 km^2) was classified as V3 class. Regarding to the pesticides, it was found that about 66.6% present V5 class, and the rest was evaluated as V4 class under the current management scenario. On the other hand, there are no changes in the phosphorus and nitrogen vulnerability, while the pesticides vulnerability classes V2 and V1 were obtained instead of the classes V5 and V4 respectively under the recommended management scenario.

- **Typic Haplosalids (SU5)**

Regarding to the *Typic Haplosalids* soil unit, the result indicates that the whole area has a vulnerability class V3 (58.0 km^2) for phosphorus, nitrogen and heavy metals, while pesticides vulnerability was distributed as V3 and V5 for 66.7 and 33.3% of the unit area respectively under current management scenario. On the other hand, the results of recommended management scenario indicate that there are no changes for the phosphorus vulnerability for the total area, while nitrogen and heavy metals vulnerability were changed to be V2 vulnerability class. Finally, the pesticides vulnerability was changed to be V3 (66.7 %) and V2.

- **Typic Torripasamment (SU6)**

Under the actual management scenario in the *Typic Torripasamment*, the obtained results indicate that the V4 vulnerability class dominates the whole area (26.0 km^2). The nitrogen and heavy metals vulnerability classes present a vulnerability risk of V4 (19.5km^2) and V3 (6.5km^2). The pesticides vulnerability class is V5 in whole *Typic Torripasamment* unit area. For the recommended management scenario the results indicate that the phosphorus vulnerability is still having V4 class, while a great change was obtained for nitrogen where the vulnerability class was changed to be V2. Also the heavy metals vulnerability was changed from moderate (V3) to high (V4) class. A great change also was obtained for the pesticides vulnerability as it was changed from class V5 to be V2 in this mapping unit.

In general, for the total area of El Fayoum depression, the vulnerability classes of phosphorus, nitrogen, heavy metals and pesticides were reduced under the recommended management practices (Figure 9). Regarding to the field vulnerability classes of phosphorus it was found that an area of 625.5 km^2 was changed from V3 the traditional scenario to be V2 in the recommend scenario. For the nitrogen contaminant it is found that the area of vulnerability classes was changed to be V1 (1409.0 km^2) and V2 (84.0 km^2) in the recommend scenario instead of an area 1473.5 km^2 (V3) and 19.5 km^2 (V4) for the current scenario. Also in case of heavy metals we noticed that the vulnerability classes was changed to be V1 (1181.0 km^2), V2 (286.0) km^2 and V4 (26.0 km^2) in the recommend scenario instead of an area 1473.5 km^2 (V3) and 19.5 km^2 (V4) for the current scenario. Finally for pesticides contamination, it was noticed that the areas of vulnerability classes were changed to be 359.3 km^2 (V1) and 1133.7 km^2 (V2) in the recommend scenario instead of an areas 38.3 km^2 (V1), 121.2 km^2 (V3), 260.2 km^2 (V4), and 1073.3 km^2 (V5) under the traditional management scenario.

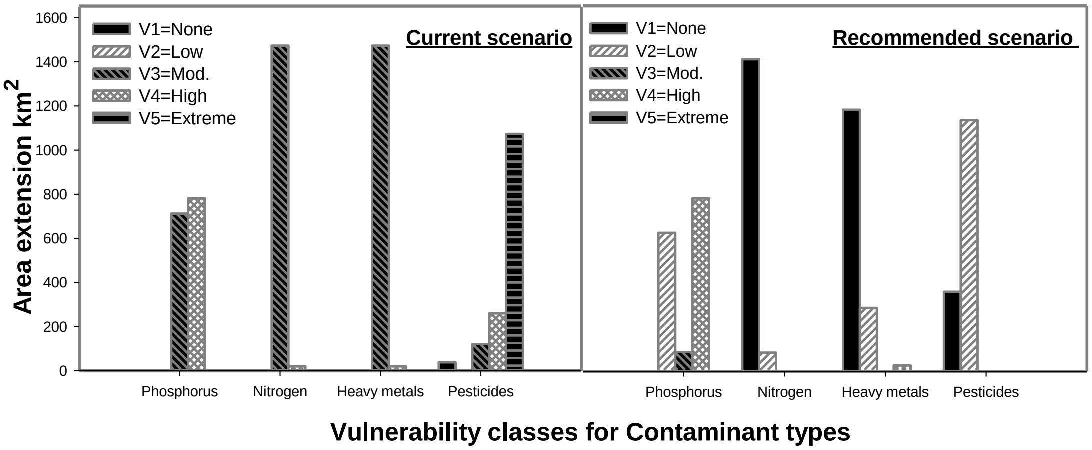


Figure 9. Comparison between vulnerability classes for current scenario and hypothetically recommended scenario for the total area of El Fayoum Province.

The above mentioned results indicate that the vulnerability to contaminants is minimal under the controlled management practices recommended by Pantanal module compared with the traditional practices which is currently used by farmers. Traditional farming practices have assumed that fields are homogeneous bodies, and management practices consider the application rates based on what is best for the field as a whole (Isik and Khanna, 2003). On the other hand recommended management scenario is based on actual requirements of crop. El-Nahry et al. (2011) found that the quantities of irrigation water that added to maize growing under controlled irrigation management were determined to 2025.8 m^3 per acre while it reached to 2634.4 m^3 per acre under traditional application. They also found that the controlled application of fertilizers saved amounts of 21.02, 2.05, 0.50 tons N, P and K respectively (for the experimental field which equals 154.79 acre).These results are in agreement with Wittry et al. (2004) and Lan et al. (2008).

4. Conclusions

Based on the results which obtained from this study we can conclude that:

1. In El-Fayoum area, the principles types of soil were classified at the soubgroup level of USDA Soil Taxonomy system as Vertic Torrifluvents (SU1), Typic Haplocalcids (SU2), Typic Torrifluvents (SU3), Typic Haplogypsids (SU4), Typic Haplosalids (SU5), Typic Torripsamments (SU6), within the orders Entisols and Aridisols.
2. The environmental database management system of MicroLEIS DSS: SDBm, CDBm and MDBm, have proved to be very appropriate tools to compile, harmonize and manipulate the soil, climate and farming information for land evaluation.
3. Pantanal model, as a component of MicroLEIS DSS, has proved that it is an excellent tool to predict the vulnerability classes of soil contamination as phosphorus, nitrogen, heavy metals and pesticides and its result showed that it is very near to the reality.
4. Due to the results of Pantanal modification of land and management vulnerability, the sustainable development of the agricultural land in the study area must be supported by the means of optimum land use and management.
5. In the hypothetical scenarios generated by Pantanal, the model showed high sensibility due to change of management.
6. The high variability of the results from this agro-ecological land evaluation research demonstrates the importance of using soil information in decision-making regarding the formulation of site-specific soil use and management strategies. There are not universal rules for environmentally sustainable agriculture.

Acknowledgment

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5. References

1. Abd Elgawad, M. Hamdi, A. A.M, Shendi M. M. and Ghabour, S. I. 2007. Status of Some Heavy Metals In Fayoum District Soils. The third Conf. for Sustainable Agricultural Development, Fac. of Agric., Fayoum Univ., Egypt 507-526.
2. Alcantara-Ayala, I., 2002. Geomorphology, natural hazards, vulnerability and prevention of natural disasters in developing countries. Geomorphology 47, 107–124.
3. Ali, R. R., 2005. Geomatics Based Soil Mapping and degradation risk Assessment of the Cultivated Land in El–Fayoum Depression, Egypt. J. Soil. Sci. 45, No.3, pp. 349 – 360.
4. CAPMAS, 2006. Statistical Year Book" Central Agency for Public Mobilization and Statistics (CAPMAS), annual report July 2006, Cairo, Egypt.
5. CLAC, 2010. The Climatic Normals - El Fayoum Station. Annual report, Central Laboratory for Agricultural Climate (CLAC), Cairo, Egypt.
6. De la Rosa, D., Anaya-Romero, M. Diaz-Pereira, E., Heredia, N. and Shahbazi, F, 2009. Soil-Specific Agro-Ecological Strategies for Sustainable Land Use – A Case Study By Using MicrolEIS DSS in Sevilla Province (Spain). Land Use Policy (26): 1055–1065.
7. De la Rosa, D., Mayol, F., Diaz-Pereira E. and Fernandez M., 2004. Aland evaluation decision support system (MicroLEIS DSS) for agricultural soil protection. Environ. Modeling Software, 19, 929-942.
8. De la Rosa, D. and Crompvoets, J. 1998. Evaluating Mediterranean Soil Contamination Risk in Selected Hydrological Change Scenarios. Agriculture, Ecosystems and Environment 67: 239–250.
9. Dong, X., Li, C., Li, J., Wang, J., Liu, S. and Ye, B., 2010. A novel approach for soil contamination assessment from heavy metal pollution: a linkage between discharge and adsorption. J. Hazard Mater. 2010 Mar 15; 175(1-3):1022-30.
10. El Naggar, M.A., 2004. Land evaluation of some soils in Arab Republic of Egypt. Ph. D. Thesis, Fac. of Agric. at Moshtohor, Zagazig Univ., Egypt.
11. El-Nahry, A.H.E., Ali, R. R and El Baroudy A., 2011. An approach for precision farming under pivot irrigation system using remote sensing and GIS techniques. Agricultural Water Management 98: 517 – 531.
12. Farrag, R. M. F., 2000. Potential effect of low quality water for soil irrigation in El-Fayoum Governorate, Egypt. M. Sc. Thesis, Fac. of agric at El-Fayoum, Cairo Univ., Egypt.
13. Gomez-Limon, J., Sanchez-Fernandez G., 2010. Empirical evaluation of agricultural sustainability using composite indicators. Ecological Economics 69 (2010) 1062–1075.
14. Hajkowicz, S., 2006. Multi-attributed environmental index construction. Ecological Economics 57 (1), 122–139.
15. Hamdi, A. A. M, 2007. Status of Some Heavy Metals and Nitrate in Some Soils and Water Resources in Fayoum Governorate. M.Sc thesis, Fac. of Agric., El-Fayoum University, Egypt.
16. Haroun, O. R. M., 2004. Soil Evaluation Systems as a Guide

to Identify an Economical Feasibility Study for Agricultural Purposes in El-Fayoum Province, Egypt. Ph.D. thesis, Fac. of Agric., El-Fayoum Cairo University, Egypt.

17. Isik, M., Khanna, M., 2003. Stochastic technology, risk preferences, and adoption of site-specific technologies. American Journal of Agricultural Economics 85 (2), 305–317.
18. Lan, Y., Zhang, S., Li, W., Hoffmann, W.C., Ma, C., 2008. Variable rate fertilization for maize and its effects based on the site-specific soil fertility and yield. In: Agricultural Engineering International: the CIGR Ejournal, Manuscript IT 08 002. vol. X. December.
19. Ponce, V.M., Pandey, R.P., Ercan, S., 2000. Characterization of drought across the climate spectrum. J. Hydrol. Engng, ASCE 5 (2), 222–224.
20. Qiu, H.J., Zhu, W.B., Wang, H.B., Cheng, X., 2007. Analysis and design of agricultural sustainability indicators system. Agricultural Sciences in China 6 (4), 475–486.
21. Rigby, D., Woodhouse, P., Young, T., Burton, M., 2001. Constructing a farm level indicator of sustainable agricultural practice. Ecological Economics 39 (3), 463–478.
22. Said, R., 1993. The River Nile Geology and Hydrology and utilization, Oxford, Britain pergmon press 320 p.
23. Shahbazi F., Jafarzadeh, A. A., Sarmadian, F., Neyshabouri, M. R., Oustan, Sh., Anaya-Romero, M., and De la Rosa, D. 2010. Climate Change Impact on Bioclimatic Deficiency, Using MicroLEIS DSS in Ahar Soils. J. Agr. Sci. Tech. 12: 191-201.
24. Shahbazi, F., De la Rosa, D., Anaya-Romero, M., Jafarzadeh, A., Sarmadian, F., Neyshaboury, M., Oustan, S., 2008. Land use planning in Ahar area (Iran) using MicroLEIS DSS. Int. Agrophysics, 22: 277-286.
25. Tellarini, V., Caporali, F., 2000. An input/output methodology to evaluate farms as sustainable agroecosystems: an application of indicators to farms in central Italy. Agriculture, Ecosystems and Environment 77 (1–2), 111–123.
26. USDA, 2010. Keys to Soil Taxonomy. United State Department of Agriculture, Natural Resources Conservation Service (NRCS) eleventh edition.
27. Van Cauwenbergh, N., Biala, K., Bielders C., Brouckaert, V., Franchois, L., Garcia, V., Hermy, M., Mathijs, E., Muys, B., Reijnders, J., Sauvenier X., Valckx, J., Vanclooster, M., Van der Veken, B., Wauters, E. and Peeters A., 2007. SAFE - A hierarchical framework for assessing the sustainability of agricultural systems. Agriculture, Ecosystems and Environment 120 (2007) 229–242
28. Vegter, J. J., 2001. Sustainable contaminated land management: a risk – based land management approach. Land Contamination & Reclamation, Vol. 9, No. 1, pp. 95-100.
29. Wittry, D.J., Mallarino, S., Antonio, P., 2004. Comparison of uniform- and variable- rate phosphorus fertilization for maize-soybean rotations. Agronomy Journal 96 (1), 26 –33.
30. WMO, 2009. Climate and Land Degradation. Climate and Land Degradation. World Meteorological Organization (WMO) No. 989.

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