Sand dunes movement and its impact on development plans, Siwa Oasis

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Abstract

Siwa Oasis is a natural depression about 23m below sea level. Siwa depression covers about 295,198 feddans boundary around human activities in Siwa Oasis, of which about 48347 feddans have been cultivated in 2015. Siwa Oasis is located north of the sand dunes belts of the Great Sand Sea. The study aims to economically evaluate hazards of sand dunes movement (SDM) and its impact on agriculture development in south of Siwa Oasis and the required adaptation measures.

The total area affected by the SDM is about 50629 feddans. The total cost of economic losses as a result of SDM risk is estimated to 3206.7 Million LE. The total protecting cost the cultivated area, roads and drainage of SDM risk in Siwa Oasis are estimated to 167.6 Million LE.

Key words: *Development Plans (DP), Sand Dunes Movement (SDM), Land Use/Land Cover (LU/LC), Decision Support Systems (DSS), Normalized Different Vegetation Index (NDVI), Remote Sensing (RS), Geographic Information System(GIS) and Digital Elevation Model (DEM).*

Introduction

Sand dunes cover about 160000 Km^2 of the Egyptian land representing about 16% of the total surface area of the country (Mounir, 1983). The Great Sand Sea covers more than one third of the Western desert. Wind causes sand particles to move threatening roads, settlements and cultivated lands. Siwa Oasis (around 300 thousand feddans) is located north of the sand dune belts of the Great Sand Sea. The patterns of dune belts in the Great Sand Sea are controlled by local morphologic and topographic features. Generally, the longitudinal dunes with north-west trends are the most significant patterns. The lengths of the dunes range from 2–7 km but their width rarely exceeds 100 m. However, other dune patterns, e.g. transverse, parabolic and star dunes, have a local distribution, reflecting local wind directions and variable morphologic features.(Philip et al, 2004; Embabi, 2000).

Siwa Oasis is a natural depression about 23m below sea level. Siwa depression covers about 295,198 feddans boundary around human activities in Siwa Oasis, of which about 48347 feddans have been cultivated in 2015. Agriculture represents the main source of Siwan economy, dates palm and olive crops cover about 98.4% from the total cultivated area. The total number of inhabitants in Siwa is about 26,881 residents in 2015(SIC, 2015). In two recent papers, desertification and agriculture sustainable development were discussed on improving the social and economic conditions in Siwa Oasis. (Abo Ragab, 2000; 2014). After 25th, Jan 2011 revolution, Siwa Oasis has gone a phase of reconstruction from the agriculture view point, and is witnessing great efforts for comprehensive agriculture development, particularly, the southwest of Siwa Oasis where the Great Sand Sea expands, which adversely affects the cultivated lands and the newly reclaimed areas, also causes severe damage to the human settlements, roads, irrigation and drainage constructions. The study aims to develop a comprehensive approach for risk

and vulnerability mapping of the SDM, and to utilize the techniques and potentials of Remote Sensing (RS) and Geographic Information System (GIS) modeling for SDM and land use Decision Support Systems (DSS).

The study aims to economically evaluate hazards of SDM and its impact on agriculture development in south of Siwa Oasis and the required adaptation measures.

The problem of the study:

Egypt's desert area covers around 96% of the total area. The Great Sand Sea covers more than one third of the Western desert. Wind causes sand particles to move threatening roads, settlements and cultivated lands. Siwa Oasis (around 300 thousand feddans) is located north of the sand dunes belts of the Great Sand Sea.

Objectives:

The study aims to develop a comprehensive approach for risk and vulnerability mapping of the SDM, and to utilize the techniques and potentials of RS and GIS modeling for SDM and land use Decision Support Systems (DSS). The study aims to economically evaluate hazards of SDM and its impact on agriculture development in south of Siwa Oasis and the required adaptation measures.

Methodology

1- The production of layers for a Land Use / Land Cover (LU/LC) Map of 2015, using Erdas imagine 10.2 and Arc/Gis10.2 software; while using STRM/GDEM (DEM) and landsat8 images. (Abo Ragab, 2010)
   1-1- Normalized Different Vegetation Index (NDVI) = (L5-L4) / (L5+L4)
   L5 Satellite8 band 5, L4 Satellite8 band 4.
   1-2- image supervise classification (SC) (Lillisand et al, 2004)

Supervised Classification: The first thing to do is training field selection, then the Bhattacharya algorithm is used. The Bhattacharya classificator is a supervised method used to classify segmented images, the object to be classified is not necessarily a pixel but a region in the image. The steps of this classification are the same as the pixel classification. The Bhattacharya distance is traditionally used as a separability measure between classes to select image attributes. This distance is calculated using the equation (3) (Woodcock et al., 1992; 1994) :

$$B = \frac{1}{8} MH + \frac{1}{2} \ln \left[\frac{|(C_a + C_b)|/2}{(|C_a||C_b|)^{1/2}} \right] \quad (3)$$

Where, Ca and Cb are the covariance matrix of classes A and B; MH is the distance defined for two distinct classes using the equation 4:

$$MH = \left[(\mu_a - \mu_b)^T \left(\frac{C_a + C_b}{2} \right)^{-1} (\mu_a - \mu_b) \right]^{1/2} \quad (4)$$

Where u is the means of each class

2- GIS Modeling of Potential SDM Risk Using Remote Sensing (RS) and Geographic Information System (GIS) of the Siwa Oasis (Effat et al, 2011).

3- Study expected losses as a result of the continuation of SDM - classification Road map of sand dunes risk index in Siwa Oasis according to LU/LC Map, year 2015.
4- Economic impact on hazard of SDM.
5- Hazard of SDM adaptation.

RESULTS AND DISCUSSION

1- **A multi-band LANDSAT8 image (2015) of the Siwa Oasis was analyzed (NDVI, Supervise Classification) to identify LU/LC classes.**

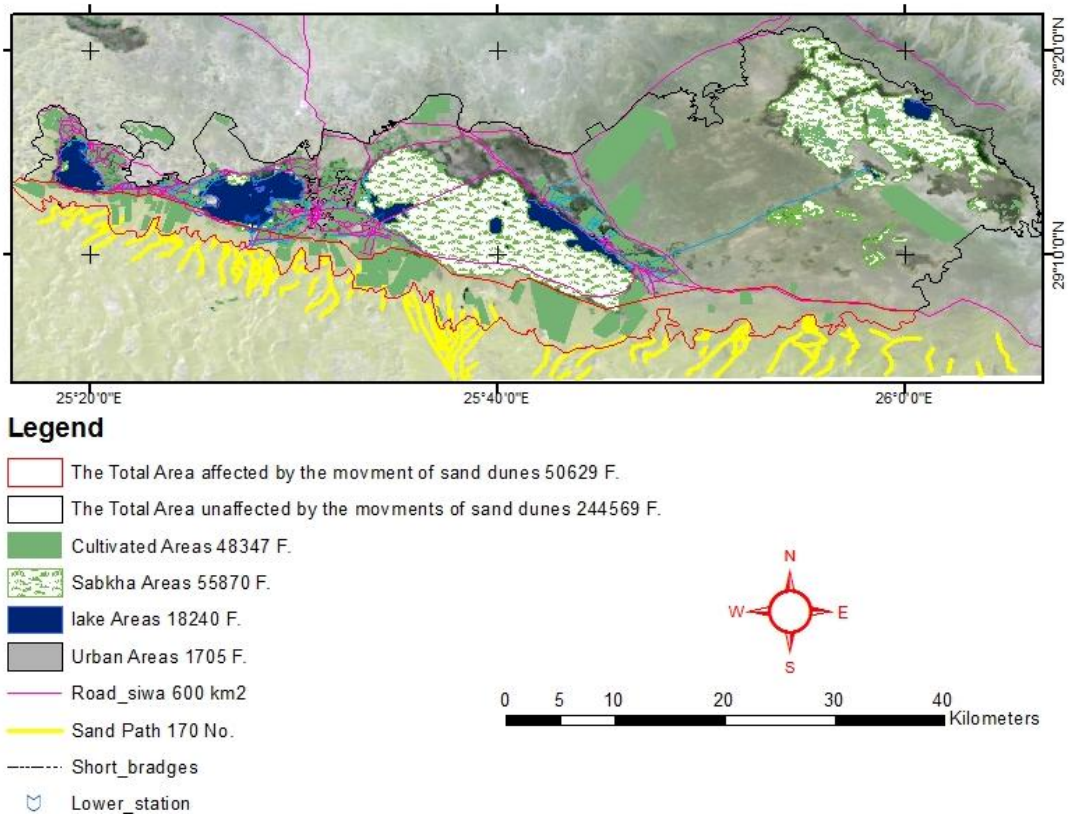

Figure (1) Land Use/ Land Cover Map, Siwa Oasis, 2015

Table (1). The areas of different LU/LC map that will be affected or unaffected by SDM, Siwa Oasis (2015).

LU/LC map	Areas		
	Total	**Unaffected**	**Affected**
Total areas (Feddans)	295198	244569	50629
Soil (unused, Feddans)	171063	135461	35602
Cultivated (Feddans)	48347	33355	14992
Sabkha (Feddans)	55870	55870	0
Lakes (Feddans)	18240	18240	0
Urban (Feddans)	1705	1670	35
Roads Length (Km)	600	556	44
Drainage canals Length (Km)	16	11.5	4.5

Data in figure (1) and table (1) show the total area of Siwa was about 295198 feddans, was classified into two categories, the first category, the total area unaffected by

SDM was about 244569 feddans, while the second category, the total area affected by SDM was about 50629 feddans. The total area of the first category classified into cultivated areas, Sabkha areas, Lake areas, Urban areas and unused area were estimated to 33355, 55870, 1824, 1670 and 135461 feddans, respectively. The lengths of roads and drainage canals were estimated to 600 and 16 km., respectively. The number of sand dunes path was about 170. Comparing LU/LC 2015 with LU/LC map in 2010 (Abo Ragab, 2010), it is clear that there is a significant increase in cultivated area versus a decrease in lakes and marshes areas, as a result of the local authorities implementation of the recommendations of the previous papers (Abo Ragab, 2010; 2014) to overcome environmental problems in Siwa Oasis.

Data in figure (1) and table (1) show the total areas affected by SDM (the second categories) classified into cultivated area, urban areas and unused area were estimated to 14992, 35 and 35602 feddans, respectively. The lengths of roads and drainage canals were about 44 and 4.5 km., respectively.

2- GIS Modeling of Potential SDM Risk Using RS and GIS of the Siwa Oasis (2000-2015).

Model Implementation for SDM (2000-2015).

For this model, the six parameters were used in the analysis to classify sand dunes based on their ability for movement during the period from 2000 to 2015 Terrain characteristics parameters used elevation, slope angle, slope angle direction (aspect), and relative moisture index derived from SRTM and GDEM (DEM) using a model (figure 2). All the previously mentioned parameters were derived from an existing Digital Elevation Model (DEM). Prevailing wind direction and wind speed were extracted from the meteorological information generated (EMA, 2015) by the available weather stations. Sand grain size is an effective parameter in SDM, yet this parameter was not considered in this study due to lack of data at the present stage

Each of the six criteria is represented as a layer in GIS data sets. Except for the moisture index map, equal ranks were assigned the rest five maps. The moisture index parameter was given least importance as the region is quite dry and thus was considered having least significant impact on sand dunes. Thus, each of the five factors was given a double importance of the moisture index. The weights were calculated using the Analytical Hierarchy process (Nijkamp, et al 1990; Janssen 1992; Beinat 1997; Belka 2005). Wind data used represented 15-year average monthly maps. The 12 monthly average wind speed and wind direction maps were combined into two annual average maps and used in the model. A weighted overlay function was applied using the six standardized criteria maps (figure 2). The values of each of the six model parameters were summed to provide an average annual index map of risk for sand dunes encroachment. From the cumulative score for each cell, high-value scores indicate a high risk and vice versa (figure 2)

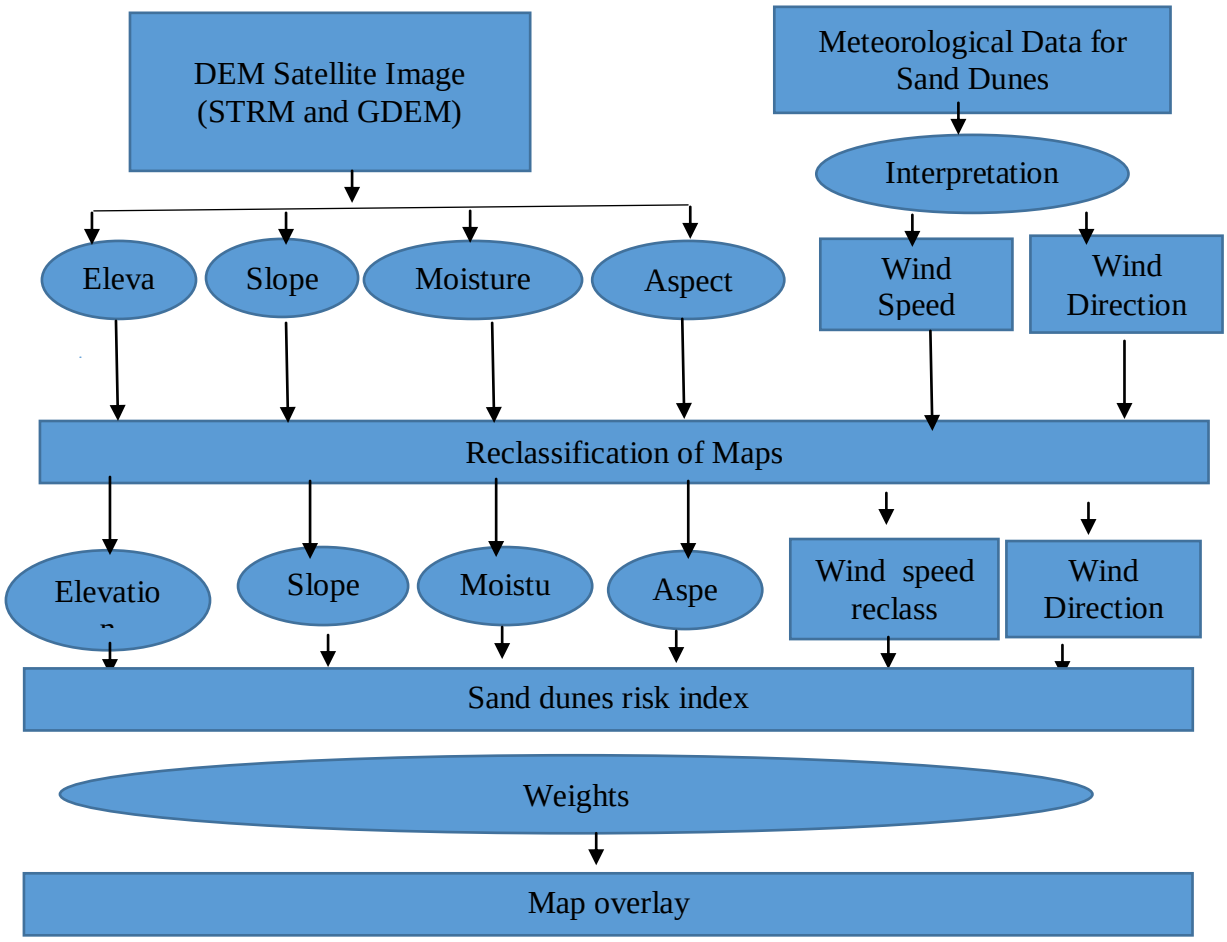

Figure 2: Road map of sand dunes risk index model.

By overlying the model output on the Siwa Oasis, data in figure (3) show that, the dune belts (linear type) locate to the south part of Siwa Oasis which its floor is rising from 10-15 meters below sea level till few meters above sea level. The bases data are the ten topographic sheet of 1998 scale 1:25000 with the recent STRM/GDEM, landsat8 satellite images (2015) were thoroughly investigated with a choice of 170 dunes sample.

The overlay of such areas on the sand dunes risk index values classified into four risk index (if no action is taken). Data in figure (3) show that the high risk area is about 8636 feddans which is located to the south part of Siwa Oasis. It is expected to be affected by the risk of sand dunes during the period from 2016 to 2026. The second risk area is about 7709 feddans, which is located above the high risk area, during (2026-2036). The third risk area is about 6997 feddans, which is located above the second risk area, during (2036-2046). The low risk area is about 27286 feddans. It is expected to be affected by the risk of SDM after 2046.

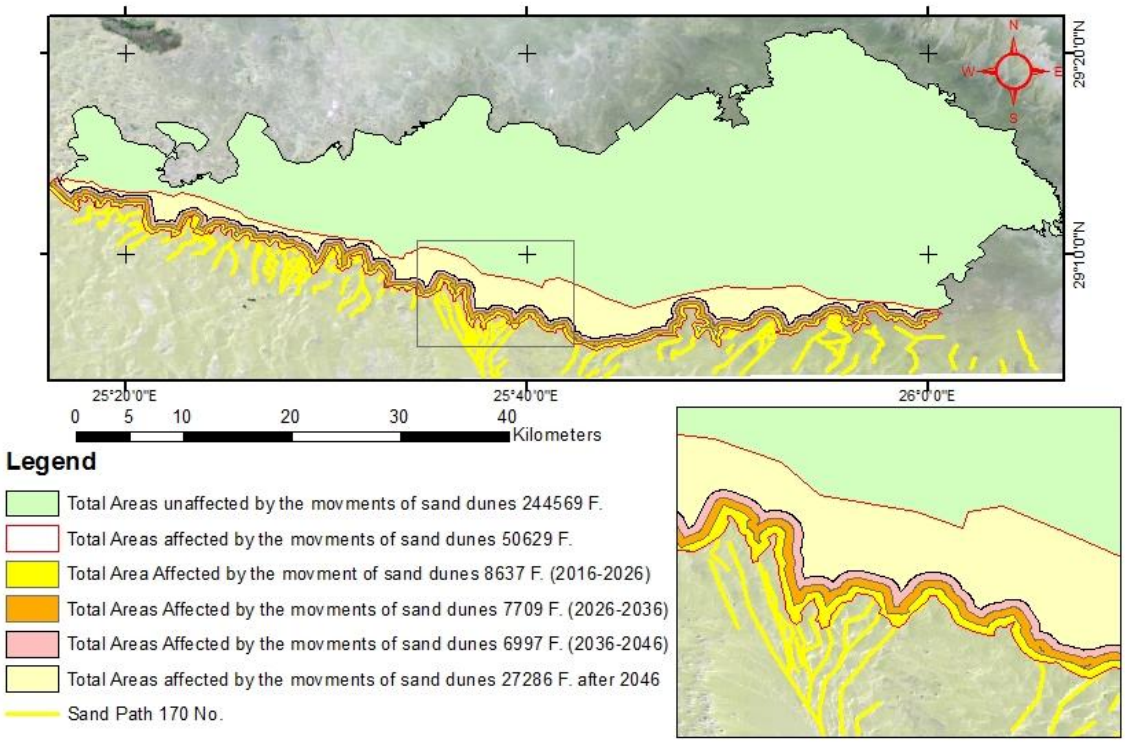

Figure 3: Road map of sand dunes risk index apply on Siwa Oasis, 2015.

3- Study expected losses as a result of the continuation of SDM - classification road map of sand dunes risk index on Siwa Oasis according to LU/LC Map, 2015.

Integration between road map of sand dunes risk index and LU/LC Map was analyzed to identify classification risk map index.

Table 2. Area loss in each LU classes, population displaced and loss of agriculture labor in each classification road map of sand dunes risk index.

Expected of the loss as a result of sand dunes movement risks as follows	2016-2026	2026-2036	2036-2046	after 2046	total (affected) loss
unused areas loss (feddans)	8556	5848	4811	16387	35602
cultivated area loss (feddans)	78	1830	2185	10899	14992
Urban area loss (feddans)	3	31	1	0	35
building lost (building/Unit)	26	261	9	0	296
Roads Length loss (Km)	2	4	12	26	44
Drainage canals Length loss (Km)	0	0.5	1	3	4.5
Population Displaced (labor)*	72	744	24	0	840
Agriculture labor loss (labor)**	156	3660	4370	21798	29984

- *Estimated on the basis every a building where lived a family of five members.
- **Estimated on the basis of every feddans need 2 agriculture labor.

Measuring the future extent to which human activities are likely to suffer from hazard occurrence in different classification road map of sand dunes risk index (if no action is taken) for the high risk areas (2016-2026), the second risk areas (2026-2036), the third risk areas (2036,2046) and the low risk areas after 2046.

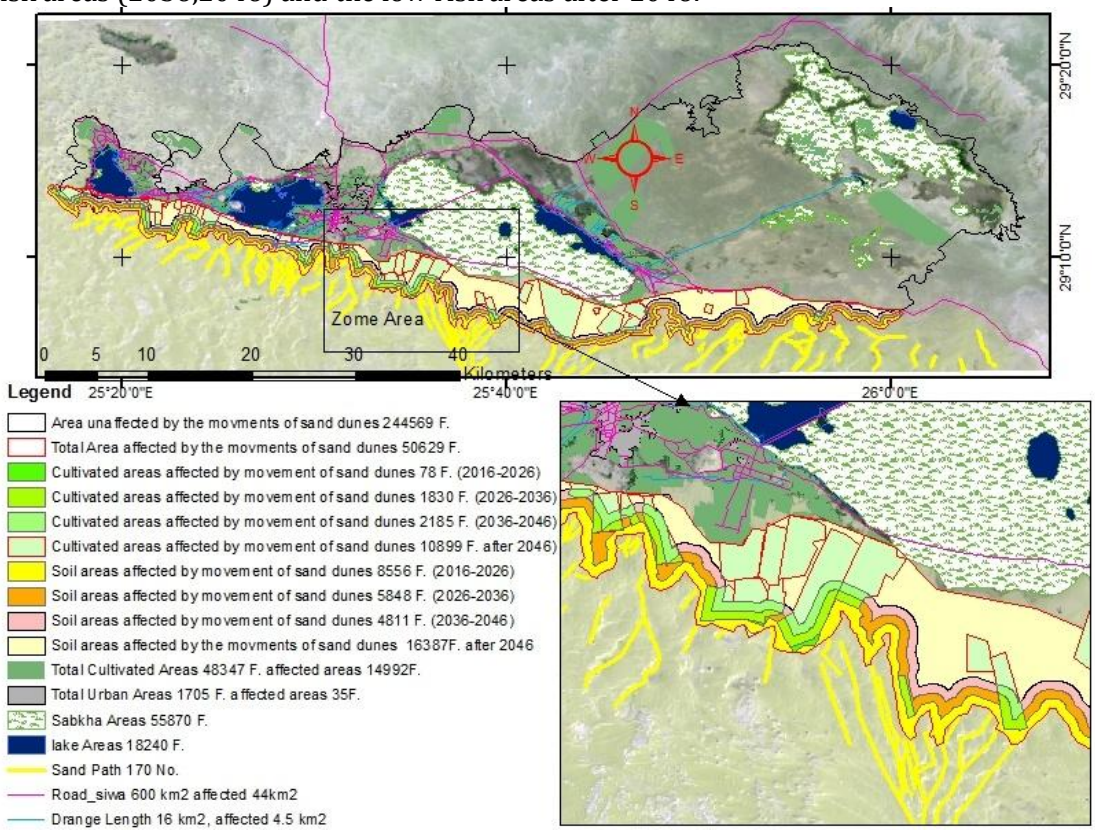

Figure 4: Classification road map of sand dunes risk index, Siwa Oasis, 2015.

Data in figure (4) and table (2) show (if no action is taken) that the high risk area (2016-2026) is about 8637 feddans which classified into unused area loss, cultivated area loss, and Urban areas loss are about 8556, 78, and 3 feddans, respectively. The lengths of roads are about 2km. The number of the population displaced is about 72 people while number of losses in agriculture jobs are about 156 people. the second risk area (2026-2036) is about 7709 feddans which classified into unused area loss, cultivated area loss, and Urban areas loss are about 5848, 1830, and 31 feddans, respectively. The length of roads are about 4km. The number of the population displaced is about 477 people while number of losses in agriculture jobs are about 3660 people. the third risk area (2036-2046) is about 6997 feddans which classified into unused area loss, cultivated area loss and urban areas loss are about 4811, 2185, and 1 feddans, respectively. The lengths of roads are about 1km. The number of the population displaced is about 24 people while number of losses in agriculture jobs are about 4370 people. The low risk area (after 2046) is about 27286 feddans which classified into unused area loss and cultivated area loss are about 16387and 10895 feddans, respectively. The lengths of roads are about 26 km. Number of losses in agriculture jobs are about 21798 people.

4-Economic impact on hazard of SDM

Data in table (3) shows that variables of the economic survey carried out in the cultivated area (2015) was affected by SDM totaled 14992 feddans. Olive crop selected of

Siwa Oasis covered about 14250 feddans, representing 95% of the cultivated area affected by SDM in Siwa Oasis

Table (3): The economic variables of the study sample of olive crop in the area affected by SDM, (2015).

Variables	affected by SDM		
	Olive	other	Total
Total area affected by SDM	14250	742	14992
Number of observations the sample/holder	119	8	127
The sample size of the total area (%)	95	5	100
The average productivity (ton/Feddan)	7.9		
The total Cost (LE/Feddan)	10250		
Sale price (ton/pounds)	3850		
The total income (LE/Feddan)	30415		
Net Income (LE/Feddan)	20165		
The average cost of reclamation (LE/Feddan)	11250		
The average cost of building a house (LE/unit)	9500		
the average cost of Roads (LE/Meter)	125		
The cost of Drainage canals (LE/Meter)	1460		
The average cost of protection from SDM (LE/Feddan)	2900		

Source: collected and calculated from the questionnaires to a sample field study, 2015.

Data shows that the total survey was about 127 holders, representing 100%, where the total olive sample is about 119 holders, and representing 94% of the cultivated area affected by SDM in Siwa. The study sample selected olive crop, representing 95% of the cultivated area which affected by SDM.

Data shows that the average productivity of olive crop was estimated to 7.9 Tons/feddan, The total cost, total income, net income, average cost of reclamation and average cost of protecting were estimated to 10250, 30415, 20165, 11250 and 2900 LE/feddan, respectively. The average cost of building a house was estimated to 9500 LE/Unit.

4-1 Economic losses as a result of the risk of SDM.

Data in table (4) shows that the total of economic losses as a result of SDM risk is estimated to 3206.7 Million LE. Data in table (4) also shows that (if no action is taken), the high risk area (2016-2026) is expected to cost losses for olive crop, reclaimed cultivated areas, roads and buildings are estimated to 15.7, 0.9, 0.3 and 0.2 Million LE., respectively. The second risk area (2026-2036) is expected to cost losses for olive crop, reclaimed cultivated areas, roads, drainage canals and buildings are estimated to 369.0, 20.6, 0.5, 0.7 and 2.5 Million LE., respectively. The third risk area (2036-2046) is expected to cost losses for olive crop, reclaimed cultivated areas, roads, drainage canals and buildings are estimated to 440.6, 24.6, 1.5, 1.5 and 0.1 Million LE., respectively. The low risk area (after 2046) is expected to cost losses for olive crop, reclaimed cultivated areas, roads, and drainage canals are estimated to 2197.8, 122.6, 3.3 and 4.4 Million LE., respectively.

Table (4). The cost value of economic losses as a result of the risk of SDM, 2015. (Million LE.).

Expected losses as follows	2016-2026	2026-2036	2036-2046	after 2046	total
cost losses in olive crop	15.7	369.0	440.6	2197.8	3023.1
cost losses in reclamation areas	0.9	20.6	24.6	122.6	168.7
cost losses in Roads	0.3	0.5	1.5	3.3	5.5
cost losses in drainage canals	0.0	0.7	1.5	4.4	6.6
cost Losses in buildings	0.2	2.5	0.1	0.0	2.8
total loss	17.1	393.3	468.2	2328.0	3206.7

- Source: collected and calculated from field research and tables (2,3).

4-2 The protecting cost for areas to suffer of SDM risk, Siwa Oasis.

Table (5). The protecting cost for cultivated area, roads and drainage canals of SDM risk, Siwa Oasis, (2015), (Million LE.).

Protecting Cost as follows	2016-2026	2026-2036	2036-2046	after 2046	total
Cultivated areas.	0.2	5.3	6.3	155.7	167.5
Roads.	0.1	0.2	0.6	1.3	2.2
Drainage canals.	0.0	0.3	0.5	1.5	2.3
Total	0.2	5.3	6.3	155.7	167.6

- Source: collected and calculated from field research and tables (2, 3).

Data in table (5) shows that the total protecting cost for cultivated area, roads and drainage canals of SDM risk in Siwa Oasis are estimated to 167.6 Million LE. Data in table (5) also shows that the high risk area (2016-2026) which is expected the protecting cost for cultivated areas, roads and drainage canals are about 0.2, 0.1 and 0.2 Million LE. The second risk area (2026-2036) which is expected the protecting cost for cultivated areas, roads and drainage canals are about 5.3, 0.2 and 0.3 Million LE., respectively. The third risk area (2036-2046) which is expected the protecting cost for cultivated areas, roads and drainage canals are about 6.3, 0.6 and 0.5 Million LE., respectively. The low risk area (after 2046) which is expected the protecting cost for cultivated areas, roads and drainage canals are about 155.7, 1.3 and 1.5 Million LE, respectively.

5-Solving the Hazard of SDM adaptation. The following steps are suggested:

- To determine the expansion of urban and agricultural areas and remove any encroachments on the land of the Siwa oasis.
- To reduce infringement on a land especially the south of Siwa Oasis, where it's suffer from risk of SDM.
- The need to take the necessary procedures to protect the areas of development south of Siwa Oasis from the risks of SDM.

The previous solutions based on the Siwa oasis data but many of countries suffered from the same problem, so, this model can be applied on many other parts of the world.

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