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EVALUATION OF PRESENT-DAY CLIMATE-INDUCED DESERTIFICATION IN EL-DAKHLA OASIS, WESTERN DESERT OF EGYPT, BASED ON INTEGRATION OF MEDALUS METHOD, GIS AND RS TECHNIQUES.

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Key words: MEDALUS, Desertification and Environmental Sensitive Area

Abstract. Limited to fourth percent or less of the country's total land area, Egypt's agricultural landscape is threatened by the repercussions of climate change, desertification, soil depletion, and looming water scarcity. Outside of the Nile river valley and scattered fertile pockets in the desert oases, the vast majority of land is desert: rocky, parched and unable to support conventional farming. According to Egyptian National Action Program 2005 (ENAP), Egypt covers an area of about one million km^2 ˜ 100 million hectares, out of which about of 76.5 thousands km^2 ˜ 7.6% of the total area are inhabited, and the remaining (92.4%) area is desert. Desertification is a very complex process governed by several variables which influence each other. It is thus not possible to conclude for the general picture from a single factor alone. This process has a high rate in arid and hyper-arid countries such as Egypt. The main objective of this research was to evaluation the present-day climate-induced desertification in El-Dakhla Oasis, so in this study, the newest method for evaluating and mapping of desertification was used. The mathematic method was carried out by European Commission (EC), (MEditerranean Desertification And Land Use) at the MEDALUS project and booked as ESAs in 1999 integrated with remote sensing and GIS. All indices of the model were revised before using, and regarding to the region condition these indices were defined as key indices which were: Temperature, precipitation, wind, albedo, ground water and soil benchmark, and each benchmark has some sub-layers getting from their geometric mean. Based on the MEDALUS model, each sub-benchmark was quantified according to its quality and given a weighting of between 1.0 and 2.0. All benchmarks should be reinvestigated and adjusted to local conditions. Ultimately, desertification severity was classified in four level including low, moderate, Severe and high Severe. ArcGIS 10 was used to analysis and prepares the layers of quality maps

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using the geometric mean to integrate the individual sub-indicator maps. In turn the geometric mean of six quality maps was used to generate a single desertification status map. Remote sensing data have great potential to improve models mapping spatial variability of temperature and precipitation since they are available as time worldwide, and have high spatial resolution. The HYDRA visualization software was used to measure the present surface albedo from MODIS product (MOD43C1). Results showed that 60% of the area is classified as Severe, 14 % as moderate and 12%, 16% as low and none affected by desertification respectively. In addition the climatic variations including rainfall, temperature, sunlight, wind indicators were the most important factors affecting desertification process in El-Dakhla Oasis.

Introduction

The phenomenon known as desertification received extensive attention in last decades, since the time of the organization of the United Nations Conference On Desertification (UNCOD), hold in Nairobi in 1977 that was mainly a result of the impact of an extended drought in the West African

Sahel in the early 1970s. That drought caused a loss of human lives and livestock and an invasive environmental deterioration. Although desertification has been investigated since the 1960s, it was during the 1990s that major research and development aid projects were launched. Satellite images seemingly showed an expansion of the North African desert belt, almost suggesting that the desert was about to migrate into the Mediterranean Fruitland, "knocking at Europe's door" (Hill et al., 2004). Desertification constitutes one of the most serious and global environmental problem in the world is facing. It has been recognized as a problem of significant importance since the early 1970s, but the international community has never given it its full attention and commitment (Philippe Cullet, 2001).

It is widely recognized that desertification is a serious threat to arid and semiarid environments which cover 40% of the global land surface and are populated by approximately 1 billion humans. Since the United Nations Conference on Desertification, held in 1977, the definition and assessing methodology for desertification have been controversial. United Nations Convention to Combat Desertification (UNCCD, 2006) has concluded that the definition of desertification is “land degradation in arid, semiarid and dry sub-humid areas resulting from various factors, including climatic variations and human activities”. Although the definition had been widely accepted, there is no consensus concerning assessment systems and methodology on the proper way to assess it and this may result in desertification being measured by different researchers using different assessment methods that cannot be compared for the same region (Duanyang Xu, et al, 2009). The most recent researches disclose as climatic elements can make the existing desertification processes worsen or cause trigger conditions. Globally, every year an additional 200,000 km^2 of productive lands are converted by desertification to the point of yielding nothing. Dry lands cover about 5.2 billion hectares, a third of the land area of the globe (UNEP, 1992). Roughly one fifth of the world population lives in these areas. Most of African countries affected by desertification are poor countries with low living standard.

Egypt has a total area of about one million km^2, under arid and hyper-arid climatic conditions, of which only a small portion (4% of total area) is agriculturally productive. Egypt ratified the United Nations Convention to Combat Desertification (UNCCD), in 1995 and ratified in 1995, with the active participation of Egypt, gave emphasis for combating the major threats to sustainability of dry lands. This convention defined desertification and also combating desertification as activities that aimed at: a) Prevention and / or reduction of land degradation, b) Rehabilitation of partly-degraded lands, and c) Reclamation of decertified land. Additionally, Desertification is a very complex process governed by several variables which influence each other. It is thus not possible to conclude for the general picture from a single factor alone. This process has a high rate in arid and hyper-arid countries such as Egypt. According to UK Hadley Centre, rainfall in Egypt could decrease of about 10% to 15% by the year 2050. For the same period, the temperature will increase between 1.5° and 2.5°C. The projections also show that for the dry season (April to September), by the year 2050 rainfall is going to decrease over much of the Mediterranean especially in the southern parts where it could diminish by up to 25%. Decreased precipitation is predicted to be accompanied by a rise in temperature of between 1.75° and 3.0°C in Egypt (De Warachien et al, 2011).

There have been many attempts to assess the extent, nature, and rate of desertification on global, regional, and local levels (Thomas, 1997). These studies are instrumental in understanding desertification myths and in effectively fighting the destruction. The earliest assessment can be dated back to Lamprey's research in central western Sudan, when he introduced the desert encroachment theory (Lamprey, 1975; Mainguet, 1994). Although this theory was criticized by fellow researchers (e.g. Hellden, 1988, 1991), nevertheless, Lamprey's research laid the groundwork for providing a process for measuring the desertification problem. Since the 1977 United Nations Conference on Desertification (UNCOD), there have been four sequential global desertification assessments by international organizations (Thomas and Middleton, 1994; Middleton and Thomas, 1998). Consequently, a provisional methodology for assessment and mapping of desertification was formulated (FAO/UNEP, 1984) and is now used for local and regional assessment and mapping (e.g. Dong, 1996; del Valle et al., 1997; FAO/UNEP/AGRIMED, 1998). Others, in contrast, questioned the methodology employed by previous studies and found no evidence for extensive desertification (e.g. Hellde´n, 1988, 1991; Tucker et al., 1991; Nicholson et al., 1998; Prince et al., 1998). New research (Huenneke et al., 2002; Vero´ n et al., 2005) has, however, also called into question these studies, as a result of methodological or conceptual problems, illustrating that desertification assessment remains controversial. The failure to achieve an accurate inventory of desertification is evident from the United Nations Convention to Combat Desertification statement of (UNCCD, 2000). (Gad, 2005) and (Abdel Mohsen et al, 2011) concluded that the desert Oases in Egypt are mostly very sensitive areas to desertification. However, as various environmental conditions may control the desertification sensitivity, some areas within the oases may be exposed to relatively less sensitivity. (Hreher and Ismael, 2014) concluded that the occurrence of El-Dakhla Oasis in a hyper-arid desert is a direct reason for environmental degradation due to the deficiency of water balance.

Much previous research has focused on investigated efficient and applicable ways of monitoring of the desertification processes and desertification vulnerability by making use of the climatic series of observations and climate-related variables, various climatic and/or aridity and drought Severeity indices, and remotely-sensed data and indices (Türkeş and Tatlı, 2010). (Reich et al, 2001) investigated the desertification vulnerability of Africa by assessing the information on soils, climate and previously evaluated land resource stresses. The GIS-based desertification vulnerability map was coupled to the interpolated population density map to estimate the number of persons affected by the desertification. On the other hand , (Karnieli and Dall'Olmo, 2003) for the Negev (Israel) and Sinai (Egypt) regions of the Middle East, (Michetti et al. 2007) for the Southern Italy, (Sonmez et al. 2005), (Türkeş 1999), (Türkeş and Tatlı 2009) for Turkey. It is generally known that El-Dakhla Oasis is characterized with a continental climate and hyper arid environmental conditions. However, the El-Dakhla climate was not studied so far in detail except those performed by (El-Tantawi, 2006), (Domoros and El-Tantawi, 2009), although some important spatial differences are evident with respect to the climate types particularly due to the scarcity of precipitation, high temperatures, evaporation, and increase of sunshine hours, and increase the influence of the wind as it passes to the Great Sand Sea in western desert.

The main aims of this study were to evaluate present-day climate -induced desertification in the study area by modifying the MEDALUS method, develop a desertification evaluation model for hyper arid region such as El-Dakhla

Oasis, and present a methodology and prerequisites for mapping and measurement of desertification in El-Dakhla Oasis.

1. Materials and methodology:

1.1.The study area

El-Dakhla (the inner in Arabic) is one of seven other Oases scattered within the vast Western Desert of Egypt at about 350 km west of the Nile and about 750 km southwest of Cairo. El-Dakhla is an old region since the Pharaohs era. The Oasis extends for about 80 km in a west-east direction and about 30 km in a north-south direction. Like most of the other Oases, El-Dakhla is bordered by a northern steep escarpment. El-Dakhla escarpment is composed of Eocene limestone and rises up to 500 m above sea level and is known as Abu-Tartur plateau. The southern side of the Oasis rises gradually until the mean level of the desert. The region is extremely arid as it is a part of the hot and dry Sahara, where descending air coming from equatorial region produces a stable air mass known as the tropical continental region (Beaumont, 1993). El-Dakhla Oasis belongs administratively to the New Valley Governorate. It is located in the southern part of the western desert of Egypt, lies between latitudes 25º30'00" and 28º30'00" N, and between 32º00'00" and 33º47'00" E (Fig. 1). The region is the driest on the earth's surface, where the incident solar radiation is capable of evaporating over 200 times the amount of precipitation (Henning and Flohn, 1977).

In El-Dakhla Oasis, the wind blows from the north-northwest direction with moving capacity to drift sand dunes, which is a common phenomenon encroaching upon farmlands, roads and settlements. There is a massive sand dune field, the Great Sand Sea, occurring north of El-Dakhla and extends until Siwa Oasis in the north. Dunes enter the Oases by cascading through the northern escarpment particularly from the western side of the plateau. Rates of dune advance have been reported around 6 m/year (Ghadiry et al., 2012).

The majority of the population in El-Dakhla, which approaches about 70,000, are working in farming and grazing. Water recourses are exclusively restricted to groundwater recharged from the Nubian sandstone aquifer system. Perennial vegetation in the Oasis is the date palm, however, vegetables, alfalfa and rice are also cultivated. A soil of El-Dakhla Oasis is classified according to the FAO/UNESCO (1977) Soil map of the world as *Calcisols* (Hereher, M and Ismael, H, 2014).

It is characterized by hyper-arid climatic conditions with rare rainfall and extremely high temperature. Temperatures range from 42°C in summer to 25°C in winter and potential evapotranspiration is as high as 5 mm/d (Beaumont, 1993). Annual precipitation does not exceed 2 mm and the number of rainy days is 0.8 / year.

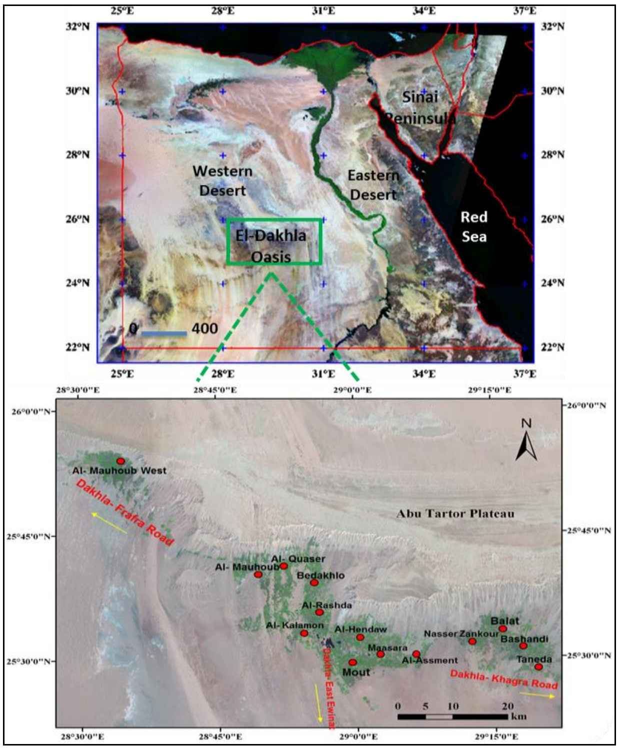


Fig.1. The Location Map

In the 1990s the EU has promoted the project "MEditerranean Desertification And Land Use (MEDALUS)" (http://www.medalus.demon.co.uk/), with the aim of carrying out basic investigations on Mediterranean desertification by consolidating fundamental areas of research and by setting up models suited to predict climate change due to enhanced greenhouse effect, and quantify the land degradation and desertification processes (Brandt et al., 1996). The MEDALUS method represents, perhaps, the most valuable compendium nowadays available of information concerning present pattern and future trends of climate, land degradation and desertification the Mediterranean region North and South.

1.2. Field investigation

During August September 2012, 2013 (the same time of image acquisition), a total of 66 representative surface soil and water samples distributed randomly throughout El-Dakhla Oasis have been collected with the aid of a hand-held GPS to locate the position of each sample. Sampling locations were designed to represent bare soils and fallow agricultural lands and avoiding actively cultivated farmlands. The laboratory analysis of 66 soil and water samples represent the physiographic units in the study area, were carried out using the soil survey laboratory methods manual, (USDA, 2004). The American soil taxonomy (USDA, 2006) was used to classify different soil samples to sub-group level. The comparison between the data extracted from the Research Institute of Soil and Water (RISW) this report has been published by the year 2000, and the data of this study was carried out to determine the status of desertification in El-Dakhla Oasis. The EC of the soil extract was determined according to (Dellavalle, 1992) using a bench-top EC meter and salinity was expressed in dS/m.

1.3. Remote sensing data:

Remotely sensed surface albedos are generated from empirical and semiempirical models. The MODIS albedo algorithm adopts a semiempirical, kernel-driven linear Bidirectional Reflectance Distribution Function (BRDF) model to characterize the anisotropy of the global surface (Lucht et al., 2000a). For the present surface albedo the MODIS product (called MOD43C1) of white-sky (completely diffuse) and blacksky (direct beam) is adopted (Gao et al., 2005; Lucht et al., 2000; Schaaf et al., 2002) (available at http://modarch.gsfc.nasa.gov/ MODIS/LAND/#albedo-BRDF), (Lucht et al. 2000), (Schaaf et al. 2002), and MOD43 User's Guide, available at http://geography.bu.edu/brdf/userguide/. The surface albedo has been validated to stage one with the highest quality retrievals generally comparing to field measurements within 0.02 (Jin et al., 2003). The MODIS product is produced every 16 days and represents the best estimate of albedo that can be achieved for that 16 day period.

1.4. Climatic data

All climate data used in this study are represented by original data, according to unpublished data from Egyptian Meteorological Authority to El-Dakhla from 1941 to 2012. The climate data consisted of solar radiation, mean monthly and annual records of temperature types (maximum, minimum, absolute), mean monthly and annual records of rainfall, Annual means are the means of all 12 months from a respective year; seasons were defined as follows: winter is the mean through December-January-February; spring through March-April-May; summer through June-July-August; and autumn through September-October-November. The winds data come in a standard format and represent the annual average of the percent of hourly occurrence of surface wind measured at 10 m height above ground and are arranged into 12 wind speed classes in 12 directions. The range of variation becomes greater further inland (from about 4 to 38°C in the oases of the Western Desert).

In continental locations, temperature extremes of less than 4 °C in the coldest month (e.g. oases of the Western Desert) have been recorded. The coldest month is between December and February and the hottest month is between June and August in hyper-arid and arid provinces, respectively.

2. Research methodology

The vulnerability of land to desertification in El-Dakhla Oasis is mainly due to climate elements, state of the soil, ground water, and the ways in which these resources are used by human communities and their livestock. The MEDALUS model (Mediterranean Desertification and Land Use) is a practical approach to assess the status of desertification and evaluating of desertification risk. This method has been tested in most of the Mediterranean countries and showed good results.

According to the local condition of El-Dakhla Oasis, six benchmarks include: temperature, precipitation, wind, albedo, ground water and soil were recognized (Table.1). Each benchmark included Several indicators accounting as factor quality determination. These indicators quantified based on their influences on desertification process. For each indicator a score ranging from 1.0 to 2.0 has been assigned and desertification weighting was extracting. Ultimately, desertification Severity was classified in four levels including low, moderate, Severe and high Severe.

(Table 1) Benchmarks affecting desertification process in the study area

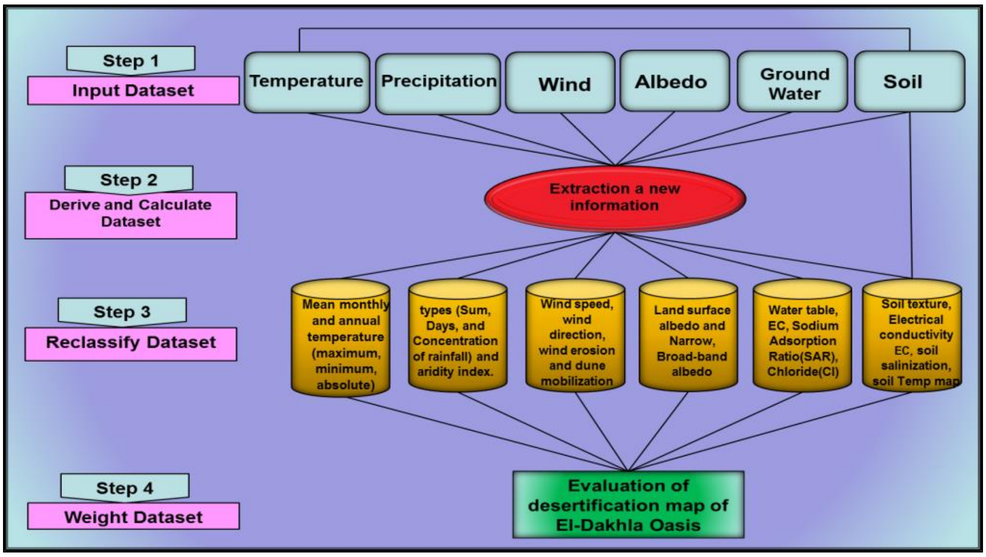
Main benchmarks (Indices)	Sub-benchmarks (Layers)
Temperature	Mean monthly and annual records of temperature (°C) types (maximum, minimum, absolute)
Precipitation	Mean monthly and annual records of precipitation (mm) types (Sum, Days, and Concentration of rainfall) and aridity index.
Wind	Wind speed, wind direction, wind erosion and dune mobilization
Albedo	Land surface albedo and Narrow, Broad-band albedo
Soil	Soil texture, Electrical conductivity (EC), Organic matter(OM), Soil Depth, SAR Value ,pH, slope gradient and soil temperature.
Ground water	Water table, EC, Sodium Adsorption Ratio(SAR), pH and Chloride(Cl)

A classification scheme with values ranging from 1 to 2 has been applied throughout the model for individual indices as well as the final classification of Desertification Sensitive Areas (DSAs). The value “1” was assigned to areas of least sensitivity, and the value“2” was assigned to areas with the most sensitivity. Values between 1 and 2 reflect relative vulnerability.

The individual factors and their indicators are described in Tables 2, 3, and 4. The next task was to develop a system which would function irrespective of the number and type of information layers at its most primitive level. This was achieved by adopting an approach as illustrated in (Fig.2). In the first stage, the six quality indices (temperature, precipitation, wind, albedo, ground water and soil) were determined from the sub-indicator layers and in the second stage the six quality layers were combined to give a single desertification sensitivity layer. The quality indices were calculated for each study unit using Eq. 1.

$$\mathbf{Index_x= [(Layer_1)^* (Layer_2)^* (Layer_3) * (Layer_4) * (Layer_5) * (Layer_6)] \ 1/N}$$

Where:
$\text{Index}_{\mathbf{x}}$ = the given benchmark
Layer= Indicator of each benchmark
N: Number of indicators for each benchmark.



(Fig. 2) Flowchart showing the steps and process of developed model

Therefore, six maps were obtained to show the status of benchmark. These maps can be used for studying the quality and effect of each indicator on desertification. The final map shows the evaluation of Present-day Climate-induced desertification in El-Dakhla Oasis, using geometric mean of all indicators.

Climate elements, soil and ground water, which usually have been used to characterize desertification. These changes of land surface conditions make the spectral characteristics of desertification land vary greatly to different degrees, which can be captured by satellite sensors. This may be fundamental for quantitatively assessing desertification by means of the indices derived from satellite images, because the accuracy of soil properties acquired from satellite images is very variable.

In the current study, the reference to present-day climate-induced desertification is related either to climate variability and climate change. Climate variability refers to the natural fluctuations that appear in the statistics representing the state of the atmosphere for a designated period of time, usually of the order of months to decades of any or all of the atmospheric variables (sunlight, temperature, precipitation, wind speed and direction, evaporation and albedo).

Furthermore, in this study, landscape pattern or heterogeneity in desertification was assessed by using MSDI, which had been proven to be a robust indicator to assess landscape heterogeneity for land degradation. Where *N* represents pixel number of filter, and here *N* =9; *DNi* is the digital number of pixel *i* in each nine-pixel window and *DN* is the average digital number value of each nine-pixel window:

$$MSDI = \frac{\sqrt{\Sigma_{I=1}^{N}(NDI - DN)2}}{N}$$

MSDI was mainly used to distinguish the low, medium and high desertification. The rule sets for different desertification grades varied greatly due to seasonal variation. Land surface albedo is an important indicator that determines energy budget and the change of micrometeorological conditions like temperature, aridity/humidity etc. of land affected by desertification (Pinet et al, 2006). For the present surface albedo the MODIS product (called MOD43C1) of white-sky (completely diffuse) and blacksky (direct beam) is adopted (Gao et al., 2005; Lucht et al., 2000; Schaaf et al., 2002) (available at http://modarch.gsfc.nasa.gov/ MODIS/LAND/#albedo-BRDF), (Lucht et al. 2000), (Schaaf et al. 2002), and MOD43 User’s Guide, available at http://geography.bu.edu/brdf/userguide/. Additionally, there are classical methods for retrieving the micrometeorological conditions of land surfaces such as land surface temperature (LST) from satellite image by using thermal infrared band or other band combinations to accurately get micrometeorological parameters of land surfaces (Liu et al, 2005). Based on these indices retrieved from images, various assessment models such as decision tree classification, unsupervised classification and micrometeorological conditions of land surface like temperature, wind and albedo have been used to characterize desertification. These changes of land surface conditions make the spectral characteristics of desertification land vary greatly to different degrees, which could be captured by satellite sensors and this might be fundamental for the analysis of desertification by means of the indices derived from satellite images (Pinet et al, 2006).

3. Results

In this study, the present desertification Severity of El-Dakhal Oasis was classified into four classes: non-desertification, low desertification, moderate desertification and severe desertification according to the modification of MEDALUS and the analysis of climate elements, soil and ground water. Based on the above methodology, maps have been produced El-Dakhla Oasis represent the three main quality index (climate, soil and ground water) used for the evaluation of present-day climate-induced desertification in El-Dakhla Oasis.

The Climate quality is calculated from indicators that influence soil and water availability to plants in El-Dakhla Oasis such as solar radiation, temperature, amount of rainfall, evaporation, albedo and aridity index. (Table, 2) shows that a very great part of El-Dakhla Oasis is characterized by low (44%) and moderate climate quality (48%). Only a little part (8%) falls into high quality class. This can be mainly attributed to rare of rain and due to very high temperature (38°C).

As illustrated in (table, 2) it can be concluded that the mean of maximum temperature and absolute record of maximum temperature were ranged between moderate and sever, it were (26-38°C) and (25-45°C) respectively. The majority (59.5%) of El-Dakhla Oasis was characterized by sever class, inducing high sensitivity to the desertification process. On the other hand, it can be indicated that the mean of minimum temperature and absolute record of minimum temperature were mostly ranged between moderate and very low, it were (4-16°C) and (-2-14°C) respectively. Taking into consideration the value of aridity index, 87% of El-Dakhla Oasis is characterized as hyper-dry climate with an aridity index less than 1(table, 2).

Tab. 2 Classes and the corresponding weight assigned for the calculation of the Climate elements quality index

Class	Description	Class Variable	Weight
Mean of Maximum Temperature		**(C ^{o})**	
1	Moderate	20-26	1
2	High	26-32	1.2
3	Very High	32-38	1.5
4	Severe	> 38	2
Mean of Minimum Temperature		**(C ^{o})**	
1	Moderate	16-24	1
2	Low	4-16	1.5
3	Very Low	< 4	2
Mean of Day Temperature		**(C ^{o})**	
1	Moderate	20-24	1
3	High	24-28	1.6
4	Very High	> 28	2
Absolute Record of Max		**(C ^{o})**	
1	High	25-35	1
2	Very High	35-45	1.5
3	Severe	> 45	2
Absolute Record of Min		**(C ^{o})**	
1	Very Low	< -2	1
2	Low	-2-6	1.7
3	Moderate	6-14	2
Total Rainfall		**mms**	
1	Very Low	0-2	2
2	Low	2-7	1.5
3	Almost Low	> 7	1
Max Rainfall in one day		**mms**	
1	Very Low	0-2	2
2	Low	2-4	1.5
3	Almost Low	> 4	1
Evaporation per day		**mms (piche)**	
1	Very Low	**10-15**	1
2	Low	15-20	1.5
3	Almost Low	> 20	2
Aridity index		**(P/ETp)**	
1	Almost Arid	AI >=1	1
2	Arid	0.1 < AI < 1	1.5
3	Very Arid	AI=< 0.1	2
Wind Speed		**(Knots)**	
1	Very Low	2-4	1
2	Low	4-6	1.3
3	Moderate	6-8	1.7
4	High	> 8	2
Wind Erosion		**Dust or Sandrising ≥1000**	
1	Low	6-12	1
2	Moderate	12-18	1.4
3	High	18-24	1.8
4	Very High	> 24	2
Solar Radiation		**MJ / m 2 / day**	
1	Moderate	18-25	1
2	High	25-32	1.5
3	Very High	>32	2
Albedo		**using MODIS images in August**	
1	Moderate	0.28-0.32	1
2	High	0.32-036	1.5
3	Very High	> 0.36	2

The study area is part of the most hyper arid region in the world. There is essentially no precipitation. As indicated in (table, 2) it can be concluded that the total rainfall and maximum rainfall in one day were very low (> 7 mm). The majority (95%) of El-Dakhla Oasis was characterized by sever of rainfall. El-Dakhla region is the driest on the earth's surface, where the incident solar radiation is capable of evaporating over 200 times the amount of precipitation.

Although wind erosion is considered as an important desertification process of soils in the arid and semi-arid lands of the Earth’s surface in addition to the adverse impacts of climate variability, little is known in Egypt about the nature and magnitude of this process and its effect on soil nutrient transport. As illustrated in (table, 2) it can be concluded that the wind speed and wind erosion were ranged between very low (38%) and very high (33%) sensitively to desertification process, only two little parts low (7%) and high (22%) sensitively to desertification process.

Consequently, (Table. 2) clearly shows that the albedo value of El-Dakhla strongly depends on the vegetation cover and type. In addition, the albedo of any surface type depends also on the soil depth. Analyses of MODIS 1 km albedo data indicate albedo dependence on vegetation type and soil depth of El-Dakhla Oasis. Surface albedo value is typically between 0.28-0.39. The majority of El-Dakhla Oasis has a very high albedo (65%), the high and low surface albedo value are 15% and 20% respectively. To illustrate this further, it is important to note that most of the Sahara desert and large parts of the North Africa have albedo values above 0.35, with two "hot spot" areas reaching above 0.5 and a minor one above 0.45. According to Charney's theory, this rather massive change in the net energy input to the surface should result in a weakening of the summer monsoon with a decrease in precipitation in the area.

Seven soil sub-indicator layers, related to water availability and erosion resistance, were considered (I.e. soil texture, electrical conductivity (EC), organic matter (OM), soil depth, SAR value, slope gradient, soil temperature and pH value) following the modification of MEDALUS model methodology. A score ranging from 1.0 to 2.0 have been assigned and desertification weighting was extracting (Table.3).

By analyzing of (Table.3) it can be concluded that the majority of El-Dakhla Oasis has low quality soils (59%) of the Oasis with respect to desertification risk followed by moderate quality soils (30.7%), Soils of high quality are greatly restricted (9.3%). The results of (ECe) were indicted that more than 60% of El-Dakhla Oasis which increasing the concentration of salts

Tab. 3 Classes and the corresponding weight assigned for the calculation of the soil quality index

Class	Description	Class Variable	Weight
Texture		**Texture Type**	
1	Moderate	SCL, S,	1.2
2	Severe	SL, S, SCL	1.5
3	Very Severe	S, SL	2
Organic Matter OM		**OM %**	
1	Good	2-3	1
2	Moderate	1-2	1.3
3	Severe	0.5-1	1.6
4	Very Severe	<1	2
Electrical Conductivity (EC)		**EC (mmhos/cm)**	
1	Moderate	8-16	1
2	Almost High	16-32	1.6
3	High	32-64	1.8
4	Very High	>64	2
Soil Depth		**Depth (cm)**	
1	Moderate	30-60	1
2	shallow	15-30	1.5
3	Very shallow	< 15	2
Soil Temperature		**Mean soil temp**	
1	Moderate	30-35	1
2	High	35-40	1.5
3	Very High	40-45	2
4	Severe	>45	
Soil Slope		**Slope %**	
1	Very gentle to flat	< 6	1
2	Gentle	6-18	1.2
3	Steep	18-35	1.8
4	Very Steep	> 35	2
Chloride (Cl)		**CL (mg/lit)**	
1	Very High	< 250	1
2	High	250–500	1.2
3	Moderate	500–1,500	1.4
4	Low	1,500–3,000	1.6
5	Very Low	> 3,000	2
Sodium Adsorption Ratio		**SAR**	
1	Low	< 10	1
2	Moderate	10–18	1.4
3	High	18–26	1.8
4	Very High	> 26	2
pH		pH	
1	High	6-7	1
2	Very High	7-8	1.5
3	Severe	< 8	2

on 16 ds/ m especially from El- Zayat in the east to Gharb El-Mawohoub in the west. However, 19% of El-Dakhla Oasis was moderate in salinity 4-16ds/m, and 21 % less than 4 ds/m.

The results of soil texture of (Table.3) were indicated that the most sensitive coarse textured soils (S, SL) dominate the El-Dakhla Oasis, covered

48.5%. It could be outlined that vicinity of El- Dakhla Oasis from the great sand sea, their vertical location as interior oases in the western desert, and wind erosion were important factors for the dominance of most sensitive soil textural classes. The moderate and severe texture was 31.5 % and 20 % respectively.

Furthermore, the results of the percent of organic matter shows that the majority of the El-Dakhla Oasis soil range between (0.3-0.8 %), it was indicated that El-Dakhla Oasis soil in very Severe category. The soil temperature is in generally high, especially during the summer months, the maximum and the minimum soil temperature about 48.4°C, 10.8°C respectively, while the highest temperature of the soil recorded was in June where amounted to 54.3 °C. However, the high percentage of moderate and low quality of soils is mainly attributed to the high soil temperature, the shallow depths favoring low rates of overland flow, wind erosion and restricting soil water storage capacity.

As illustrated in (fig.3), the pH analysis was show that 25% of the collected soil samples in El-Dakhla Oasis had pH values < 7. However, 43% of collected soil samples from El-Dakhla Oasis had pH values between 7 and 8. The highest subsoil pH value was 8.4 and it found in Mut. However the lowest value (6.3) was reported in at El-Bashandi village.

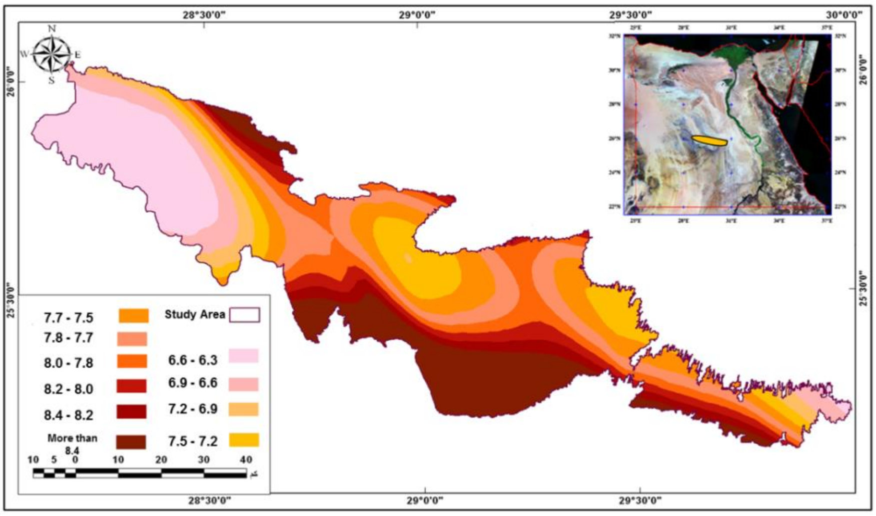


Fig.3 Distribution of mean (PH) value of the soil in El-Dakhla Oasis

The slope gradient in El-Dakhla Oasis mostly ranged between not very gentle to a very abrupt covered areas representing 37.3 to 18.9% of its terrain respectively. Also, mostly of E-Dakhla Oasis characterized either by a very shallow or very deep soil depth. The average rate of soil loss via wind erosion in

El-Dakhla Oasis has been estimated as 5.5 ton/ha/year, indicating that the rate of wind erosion is of moderate class, meanwhile the rate of deposition varied from 4.5 to 66.9 ton/ha/year. Data of the percentages of total hours of the active wind speed per year showed that their values varied between 9.4 and 29.0, indicating that wind erosion hazard in this area ranges between moderate and Severe. However, the calculated annual rate of wind erosion in El-Dakhla Oasis (NWC) using WEQ (Wind Erosion Equation) reached 100ton/ha (Hegazi et al, 2005).

El-Dakhla Oasis is dominated by longitudinal and linear dunes covering about 400 km^2. The source of the longitudinal mobile dunes is the Great Sand Sea in the Western Desert. Due to the fact that such area is almost rainless, flat in topography and has an increasing gradient in wind velocity, such dunes are active and migrate from the North and northeast to the South and southeast. These dunes seriously affect infrastructure and even engulf the villages and Palm grooves in the area.

Additionally, by analyzing of (Table.3), it can be concluded that although the majority of El-Dakhla Oasis is classified as threatened by desertification (62%), there is still a great part (38%), that is in a critical situation as it concerns desertification and land degradation processes. These critical areas exist somehow all over the Oasis and coincide with severely eroded soils.

Therefore, the climatic elements induce an evaporative demand of the atmosphere, but the actual evaporation resulting will be influenced by the nature of the evaporating surfaces, as well as the availability of water. On the other hand, the Sodium Adsorption Ratio (SAR) in El-Dakhla Oasis mostly ranges between high and very high, it was (18-26) and (> 26 meq/le). A maximum value of (83.30 meq/le) in the topsoil, it was found in Asment well (well No.6 A). However, the lowest soluble value Na was found in El-Rashda well (well No. 1 B) with value of (4.84 meq/le). The overall average of the soluble sodium of the collected topsoil samples was 69.00 meq/le.

In the soil samples, soluble chlorides reached a maximum value of (6,2030 mq/lit) in the topsoil at El-Mawhoub well (well No. 2 C). However, the lowest value was found at Balat/Bashandi well (well No. 30) with value of (245 meq/lit). The overall average of the soluble chlorides of the collected soil samples was (3,620 mq/lit). The highest soluble chloride value in the subsoil was 185.00 meq/le which was found at Gharb El-Mawhoub well (well No. 18).

However, the lowest value of (220 mq/lit) was found at Maasara well (well No. 1-4). The overall average of the soluble chlorides of the collected soil samples was (3041 mq/lit). El-Dakhla Oasis soil is classified in to low to very low in Chloride (Cl mg/lit), it indicates that it can be concluded that it mostly very sensitive areas to desertification

Tab. 4 Classes and the corresponding weight assigned for the calculate of the ground water index

Class	Description	Class Variable	Weight
Electrical Conductivity (EC)		**EC (µmohs/cm)**	
1	Moderate	< 250	1
2	High	250–750	1.5
3	Severe	750-1000	2
Chloride (Cl)		**CL (mg/lit)**	
1	Moderate	< 200	1
2	High	200-300	1.4
3	Severe	300-400	1.6
4	Very Severe	<400	2
Sodium Adsorption Ratio (SAR)		**SAR**	
1	Moderate	< 10	1
2	High	10–20	1.5
3	Very High	< 20	2
pH		pH	
1	High	6-7	1
2	Very High	7-8	1.5
3	Severe	< 8	2

As illustrated in (table, 4), the Electrical Conductivity (EC) analysis showed that 18% of shallow groundwater irrigated surface soils of El- Dakkhla Oasis has salinity range between of 0 to 4 dS/m, 42% have a range between 4 and 8 dS/m. However, 20 and 22% of the surface soil samples show a range between 8 and 16 and >16 dS/m, respectively.

The ECe values reached maximum value of 128.67 dS/m in the topsoil of Taneda. However the lowest ECe value was found in the topsoil irrigated with Gharb-El-Mawhoub drainage water, with an ECe value of 1.44 dS/m. The overall average of the soil salinity of the collected top-soil samples was 18.30 dS/m. The ECw of the shallow groundwater has higher values in Gharb-El-Mawhoub village, while the salt contents the water increased toward the east at El-Shekh Waly well (No.1 /2).

The pH analysis was show that 34% of the collected shallow groundwater samples in El-Dakhla Oasis have pH values < 7.3 (high class). However, 66% of collected groundwater samples from El-Dakhla Oasis have pH values between 7.3 and 9.50. The highest subsoil pH value was 9.50 and it found in Gharb El-Mawhoub (well No. 13-28). However the lowest value (5.90) was reported in at Asment (well No. 9). The overall average pH of the subsoil samples was 8.30. The shallow groundwater pH reached a high value of 8.70 in

Mut well (well No.4 A), while the lowest value of 6.07 was found in El-Shekh Saleh well (well No. Mut/21).

According to the results of Soluble Sodium analysis, it was concluded that Sodium (Na) in the shallow groundwater (SAR) has a high and very high class. It was 87.48 meq/l found in Gharb El-Mawhoub well (well No. 8 A). The lowest value of soluble sodium 7.20 meq/l was found at old and desert Bedakhlo well (well No. 1). The overall average of the soluble sodium of the collected water samples was 32.00 meq/l. The highest soluble sodium value in the subsoil samples was 257.47 meq/le, which was found in El-Mawhoub (well No. 2 C). However the lowest value (5.44 meq/le) was found in Bedakhlo (well No. 6). The overall average of the soluble sodium of the collected subsoil samples was 70.60 meq/le.

4. Discussion and conclusions

4.1. Discussion

Spatially and temporarily continuous climatic data are important for natural resource monitoring, agricultural management, environmental and desertification assessment (Daly et al. 1994, Holdaway 1996, Perry & Hollis 2005). However, climatic data are commonly measured at discrete points presenting a challenge to these applications, particularly in deserts (Daly et al. 1994, Brown & Comrie 2002, Frei et al. 2003). The present study is based not only on modifying MEDALUS model but also on raw climate data, satellite images analysis as well as field investigations on El-Dakhla Oasis. Field work was carried out from March 2012 and May 2013. All reference data were collected from Egyptian Meteorological authority and Agricultural Research Centre.

Desertification in El-Dakhla Oasis involves a complex set of factors, interacting in space and time leading to a decrease in land productivity. It is closely related to many environmental factors such as climate elements, soil, ground water cover, and morphology the character and intensity of which contribute to the evolution and characterization of different degradation levels. El-Dakhla Oasis has a high rate, and suffered from desertification hazard According to Aridity index of Mayer, De-Martonne and the FAO:

$$\text{Mayer Aridity Index} = \frac{R}{(M+m)(M-m)} \times 100$$

Where: R=Mean Annual Rainfall (mm) m M= Mean Temperature to the summer (C), M=Mean Temperature to the winter (C)

$$6.9 = \frac{0.04}{(30.1 + 18)(30.1 - 18)} \times 100$$

De Martonne $\text{Aridity Index} = \frac{R}{T+10}$

Where: R= Mean Annual Rainfall (mm), T= Mean Annual Temperature

$$(C)0.011 = \frac{0.04}{24.1+10}$$

On the other hand, for the purposes of the United Nations Convention to Combat Desertification (UNCCD), arid, semi-arid and dry climates were defined as “areas, other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.65 (UNCCD 1995). *UNCCD Aridity Index (AI)* is used as one of the base methods for determining dry land types in the study area and assessing their vulnerability to the desertification processes. Following the UNEP (1993), *AI* is written as: *Aridity Index (AI)* = (*P/ PE*). 0.7 = (2.5/3.56). Where, *P* and *PE* are annual precipitation (mm) and potential evapotranspiration (mm) totals, respectively. The *AI* values show that El-Dakhla Oasis strongly suffered from aridity.

For the preparation of the climatology indicator, El-Dakhla and El-Kharga meteorological stations have been used. All climate data used in this study is represented by original data, according to unpublished data from Egyptian Meteorological Authority to El-Dakhla from 1941 to 2012. Based on the results of current research, modified MEDALUS model has high efficiency for desertification mapping in El-Dakhla Oasis. The uneven interannual distribution of rainfall, the extreme temperature, wind erosion and the out of phase of rainy and vegetative seasons in El-Dakhla Oasis, are the main climatic attributes that leading to desertification.

Additionally, according to the FAO aridity index P/ETP (P = precipitation and ETP = potential evapotranspiration, calculated by Penman’s formula), the arid regions are classified to hyper-arid (P/ETP< 0.03) and arid (P/ETP = 0.03 – 0.20). These classes are, in turn, subdivided according to the mean temperature of the coldest month and that of the hottest month of the year. December is the most months of the year drop in the number of hours of sunshine with an average of approximately (9.3 hours / day) in the study area. Increase the number of sunshine hours gradually during the months of spring. In March there will be a slight increase resulting from exposure to the region of desert Oases and they happen under high pressure belt coupled atmosphere net.

The number of sunshine hours is increased in the month of May average range (6/10 to 6/11 hours / day) in the study area. This increase is due to a decline in the amount of drag and increase the length of the day. The rising rates of the number of hours the solar brightness in the summer months of July to record a substantial rise in the solar brightness be recorded (12.2 hours / day) in the study area. And shows a clear reduction in the monthly averages for the number of hours of sunshine during the months of autumn, The reason is due to the existence of a state of instability in the air and exposed the region to the vagaries of weather caused by exposure area of Oases air, where the recorded station outflows (10 hours / day in September, compared to 9.4 hours / day in December).

The study area is part of the most hyper arid region in the world. There is essentially no precipitation. Winds are predominantly from the north. The temperature ranges from 5 °C to 26 °C in winter and from 26 °C to 45 °C in summer. The study area is characterized by tropical arid climate. The maximum day time temperature fluctuates within a wide range, reaching up to 45–52 °C in summer months, meanwhile in winter, the minimum temperature may drop to as low as zero at night. It can be observed that annual, winter and summer temperatures over El-Dakhla Oasis increase gradually from east to west; additionally, the specific location of the station must be taken into account. The highest month in El-Dakhla is August, while January is the coldest month. The dry air enables rapid relative cooling during winter, when temperatures reach at El-Dakhla (13.8°C) and at El-Kharga (12.4 °C) (fig, 4).

Evidently, this is mainly attributed to the wide of temperature ranges from 5 °C to 26 °C in winter and from 26 °C to 45 °C in summer. The maximum day time temperature fluctuates within a wide range, reaching up to 45–52 °C in summer months, meanwhile in winter, the minimum temperature may drop to as low as zero at night. Furthermore, the low amount of precipitation occurs in the Oasis and the high aridity index. The desert climate type in El-Dakhla Oasis is distinguished by high mean annual temperature, El-Dakhla station (24.3 °C), El-kharga (23.6 °C), and by erratic annual rainfall, El-Dakhla (2.5 mm), El-Kharga (4.0 mm), and a very high mean annual temperature range, El-Dakhla (18.7 °C), El-Kharga (17.6 °C) recorded in spring.

In El-Dakhla Oasis, the summer temperatures are extremely hot, mean summer temperature is 31.2°C and 22.2 °C, 39.6°C to the minimum and maximum temperature respectively. Furthermore, the spring and autumn temperature are also extremely hot, maximum spring and autumn temperatures are 32.2 °C, 32.9 °C respectively. The mean of annual temperature ranges were computed at study stations. (Fig. 3) showing the highest ranges (e.g. minimum range of 13.6 °C in winter and 17.7 °C in spring, with southward the values of the mean annual temperature ranges rise to a maximum value of 15.5 °C at spring and 18.7 °C at the summer.

According to the record of the absolute temperature, it can be observed that May and June months had the record 48.2 °C at (29/5/1979) and 48.4 °C at (29/6/1995) respectively. On the other hand, it can be observed that January had the record -4°C at (7/1/1978) in El-Dakhla station. The soil temperature is in generally high, especially during the summer months, the maximum and the minimum soil temperature about 48.4°C, 10.8°C respectively, while the highest temperature of the soil recorded was in June where amounted to 54.3 °C.

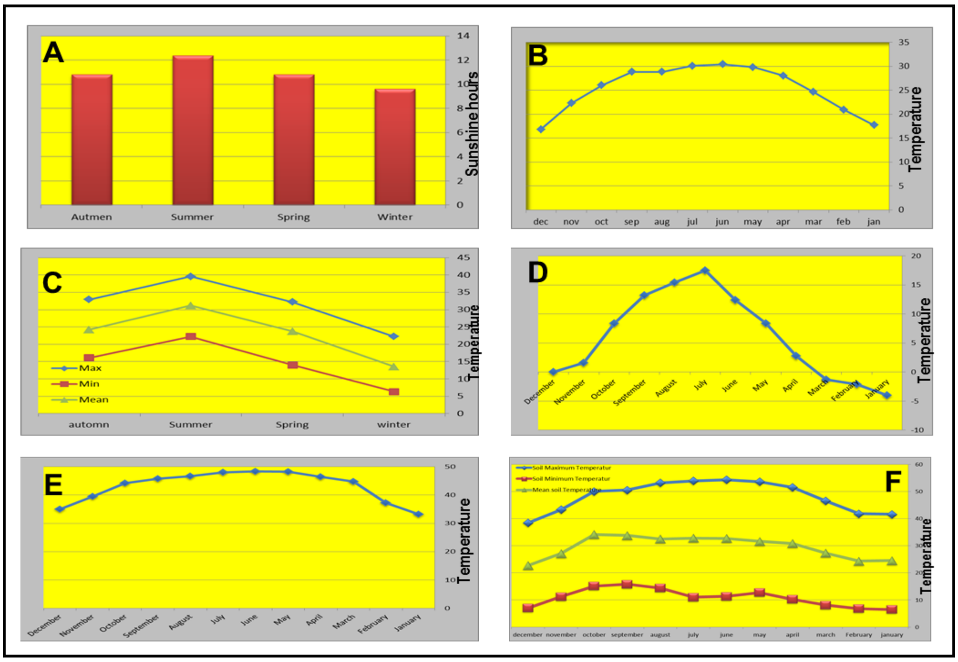
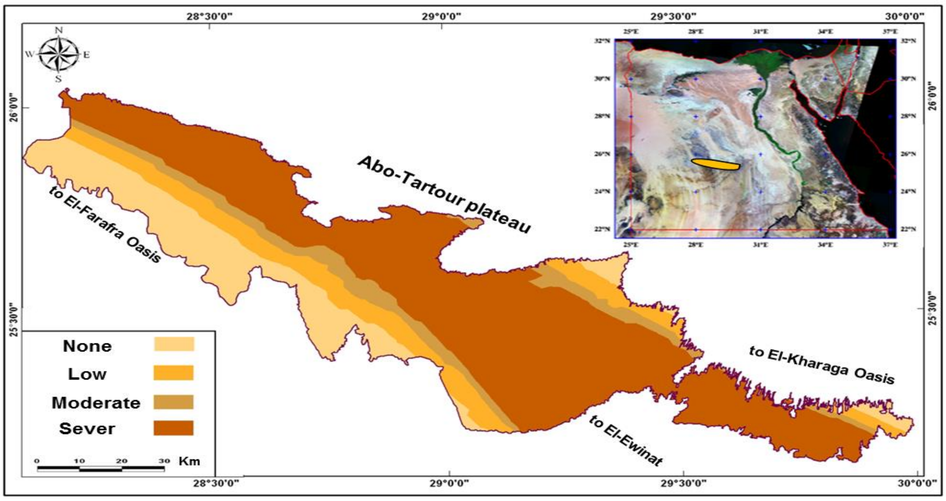


Fig.4. (A) seasonal amount of sunshine per hours (1941-2012) in El-Dakhla Oasis; (B) The mean annual temperature; (C) maximum, minimum and mean temperature; (D) Highest absolute temperature; (E) lowest absolute temperature; (F) soil Maximum, Minimum and mean temperature.

About 82 % of the annual precipitation total falls during winter. Annual precipitation totals under the desert climate type are generally less than 50 mm; it sometimes falls violent after thunderstorms. The rare and isolated rain showers are caused chiefly by incursions of unstable maritime polar air (mP) from the northwest or the occasional penetration of moist equatorial air from the south. The highest rate of relative humidity in El-Dakhla station about 42 mm reached in December, while the monthly average of humidity was about 29 mm, the lowest rate of relative humidity was 19 mm in May. The monthly mean in El-Kharga station about 31 mm, the higher value of 46 mm in December, and the lowest value of 21 mm in May and June. The annual rate of evaporation in El-Dakhla was about 16.4 mm, the highest rate of evaporation was 30.3 mm in September, and the lowest rate of evaporation was 7.7 mm in December and January. The annual evaporation rate was 16.3 mm, the highest 24.7 rate mm in June, and the lowest rate 7 0.8 mm in December and January in El-Kharga station.

Conclusions

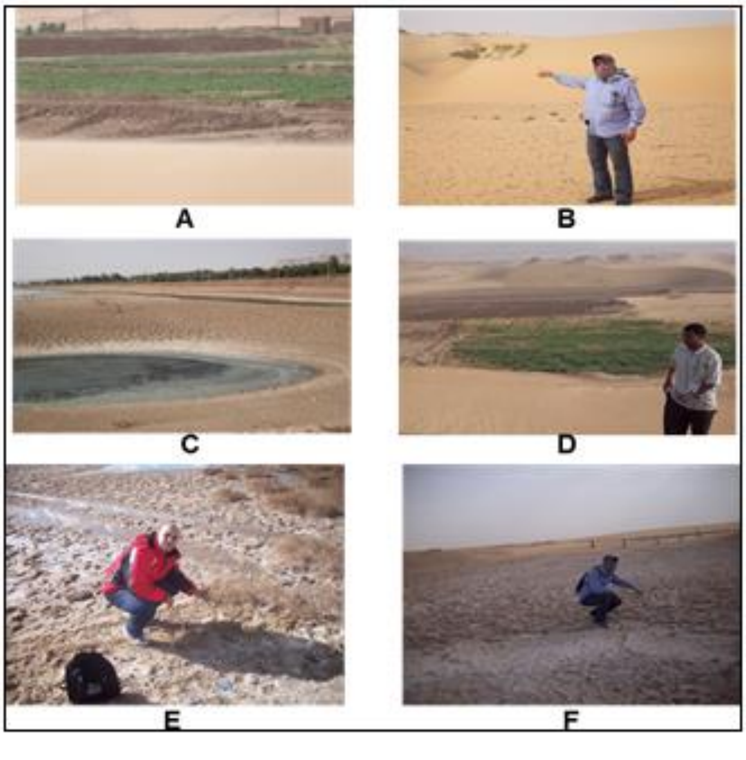
Based on the results of current research, modified MEDALUS method has high efficiency for desertification mapping in El-Dakhla Oasis, Western desert of Egypt. The important issue for using MEDALUS model, declared by European Commission staff, is to adjust its benchmarks and indicators for desertification evaluation based on the regional condition.



(Fig. 5) present status of desertification Severity classes in El-Dakhla Oasis

In this study, desertification parameters were collected in the study area using GIS. Six composite indices each comprising several sub-indicators was analyzed. Results showed that the climate elements are the most important indicators for describing desertification process in El-Dakhla Oasis. Based on the developed desertification map, almost 74% of study area was sensitive to and affected by desertification (critical). The results obtained showed that 60% of the area is classified as Severe, 14 % as moderate and 12%, 16% as low and none affected by desertification respectively (Fig. 5) and (Fig. 6).

Desertification is a serious threat to the ecological environment and social economy on the most promising and strategic region in Egypt. There is a pressing need to develop a reasonable and reproducible method to assess it at different scales. The modification of MEDALUS method, to evaluate the desertification with local conditions, tacked into account, that the desertification process has not the same weight over the general deterioration of El-Dakhla Oasis. The final results of the current research, which presents the status of desertification severity classes in El-Dakhla Oasis; gives the real desertification status, it will help decision makers to develop the best strategies for rehabilitation works and fight against desertification in El-Dakhla Oasis (Fig. 5).



(Fig.6) Typical photographs of El-Dakhla Oasis showing an examples of desertification status, (A, B, D) encroachment of sand dunes upon cultivated field,(C) accumulation of salts by evaporation of water from a drainage pool, (E) soil salinity in winter, and (F) soil salinity in summer.

The climatic conditions are aggressive by rarely rain, at the same time, the high temperatures and the long drought sequences are also harmful for soils and vegetation for lack of moisture and excessive evapotranspiration. Hot and dry local winds (Khamasen) worsen more the situation in all seasons and especially in summer and spring. In addition, the dominant winds remain very active, in the absence of sufficient orographic or vegetation obstacles. By taking the contemporary desertification and vulnerability definitions and concepts into account (UNCCD, 1995 and UNEP, 1993), it should be recognized that El-Dakla Oasis characterized entirely with hyper-arid climatic conditions, is vulnerable to adverse effects of the desertification processes. It should be also expected that these influences will be stronger in a warmer and drier Egypt in the future.

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