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POTENTIAL OF SOLAR POND AS SOURCE OF THERMAL ENERGY TO SUSTAIN THE DEVELOPMENT IN MENA REGION

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ABSTRACT

In terms of the importance of solar radiation sustainability in middle east and north Africa (MENA) Region, this research was initiated with the objective of mapping solar ponds to provide solar energy by Geographic Information Systems (GIS) and multi-criteria decision-making method to ensure their efficiency, in terms of cost. Primarily, literature in the field of solar ponds and clean energy was assembled, reviewed, analyzed and categorized to deduce data about solar pond locations and analyze. Accordingly, different variables were considered such as road networks and different countries. In addition, land cover as environmental parameter was considered. Furthermore, technical variables like direct normal radiation, temperature, wind, and relative humidity were taken into consideration using control points covered this area where a number of control points reach 65500 points each point calculated the mean wind, temperature, relative humidity, and direct normal radiation from thirty years. ArcGIS process was applied to solar pond technique locations were selected. The deduced data were comprehended, analyzed, and presented to perceive a complete data picture about MENA Region, from which it was apparent that different zones have different characteristics, in terms of the capability of encompassing solar ponds. Based on the investigation results, it was concluded that Morocco, Algeria, Libya, Egypt, Sudan, Syria, Iraq, Saudi Arabia, United Arab Emeritus, Oman, and Yamen show in map satisfies the renewable energy potential. In addition, it was recommended to implement solar ponds in their vicinity, as they satisfy the solar pond requirements, in terms of renewable energy efficiency and cost.

KEYWORDS: Solar Pond, Solar Energy, Geographic Information System, GIS, MENA Region.

1. INTRODUCTION

In 1900, 10 million barrels of oil was consumed worldwide. It is expected to increase to 400 million barrels by 2030. This means that in the future, more energy will be consumed worldwide. Consequently, more pollution is anticipated to discharge into the atmosphere. Accordingly, the world decided to go for clean energy [1].

Solar energy is a clean energy with no emissions during generation. This energy implements advanced technology to transform it to electrical energy by photovoltaic panels, solar pond or direct heating. Solar pond is a recent technique that emerged worldwide to provide clean energy. Accordingly, this investigation was commenced with the impartial of mapping solar ponds by GIS and multi-criteria decision-making method to ensure their efficiency, in terms of cost [2,3].

Literature in the field of solar ponds were accumulated and revised. Data sets regarding ponds were reviewed and processed. The data sets encompassed solar direct normal radiation, temperature, wind speed and relative humidity.

Based on the assembled literature, some investigators stated that the world faces an enormous problem in energy. Others advocated that surplus emissions lead to international agreements to mitigate pollution risks of toxic gases. In addition, the literature documented that MENA Region, as a Sunbelt country, unquestionably ratified the Kyoto Protocol in 2009 [5].

From the literature, it was clear that many researchers investigated solar ponds. among them the following examples.

- documented that many MENA Region became a member to the United Nations Framework Convention on Climate Change [6].
- provided the solar direct normal radiation map of MENA Region, as it is on the sunbelt [7], figure (1).

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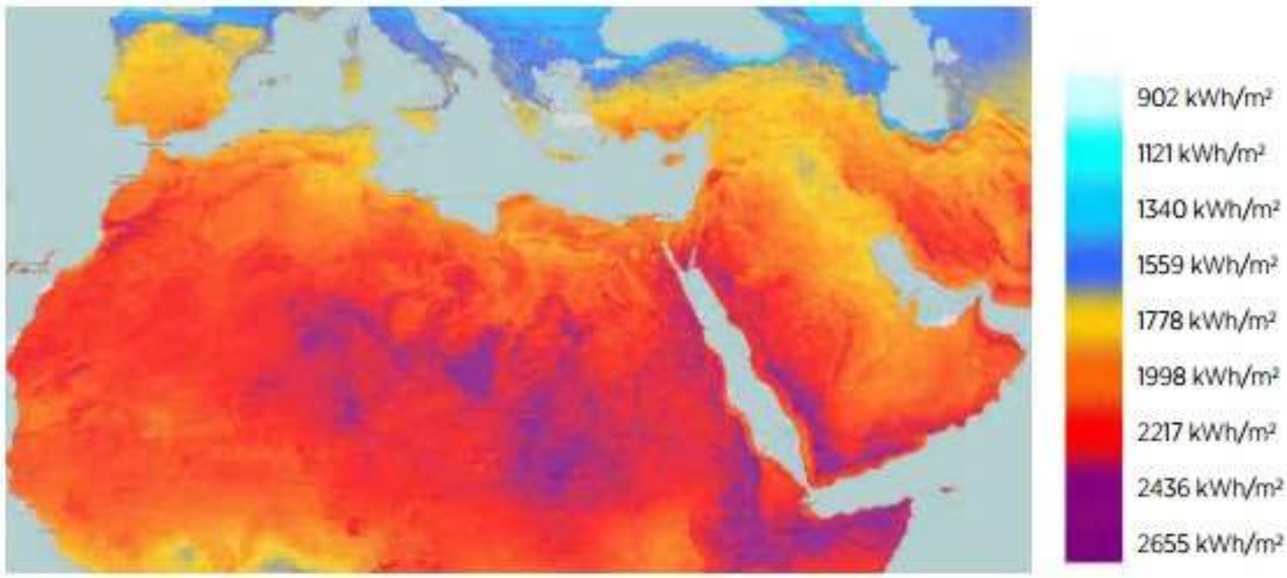

Figure 1: Sunbelt of MENA Region [1]

The main objective of this research is mapping the best locations of solar ponds technique in MENA Region to provide solar energy by using Geographic Information Systems (GIS) and multi-criteria decision-making method as economics source of energy.

2. MATERIAL AND METHODS

2.1. DATA ASSEMBLY

Data was obtained from the literature. These data are presented here, as follows:

- Meteorological radiation data from NASA [8]
- Solar atlas maps for MENA Region [9]

2.2. DATA PROCESSING

The assembled data were processed, as follows:

2.2.1. RASTER DATASET

During that processing stage, the following was accomplished:

- The meteorological data (wind, temperature, relative humidity and Direct Normal Radiation) was collected each half degree in vertical and horizontal direction from NASA for MENA Region in control points where the number of control points covered this area 65500 points each point calculated the mean wind, temperature, relative humidity and direct normal radiation from thirty years [8], Figure (2).

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- Based on thirty years recorded data form NASA [8], spatial analysis was applied to forecast a map for each meteorological parameter.
- A solar radiation map was created by ArcGIS 10.8, A view-shed analysis was executed and table of irradiance, in each sky direction was obtained.
- A geometric solar radiation model (Solar Analyst) was implemented to calculate insolation maps from digital elevation models (DEM) by ArcGIS (10.8).
- The direct normal radiation (KW-hr/m2/day) was created, for each month.

2.2.2. VECTOR DATASET

During that processing stage, the following was achieved:

- ArcGIS converted a solar radiation map from raster dataset to vector dataset, its original resolution and without generalization.
- Appling the vector Geo-processing to create best locations maps for meteorological parameter. It is aesthetically pleasing rather than traditional cartographic representation. It is allowing efficient encoding of solar radiation.

Figure 2: Data locations in MENA Region

2.3. APPLYING GEOGRAPHIC INFORMATION SYSTEM

In order to mapping solar ponds, geographic information system, and its analysis tools were implemented to prepare map layers with their criteria and weightings of their sub-criteria by:

- Reviewing the previous literature
- Preparing the database of digital maps within GIS software
- Creating suitable buffer zones or special constraints to suit each criterion map
- Transforming Raster maps to Vector maps
- Determining the weightings of the criteria from the final maps
- Determining land suitability index
- Reclassifying the obtained maps
- Applying parameters constraints to mapping the suitable location for solar ponds

The incorporated technical criteria in the GIS are important, as they determine the potential energy production of the solar ponds. These criteria are as follows:

2.3.1. SOLAR RADIATION (kW-hr/m2/day)

Direct Normal Radiation (DNR) data was obtained from NASA [6]. It is the amount of solar radiation per unit surface area normal to the straight rays from the sun in grid points shown in Figure (2). The ArcGIS software analyzed and modeled specific areas or points in a specific time to model solar radiation. It considered local factors to generate the minimum, maximum, range, mean, standard deviation, coefficient of variation, skewness and kurtosis. These are indicators of the central tendency. Distribution maps of the parameter were produced by ArcGIS (10.8) and area of solar energy distributions was obtained for MENA Region, Figure (3) and Figure (4).

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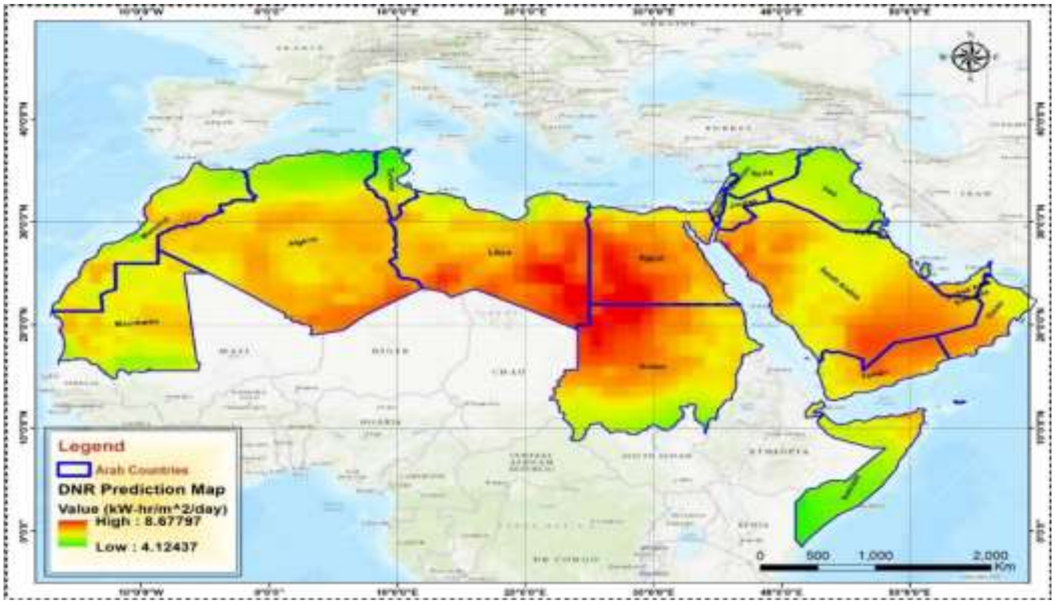

Figure 3: Direct normal radiation raster map in MENA Region

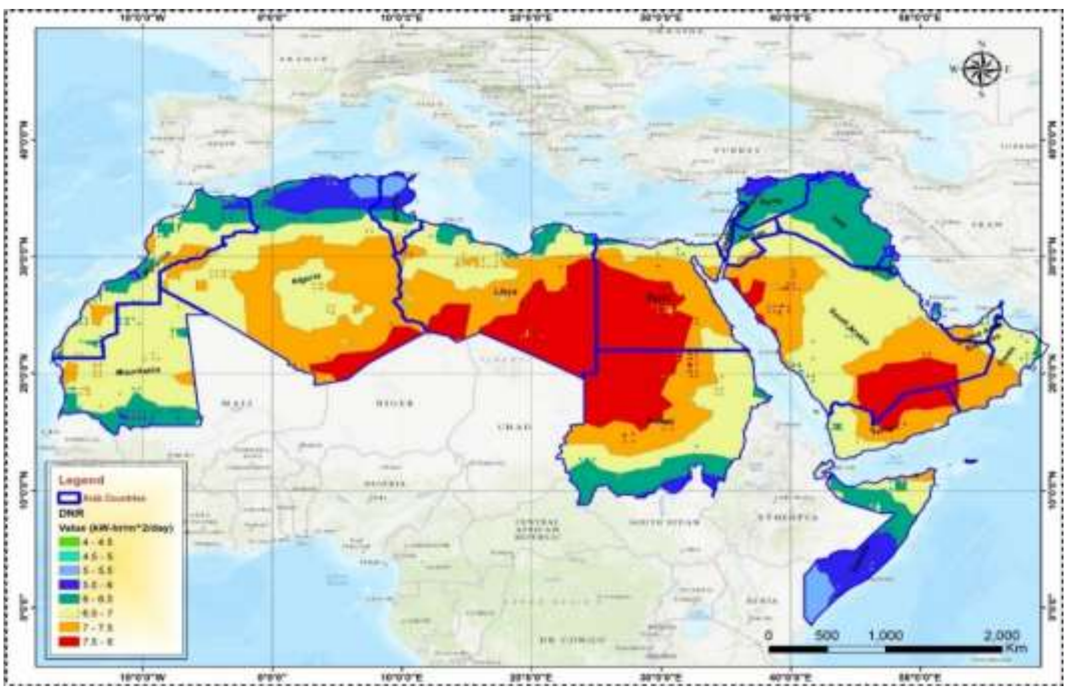

Figure 4: Direct normal radiation vector map in MENA Region

2.3.2. WIND SPEED (m/s)

Monthly average wind speed at 10 meters above Earth surface for 30-years period (January 1984 to December 2013) was obtained from NASA [6] for MENA Region.

A spatial analyst tool of ArcGIS was implemented to support database wind-speed mapping, analyze and model specific areas or points in a specific time. This tool succeeded to model wind energy. Distribution maps of the parameter were produced by ArcGIS (10.8) and area of wind energy distributions was created for MENA Region, Figure (5) and Figure (6).

2.3.3. TEMPERATURE (C)

Data was obtained from NASA MENA Region. They are monthly average temperature at 2 meters above Earth surface, averaged over 30-years period (January 1984 to December 2013) [6]. The software ArcGIS supports database temperature distribution mapping, analyzing, and modeling specific areas or points in a specific time to signpost the area of temperature distribution in MENA Region; Figure (7) and Figure (8).

2.3.d. RELATIVE HUMIDITY (%)

Data was obtained from NASA MENA Region. It encompassed the ratio of actual partial pressure of water vapor to the partial pressure at saturation in percent. The monthly average of relative humidity at 2 meters above Earth surface, averaged over 30-years period (January 1984 to December 2013) [6]. ArcGIS was implemented to designate the area of relative humidity percentage distribution in MENA Region; Figure (9) and Figure (10).

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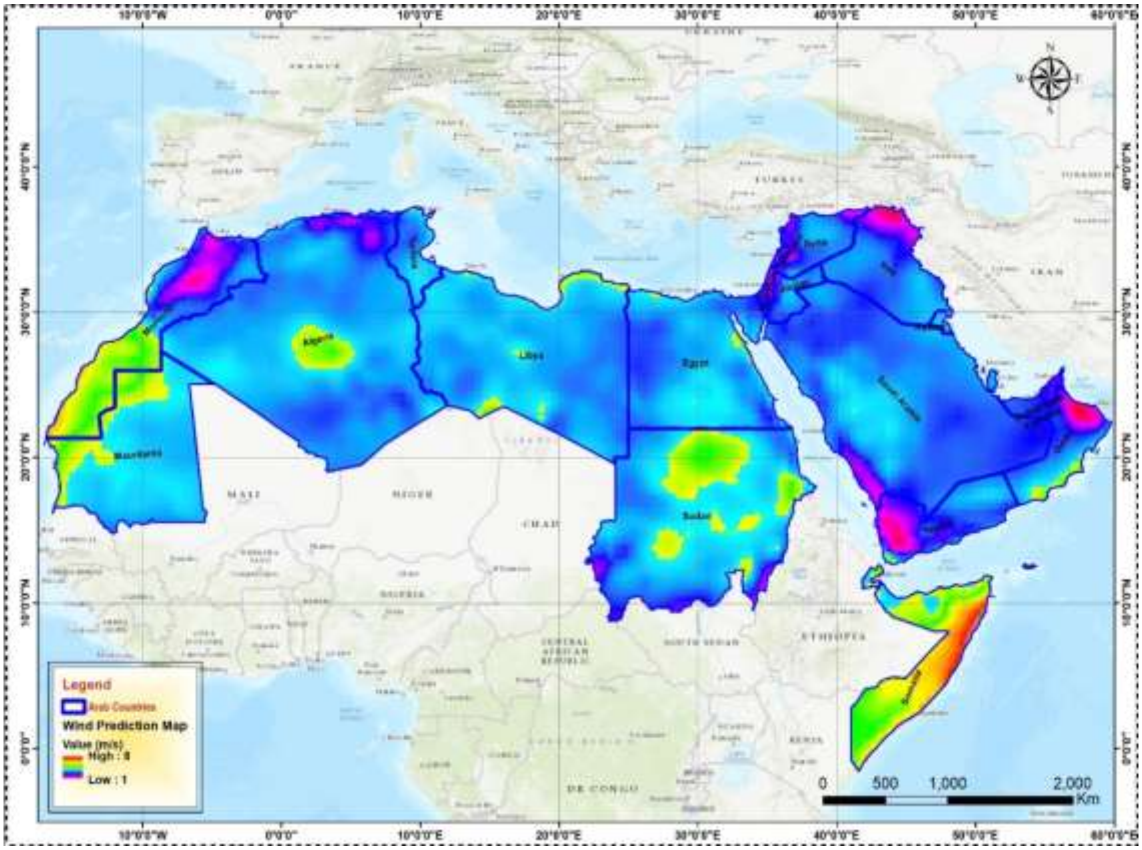

Figure 5: Wind speed raster map in MENA Region

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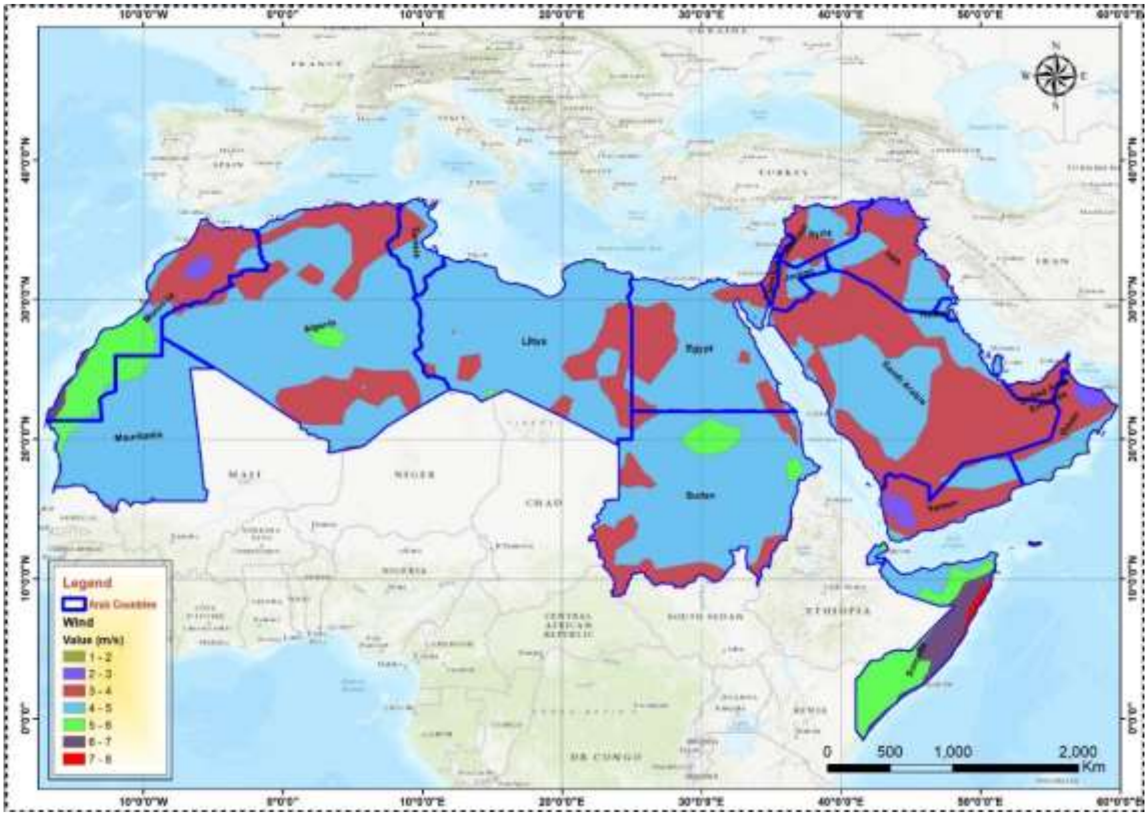

Figure 6: Wind speed vector map in MENA Region

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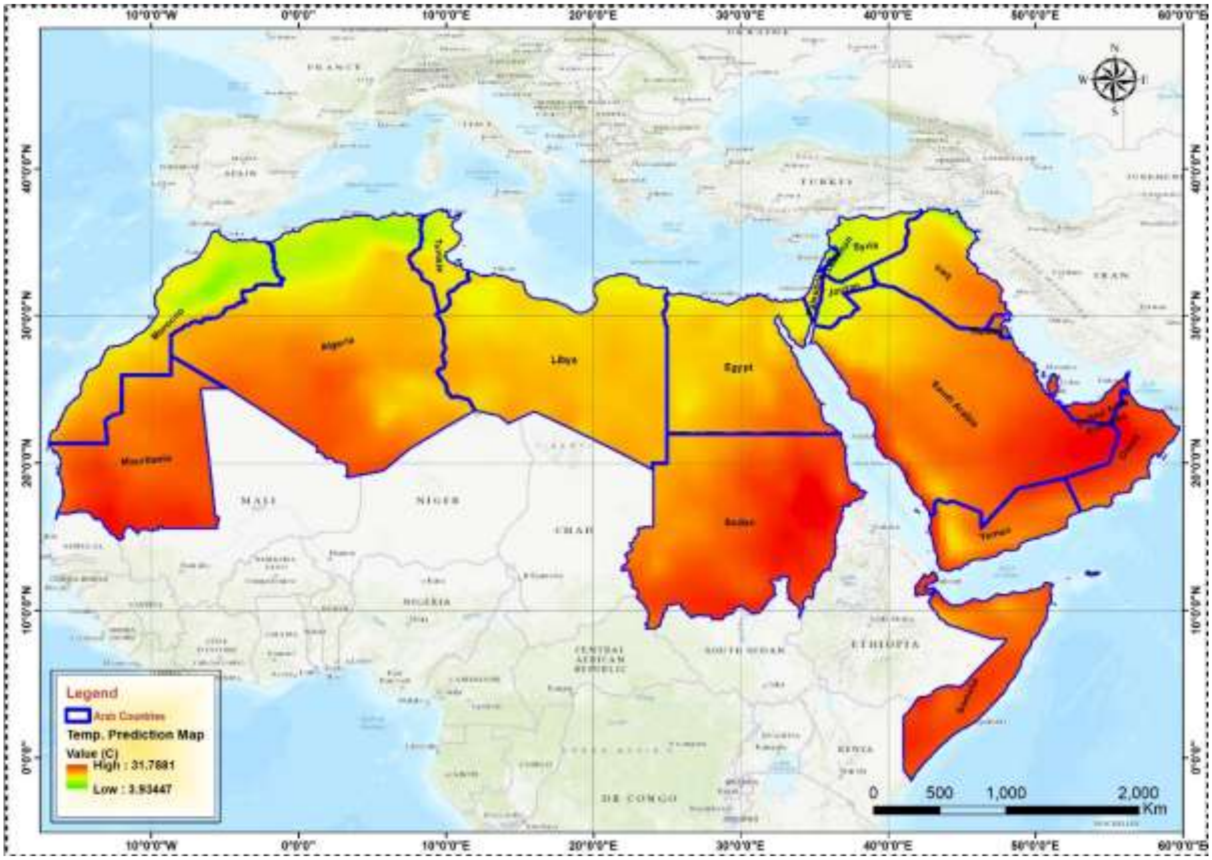

Figure 7: Temperature distribution raster map in MENA Region

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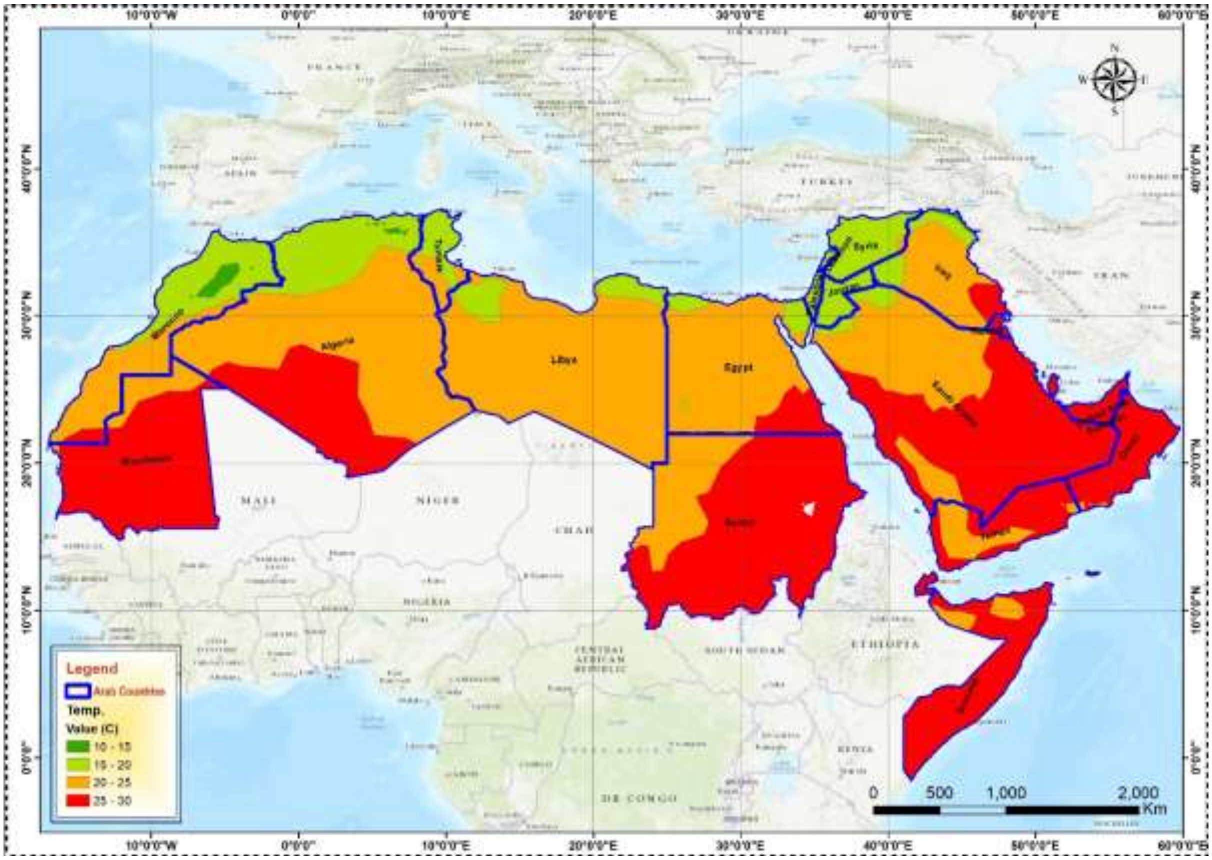

Figure 8: Temperature distribution vector map in MENA Region

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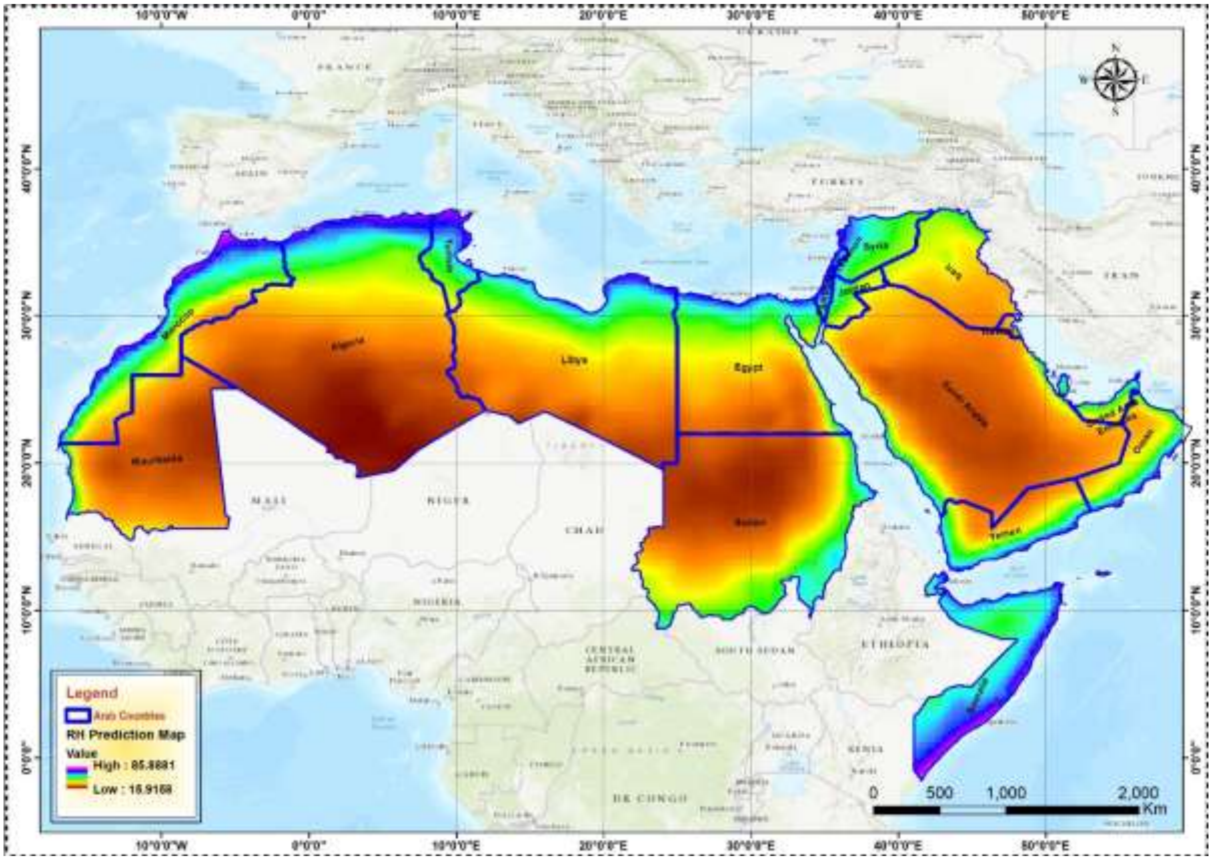

Figure 9: Relative Humidity raster map in MENA Region

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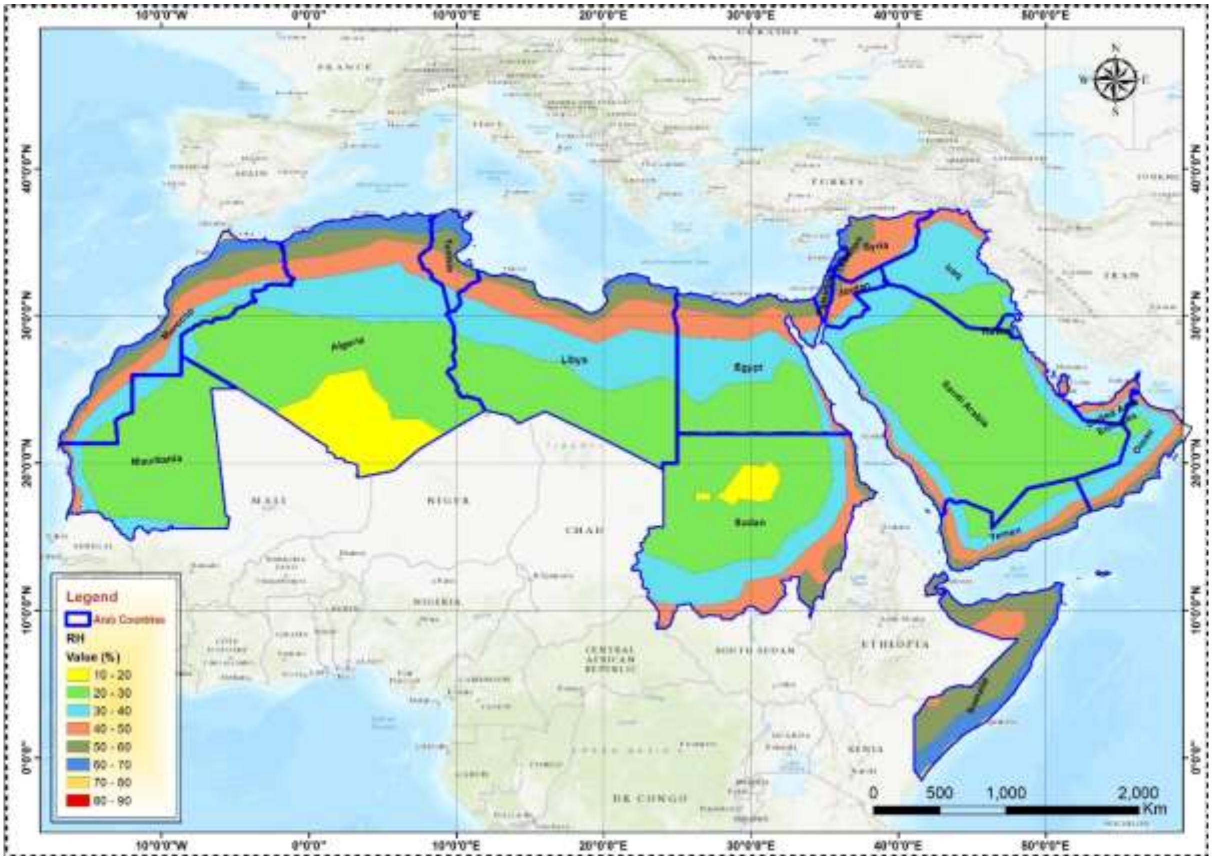

Figure 10: Relative Humidity vector map in MENA Region

2.4. CRITERIA LIMITS AND CONSTRAINS

Constrains for each criterion were obtained from the literature, as follows:

- Surveys were carried out for some international places executed and successful examples of implemented solar ponds [1,10], Table (1).
- The impact of factors was calculated and compared to MENA Region records of climate conditions, Table (2).
- By using the average value for each element from the executed and successful examples of implemented solar ponds shown in Table (1). The best locations were reclassified and obtained according to the regions of solar ponds worldwide, Table (2).

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Table 1: Some executed and successful examples of implemented solar ponds

Latitude	Longitude	Location	DNR (kW-hr/m²/day)	Temp. (C)	Wind (m/s)	Relative humidity %
31.19761	35.36251	Ein Bokek, Israel	6.01	19.81	3.1	52.8
31.80831	35.47901	Beith Ha'rava, Israel	6.01	19.94	3.11	56.53
31.77171	-106.503	University of Texas (El Paso), US	6.55	17.15	3.86	38.06
-17.0998	145.8001	Pyramid Salt Ltd, Australia	5.83	22.06	2.93	81.26
41.38591	16.08571	Margherita Di Savoia, Italy	4.95	16.05	4.16	69.63

Table 2: MENA Region classification with limit factors affecting the choice of solar ponds

DNR (kW-hr/m²/day)		Temp. (C)		Wind (m/s)		Relative humidity %	
1	5.5-6	1	18-19	1	3.5-3.75	1	20-25
2	6-6.5	2	19-20	2	3.75-4	2	25-30
3	6.5-7	3	20-21	3	4-4.25	3	30-35
4	7-7.5	4	21-22	4	4.25-4.5	4	35-40
5	7.5-8	5	22-23	5	4.5-4.75	5	40-45
6	8-8.5	6	23-24	6	4.75-5	6	45-50
ACCEPT > 6.0		7	24-25	7	5-5.25	7	50-55
		8	25-26	8	5.25-5.5	8	55-60
		9	26-27	ACCEPT<4		9	60-65
		ACCEPT > 20				ACCEPT< 55	

3. RESULTS DISCUSSION AND ANALYSIS

The output results from the GIS technique for solar energy sites were assessed by evaluating the technical, economic, and environmental standards. These were converted to spatial maps according to the accepted values mention in Table (2), as represented in figures (11) to (14).

The suitable locations for the solar pond in MENA Region were created by identifying and clipping the areas that apply to the limits of all factors that affecting the choice of the solar pond as represented in figures (15), it will be the best locations for applying the solar bond technique.

The results of the analysis of the maps of the factors that affecting solar pond shown that the Direct normal radiation (DNR) is the main criterion affecting the locations of solar pond.

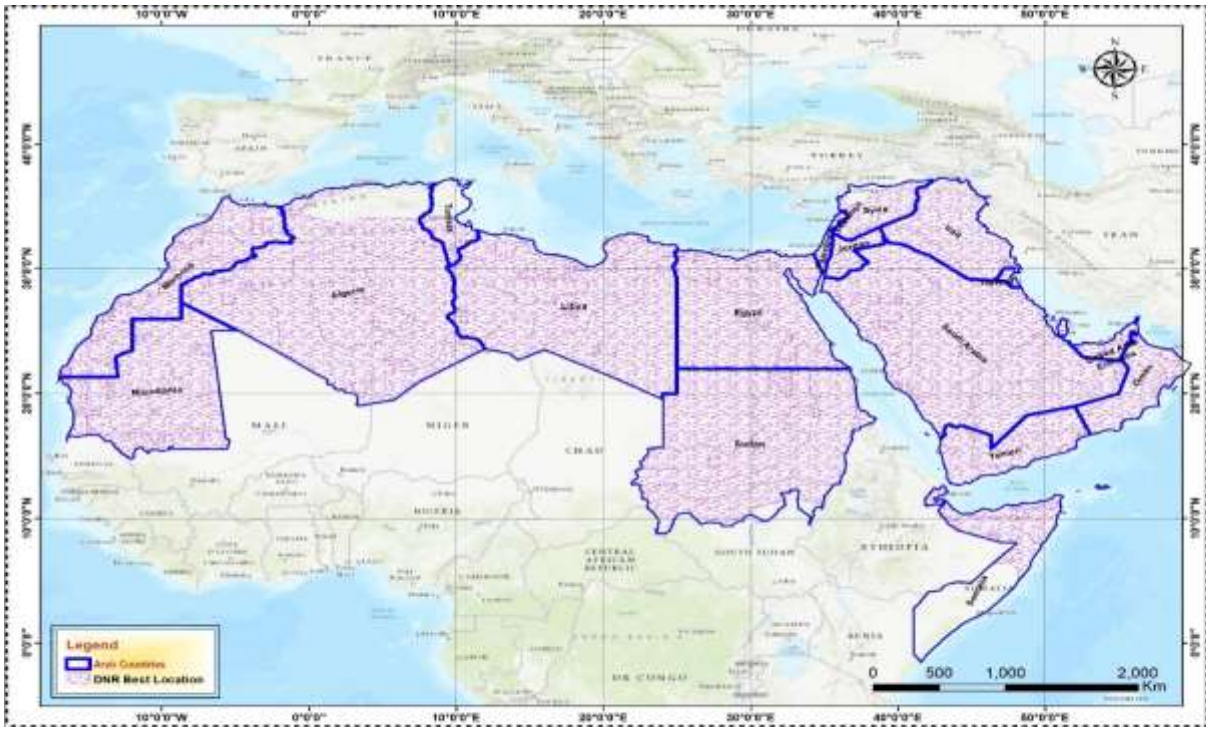

Figure 11: Solar ponds in terms of DNR criterion

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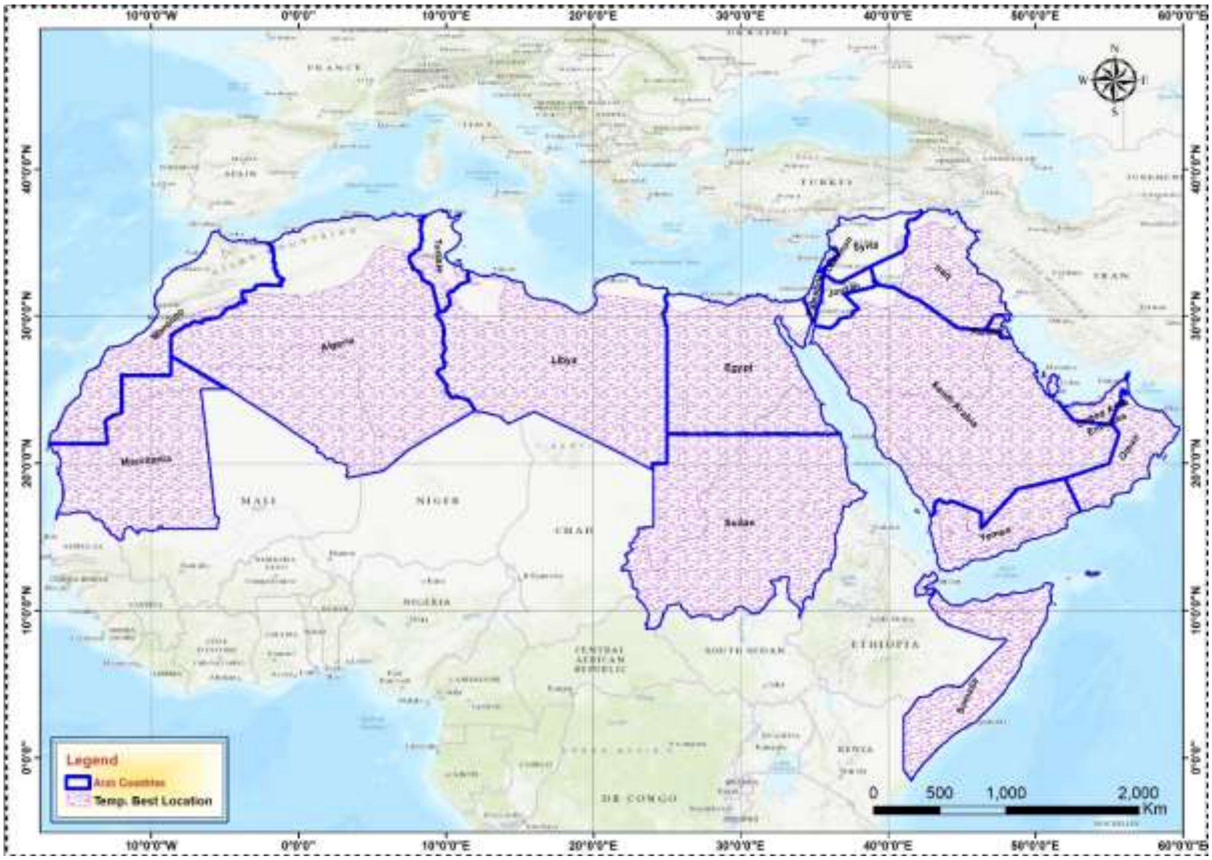

Figure 12: Solar ponds in terms of temperature criterion

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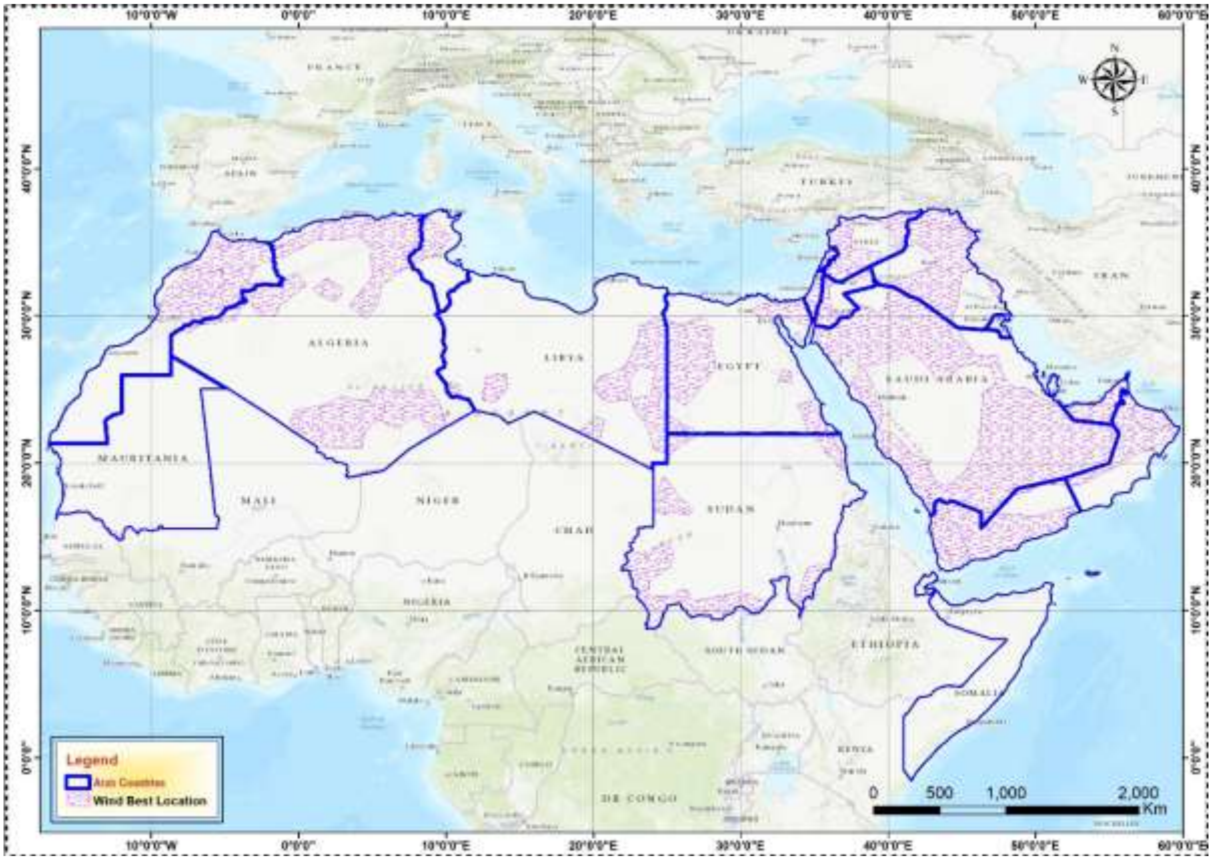

Figure 13: Solar ponds in terms of wind criterion

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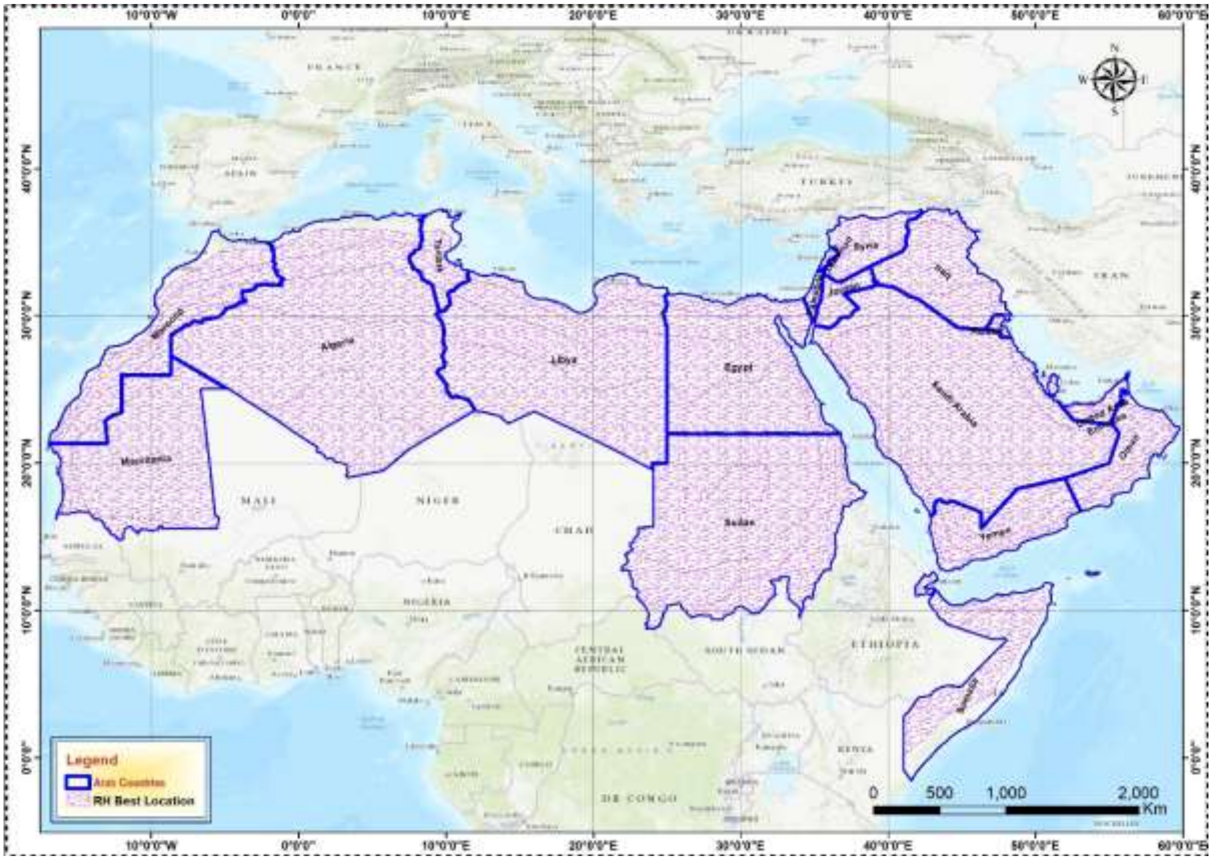

Figure 14: Solar ponds in terms of relative humidity criterion

4. APPLYING GIS-AHP MODEL

Analytic Hierarchy Process (AHP) was implemented. The resultant map of each criterion and factor were reclassified by GIS-AHP and the raster map for the suitable location of solar pond in MENA Region was obtained. Accordingly, Morocco, Algeria, Libya, Egypt, Sudan, Syria, Iraq, Saudi Arabia, United Arab Emeritus, Oman, and Yamen were recommended to be the suitable locations in MENA Region as shown in figures (15).

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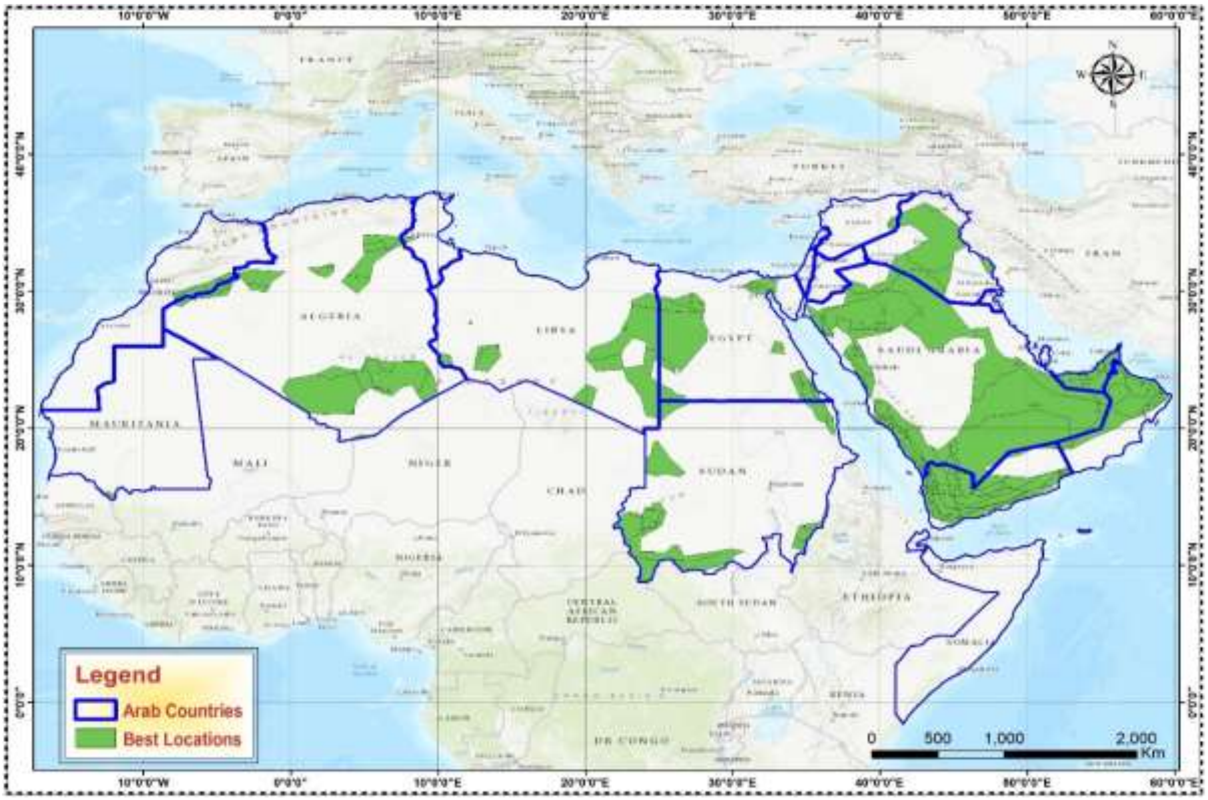

Figure 15: Suitable locations for solar pond

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the obtained results, the following conclusions were deduced:

- GIS is a successful tool to produce solar radiation, temperature, wind and relative humidity maps.
- The areas that have potential for solar ponds in MENA Region are Morocco, Algeria, Libya, Egypt, Sudan, Syria, Iraq, Saudi Arabia, United Arab Emeritus, Oman, and Yamen.
- Serious work is to be done to reduce the dependency on non-renewable energy like solar pond.
- It is necessary to meet the increasing energy demand by using the new technology.
- Solar Pond is a cheap and environment friendly technology.
- Solar pond technique can be applied in power generation, industrial heating processes and desalination.

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Mohamed Embaby has a Ph.D. In the field of GIS, RS and water resources management. He is the head of the central GIS unit and researcher at the National Water Research Center, Egypt, as well as a part time staff & lecturer of GIS/Remote Sensing Applications, Geomatics and Hydro informatics in the Heliopolis University (HU) and British University in Egypt (BUE). He has 17 years of experience in the field of Civil Engineering, integrated water resources management and water quality using remote sensing and GIS applications. Also, I work as a GIS and remote sensing consultant for a number of foreign funded research projects, in addition to local programs in the field of water quality monitoring, modelling and assessment, GIS, remote sensing and e-learning. I have a wide experience in developing specialized training programs in the field of Geomatics, Hydro-informatics and land surveying.

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