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Estimation the best areas of Sun duration hours in Iraq by applying IDW type of interpolation techniques by using GIS program

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Abstract

In this paper solar radiation was studied over the Iraqi countary land. The best sun duration hours regions (maximum hours) in Iraq were estimated detected by using Geographic information system (GIS Ver. 9.2) program to apply the (Inverse distance weighting) IDW exact interpolation technique depending on the measured data of metrological stations were distributed on the land areas of Iraq. The total area of the best regions was calculated .Excel 2007 program is used in calculation, graphics and comparison the results.

Keywords: solar radiation, sun duration hours, IDW interpolation.

تقدير أفضل المناطق في مدة ساعات سطوع الشمس في العراق عن طريق تطبيق نوع تقنيات الاستيفاء IDW باستخدام برنامج نظم المعلومات الجغرافية

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الخلاصة

في هذه الورقة تمت دراسة الإشعاع الشمسي الساقط على أرض بلد العراق. وقد تم تخمين والكشف عن أفضل المناطق سطوعا (أعلى عدد ساعات) في العراق باستخدام برنامج نظم المعلومات الجغرافية (GIS الإصدار 9.2) بتطبيق تقنية IDW تقنية الاستيفاء المحدد اعتمادا على البيانات المقاسة من محطات الانواء الجوية الموزعة على مناطق عديدة من أرض العراق . تم حساب مجموع أفضل تلك المناطق .تم استخدام برنامج Excel 2007 في الحسابات ، والرسومات ومقارنة النتائج.

Introduction

The sun is 93 million miles away from Earth and yet, this ball of hot gases is the primary source of all energy on earth. In the high temperature of the sun, small atoms of hydrogen are fused, that is, the centers of the two atoms are combined. Fusion releases far greater energy than splitting the atom [1].

Everything in nature emits electromagnetic energy, and solar radiation is energy (electromagnetic radiation) emitted by the sun. The energy of extraterrestrial solar radiation is distributed over a wide continuous spectrum ranging from ultraviolet to infrared rays. In this spectrum, solar radiation in short wavelengths (0.29 to 3.0 µm) accounts for about 97 percent of the total energy [2]. Figure- 1 shows the spectrum distribution of solar radiation.

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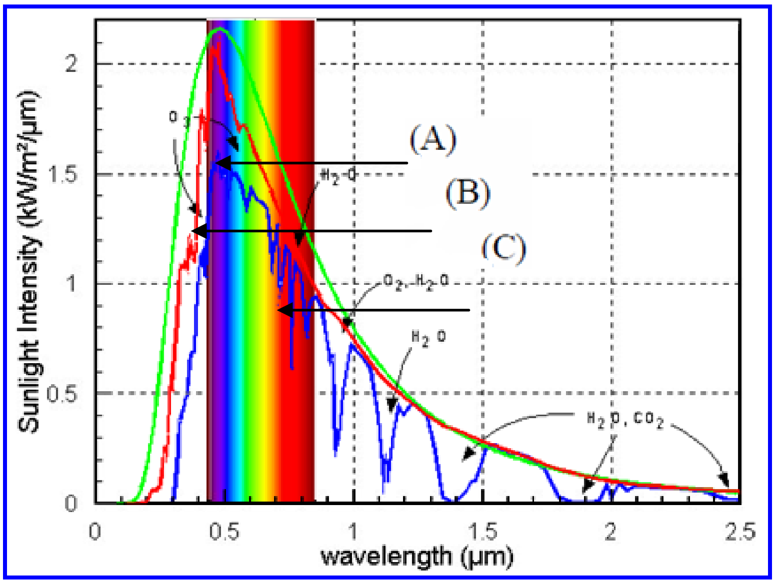

Figure1- Spectrum distribution of solar radiation **(A)** Extraterrestrial solar radiation**,(B)** Direct solar radiation on the earth's surface, **(C)** Blackbody radiation at 5,900 K,(Shaded areas indicate absorption by the atmosphere) [2].

Atmospheric effects on solar radiation

Atmospheric effects have several impacts on the solar radiation at the Earth's surface, see Figure -2. The major Atmospheric effects for photovoltaic applications are:

- A reduction in the power of the solar radiation due to absorption, scattering and reflection in the atmosphere;
- A change in the spectral content of the solar radiation due to greater absorption or scattering of some wavelengths;
- The introduction of a diffuse or indirect component into the solar radiation; and
- Local variations in the atmosphere (such as water vapor, clouds and pollution) which have additional effects on the incident power, spectrum and directionality. These effects are summarized in the figure below.

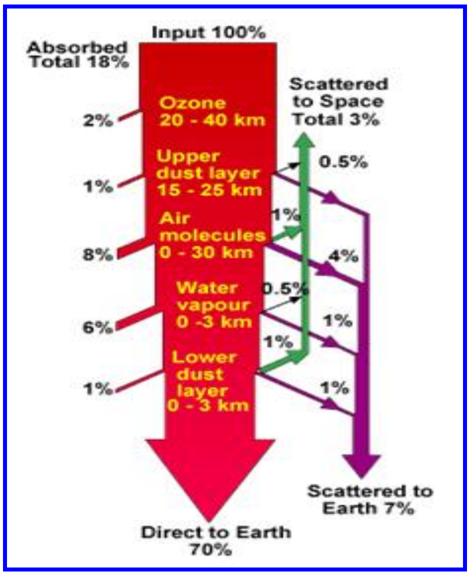

Figure 2- Show atmospheric effects on solar radiation ,typical clear sky absorption and scattering of incident sunlight [3].

Absorption in the Atmosphere

As solar radiation passes through the atmosphere, gasses, dust and aerosols absorb the incident photons. Specific gasses, notably ozone (O_3), carbon dioxide (CO_2), and water vapor (H_2O), have very high absorption of photons that have energies close to the bond energies of these atmospheric gases. This absorption yields deep troughs in the spectral radiation curve. For example, much of the far infrared light above 2 µm is absorbed by water vapor and carbon dioxide. Similarly, most of the ultraviolet light below 0.3 µm is absorbed by ozone (but not enough to completely prevent sunburn) [4].

While the absorption by specific gasses in the atmosphere changes the spectral content of the terrestrial solar radiation, they have a relatively minor impact on the overall power. Instead, the major factor reducing the power from solar radiation is the absorption and scattering of light due to air molecules and dust. This absorption process does not produce the deep troughs in the spectral irradiance, but rather causes a power reduction dependent on the path length through the atmosphere. When the sun is overhead, the absorption due to these atmospheric elements causes a relatively uniform reduction across the visible spectrum, so the incident light appears white. However, for longer path lengths, higher energy (lower wavelength) light is more effectively absorbed and scattered. Hence in the morning and evening the sun appears much redder and has a lower intensity than in the middle of the day. The human eye has evolved to the point where sensitivity is greatest at the most intense wavelengths [4].

Direct and Diffuse Radiation Due to Scattering of Incident Light

Light is absorbed as it passes through the atmosphere and at the same time it is subject to scattering. One of the mechanisms for light scattering in the atmosphere is known as Rayleigh scattering which is caused by molecules in the atmosphere. Rayleigh scattering is particularly effective for short wavelength light (that is blue light) since it has a λ^{-4} dependence. In addition to Rayleigh scattering, aerosols and dust particles contribute to the scattering of incident light known as Mie scattering[5].

Scattered light is undirected, and so it appears to be coming from any region of the sky. This light is called "diffuse" light. Since diffuse light is primarily "blue" light, the light that comes from regions of the sky other than where the sun is, appears blue. In the absence of scattering in the atmosphere, the sky would appear black, and the sun would appear as a disk light source. On a clear day, about 10% of the total incident solar radiation is diffuse [5].

Effect of Clouds and Other Local Variations in the atmosphere

The final effect of the atmosphere on incident solar radiation is due to local variations in the atmosphere. Depending on the type of cloud cover, the incident power is severely reduced. An example of heavy cloud cover is shown below, see Figure -3.

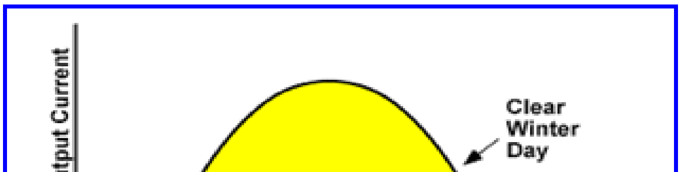

Figure 3 - Show relative output current from a photovoltaic array on a sunny and a cloudy winter's day [5].

Insolation (incoming solar radiation) is modified as it travels through the atmosphere, is further modified by topography and surface features, and is intercepted at the earth's surface as direct, diffuse, and reflected components, see Figure-4. Direct radiation is intercepted unimpeded, in a direct line from the sun. Diffuse radiation is scattered by atmospheric constituents, such as clouds and dust.

Reflected radiation is reflected from surface features. The sum of the direct, diffuse, and reflected radiation is called total or global solar radiation.

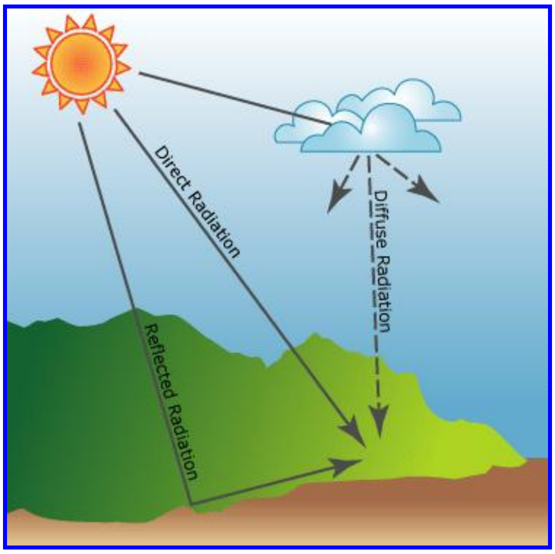

Figure 4- Showing the Incoming solar radiation and is intercepted at the earth's surface as direct, diffuse, and reflected components [6].

Generally, direct radiation is the largest component of total radiation, and diffuse radiation is the second largest component. Reflected radiation generally constitutes only a small proportion of total radiation, except for locations surrounded by highly reflective surfaces such as snow cover. Most calculated method does not include reflected radiation in the calculation of total radiation. Therefore, the total radiation is calculated as the sum of the direct and diffuse radiation. Direct solar radiation is observed from sunrise to sunset, while global solar radiation is observed in the twilight before sunrise and after sunset [2].

Cloudiness in Iraq

At all the meteorological stations in Iraq the degree of cloudiness is observed every day at 00.00, 09.00, 12.00, 15.00 and 21.00 hours local time. From these daily observations, the average daily values for the different months of the year. It can be concluded that the degree of cloudiness is, in general, low over the entire country. It is relatively lower in the south (specially in summer) than in the north and in summer than in autumn. Its maximum value (sky half covered) is in March and April. Although the degree of cloudiness is relatively high in winter and spring there are many clear days with cloudiness less than 1.4 oktas. The number of clear days is in the order of 200 per year, of which about 10 days per month occur during the eight months of October to May. Such information confirms the possibility of the economic success of solar energy utilization in the Republic of Iraq [7].

Sunshine Duration

Sunshine duration is the length of time that the ground surface is irradiated by direct solar radiation (i.e., sunlight reaching the earth's surface directly from the sun). Sunshine duration is defined as the period during which direct solar irradiance exceeds a threshold value of 120 watts per square meter (W/m^2). This value is equivalent to the level of solar irradiance shortly after sunrise or shortly before sunset in cloud-free conditions. It was determined by comparing the sunshine duration recorded using a Campbell-Stokes sunshine recorder with the actual direct solar irradiance [2].

Interpolation Techniques

Interpolation is the process of using known data values to estimate unknown data values. Various interpolation techniques are often used in the atmospheric sciences. One of the simplest methods, linear interpolation, requires knowledge of two points and the constant rate of change between them.. They are often applied to station datasets with irregular spacing between stations.

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on.

"Spatial interpolation is the procedure of estimating the values of properties at unsampled sites within an area covered by existing observations."
Estimations of nearly all spatial interpolation methods can be represented as weighted averages of sampled data. They all share the same general estimation formula, as follows:

$$\hat{z}(x_0) = \sum_{i=1}^{n} \lambda_i z(x_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\hat{z}$ is the estimated value of an attribute at the point of interest $x0$, z is the observed value at the sampled point xi, λi is the weight assigned to the sampled point, and n represents the number of sampled points used for the estimation. The attribute is usually called the primary variable, especially in geostatistics [8].

Interpolation Methods

1. Deterministic: deterministic interpolators; makes predictions from mathematical formulas that form weighted averages of nearby known values.
A. Local: Nearest Neighbor (Thiessen), Fixed Radius, Inverse Distance Weighting (IDW), Splines.
B. Global: Classifications, trend surfaces, regressions.
2. Geostatistics: Geostatistics interpolators**;** uses weighted averages as well, but also probability models to make predictions Kriging (optimal weighting interpolation), Co-Kriging.
Note: Deterministic interpolation techniques are considered nearly ***exact*** if the resulting surface passes through the data value (i.e., minimum and maximum values of the generated surface occur only at sample points), and ***inexact*** if they do not pass through measured data values. All interpolation methods have been developed based on the theory that points closer to each other have higher correlation and similarities than those farther away. In the IDW method, it is assumed that the rate of correlations and similarities between neighbors is proportional to the distance between them. It is assumed that this correlation can be defined as a reverse distance function of every point from neighboring points. The definition of the neighboring radius and the related power to the reverse distance function are considered as important factors [9].

Inverse Distance Weighted Interpolation

Inverse Distance Weighted (IDW) interpolation implements a basic law of geography; i.e. things that are close to one another are more alike than things that are far apart. To predict a value for any unmeasured location, IDW uses the measured values surrou nding the prediction location. Those measured values closest to the prediction location have more influence on the predicted value than those that are farther away (hence it named ***inverse distance weighted***). Which values are included in the calculation can be determined by specifying and customizing the search neighborhood, which is the region of the map around a selected point, in which data points are considered for the extrapolation. IDW assumes that each measured point has some local influence that diminishes with distance [10].

IDW is an "exact" interpolator; meaning that the predictions will be exactly equal to the data value when predictions occur at locations where data have already been collected. This method basically depends on estimating the height of the unknown points by computing the distances from this point to the other known points, as it mathematically clarified by the following .

$$Z(X,Y) = \frac{\sum_{i=1}^{n}\left[\frac{Z_i}{d_i^p}\right]}{\sum_{i=1}^{n}\left[\frac{1}{d_i^p}\right]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$Z\ (X,Y) = \sum \lambda_i \times Z_i \xrightarrow{Where} \sum \lambda_i = 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$d_i = \sqrt{(X_i - X)^2 + (Y_i - Y)^2} \quad \text{...(4)}$$

Where Z(X,Y) is the predicted value at the ensample location X,Y; i is the number of measured sample points within the neighborhood defined; Zi is the observed value at location i; di is the distance between the predicted location X,Y and the measured location i; λi is the distance-dependent weight associated with each sample point; and p is the power parameter that defines the rate of reduction of the weight as distance increases [10].

Sunshine Regions (IraqiGeography)

Iraq is located in the Middle East between latitudes 29° 5' and 37° 22' N and longitudes 38° 45' and 48° 45' N; It is bounded By: Turkey to the north, Iran to the east, Jordan, Syria and the Saudi Arabia to the west, and the Arabian Gulf, Kuwait and Saudi Arabia to the south.

Weather in Iraq

Iraq as a Middle Eastern country is one of those countries which are situated on yellow belt of earth that can receive the maximum light during the day and different months in the year. Iraq climate describe as hot weather in summer and cold in the winter season. A typical meteorological data set is not available in Iraq, mainly due to the lack of sufficient raw data [11].

Figure 5 - Illustrated Iraq country region and Baghdad city location

Methodology

For the studied Iraqi metrological Stations of the values of the studied sunduration were illustrated in Table-1.

Table -2 represents the average day number of sun shine hour's(n), plotted in Figure -6.

Table 1- The measured values of the sunduration for the studied Stations

Station name	Station No	Long E^o	lat N^0	Elevation (m)	Sun dur.
Basrah-husain	689	47.47	30.31	2	8.923951
Nasrya	676	46.14	31.01	5	8.760606
Samawa	674	45.16	31.16	11.4	9.13935
Aldiwanya	672	44.57	31.57	20	9.018923
Hai	665	46.02	32.08	17	8.994462
Kerbela	656	44.03	32.34	29	8.81058
Rutba	642	40.17	33.02	630.8	8.995417
Baghdad	650	44.24	33.18	31.7	8.719084
Ramadi	645	43.19	33.27	48	8.7708043
Khanaqin	637	45.23	34.21	202	7.977162
Tikrit	633	43.42	34.34	107	7.708043
Kirkuk	621	44.24	35.28	331	8.230881
Mosul	608	43.09	36.19	223	8.088286
Rabiah	602	42.06	47.36	382	8.212987

Table 2 - The average day number of sun shine hours n

Lat. / Long	29^o	30^o	31^o	32^o	33^o	34^o	35^o	36^o	37^o
39^o				9.01613	8.80626				
40^o			8.98679	8.95121	8.76194	8.50047			
41^o			8.896	8.8386	8.62369	8.25989	8.33196	8.05629	
42^o			8.91495	8.55265	8.60958	8.44207	8.41555	8.02021	
43^o		8.95139	8.72367	8.41658	8.15091	8.31233	8.48584	8.12766	7.9175
44^o	8.77973	8.69916	8.410994	8.28735	8.045019	8.461431	8.265661	8.040703	7.7487
45^o	8.58031	8.50305	8.247695	8.302992	8.372961	8.274995	8.121016	7.6007	
46^o	8.5792	8.186413	8.222573	8.206408					
47^o		7.839516	8.150363	7.946499					

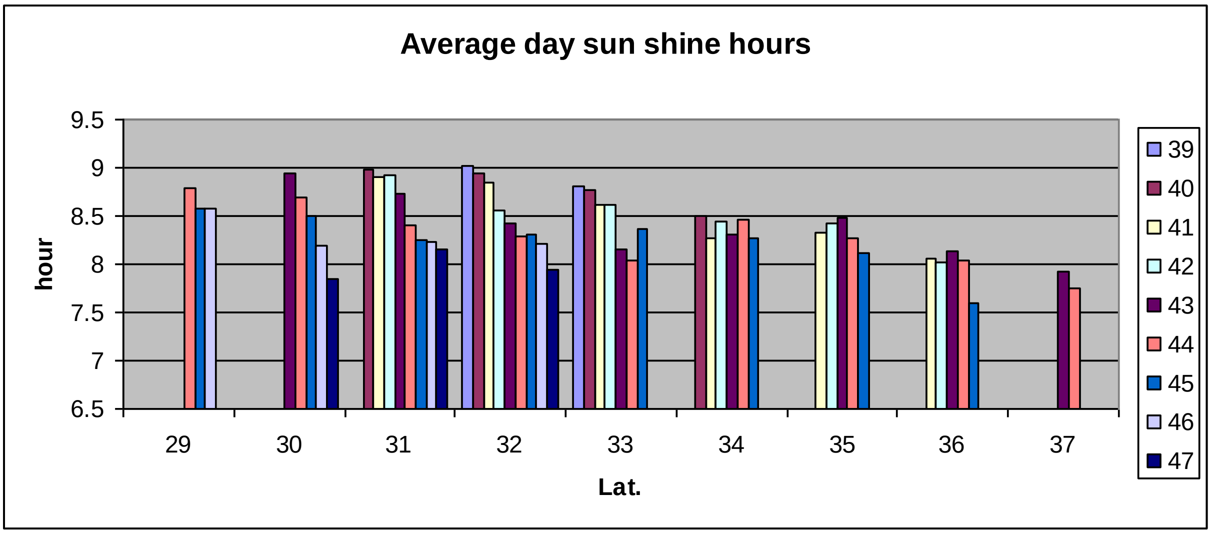

Figure 6 - The average day sun duration data.

A metrological data points of the No. of average daily sun shine hours at a period (1983-2005) were used to interpolate them by using following steps:

1. Image of map for Iraq was scanned and opened in GIS program.
2. A georefrance technique was applied on this map.
3. A polygon shape file commond is applied on it to detect the exact boundaries of Iraqi provinces.
4. Transformed the data points to digital form (sheet file) by using Excel 2007 program.
5. The sheet file was opened in GIS.9.2 Program.
6. The opened sheet file was transformed to layer data.
7. IDW interpolation type was applied on the transformed layer to estimate the most long sun shine day regions in Iraqi lands.

Results and discussions

For this study, as a primary results of applying the IDW interpolation upon the transformed layer of data were the regions of a long sunshine duration hours over the land of Iraq are located at the south west of the country as shown in Figure -7 . Figure-8 illustrates the located Iraqi provinces boundaries over the interpolated Iraqi areas to detect the maximum sun duration hours places. The maximum share of solar radiation areas were form 33770.45 Km^2.

This segment parts are located at the Iraq provinces: Anbar, Najaf, Kerbala, Dewania, Wassit and Thi- car, as shown in Figure-9. Finally these results mean that the south west of Iraq is the favor place to establish solar cells farms.

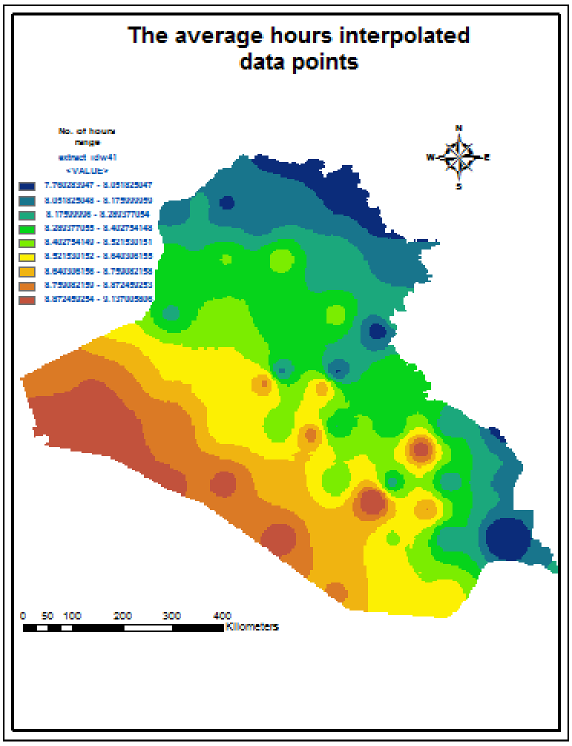

Figure 7 - The interpolated metrological data of the no. of average daily sun shine hours at a period (1983-2005) by using IDW interpolation type over the area of Iraqi country.

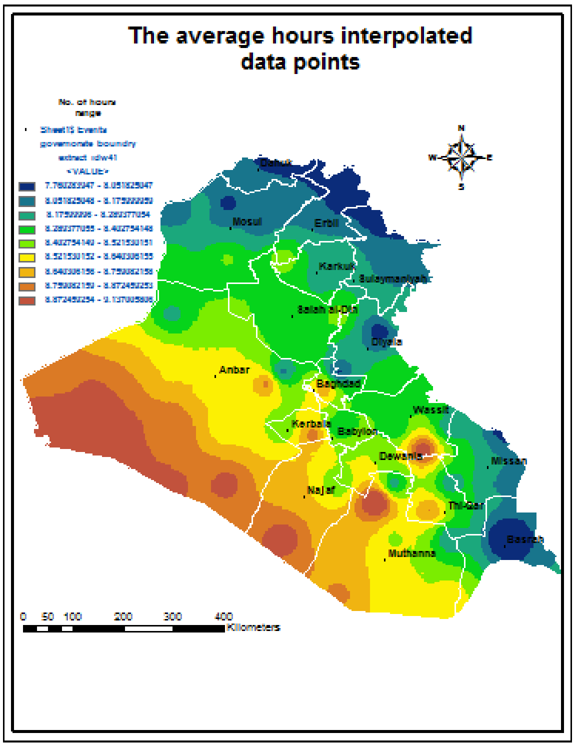

Figure 8 - The located Iraqi provinces boundaries over the interpolated Iraqi areas to detect the maximum sun duration hours places.

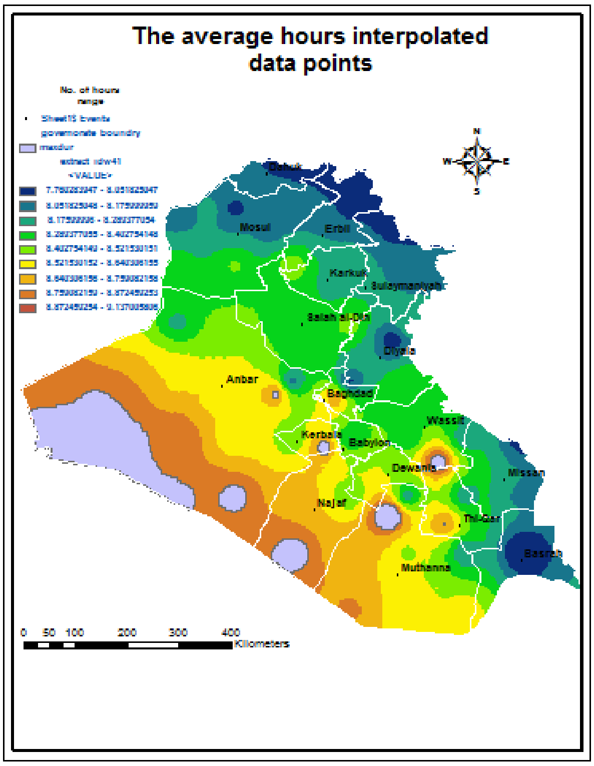

Figure 9 - The located segment on the Iraq provinces map layer

Conclusion

At the first experiments in the field of studying solar radiation, sun duration hours was an effective measured data to estimate global solar radiation. The metrological measured data of average monthly mean sunshine duration hours for Iraqi country at a period (1983-2005) is used in this work . IDW interpolation technique was used in this study to estimate the sun shine hours for the far away regions from the the metrology stations.

The regions are dry and are the nearest regions of Iraq with the equator.

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