Evolution and set up the maps for solar radiation of Iraq using Data observation and Angstrom model during monthly July 2017

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Abstract.
The development that solar energy will have in the next years needs a reliable estimation of available solar energy resources. Several empirical models have been developed to calculate global solar radiation using various parameters such as extraterrestrial radiation, sunshine hours, albedo, maximum temperature, mean temperature, soil temperature, relative humidity, cloudiness, evaporation, total perceptible water, number of rainy days, and altitude and latitude. In present work i) First part has been calculated solar radiation from the daily values of the hours of sun duration using Angstrom model over the Iraq for at July 2017 . The second part has been mapping the distribution of solar radiation energy to Iraq using interpolation technique in Arc _GIs software Version 10.3.

Keyword: solar radiation, sun duration, Angstrom model, Arc _GIs

1. Introduction
The sun is a nuclear power, which is, generates power in form of radiation at the phenomenally high rate of 3.8x1023 kilowatts. An extremely small fraction of this is intercepted by the earth's surface, but this small fraction amounts to a huge 1.8x1014 kilowatt. On the average about 60% of this amount penetrates the atmosphere to reach the earth's surface (1.1x1014 Kw.). Of course this amount of power is distributed over the entire surface of the earth. To bring this number closer to home, consider that on bright sunny day each square meter of surface facing the sun receives about one kilowatt [1]. Energy form the sun is basis for life on earth, and the solar spectrum a mixture of radiative, visible, ultraviolet
and infrared radiation has to be known to design any solar conversion system. Total daily solar radiation is considered as the most important parameter in the performance prediction of renewable energy system, particularly in sizing photovoltaic (pv) power and solar heating system. [1]. In developing countries, such as Iraq, interest in solar energy applications has been growing in providing electricity and water supply in different areas. Understanding solar radiation data is essential for modeling solar energy systems. Solar radiation is used directly to produce electricity for photovoltaic (PV) systems and solar thermal systems.[2]

2. Solar Radiation

The radiation from the sun is the primary natural energy source of the planet Earth. Other natural energy sources are the cosmic radiation, the natural terrestrial radioactivity and the geothermal heat flux from the interior to the surface of the Earth, but these sources are energetically negligible as compared to solar radiation. When the spoken is of solar radiation, it means the electromagnetic radiation of the Sun. The energy distribution of electromagnetic radiation over different wavelength is called Spectrum. The electromagnetic spectrum is divided into different spectral ranges (Figure 1).

![Figure 1. Spectral ranges of electromagnetic radiation, [3].](image-url)
The quantity of solar radiation reaching the earth's surface varies dramatically as a function of changing atmospheric condition as well as the changing position of the sun through the day, [3].

Article I.

3. 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 also defined as the period during which direct solar irradiance exceeds a threshold value of 120 watts per square meter \( \text{W/m}^2 \). 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 [4].

4. Angstrom Model

Angstrom proposed first theoretical model for estimating global solar radiation based on sunshine duration. The fundamental Angstrom model can be considered as a base model. rebuilt this model in order to make it possible to calculate monthly average of the daily global radiation on a horizontal surface from monthly average daily total insolation on an extraterrestrial horizontal surface as per the following relation:[5]

\[
\frac{H}{H_c} = a + b \frac{n}{N} \tag{1}
\]

Where

\( H \) = Monthly average daily global radiation \((\text{Wh/m}^2/\text{day})\).

\( H_c \) = Monthly average clear sky daily global radiation for the location solar radiation in a given day.

\( n \) = Actual sunshine duration in a day respectively \((\text{Hours})\).

\( N \) = Monthly average maximum possible bright sunshine duration in a day. Also known as monthly mean length of the day in hours.

\( a \) and \( b \) = Empirical coefficients. These coefficients are location specific coefficients referred to as fractions of extra terrestrial radiation on overcast days and on average days respect [7].
a = 0.25 …………………….(2)

b = 0.50 ……………………(3)

N = (2/15) \cos^{-1}(-\tan \varphi \tan \delta) ………..(4)

The ratio \(H/H_0\) called clearness index. Values of the monthly average daily extraterrestrial radiation \(H_0\) is calculated from the following equation, [8]:

\[
H_0 = \frac{24 \times 3600 \times I_{sc}}{\pi} \left[1 + 0.033 \cos \left(\frac{360 \times d}{365}\right)\right] \cos \varphi \cos \delta \sin \omega + \frac{\pi \omega}{180} \sin \varphi \sin \delta \] ……. (5)

**Where:**

\(I_{sc}\) = is the solar constant of a value 1367 Wm\(^{-2}\)

d = day of the year from January 1 to December 31 taking January 1\(^{st}\) as 1.

\(\Phi\) = latitude of location

\(\omega\) = sunset hour angle

\[\omega = \cos^{-1}(-\tan \varphi \tan \delta) \] ……………. (6)

\(\delta\) = declination angle

\[\delta = 23.45 \sin \left[360 \left(\frac{284 + d}{365}\right)\right] \] ……………..(7)

4.1 Interpolation techniques

Spatial interpolation is tool in GIS used to find the values of unknown points. It can be defined as a procedure of estimating the values of properties at unsampled locations based on the set of observed values at known locations. A large number of interpolation methods have been developed for use with point, line, and area data. No matter which interpolation technique is used, the derived values are only estimates of what the real values should be at a particular location. The quality of any analysis that relies on interpolation of observed data is, therefore, subject to a degree of uncertainty. Different interpolation methods can therefore generate different predictions at same locations. Many researchers have evaluated various methods for interpolation of different hydro climatic data. But accuracy of estimated values is varying from each methods based on the topography of the area, concentration and
distribution of the measurement stations. So in this study some of these interpolation methods used in GIS were analysed and checked their accuracy based on the results produced. [9]

There are two main groupings of interpolation techniques: deterministic and geostatistical.

- **Deterministic interpolation techniques** create surfaces from measured points, based on either the extent of similarity (Inverse Distance Weighted) or the degree of smoothing (Spline). [9]

- **Geostatistical interpolation techniques** (kriging) utilize the statistical properties of the measured points[9]

### 4.2 Methodology

**Using the data of the General** Organization for Aerial Meteorology and Seismic Monitoring in Baghdad, the daily sun duration values were found. Values were found in the stations (Mosul, Kirkuk, Baghdad, Nasiriya, Khanakin, Amara, Najaf, Hay, Diwaniya, Karbala) listed in below table(1) for the 2017.

| Day | Baghdad | Mosul | Nasiriya | Alhay | Kirkuk | Karbla | Khanqien | Dewania | Emara | Najaf |
|-----|---------|-------|----------|-------|--------|--------|----------|---------|-------|-------|
| 1   | 12.0    | 11.8  | 5.7      | 10.6  | 10.6   | 11.2   | 10.1     | 11.6    | 10.5  | 10.3  |
| 2   | 11.6    | 11.5  | 10.2     | 11.0  | 11.7   | 10.8   | 9.4      | 11.9    | 9.0   | 11.5  |
| 3   | 11.4    | 11.6  | 10.8     | 11.2  | 12.0   | 10.9   | 9.2      | 11.3    | 11.2  | 10.8  |
| 4   | 10.9    | 11.2  | 9.9      | 11.4  | M      | 10.3   | 10.2     | 10.9    | 11.2  | 10.6  |
| 5   | 7.4     | 11.8  | 10.9     | 10.4  | 12.0   | 8.9    | 7.2      | 5.0     | 11.0  | 6.3   |
| 6   | 11.4    | 11.6  | 9.6      | 10.7  | 12.0   | 11.0   | 9.0      | 11.2    | 9.6   | 12.0  |
| 7   | 11.8    | 7.9   | 8.8      | 11.0  | M      | 11.6   | 9.2      | 10.3    | 11.5  | 11.1  |
| 8   | 11.3    | 9.0   | 4.8      | 3.5   | 11.4   | 10.7   | 8.0      | 7.4     | 4.8   | 8.5   |
| 9   | 9.7     | 11.8  | 9.7      | 11.1  | M      | 10.3   | 8.0      | 10.0    | 11.0  | 9.7   |
| 10  | 9.2     | 11.6  | 10.4     | 11.1  | M      | 10.3   | 8.4      | 10.8    | 11.0  | 10.4  |
| 11  | 11.2    | 12.1  | 10.4     | 11.2  | 12.0   | 11.0   | 11.5     | 11.0    | 11.4  | 11.0  |
| 12  | 10.5    | 12.0  | 5.6      | 10.8  | 12.1   | 10.2   | 11.4     | 10.3    | 11.0  | 9.6   |
| 13  | 12.1    | 12.0  | 9.2      | M     | 12.3   | 10.9   | 12.0     | 9.9     | 11.0  | 10.3  |
| 14  | 11.5    | 11.8  | 9.1      | 10.2  | M      | 10.8   | 11.8     | 10.1    | 9.0   | 11.1  |
5. Experimental work

In this work we obtain daily solar radiation for July and August in year 2017 from daily values of sun duration using Angstrom Model and then show the results in map using interpolation techniques in ArcMap GIS 10.3 program.

Table 2. Represents estimation values of the solar radiation from sun duration for July

| day | Badhdad | mosoul | Nasriya | Alhay | kirkuk | Karbla | Khanqien | Dewania | emara | najaf |
|-----|---------|--------|---------|-------|--------|--------|----------|---------|-------|-------|
| 1   | 27.94625| 27.46217| 18.73985| 25.94418| 25.79419| 26.81684| 25.12348| 27.43508| 25.80539| 25.50474|
| 2   | 28.05661| 27.71435| 26.02931| 27.20851| 28.08642| 26.89663| 24.71426| 28.58799| 24.19682| 27.96558|
| 3   | 28.56532| 28.6722 | 27.72452| 28.31322| 29.36334| 27.83646| 25.12525| 28.48912| 28.32342| 27.69415|
| 4   | 27.98145| 28.25083| 26.50237| 28.82012| 28.08999| 26.84585| 28.0578 | 28.51769| 27.5708 |
| 5   | 22.05658| 28.55622| 27.48405| 26.68355| 28.93899| 24.3773 | 21.72413| 18.41286| 27.61308| 20.40249|
| 6   | 27.28318| 28.27699| 24.69708| 26.30295| 28.04043| 26.73743| 23.69814| 27.06629| 24.67746| 28.2365 |
| 7   | 27.49547| 21.68286| 23.18618| 26.38583| 27.25304| 23.66441| 25.37848| 27.12953| 26.53492|       |
| 8   | 27.21291| 23.648  | 17.592  | 15.64873| 27.23493| 26.36893| 22.28467| 21.47265| 17.58829| 23.10286|
| 9   | 25.61217| 28.60097| 25.69716| 27.81733| 26.57612| 22.97552| 26.1458 | 27.67495| 25.6672 |        |
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 25.26479 | 28.77242 | 27.2305 | 28.2876 | 27.02463 | 23.9797 | 27.84148 | 28.14308 | 27.19548 |
| 11 | 28.03844 | 29.18284 | 26.90786 | 28.1062 | 29.12173 | 27.7839 | 28.43953 | 27.8211 | 28.42808 | 27.79994 |
| 12 | 26.13427 | 28.13688 | 23.72 | 28.00451 | 26.16532 | 28.14308 | 27.84148 | 28.14308 | 27.19548 |
| 13 | 27.86228 | 27.48264 | 23.72 | 28.00451 | 26.16532 | 27.65371 | 24.73402 | 26.33696 | 25.30183 |
| 14 | 27.13748 | 27.34194 | 23.72 | 28.00451 | 26.16532 | 27.65371 | 24.73402 | 26.33696 | 25.30183 |
| 15 | 28.52364 | 27.67941 | 24.39022 | 28.1687 | 28.1324 | 27.70482 | 25.13532 | 25.73175 | 26.62302 |
| 16 | 29.23081 | 28.81727 | 23.74712 | 27.13617 | 29.52795 | 27.89887 | 29.31432 | 26.85096 | 24.81337 | 26.51693 |
| 17 | 29.03533 | 27.85793 | 28.08314 | 29.12012 | 29.7894 | 29.25839 | 25.42308 | 29.15179 | 29.13592 | 28.34654 |
| 18 | 28.71679 | 27.26118 | 20.19892 | 21.08243 | 27.65383 | 28.48403 | 26.09473 | 27.62999 | 28.8.3299 |
| 19 | 27.87075 | 27.17157 | 26.39145 | 27.07557 | 28.2827 | 27.49964 | 25.61424 | 27.54844 | 27.32814 | 27.5205 |
| 20 | 28.1293 | 26.99244 | 26.51992 | 27.1973 | 27.61808 | 27.76378 | 28.10849 | 26.77438 | 27.93226 |
| 21 | 28.46364 | 27.59207 | 23.74712 | 27.13617 | 29.52795 | 27.89887 | 29.31432 | 26.85096 | 24.81337 | 26.51693 |
| 22 | 28.84309 | 27.34354 | 28.38575 | 29.0941 | 28.92045 | 27.08527 | 28.97683 | 29.421 | 28.79041 |
| 23 | 28.80106 | 28.35049 | 28.65322 | 28.89989 | 29.19067 | 27.7953 | 28.81549 | 28.93054 | 28.20944 |
| 24 | 29.31034 | 28.39614 | 26.72767 | 26.05718 | 28.66048 | 27.56472 | 26.95657 | 28.53846 | 24.54494 | 28.04657 |
| 25 | 27.78424 | 27.48017 | 25.42988 | 27.14661 | 28.02943 | 27.71769 | 26.38331 | 26.88738 | 27.46125 | 27.29904 |
| 26 | 28.31136 | 27.1359 | 23.67519 | 27.40238 | 27.67906 | 27.38147 | 26.92724 | 27.44182 | 27.56756 | 26.09806 |
| 27 | 27.33112 | 25.31151 | 27.92048 | 27.15853 | 26.99736 | 27.70597 | 27.94398 | 28.21818 | 28.05488 |
| 28 | 29.83927 | 27.70108 | 27.75509 | 28.74569 | 28.26965 | 28.41893 | 27.63633 | 28.63746 | 28.61546 | 27.68727 |
| 29 | 29.01372 | 27.60668 | 26.87992 | 28.35813 | 28.03276 | 27.40682 | 28.45734 | 28.40209 | 27.60465 | 27.58882 |
| 30 | 27.20861 | 28.38082 | 26.93291 | 28.54786 | 29.26494 | 28.83014 | 28.33198 | 28.59388 | 28.10965 | 27.93923 |
| 31 | 29.03889 | 27.35941 | 27.16028 | 28.27342 | 28.2187 | 27.95096 | 25.69624 | 27.72373 | 28.74424 | 26.93852 |
Figure 2. distribution map of solar radiation in 1-7-2017
Figure 3. Distribution map of solar radiation in 7-7-2017

Figure 4. Distribution map of solar radiation in July
6. Conclusion

Estimation of solar radiation from measured meteorological variables offers an important alternative in absence of measured solar radiation. The existing and developed models are comparatively studied and evaluated using monthly average daily solar radiation and measured meteorological data, monthly average daily sunshine duration. The most important outcomes of the study can be summarized as: the estimation of global solar radiation can be predicted with reasonable accuracy with all developed models considered in this study, due to its simplicity and better model performance evaluation. Therefore, it can be recommended that these models are used reasonably well for estimating the solar radiation in Iraq and possibly in its surroundings sites with similar climatic conditions if empirical coefficients are correctly calibrated.
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