Producing Global Solar Radiation maps in Iraq Using Geographic Information Systems

Hussain Zaydan Ali
Expert / Remote Sensing
Chief Researchers
hussainzayali53@yahoo.com
Ghusoon Idan Arb
Al-Mustansiryah University / College of Engineering / Computer Department
Eng.computer38@gmail.com
Ziena Jameel yusif
Baghdad University / College of Education Humanities Ibn Rushed / Department of Geography
zienagameel@gmail.com

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Abstract:
The design and operation of any solar energy system requires a good knowledge of the solar radiation data in a location. This data finds application in agriculture, climatology, meteorology, etc. Since the solar radiation reaching the earth's surface varies with climatic conditions of a place, a study of solar radiation under local climatic condition is essential. Global solar radiation is of economic importance as renewable energy alternatives. In this research 14 Iraqi climatic stations radiation data were used for the years 2013 to 2015. Data have been designed and calculated by using Excel. ArcGIS 10.2 is used for spatial interpolation and mapping activities. Surface radiation map have been generated by using ordinary kriging interpolation technique. Different models are tested, namely Spherical, Gaussian and Circular model. Creation of digital grid maps makes it possible to obtain climatic information at any point, whether there is a weather station or not. Results show that the spherical model outperforms Gaussian and circular models.
Keywords: Renewable Energy, Solar Radiation Maps; GIS; Iraq.

انتاج خرائط الإشعاع الشمسيّ الكلي في العراق عن طريق تقنية نظم المعلومات الجغرافية

حسين زيدان علي
خبير/ تحسس نائي - رئيس باحثين
غصون عيدان عرب
الجامعة المستنصرية / كلية الهندسة - قسم الحاسوب
زينة جميل يوسف
جامعة بغداد / كلية التربية للعلوم الانسانية ابن رشد - قسم الجغرافية

الملخص:

إن تصميم أي نظام للطاقة الشمسية يحتاج إلى فهم جيد لبيانات الإشعاع الشمسي في الموقع. وإن هذه البيانات تخدم تطبيقات في الزراعة، علم المناخ، الأنواء الجوية ..الخ. بما أن الأشعة الشمسية التي تصل إلى سطح الأرض تتغير مع الظروف المناخية للموقع، فان دراسة الاشعاع الشمسي تحت الظروف المناخية المحلية تعد ضرورية. يعتبر الإشعاع الشمسي الكلي من العوامل الاقتصادية المهمة كبدائل للطاقة المتجددة. في هذا البحث، تم استخدام بيانات الإشعاع لأربعة عشر (١٤) محطة مناخية للسنوات ٢٠١٣-٢٠١٥. وقد تم تصميم وحساب البيانات باستخدام برنامج أكسل. لغرض نشاطات الاستنباط المكاني وانتاج الخرائط تم استخدام برنامج ArcGIS 10.2.

وقد تم إنتاج خريطة الإشعاع السطحي باستخدام تقنية كريجنك العادية للاستنباط . تم اختبار نماذج مختلفة، وهي الكروي، الكاوسي والدائري. ان انتاج الخرائط الشبكية الرقمية يجعل بالإمكان الحصول على المعلومات المناخية في أي مكان، سواء كانت هناك محطة انوائية أم لا. بينت النتائج أن الموديل الكروي يتفوق على الموديل الكاوسي و الدائري.

الكلمات الدالة: الطاقة المتجددة ، خرائط الإشعاع الشمسي ، نظم المعلومات الجغرافية ، العراق.

INTRODUCTION:

Solar radiation data on the earth's surface is required for solar engineers, agriculturists and hydrologists in many applications. Solar energy is free, clean, abundant and inexhaustible source of energy. Its effective harnessing and utilization are of importance to the world, especially at the time of rising fuel costs and environmental effects such as depletion of the ozone layer and green house effects. Since the solar radiation reaching the earth's surface varies with climatic conditions of a place, a study of solar radiation under local climatic condition is essential [3, 12]. Measured values of solar radiation can be in the form of global solar radiation, diffused solar radiation or beam solar radiation [5]. The average daily values of these three parameters are sought after for various applications. Spatial interpolation is an essential tool in processing the data of natural and social science. It has been widely used especially in the discipline of hydrological, meteorological climate, ecology, environment, geology etc. The essence of spatial interpolation is to estimate the values of unobserved points based on known sample data. A wide review of spatial interpolation can be found in [2, 6, and 7]. The interpolation methods used in this paper will be briefly introduced. A detailed presentation of geostatistical theories can be found in [1, 10, and 13]. The objective of this paper is to test few models, namely Spherical, Circular and Gaussian models. The following errors, Prediction Errors include: Mean, Root Mean Square, Average Standard Error, Mean Standardized, Root Mean Square Standardized were calculated.

Kriging Methodology:

Many environmental processes depend on the amount of solar radiation at the ground level. Ground measurements are often available, even for long time series, and are used as input for spatial interpolation models to produce continuous maps of solar radiation [9]. Over the past several decades, Kriging has become a fundamental spatial prediction tool in Geostatistics - geostatistics: a branch of statistics focusing on spatial or spatio-temporal data [8]. Kriging is a geostatistical interpolation technique that considers both the distance and the degree of variation between known data points when estimating values in unknown areas [11]. The basic form of the kriging estimator is:

$$Z^{*}(u) - m(u) = \sum_{\propto=1}^{n(u)} \lambda_{\propto[Z(u_{\alpha}) - m(u_{\alpha})]}$$

The goal is to determine weights λ_{α} that minimize the variance of the estimator

$$\sigma_E^2(u) = Var\{Z^{*}(u) - Z(u)\}$$

Under the unbiasedness constraint

$$E\{Z^{*}(u) - Z(u)\} = 0$$

The random field (RF) $Z(u)$ is decomposed into residual and trend components,

$Z(u) = R(u) + m(u)$, with the residual component treated as an RF with a stationary mean of 0 and a stationary covariance (a function of lag, h, but not of position, u)

$$E\{R(u)\} = 0$$

$$Cov\{R(u), R(u+h)\} = E\{R(u).R(u+h)\} = C_R(h)$$

The residual covariance function is generally derived from the input semivariogram model, $C_r(h) = C_r(0) - \gamma(h) = Sill - \gamma(h)$.

Thus the semivariogram we feed to a kriging program should represent the residual component of the variable. The three main kriging variants, simple, ordinary, and kriging with a trend, differ in their treatments of the trend component, $m(u)$ [4].

Results and Discussion

In this study 14 Iraqi climatic stations' radiation data were used for the years 2013 to 2015, measured in Mega Joules / m^2/ Day. Data have been designed and calculated by using Excel. ArcGIS 10.2 is used for spatial interpolation and mapping activities. Surface radiation Maps have been generated by using ArcGIS ordinary kriging interpolation technique. Below represent samples of produced maps of solar radiation. The samples are for February for year 2013 to 2015.

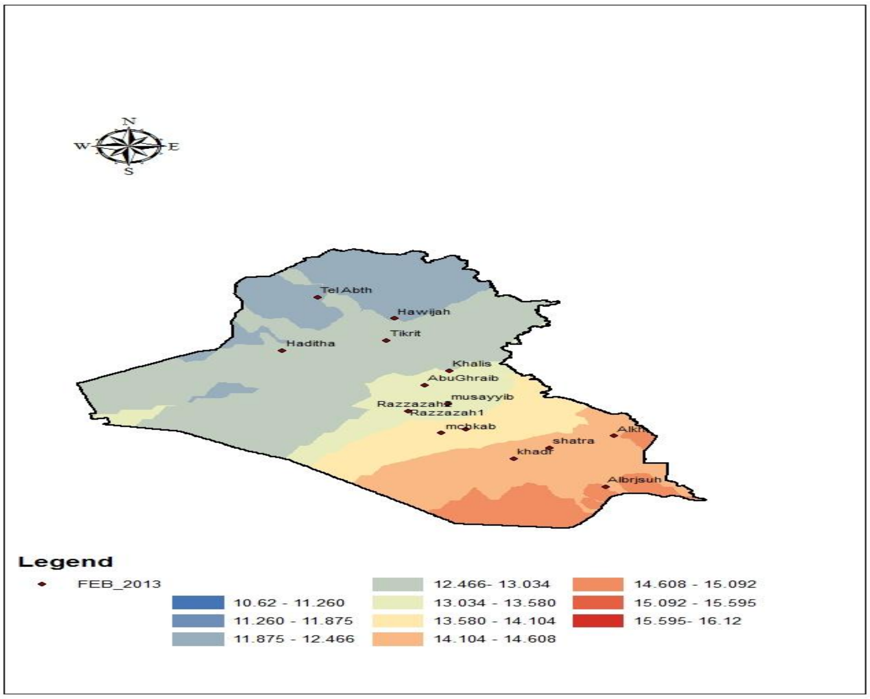

Figure (1): Solar Radiation Map, February 2013.

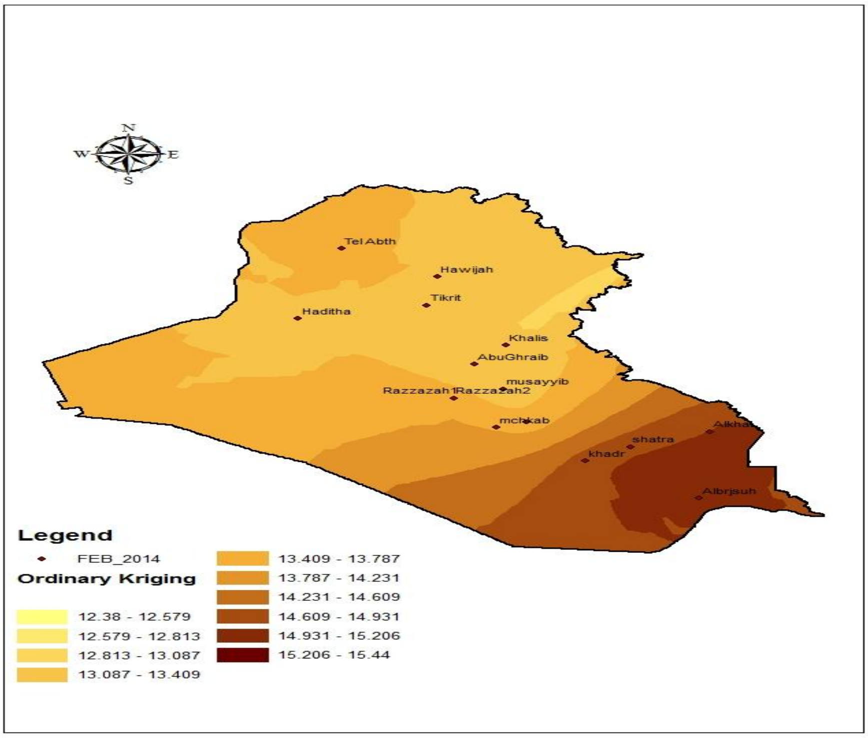

Figure (2): Solar Radiation Map, February 2014.

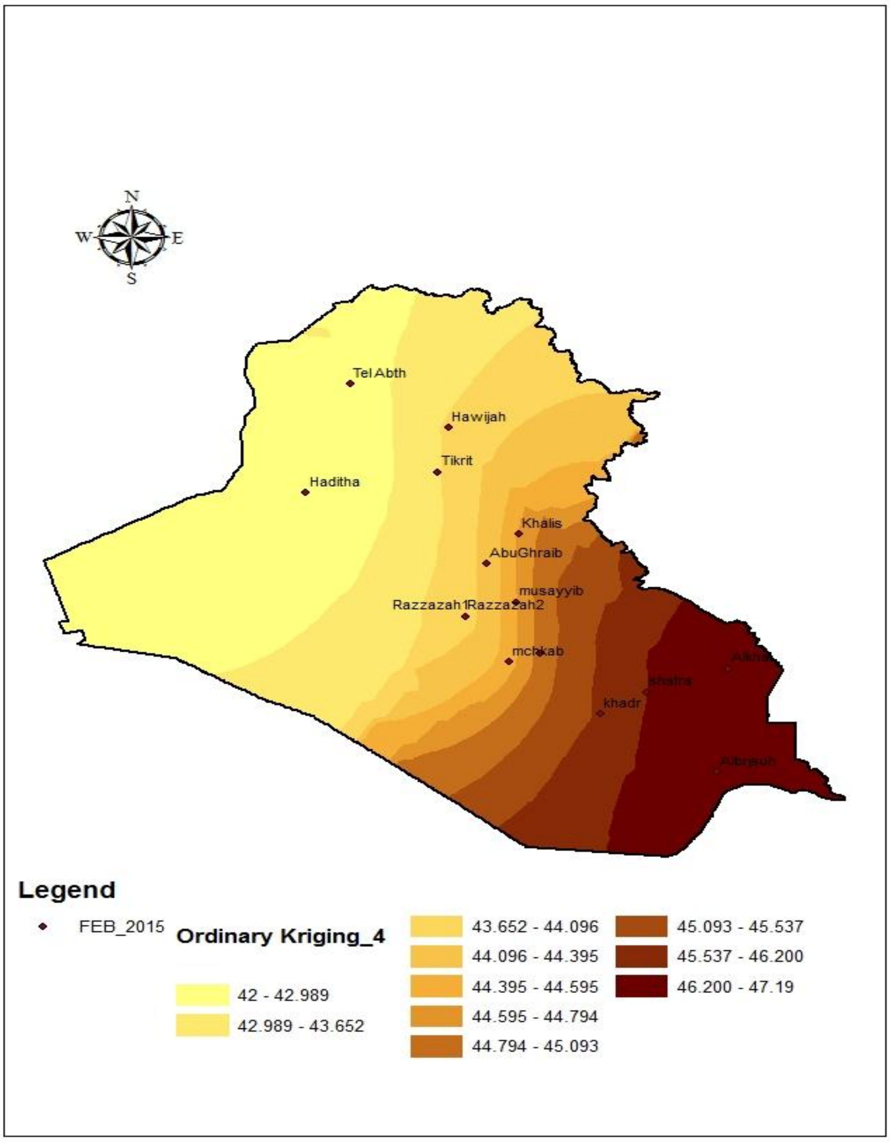

Figure (3): Solar Radiation Map, February 2015.

ArcGIS Geostatistical Analyst can be used to perform cross-validation. The cross-validation procedure provides measures of accuracy for the predictions made using the ordinary kriging method. The measures produced include Mean Prediction Error(MPE), Root Mean Square Prediction Error (RMSPE), Average Standard Error (ASE), Mean Standardized Prediction Error (MSPE), Root Mean Square Standardized Prediction Error (RMSSPE).
Values calculated for RMSE are documented in Table 1 below.

Table (1): Cross Validation Values

Month/Year	Model	Method	RMSE
February/2013	Spherical	Ordinary Kriging	0.9945
February/2014	Spherical	Ordinary Kriging	0.8674
February/2015	Spherical	Ordinary Kriging	0.4322
January/2013	Spherical	Ordinary Kriging	0.9687
January/2014	Spherical	Ordinary Kriging	1.023
January/2015	Spherical	Ordinary Kriging	0.8639
July/2013	Spherical	Ordinary Kriging	1.348
July/2014	Spherical	Ordinary Kriging	0.9772
July/2015	Spherical	Simple Kriging	1
October/2013	Circular	Ordinary Kriging	0.9271
October/2014	Gaussian	Ordinary Kriging	0.8837
October/2015	Circular	Ordinary Kriging	0.9326

It was found that the Spherical model gives best results except for October, where the Gaussian and Circular models were better than the Spherical model.

Conclusions:

Creation of digital grid maps makes it possible to obtain climatic information at any point, whether there is a weather station or not. Multiple factors condition the difficulty of map creation, such as the location of the site samples, spatial density, spatial variability etc. Given a set of meteorological data, it's possible to use a variety of stochastic and deterministic interpolation methods to estimate meteorological variables at unsampled locations. Solar energy is an important renewable energy source for the country, both in the generation of PV electricity and as heat. Therefore, it is necessary to quantify the solar potential of an area, but the achieving of this goal requires first an adequate estimation of solar radiation incident on the Earth's surface.

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References:

[1] Andreas Georgiou and Dimitrios Skarlatos, 2016, Optimal site selection for sitting a solar park using multi-criteria decision analysis and geographical information systems, Geosci. Instrum. Method. Data Syst., 5, 321–332.

[2] Burrough PA, McDonnell,1998, Principles of geographical information systems. Claredon Press Oxford; p. 333.

[3] Cano, D., Monget, J. M., Albuisson, M., Guillard, H., Regas, N. & Wald, L., 1986, A method for the determination of the global solar radiation from meteorological satellite data, Solar Energy 37(1), 31-39.

[4] Geoff Bohling, 2005, "KRIGING", Kansas Geological Survey, 19 October.

[5] Iqbal, M., 1983, "An Introduction to Solar Radiation". Academic Press.

[6] Isaaks, E. & Srivastava, R. (Ed.), 1989, An Introduction to Applied Geostatistics. Oxford University Press.

[7] Lam NS., 1983, Spatial interpolation methods: A review. American Cartography **10**: 119-138.

[8] Marc Gentile, Guldariya Nurbaeva, 2011, " Kriging Interpolation Application to the GREAT10 Star Challenge ", Laboratoire d'Astrophysique de l'EPFL, Switzerland.

[9] Marco Bezzi, Alfonso Vitti , 2005, A comparison of some kriging interpolation methods for the production of solar radiation maps, Department of Civil and Environmental Engineering, University of Trento.

[10] Nogoye Diaw, Thi Thi Soe, Swathi. A, IV Prasun Kumar Das, V G.Giridhar, 2017, Estimation of Solar Potential in Senegal Using GIS Application , International Journal of Advanced Research in Education & Technology (IJARET), Vol. 4, Issue 1.

[11] Olea R., editor, 1991, Geostatistical Glossary and Multilingual Dictionary Oxford University Press, New York, NY.

[12] Rehman S, Ghori SG. 2000, Spatial estimation of global solar radiation using geostatistics. Renewable Energy **21**: 583-605.

[13] Samer Alsadi and Yasser Fathi Nassar, 2016, Correction of the ASHRAE clear-sky model parameters based on solar radiation measurements in the Arabic countries, International Journal of Renewable Energy Technology Research, Vol. 5, No. 4, pp. 1-16.