OPTIMAL LOCATION FOR SOLAR CELLS BY USING REMOTE SENSING AND GIS TECHNIQUES, WITHIN NAJAF CITY - IRAQ AS A CASE STUDY

Modher H. Abd
sonlargeiraq@yahoo.com
[1]*Technical Colleges, Middle Technical University, Iraq*

ABSTRACT: *Solar energy is one of the most important components of renewable energy, which is a significant source of energy for many developing countries especially within generating electricity field. With increasing the requirements for electricity energy in general of Iraq and particularly in Najaf city, so it has been focused on the use of solar energy. The present study aims to apply GIS technique to determine the most optimum location for the collection of solar energy in the south and southwest of the Najaf city. Where a set of random locations to obtain a digital model are used to show the best location for establishing a solar power plant. The study is based on the digital elevation model (DEM) and point layer, by using kriging method which is integrated geographical information systems in order to obtain the model (optimum spatial location). The application of these models are for all months of the year 2017. The results indicate that southern part is the optimum location, where the highest Solar energy ranges from(6005 to 6377 W/m^2.). A digital map is produced to illustrate the spatial distribution of suitable land for solar energy harvesting. The study recommends that the results obtained by the decision makers be applied to the implementation of solar cells in the optimum location within the city of Najaf.*

Keyword: GIS, Solar Cells, Remote sensing, Najaf city**.**

INTRODUCTION:

Remote sensing (RS) and geographic information systems(GIS) are used in many applications as given by the studies of [1,2,3,4,5]. Remote sensing techniques with utility applicable site evaluation that included environmental parameters necessary and important for an environmental impact assessment in terms of site selection for an electric power plant are defined , where Problem areas are discussed within study of [6]. In this study, select the most appropriate places to put solar cells by using the remote sensing and GIS. Solar cells are an important source for providing spacecraft and satellites with the necessary electrical energy, as they are an alternative to traditional energy sources of oil and gas. photovoltaic cells are installed as one unit that is directed to a single surface and is called a solar panel, where convert the energy of solar radiation directly into electricity and is characterized by the production of electricity without operate contaminated waste, noise, radiation or even fuel, and the default age of up to 30 years. The intensity of its current depends on the time of sun's brightness and the intensity of the sun's rays, as well as the efficiency of the photovoltaic cell itself in converting solar energy into electrical energy. Winter temperatures rise to a maximum of about 16 ° C (60.8 ° F) in Western Sahara (Najaf city is considered to be the largest part of Western Sahara), while the minimum summer temperatures range from about 27 - 34 ° C (80.6 - 93.2 ° F) and rise to an almost maximum between 42 and 47 ° C (107.6 and 116.6 ° F), some times to 50 degrees (General Organization for Aeronautical and Seismic Monitoring in Iraq). The sun is the earth's major energy source and radiates its energy from a distance of 150 million kilometers, or 8.3 light minutes. The total of radiation calculated for an individual (points) location or region(area) is given as global radiation, where a calculation of direct, diffuse, and global insolation are repeated for each feature location or every location on the topographic surface, producing insolation maps for an entire geographic area.

Literature Review:

The work of [7], showed that quality assessment of the resulting roof areas by means of a 3D dataset which is semi-automatically acquired from panchromatic stereo photogrammetric aerial photographs. Also, focuses on a field test that locates roof areas with a high solar potential and predicts the solar "harvest" per m^2 .

The report of [8], use Google Earth to identify appropriate rooftops. suitable rooftops. In addition, Rooftops are also visually searched for shading and building obstructions.

The research of [9] , the purpose is to estimate the roof-top area suitable for installation of solar energy systems, where the experiment is applied in an area located in heart of the city in the city of Lisbon, Portugal. the Digital Surface Model (DSM),the normalized DSM (nDSM), and Digital Terrain Model (DTM) based on a LiDAR flight from 2006 with considering the optimal location for solar Photovoltaic (PV) systems is performed, but no social or economic parameters are classed. finally, the result showed that the building with the highest potential in the study area is a High School, with an estimated production of 142.58 MWh.

The research [10], utility the ArcGIS Solar Analyst tool to model the solar resource useful on rooftops, where concludes that solar radiation on rooftops varies from seasonally and hourly. Also, trees lessen solar radiation on rooftops by an average of 38%.

The study of [11], showed demonstrates the technique using the LiDAR data merge with the Geographical Information System(GIS) to determine the appropriate location to locate the PV solar panels according to five: the ground mask, slope mask , aspect mask, human mask and high radiation layer. then, the output of the suitable location, the estimating number of solar panel can be generated depending on the calculation of one-and-half square area meter.

The article of [12], shows that the Gulf Cooperation Council (GCC) countries have start to adopt a more pro-active program toward renewable energy that will help advance the

GCC countries towards sustainability. In addition, reduce high oil dependency and diversify economies.

The study of [13], showed a sample of 265 buildings footprints which was extracted from the classification and used for the estimation for the year 2015, with assuming that 50%,12%, and 0.6 roof areas (PV),grid conversion efficiency and performance ratio respectively. A solar radiation model was applied using a digital surface model (DSM) generated from two Worldview stereo satellite images as inputs. The processes included applying orientation with Rational Polynomial Coefficients with and without GCPs, aerial triangulation , tie point measurements, true ortho-rectification , automatic DSM and editing. Two classification methods were conducted (SVM and ANN) on the true ortho-image. First method without utilizing texture(the ortho-image and texture features overall accuracy was 93.4%), the second utilizing texture features of Grey Level Co-occurrence Matrix(ortho-image and texture features overall accuracy of 91.2%) with kappa coefficient was 0.90. Also, ESRI zonal statistics tool was used. In addition, the area solar radiation model was done by ESRI ArcGIS.

The work of [14], examines future renewable energy development aims for Middle Eastern and North African (MENA) countries because of This region of the globe captures a plentiful amount of direct sunshine. Also, illustrates how solar and wind resource estimate and site selection models. therefore, tapping into this chance will dramatically decrease fossil fuel.

The report of [15], recommended resource data from high-resolution wave models, co-located and co-temporal wind is offered in a GIS with a scope of physical and environmental parameters, where the work was Previous focuses on a single technology with fixed site-selection criteria. Also, combining with over a large region, has been examined relatively low level of detail. In addition, highlight on some time-series tools of the extra detailed factors influences on a site-selection decision.

The study of [16], aimed at assessing the potential of European regions to solar power generation from merge already existing information on the solar radiation (SR) with other geographical characteristics: population distribution, slope, urban extent and land use. The main result is an appropriate map for solar energy power plants .then, an appropriate map compared to the regional distribution of European funds for development of solar energy.

Also the work of [17][18], applied a multi-standard method to determine the most suitable solar collectors. The current study concern application of GIS and remote sensing in determining the most appropriate local sites for the construction of solar cells projects in Najaf city.

Location of the Study Area:

One of the most prominent cities of Iraq, located to the southwest of the capital Baghdad [19] with a population of 1,221,248 people, according to the statistics of 2011. The Najaf city lies on the edge of the western plateau, which separates Iraq from the eastern border of Saudi Arabia. It is bounded between latitudes (30° 50′ 00″ to 32° 25′ 00″N) and longitudes (42° 20′ 00″ to 44° 30′ 00″E), as shown Figure (1). It occupies its natural geographical position between the sedimentary plain and the desert plateau. The city is an important city in Iraq for its religious and tourist center. The city has several historical landmarks and most of them are Islamic monuments. Najaf was chosen as the capital of Islamic culture in 2012[20]. The area of Najaf (28824) Km^2. (6%) of Iraq. Its current administrative divisions consist of three districts: Najaf, Kufa and Manatharah. It has a desert climate (being a bare area of vegetation) and for the most drier months the climate is BWh/BWn according to the Copen climate classification.

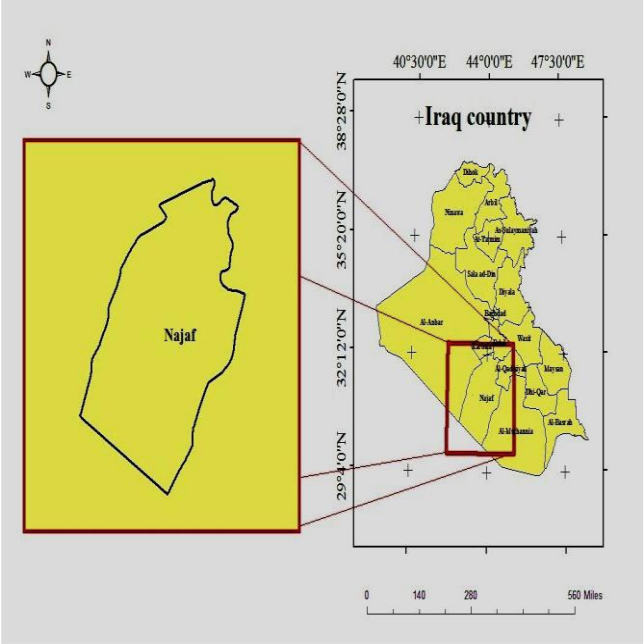
Methodology:

The Data Set:

The following data Sources were available

1- Digital Elevation Model (DEM) from (https://vertex.daac.asf.alaska.edu/#) to cover study area.

2- points layer made in Arc Catalog 10.2.2 to cover study area.



Figure(1): Study Area.

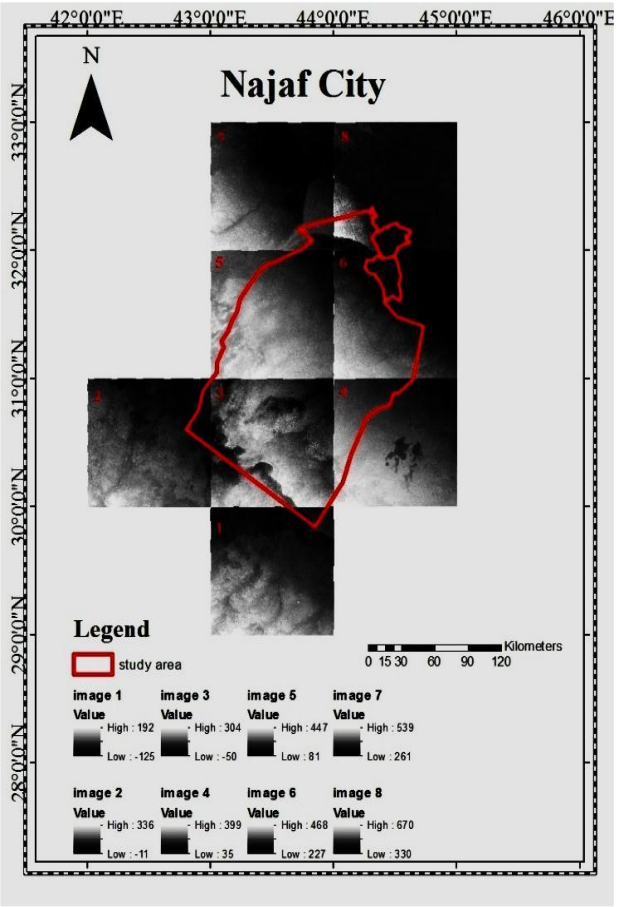
GIS Technique :

The locations of solar energy projects are very important to get the most efficient generated energy. The price and by environmental impacts for these projects, where Solar modeling functions in GIS require data is spatially referenced with detailed elevation information in raster data format (digital elevation model or digital surface model). There are two types of digital elevation models (DEM), digital terrain model (DTM) and digital surface model (DSM). The current study concern application of digital elevation model(8 images for cover study area), as shown Figure (2) . It is found that the surface levels of the earth in Najaf city ranging between (-87 – 468) meters . The most appropriate method of solar collectors is aimed at a specific spatial area providing

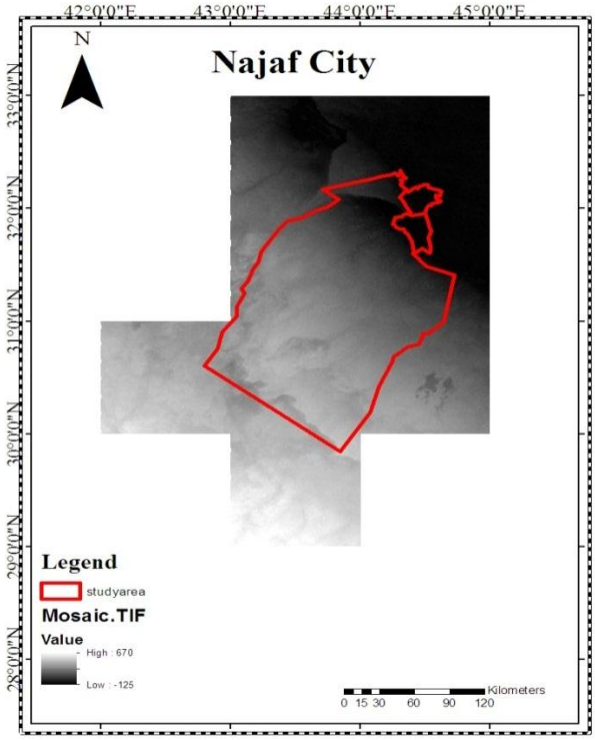
several options or alternatives to decision makers. This technique is usually applied in the GIS environment as it provides from the possibilities of data analysis and processing to display the results through several optical means. There are four ways to apply this technique : Mosaic, Clip, Kriging and Points solar radiation.

Mosaic method :

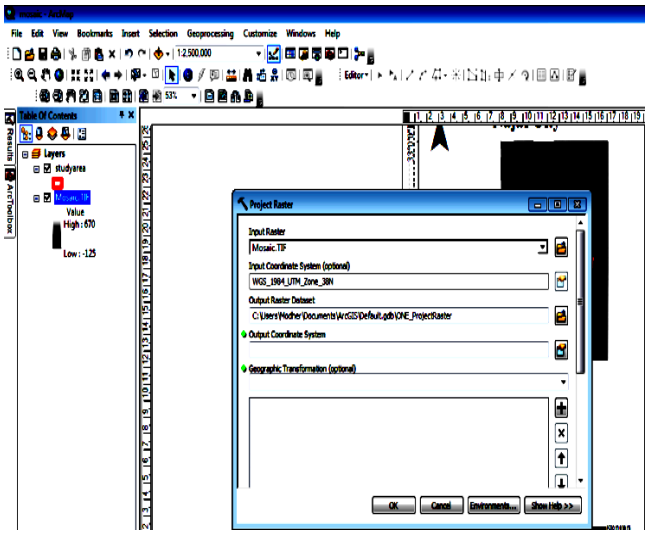
A project was created to include 8 images for a cover study area, the datum were chosen WGS-84 and convert to the projection UTM ZONE 38. The tool projections and transformations software ArcGIS10.2.2 was utilized for the processing of images, as shown Figure (3). Then, the tool mosaic (multiple input raster into an existing raster dataset) was applied to the project, as shown Figure (4).



Figure(2): Digital Elevation Model (DEM) study area.



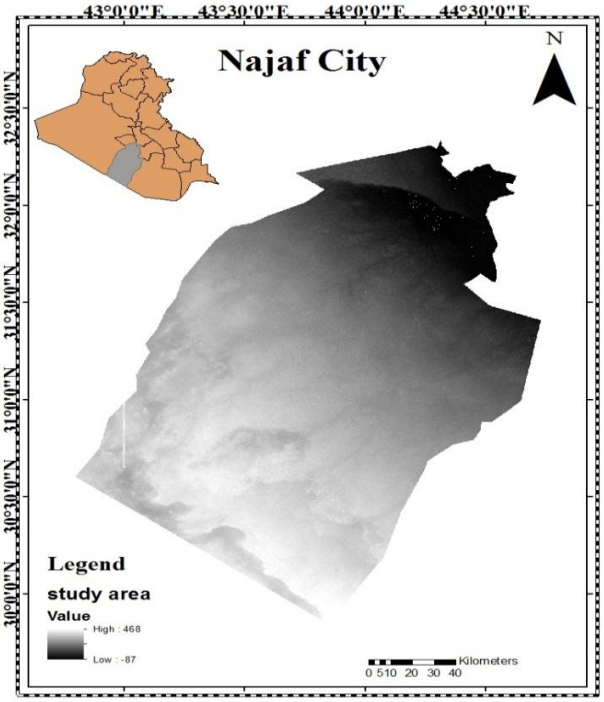
Figure(3): Process projections and transformations ArcGIS10.2.2 software.



Figure(4): Mosaic Digital Elevation Model (DEM) images.

Clip method :

This tool is to cut out a piece (raster data set) of one feature class(shape file study area). This is particularly useful for creating a new feature class—also referred to a study area or area of interest (AOI), as shown Figure (5).



Figure(5): Clip Mosaic Digital Elevation Model (DEM) images.

Points solar radiation method :

The stopped solar radiation at a given location on the earth's surface is affected by sky obstruction and surface orientation, where sky obstruction can be used to calculate for any given location by View shed models. The study of [21] is developed an algorithm for rapid calculations of stopped solar radiation using a collection of viewshed analysis and a lookup table of irradiance in each sky direction. While the work of [22] is developed a geometric solar radiation model, the Solar Analyst, which calculates insolation maps from digital elevation models (DEMs). The aims focus on its application for spatial interpolation of soil temperature measurements over complex topography at landscape scales, where algorithms depended on influences of surface orientation the upward–looking viewshed, atmospheric conditions, and elevation. The result is generated daily minimum and maximum soil temperature maps based on regression analyses.

Total of radiation calculated for a particular location as global radiation [23].

$$\mathbf{Global_{tot} = Dir_{tot} + Dif_{tot}}$$

Where:

$\mathbf{Dir_{tot}}$: Total of direct.

$\mathbf{Dif_{tot}}$: Total of diffuse.

Total of direct insolation (Dir_{tot}) for a given location is calculated:

$$\mathbf{Dir_{tot} = \Sigma\ Dir_{\theta,\alpha}}$$

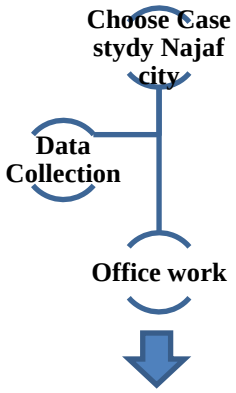
Total diffuse solar radiation for the location (Dif_{tot}) is calculated:

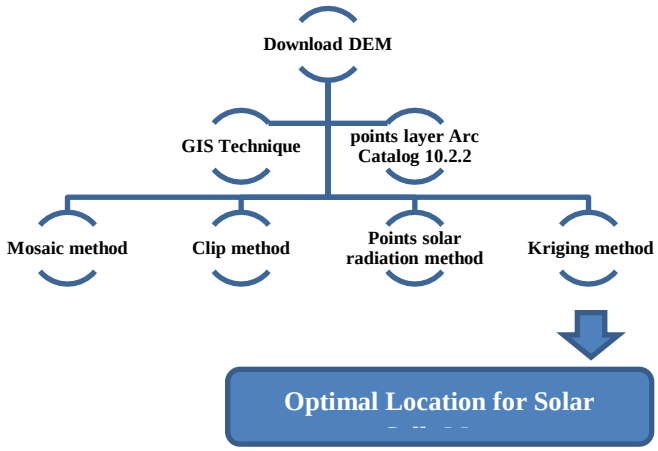
$$\mathbf{Dif_{tot} = \Sigma\ Dif_{\theta,\alpha}}$$

Kriging method :

An interpolation technique in which the surrounding measured values are weighted (solar) to derive a predicted value for an unmeasured location, where weights are based on the distance between the measured points(choose randomly to cover study area), the prediction locations, and the overall spatial arrangement among the measured points. Kriging method is the best interpolation category because of providing the precision of predictions and an easy method for characterizing the variance. In addition, it assumes that the spatial variation in the data being modeled is homogeneous across the surface.

The methodology of this research can be described in Flowchart (1) .





Flowchart (1): Schematic diagram of the methodology.

RESULTS :

Solar radiation is the driving force for the earth's physical and biological systems. Information of the amount of insolation at particular geographic locations is helpful for application in diverse fields, such as cells solar locations. Using the area solar radiation analysis, the global insolation (direct+diffuse, W/m^2) has been calculated for the entire study area, but the calculation of direct, diffuse, and global insolation are repeated for every location on the topographic surface and producing insolation maps for an entire geographic area for every month, as shown Figures (6),(7),(8),(9), (10),(11),(12),(13), (14),(15),(16),(17). Where the highest amounts of radiation are during the June months range between 6005-6377 WH/m^2 (red = high insolation; blue = low insolation).

The suitability map(15/June) was compared to the official development assistance (ODA) has been released in parallel with Global Solar Atlas - published by the World Bank Group, funded by ESMAP, and prepared by Solar GIS(1999-2015), as a shown Figure (18).In addition, it was validated that suitability map is able to inform on suitable locations for put cells solar with a satisfactory degree of accuracy.

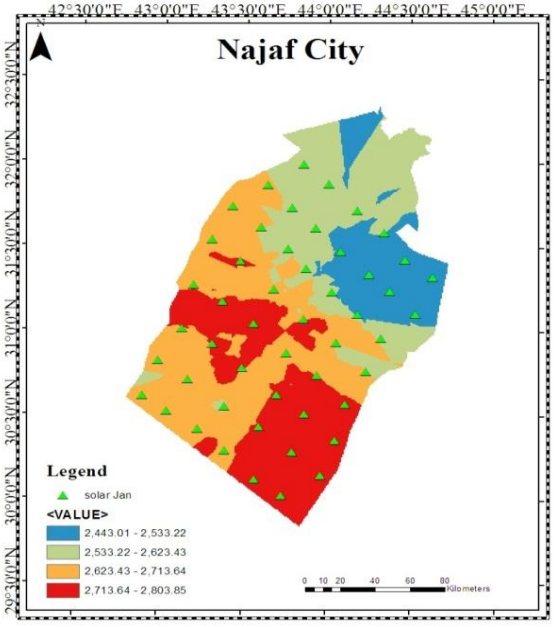


Figure (6) 15/June/2017

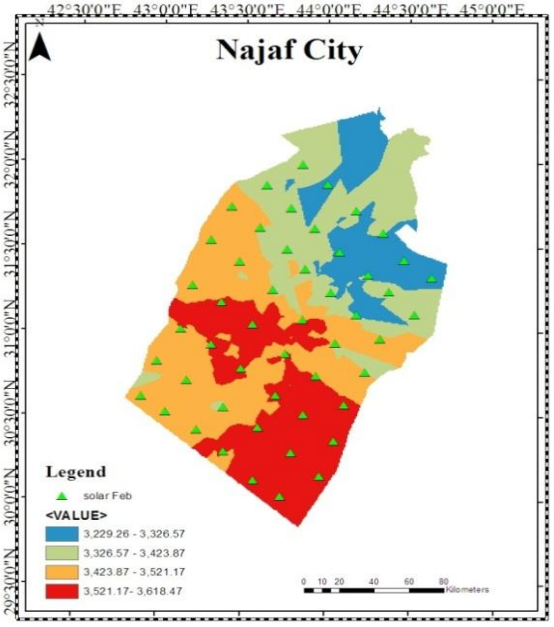


Figure (7) 15/Feb/2017

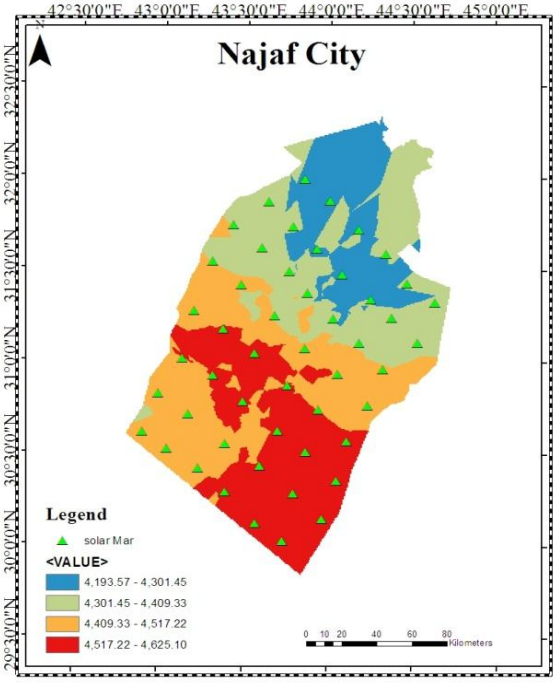


Figure (8) 15/Mar/2017

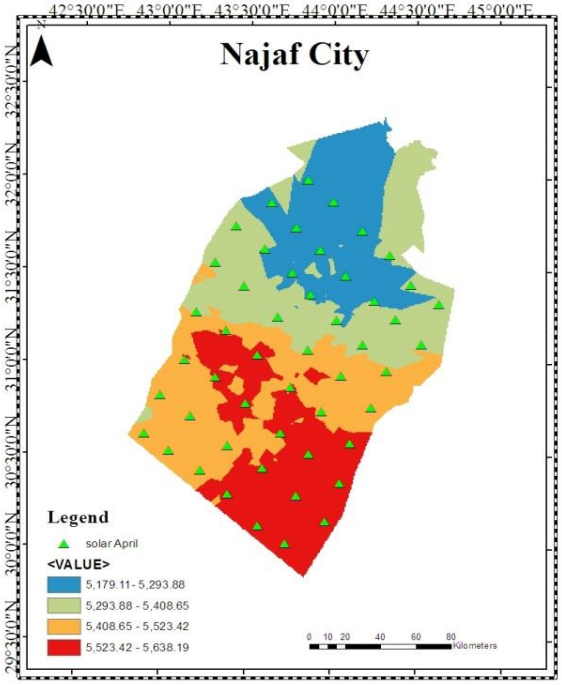


Figure (9) 15/Apr/2017

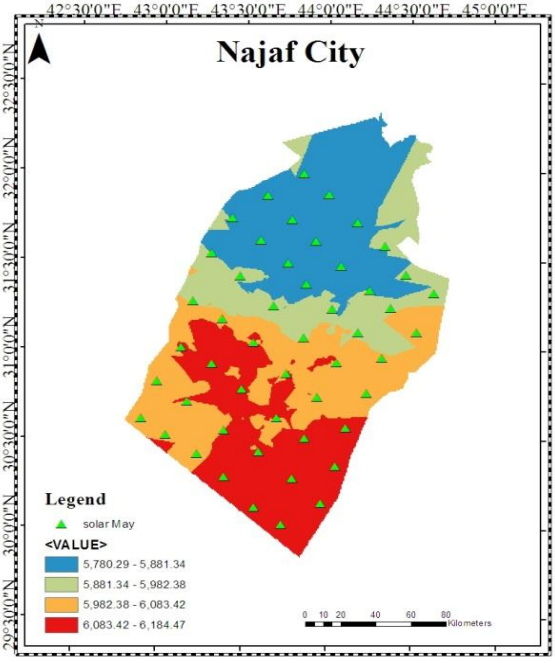


Figure (10) 15/May/2017

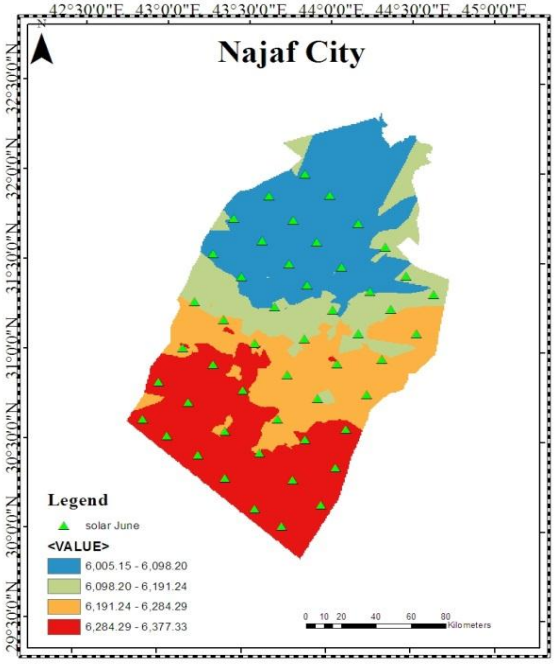


Figure (11) 15/Jun/2017

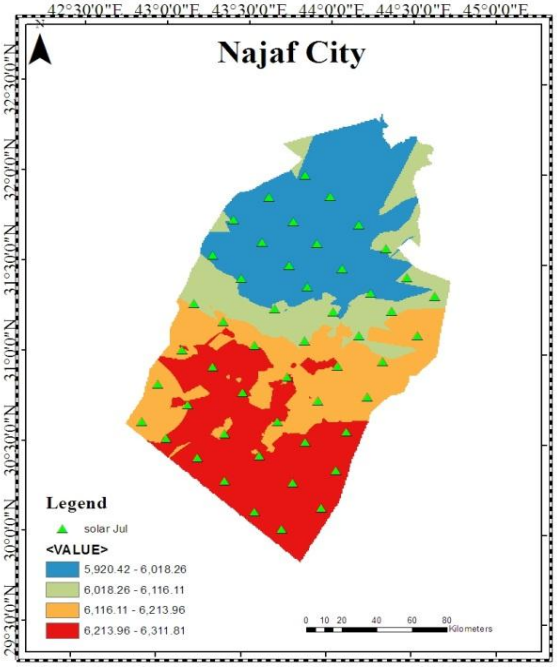


Figure (12) 15/Jul/2017

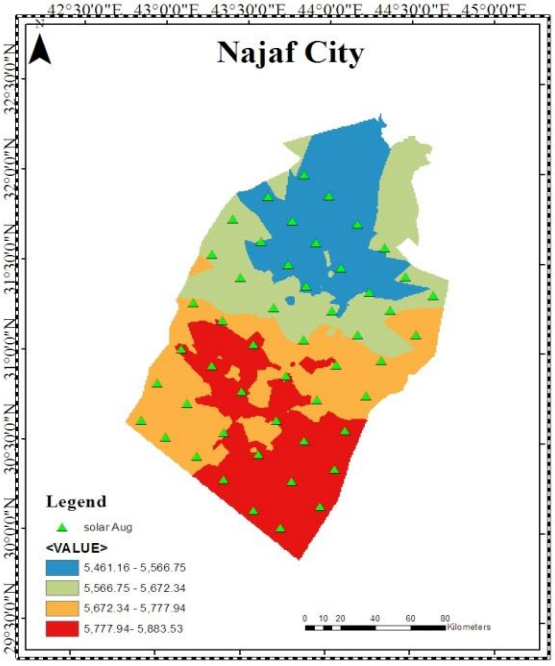


Figure (13) 15/Aug/2017

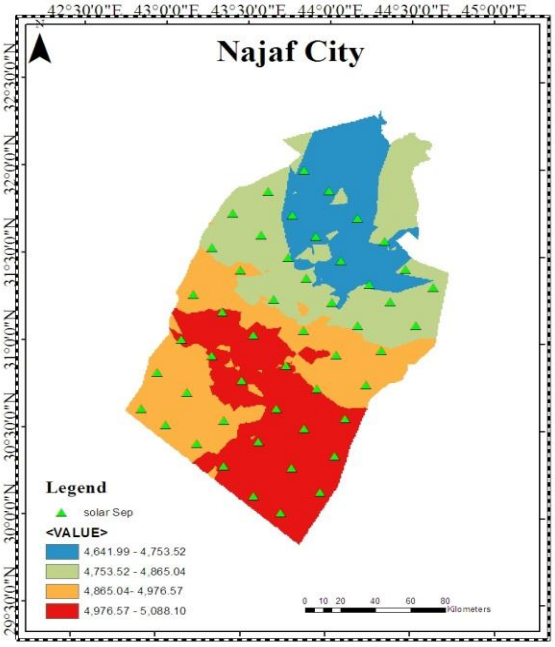


Figure (14) 15/Sep/2017

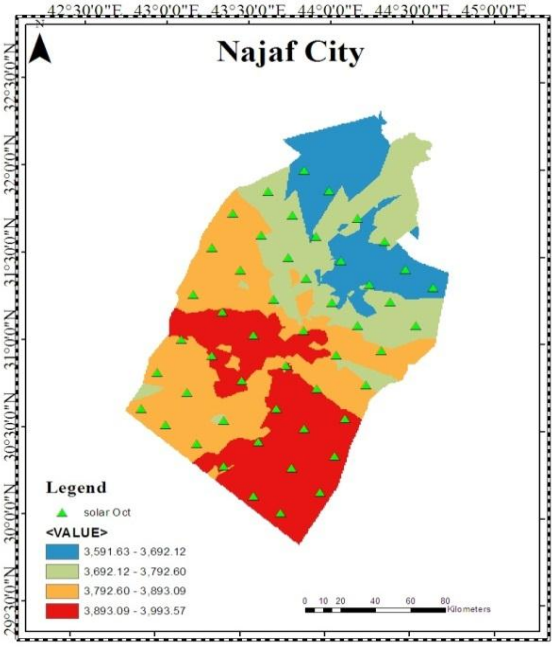


Figure (15) 15/Oct/2017

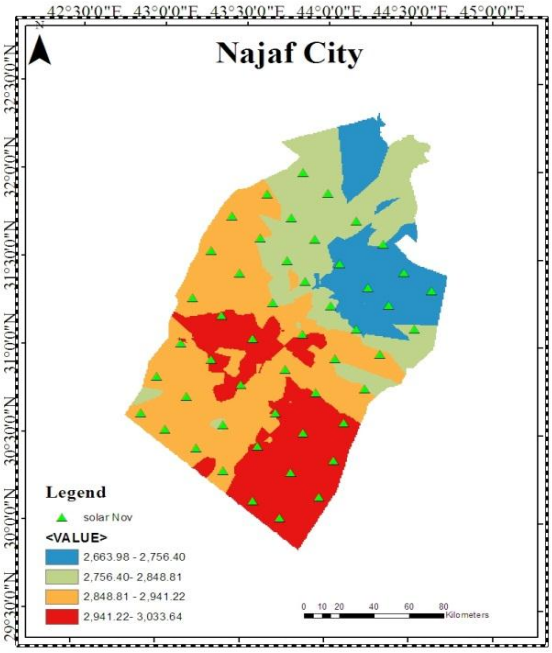


Figure (16) 15/Nov/2017

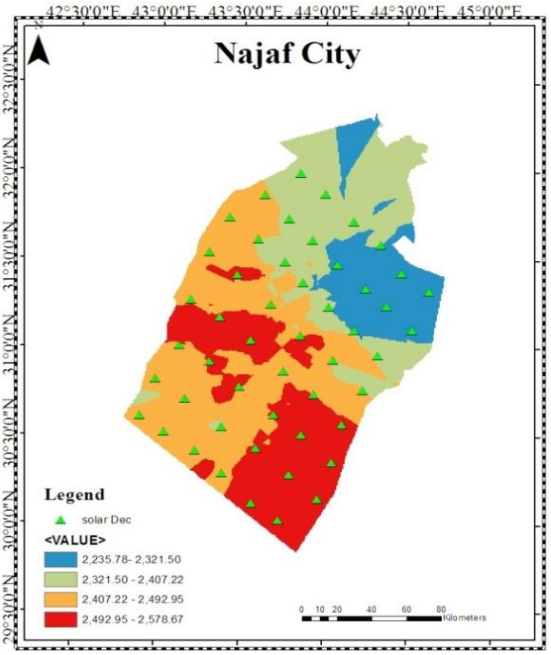
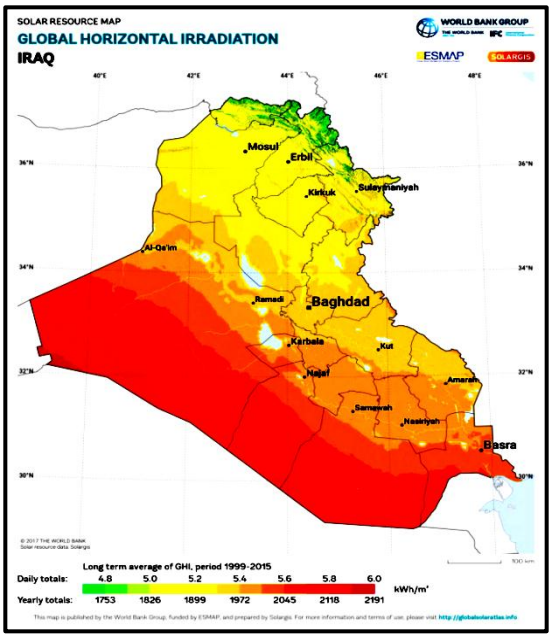


Figure (17) 15/Dec/2017

Figures (6,7,8,9,10,11,12 ,1,14,15,16,17): Insolation Maps For An Entire Geographic Area For Every Month.



Figure(18): Solar Resource Map Global Horizontal Irradiation ,IRAQ

CONCLUSIONS:

1. The analysis of GIS technique which is based only on the Metadata provided by (https://vertex.daac.asf.alaska.edu/#) with random layer points (RLP) has better accuracies with official development assistance (ODA).
2. – The stopped solar radiation model which is used to calculate the global radiation (direct and indirect), is considering the sun duration in a month with 8-hour interval.
3. The best location is chosen based on the highest global radiation (direct and indirect).

RECOMMENDATIONS:

1. An optimum location that has been developed should be taken by the decision makers to take it into

consideration for future plans within new energy projects in Najaf city.

2. The study recommends the generalization of the multi-criteria GIS technique in finding the best location for solar cells.

REFERENCE :

[1] Carfagna, E., & Gallego, F. J. (2005) Using remote sensing for agricultural statistics. International statistical review, 73(3), 389-404.

[2] Wiseman, J. R., & El-Baz, F. (Eds.) (2007) Remote sensing in archaeology. Springer Science & Business Media.

[3] Perez Gonzalez, M. E., & Garcia Rodriguez, M. P. (2013) Use of remote sensing in soil degradation. Boletín de la Asociación de Geógrafos Españoles, (61), 285-+.

[4] Colantoni, A., Delfanti, L., Recanatesi, F., Tolli, M., and Lord, R. (2016) Land use planning for utilizing biomass residues in Tuscia Romana (central Italy): Preliminary results of a multi criteria analysis to create an agro-energy district, Land use policy, No. 50, pp. 125–133.

[5] Pradhan, J. and Samanta, K. (2015) Site suitability analysis using remote sensing and GIS for proper selection of solid waste disposal ground within Rajarhat, Gopalpur municipal area, Kolkata, West Bengal, International journal of geomatics and geosciences, V. 5, No. 4, pp. 640-654.

[6] Moon, M. L., Hunt, R. F., McFall Jr, J., Pijanowski, J. A., & Price, R. D. (1978). Use of remote sensing in facility siting.

[7] Kassner, R., Koppe, W., Schüttenberg, T., & Bareth, G. (2008). Analysis of the solar potential of roofs by using official lidar data. In Proceedings of the International Society for Photogrammetry, Remote Sensing and Spatial Information Sciences,(ISPRS Congress) (pp. 399-404).

[8] Zhang, X., Walker, R., Salisbury, M., Hromiko, R. and Schreiber, J. Creating a Solar City (2009). Determining the Potential of Solar Rooftop Systems in the City of Newark. University of Delaware, Center for Energy and Environmental Policy.

[9] Santos, T., Gomes, N., Brito, M., Freire, S., Fonseca, A., & Tenedório, J. A. (2011). Solar potential analysis in Lisbon using LiDAR data. In *31st EARSeL Symposium, Prague* (Vol. 30).

[10] Tooke, T.R., Coops, N.C., Voogt, J.A. and Meitner, M.J. Tree Structure Influences on RooftopReceived Solar Radiation. Landscape and Urban Planning (2011). 102; 73-81.

[11] Latif, Z.A.; Zaki, N.A.M.; Salleh, S.A. (2012) "GIS-based Estimation of Rooftop Solar Photovoltaic Potential using LiDAR." Prepared for the 2012 IEEE 8th International Colloquium on Signal Processing and its Applications, March 23–25, 2012. Melaka, Malaysia.

[12] Bhutto, A. W., Bazmi, A. A., Zahedi, G., & Klemeš, J. J. (2014). A review of progress in renewable energy implementation in the Gulf Cooperation Council countries. *Journal of cleaner production*, *71*, 168-180.

[13] Taha, L. G. E. D., & Effat, H. A. (2015) GIS-Based Estimation of Potential Solar Energy on Flat Roofs in Maadi, Cairo, using True Ortho World View Image and Digital Surface Model. *International Journal of Advanced Remote Sensing and GIS*, *4*(1), pp-1092.

[14] Darwish, A. S., & Shaaban, S. (2016). Solar and Wind Energy–Present and Future Energy Prospects in the Middle East and North Africa. In *Renewable Energy in the Service of Mankind Vol II* (pp. 173-184). Springer, Cham.

[15] Castillo, C., Silva, F., and Lavalle, C. (2016) Assessment of the regional potential for solar power generation in EU-28, Energy policy, 88, pp. 86-99.

[16] Cradden, L., Kalogeri, C., Barrios, I. M., Galanis, G., Ingram, D., & Kallos, G. (2016). Multi-criteria site selection for offshore renewable energy platforms. *Renewable energy*, *87*, 791-806.

[17] Tahri, M., Hakdaoui, M., and Maanan, M. (2015). The evaluation of solar farm locations applying geographic information system and multi-criteria decision-making methods: Case study in southern Morocco, Renewable and sustainable energy review, No. 51, pp. 1354-1362.

[18] Matejicek, L. (2015). Multi-criteria analysis for sources of renewable energy using data from remote sensing, Presented at the 36th international symposium on remote sensing of environment, Berlin, Germany, May 11-15.

[19] Jaafar Baqir al-Mahboobah. (2008). Najaf past and present P3.

[20] Lousani, Ahmed / Khalili, Jafar. (1987).The first part of the Kadhimin section of the Encyclopedia of the Holy Saints.

[21] Rich, P.M., R. Dubayah, W.A. Hetrick, and S.C. Saving. 1994. Using viewshed models to calculate intercepted solar radiation: applications in ecology. American Society for Photogrammetry and Remote Sensing Technical Papers. pp 524–529.

[22] Fu, P. and P.M. Rich. 2002. A geometric solar radiation model and its applications in agriculture and forestry. Proceedings of the Second International Conference on Geospatial Information in Agriculture and Forestry. I357-364.

[23] Fu, P., and P. M. Rich (2000). The Solar Analyst1.0 Manual. Helios Environmental Modeling Institute (HEMI), USA.