Photovoltaic Energy Asessment Using Geospatial Technology

Deepak Kumar, Sulochana Shekhar

ABSTRACT: Now days, Geospatial Technology have become an important segment for evaluation and deployment of solar renewable energy systems, demanding close attention to issues of functionality, sustainability and usability. Whilst some research has begun to examine the functionality of Modelling & Assessment of systems but little attention has been paid. The work influences Solar Energy Modelling for Photovoltaic (PV) potential assessment for local energy management. An accurate assessment of projects requires a spatial analysis of resources, which can be most easily completed within a Geographic Information System (GIS). Methodology explains how the general Geospatial tools are used to identify and quantify these potential, constraints of these projects to enhance their efficiency. The methodology section of this paper offers insight to work the done and the ways in which other researchers can use GIS in the field of Solar Energy. When it comes to sound energy management, conservation is always top priority. At the Regional Peel, we recognize the reducing energy use helps to save money, decrease the need for additional power generation and best of all — it helps to protect our environment. This paper describes for solar energy assessment modelling using GIS and its application to the regional scale. It also explains the value of GIS for renewable energy resources problems and suggests the use of the tool for energy supply- demand matching.

KEY WORDS: Incident Solar Radiation, Photovoltaic (PV), Object Relational Database (ORD), Geostatistics, Energy Spatial Data Infrastructure (ESDI), Climatological Solar Radiation.

1. INTRODUCTION

Solar energy is an abundant source of renewable & viable energy having an enormous potential to reduce greenhouse gases foot print. Solar Energy or power explicitly refers to the conversion of sunlight into electricity by photovoltaic's (PV), concentrating solar thermal devices or by various experimental technologies. Quantifying and modelling of broadband solar radiation is important for the evaluation and deployment of solar energy systems. Solar energy technologies comprise various applications like architecture and urban planning, agriculture and horticulture, Solar thermal and Electricity. Solar energy is used to provide electricity to homes, businesses, schools, universities and space vehicles. Furthermore its use is growing at a rate of 25 per cent a year due to traditional energy price rise.The society of the 21st century is often called information society. A large number of decisions in our daily life made by governmental, non-governmental organizations and by individuals are based on geospatial information. Nevertheless, especially in developing countries, we can observe a lack of spatial information. A well-known adagio is *'Geography matters'* and it is certainly true, however when it come to the need to have methods and techniques available to deal with increasingly availability of data required everywhere, being north or south. All locations will find huge amounts of data which often are inherently ill-defined, and lacking methods to cope with the questions asked. Addressing these issues requires strategies and tools that enable a multi perspective, collaborative approach- bringing wide-ranging expertise to deal with complex, disparate geo-data sources.

1.1 Geospatial Technology

Geospatial Technology or Geo-Informatics is a hi tech branch of Geo science which deals with the information technology to improve the organization and access of geoinformation to geographers, geologists and engineers. By applying collected data and developing complex models based upon these data, geoinformatics can be used to advance both geoinformatics and engineering to deal with many of the problems of these sciences. Geoinformatics technology includes geographic information systems, spatial decision support systems, global positioning systems (GPS), image processing and remote sensing. Geo Informatics uses geo-computation for analysing geo information, which includes tools include:

- An object-relational database (ORD) or object-relational database management system
- Object-relational mapping (or O/RM)
- Geostatistics

A Geospatial Technology also familiarises GIS as a technological tool to capture, manage and help the all forms of geographic reference data analysis to facilitate informed decision making. It integrates and presents the geographical data as per specific project requirements. GIS is also a supportive tool for renewable energy assessment, which is currently used as decision support tool in regional renewable energy management. With our nation's increasing use of technology, expanding industrialization and urbanization towards our demands for goods and services, we're increasing our demand for electricity. As a result, our fossil fuel consumption is increasing and our natural resources are deteriorating. Transitioning to a more sustainable use of our resources and development may require tapping into renewable energy for electricity generation, which can include wind, solar, hydro, and bioenergy. It also reduces our fossil fuel demand and could increase our energy independence and security. For such reasons, the implementation of these projects is becoming more common and attractive in energy policies. In many cases, of economically feasible project with minimal land use impacts, encompasses the threat of public acceptability. Incorporating the analytical assessment modelling tools of the GIS for renewable energy projects for local and regional decision makers to enable more informed decisions and increased integration of renewable energy technologies to our electric grid. Hydroelectric energy resources management was the first Renewable Energy to take advantage of GIS capabilities. Biomass energy is also integrated in land use and Agricultural Resources Management. Some methods to assess Wind and Solar Resources have been developed and applied in different countries and with the availability of geological and hydrologic maps lead to the use of GIS in geothermal resources as well. GIS mapping continues to play a critical role in renewable energy planning. It's ability gives project planners to identify optimal sites for renewable energy production and assists project planners towards probable future complications to provide valuable service to the renewable energy industry.

1.2 Renewable Energy

The choice among different renewable energy technologies provides an energy services based on the analysis of the best linkage within local renewable energy sources (RES), technical aspects of each renewable energy technology including the specific characteristic of the Energy Demand. Most variables related to distribution of linked space and time have geography as their organizing principle. Many sustainability linked variables (if extrapolated) have geography as their primary driver such as:

- sources of renewable energy (solar, wind, biomass, tides, geothermal etc.),
- logistics (timing and pattern of resource availability and consumption),
- Climate change (rainfall, floods, drought, etc.)

1.2.1 Why Solar Energy

- The amount of sunlight that hits the earth's surface in one hour is enough to power the entire world for one year.
- Solar PV costs have declined dramatically due to widespread adoption, economies of scale and technology advances.

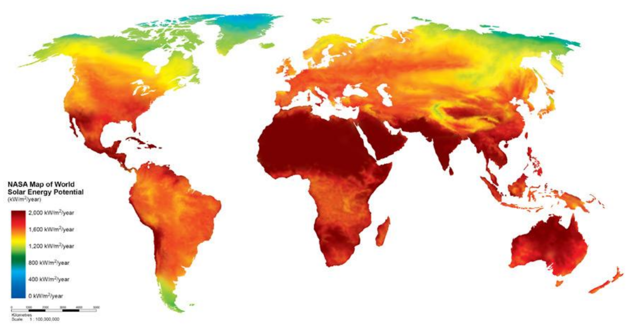


Figure 2: World Solar Energy Potential Map

1.2.2 Solar Energy Breakdown

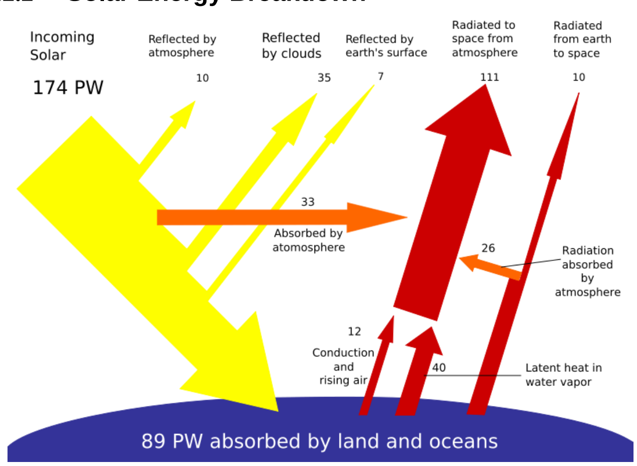


Figure 3: Solar Energy Budget

1.2.3 Spectral curve

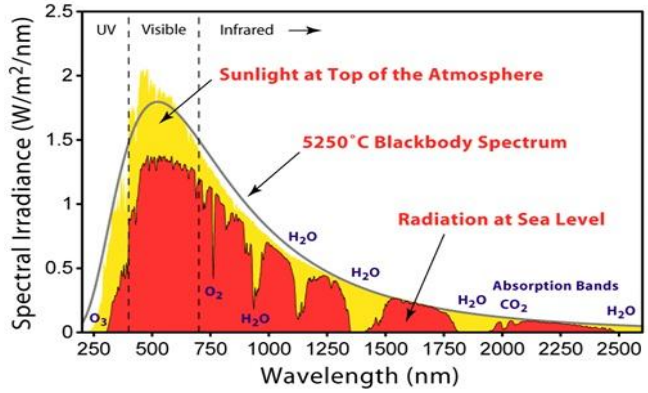


Figure 4: Spectral Bandwidth of Solar Energy

1.3 Modelling

A scientific activity wishes to make a particular part or feature of the world easier to understand, define, quantify, visualize, or simulate. It requires selecting and identifying relevant aspects of a situation in the real world to use different models for different aims, like a conceptual models for better understand, operational models to operationalize, mathematical models to quantify, and graphical models to visualize the subject. It is an essential and inseparable part of scientific activity, and many scientific disciplines have their own ideas about specific types of modelling. There are also an increasing attention to modelling in fields such as philosophy of science, systems theory, and knowledge visualization. There is growing collection of methods, techniques and meta-theory about all kinds of specialized scientific modelling.

1.3.1 Why Modelling and Types of Models

Modeling facilitates the fundamental and quantitative way to understand and analyses the complex systems and phenomena. It is often used in place of experiments when experiments are too large, too expensive, too dangerous, or too time consuming. These are complement to theory and Experiments, and often integrate them. These are becoming popular in the field of Computations, Earth and Space System Modeling. There are various types of model which are being used for different purposes but generally we refer to following types of models:

- **Deterministic/Mathematical Model**
  (Model in which outcomes are precisely determined through known relationships without any room for random variation and allows to make predications of y based on x. For example $y=2+3x-0.4x^2$).
- **Stochastic/Probabilistic Model**
  (Use ranges of values for variables in the form of probability distributions.)

1.4 Modelling Framework

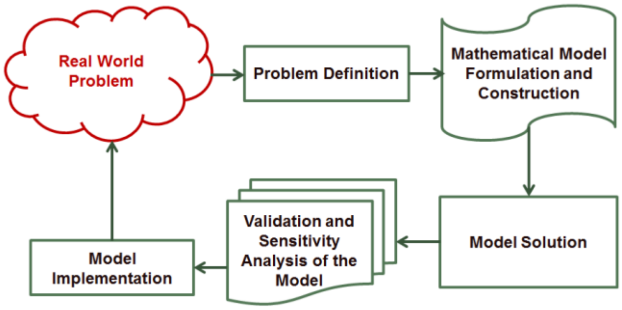


Figure 5: Schematic for Modeling Framework

1.5 Aims & Objectives

The aim of this effort series is to carry out operational research to develop model for ascertaining scope of solar energy modeling for managing energy associated issues using spatial analysis. It is also intended to identify the prospects of geospatial technology to provide expertise, advice and quality assurance for decision making to enhance analysis aspects. The current work will focuses towards the global and local energy utilities of communities, individuals and organizations engaged in the geospatial aspects of the planning, delivery, operations, reliability and ongoing management of electric, gas, oil and water services throughout the world in the domain of GIS framework. This facilitates information exchange and collaboration between agencies and industry. The set of objectives in order to meet these goals are:

- To model and estimate the incoming solar radiation.
- To delineate the feasible zones of solar energy.
- To assist decision makers for societal applications of solar energy.

2. DATA AND METHODS

In the past, theoreticians have tended to deploy hierarchical models for estimation and investigation in spatial processes. The underlying stochastic processes inherent in these methods of spatial analysis deals with analysis, modeling and estimation procedures to take account of geographical (spatial) relationships.

2.1 Study Ares

The study area for this research has been selected at Central University of Karnataka (CUK) Campus in Karnataka state. It has 621 acres of land at Kadaganchi Suntanur villages and lies on the Gulbarga- Waghdhari Inter-State Highway in Aland taluka. The Geographical extend is confined roughly within 17°41’ N and 17°44’ N latitudes and 76°65’ E and 76°68’ E longitudes and lies in the North-Western part of the Gulbarga City.

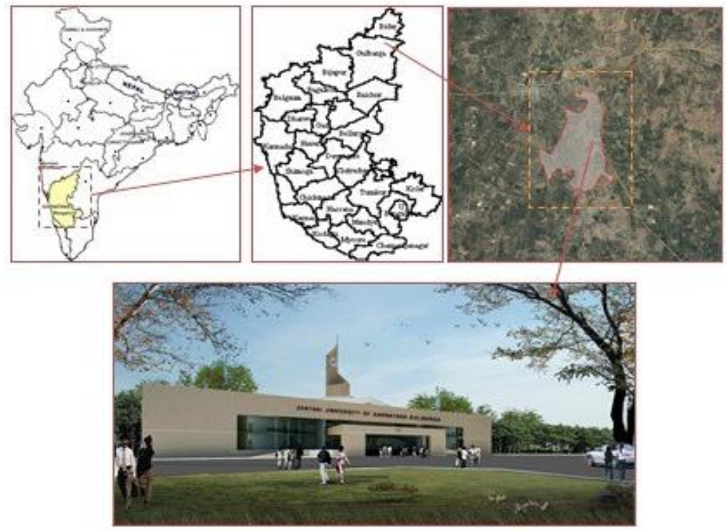


Figure 5: Location of Study Area

2.2 Datasets Used

- Satellite Imagery
- Topographic Information.
- Survey of India Toposheet.
- DEM Data.
- Ancillary data for validation
- India Meteorological Department weather Data

2.3 Applications used

- ArcGIS 10.x (especially Solar Analyst)
- NREL Geospatial Toolkit
- Homer Analysis Tool
- Energy Plus 8.0
- PV Studio 5.0

2.4 Methodology

2.4.1 Solar Radiation Modelling Outline

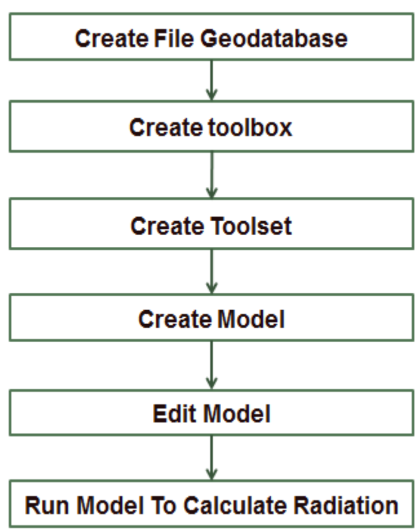


Figure 7: *Solar Radiation Modelling Framework*

2.4.2 Area Solar Radiation Model Creation

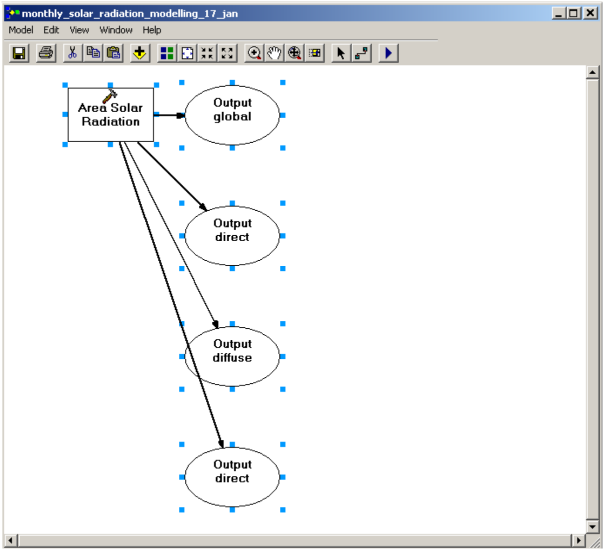


Figure 8: *Model Building for Area Solar Radiation*

These builds a toolbox to calculate solar radiation within a given area in terms of Wh/m^2.This setup deals for assessing the amount of solar radiation at a patch of area under different restrictive bearings and set ups.

2.4.3 Point Solar Radiation

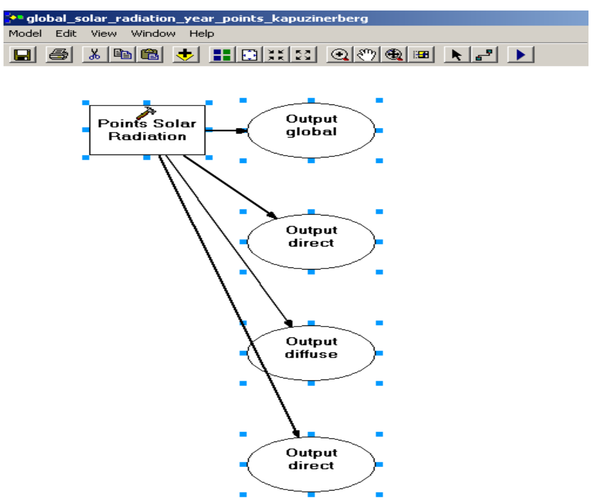


Figure 9: *Model Building for Point Solar Radiation*

This phase introduces the modelling framework to assess the amount of solar radiation available at particular point or location. These model also creates a toolbox to calculate the solar radiation at different points with different set of constraints.

2.5 Solar Energy Assessment Modelling Within GIS

- Enables to map and analyze the effect of the sun over a geographic area for specific time periods.
- It accounts for atmospheric effects, site latitude and elevation, steepness (slope) and compass direction (aspect), daily and seasonal shifts of the sun angle, and effects of shadows cast by surrounding topography.
- The resultant outputs can be easily integrated with other geographic information system (GIS) data and can help to model physical and biological processes as they are affected by the sun.

2.2 Solar Radiation Analysis

The solar radiation analysis tools calculate insolation across a Landscape or for specific locations, based on methods from the Hemispherical view shed algorithm developed by Rich et al. (Rich 1990,Rich et al. 1994), as further developed by Fu and Rich (2000, 2002). The total amount of radiation calculated for a particular location or area is given as global radiation. The 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.

▪Global radiation calculation

Global radiation ($Global_{tot}$) is calculated as the sum of direct (Dir_{tot}) and diffuse (Dif_{tot}) radiation of all sunmap and skymap

sectors, respectively. $\mathbf{Global_{tot} = Dir_{tot} + Dif_{tot}}$

With respect to the above-mentioned environment, a working model for the study has been designed and shown to develop a GIS based solar energy management.

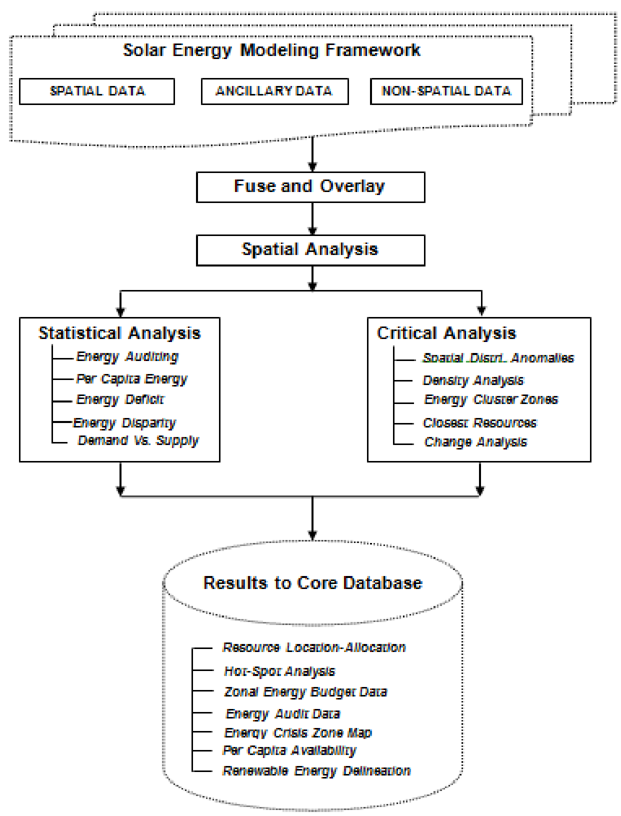


Figure 6: *Layout of Solar Energy Modelling Framework*

2.3 Spatial Pattern Analysis: Mapping Trends and Clusters
These tools can helps us to summarize and evaluate geographic distributions, identify statistically significant spatial outliers and clusters (hot spots), to assess broad geographic patterns and trends over time. These resources helps to find patterns and relationships in the data, facilitating discussion, contributing to research, and decision making.

2.4 Finding Cluster
Using analysis, we can feel confident in the spatial patterns we see, and in the decisions that we make. Putting the data on a map is an important first step for finding patterns and understanding trends. Looking at the points on a map, we can find the clusters or patterns in this point data. We can decide where the department should allocate its resources, but just looking at points on a map is often not enough to answer questions or make decisions using this kind of point data. That's where the spatial analysis tools in GIS come in.

3. RESULTS AND ANALYSIS
This section deals with archiving and recording of the experimental results obtained through the developed prototype or model. These results obtained, explains to the questions posed to fulfill the objectives. The prototype architecture being developed may be used for scientific research work for detecting and delineating precise boundaries from the input set of data for analysis to derive the results in graphical, pictorial or tabular format to assist or handle energy related adversities. Finally the perceived outlines are estimated and discussed. The significant outputs being generated are as follows:

- Area Under Solar Radiation
- Feasible Solar radiation regions.
- Amount of isolation being received.
- Points solar radiation.
- Solar Radiation Graphics.

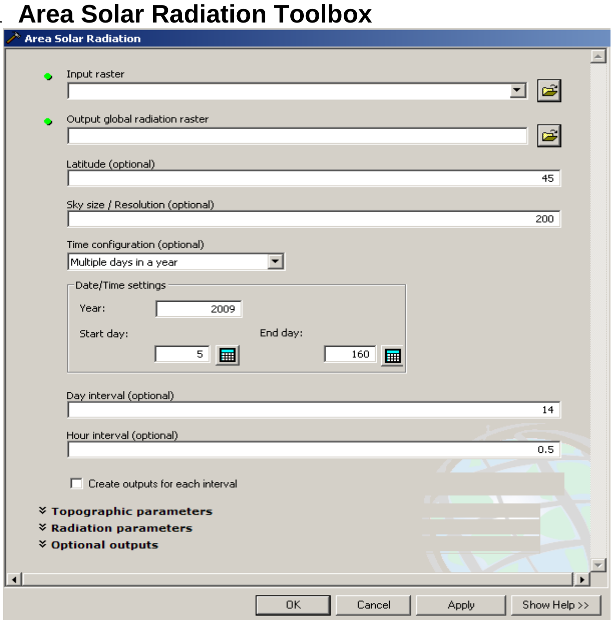
3.1 Area Solar Radiation Toolbox


Figure 10: Area Solar Radiation Window

Input: Digital Elevation Model grid (X m)

Output: radiation raster's (watt hours per square meter), duration (hours)

Diffusion proportion: the proportion of global normal radiation flux that diffuse (0.3 generally clear sky conditions

Transmittivity: the fraction of radiation that passes through the atmosphere (0 – no transmission, 1 – transmission; 0.5 – generally clear sky)

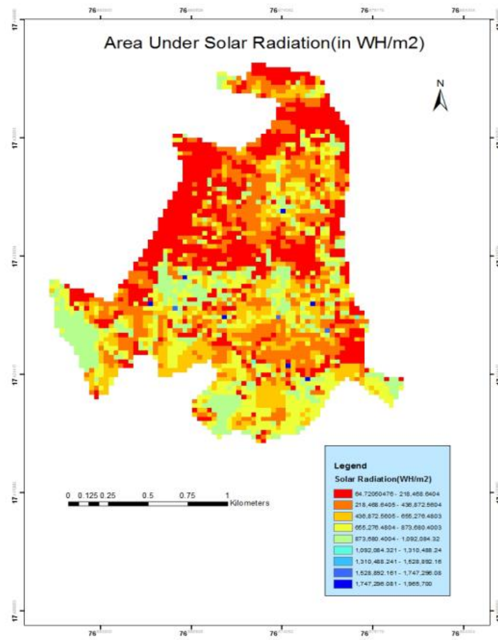


Figure 11: Sample Output Using Area Solar Radiation Tool

The result obtained shows the spatial distribution and variation of solar radiation in the shown area.

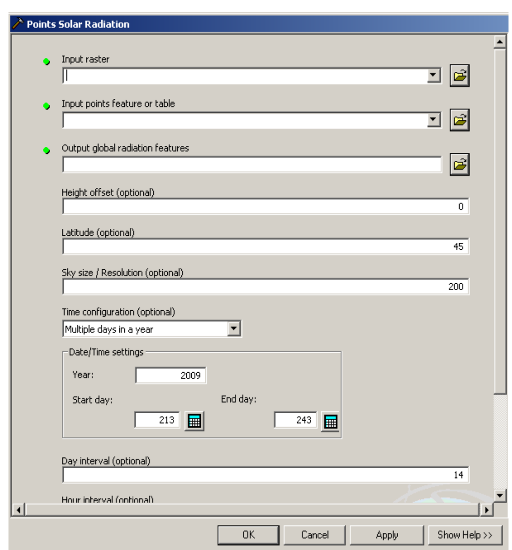
3.2 Point Solar Radiation Toolbox


Figure 12: Point Solar Radiation Window

Input: Digital Elevation Model grid (X m) & Example points

Output: global solar radiation on the example points

Attributes of glob_su...

FID	Shape	T0
2	Point	74233.926637
3	Point	133770.247377
1	Point	135854.956065
0	Point	142733.609872

Record: 0

Attribute Table: T_0 … value of solar radiation at specific points in Wh/m²

Figure 13: Sample Output Using Point Solar Radiation Tool

4. FUTURE WORK

To get started on the road to energy conservation, we need to take a look on energy saving tips which feature several practical, easy to implement efficiency measures.The emerging use of mapping to support energy decision-making, among both communities and utilities, underscores the need for web-based communication of geospatial data for interoperable geospatial processing queries and responses. It also requires the construction of a "nervous system" that connects the diverse set of parties involved in energy decision-making to advance the concept of an "Energy Spatial Data Infrastructure" (Energy SDI) that would inform planning and management. The structural prototype module needs to be developed and tested with feedback for design and develop a functioning system. This will also aid in presenting the overall advantages of utilizing the concept for energy management. A pilot project needs to be framed or customised to respond to an assumed scenario. A software and database model need to be also developed based on the concept in prototype model. The major objectives of this pilot work may consists:

- to develop a practical model from conceptual model;
- to test the system and gain feedback for the design and development of a real functioning system;
- to present the overall structure, concept and advantages of developing such a system;
- and to present the advantages of utilizing the model in developing a support system for energy related issues.

5. CONCLUSIONS

Solar energy is an alternative source of renewable energy that is non- polluting and can be easily converted into electricity through the usage of photovoltaic (PV) systems. It signifies an important source of energy for the environment, reducing the risks for climate change by helping to mitigate fossil fuel emissions and dangerous greenhouse gases, in particular, carbon dioxide. In order to encourage the implementation of PV systems for alleviating the huge demands of the electrical grid.Solar Energy is competitive, economic alternative to all form of the energy. The key to success is long lifetimes and require minimal maintenance. Creates local jobs and promotes economic development in rural areas. Avoids the external environmental costs associated with traditional technologies. The numerous applications of solar energy technology includes:

- Architecture and urban planning
- Agriculture and horticulture
- Solar lighting
- Solar thermal (water heating, cooling and ventilation, desalination and disinfection, cooking, process heat)
- Solar electricity (photovoltaic's, concentrating solar power, experimental solar power)

6. ACKNOWLEDGMENTS

The author would like to acknowledge the research grant received from DST-INSPIRE Division, Ministry of Science & Technology, Govt. of India for carrying out full time PhD research work. Author is also thankful to the faculty members of the Department of Geography, Central University of Karnataka for providing valuable inputs. Special thanks to DKD for being continuous source of inspiration to carry out the contemporary work.

References

[1]. Bangemann, M. 1994. Europe and the Global Information Society:Recommendations to the European Council, May, 1994. Office for official publ of the European Union.

[2]. Brand, M J D. 1995. The European geographic information infrastructure (EGII). Paper presented at the ESIG conf, 27-29 Sept 1995, Lisbon, Portugal.

[3]. Burger, R. 1993. Information Policy: A Framework for Evaluation and Research. Ablex, Norwood, NJ.

[4]. Chorley, Lord Roger. 1987. Handling Geographic Information,

[5]. Report of the Committee of Enquiry chaired by Lord Chorley. HMSO, London.

[6]. Committee on Science, Engineering, and Public Policy, "Policy Implications of Global Warming,"

pp. 620�628 (Washington, DC: National Academy Press, 1992).

[7]. Coopers and Lybrand. 1996. Economic Aspects of the Collection,Dissemination, and Integration of Government's Geospatial Information. A report arising from work carried out for the Ordnance Survey, publ by Ordnance Survey, Southampton, UK.

[8]. Dutton, W H (ed). 1996. Information and Communication

[9]. Technologies, Visions and Realities. Oxford Univ Pr, Oxford, UK.

[10]. Estes, J E (ed). 1994. Report of the International Symposium on Cotre Data Needs for Environmental Assessment and Sustainable Development Strategies. Vols 1 and 2, 15-18 Nov 1994, Bangkok,Thailand.

[11]. Hannes Jonsson, Friends in Conflict (London: Hurst & Co., 1982); <http:// gurukul.ucc.american.edu/ted/ICEFISH.htm>.

[12]. Kirill Ya Kondratyev, Climate Shocks: Natural and Anthropogenic (New York: Wiley, 1988).

[13]. Groot, R. 1993. Making IT work. ITC J 1993-3, pp 228-235.

[14]. Hernon, P. 1989. Discussion forum: national information policy.Gov Info Quarterly 6, 3, pp 229-236.

[15]. Juan Carlos di Primio, "Data Quality and Compliance Control in the European Air Pollution Regime," in The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice, David K. Victor, Kal Raustiala, and Eugene B. Skolnikoff, eds., pp. 283�303 (Cambridge: MIT Press, 1998).

[16]. Kenneth E. Boulding, Conflict and Defense: A General Theory (New York: Harper, 1962).

[17]. Leo Szilard and Barton J. Bernstein, The Voice of the Dolphin and Other Stories (Stanford: Stanford University Press, 1992).

[18]. Mapping Sciences Committee. 1990. Spatial Data Needs: The Future of the National Mapping Programme. National Research Council, National Acad Pr, Washington DC, USA.

[19]. Mapping Sciences Committee. 1995. A Data Foundation for the National Spatial Data Infrastructure. National Research Council,National Acad Pr, Washington DC, USA.

[20]. Netherlands Commission for Geodesy. 1995. Wat is waar? Reflections on the Role of Geodesy as a Science of Spatial Information and the Desirable Developments of the Field in the Netherlands. Sub-commission National Geodetic Plan, Publ 31, Delft, The Netherlands.

[21]. Peter H. Gleick, "Water and Conflict: Fresh Water Resources and International Security," International Security 18, 1 (1993): 79�112.

[22]. Rajabifard, A., Feeney, M., and Williamson I.P. (2002). Future Directions for the Development of Spatial Data Infrastructure, Journal of the International Institute for Aerospace Survey and Earth Sciences, ITC, Vol. 4, No. 1, The Netherlands, PP 11-22.

[23]. Shirley Oakes Butler, "Owning Antarctica: Cooperation and Jurisdiction at the South Pole," Journal of International Affairs 31 (1977): 35�52.