Solar Energy Planning Using Geospatial Techniques and Big-Data Analytics

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Abstract:

The objective is to calculate the solar potential of Uttarakhand in a cloud computing environment using Perl and GIS. Citrix XenCenter, a bare-metal hypervisor has been used to create the cloud computing environment. The GHI data of few locations have been obtained from the NREL website and Pyranometer. Perl programming has been used to convert the GHI on the tilted surface to get the maximum quantum of the solar irradiance falling on the solar PV at that location. These solar resource maps are useful for the people, organizations, and government for PV installations, energy planning, energy banking, energy trading, and subsidies.

Keywords: photovoltaic, big data, solar energy, remote sensing

1. Introduction

The smart monitoring device has been developed for solar plant management using IoT, sensors to provide data analytics, SPV control, and detect faults (Spanias, 2017). Integrated Information System has been created for environmental monitoring and management by utilizing the latest technologies such as IoT, Geoinformatics, big data, and cloud computing (Fang et al., 2014). IoT has been used by many research for the solar potential assessment, management, and monitoring purpose with the application of remote sensing, GIS, big data and cloud computing (Escolar et al., 2014; Hu et al., 2015; Markovic et al., 2013; Sharma, 2016). Aeris IoT services provide solutions for the maintenance for the solar power projects using both GSM and CDMA connectivity including 2G, 3G, and 4G LTE (Hermann et al., 2014; Kapoor and Garg, 2021; Litjens et al., 2018; Mohseninia, 2017; Mulder, 2014; Ranganadham, 2018; Saran et al., 2015). Researchers have used solar irradiance (NASA), and land use dataset (European Space Agency) to perform the solar irradiance analysis (Kapoor and Garg, 2021; Teluguntla et al., 2018; Yingzi and Yexia, 2019).

The objectives of this study are as follows: Estimation of the solar energy available in Uttarakhand, India using tilted GHI, reflected and diffuse irradiance and Integration of the technologies such as ML, MapReduce, cloud computing, and Geoinformatics to prepare solar potential estimate annual maps.

2. Study area and data used

The study area selected for this study is Uttarakhand state located in the northern part of India with geographic extent as 28°43’ to 31°27’ N latitude and 77°34’ to 81°02’ E longitude covering an area of 53,883 km2. (Roy et al., 2016). It has a forest cover of 34,666 km2 i.e. 65% of the total area (Wikipedia, 2019). Uttarakhand is sharing its boundary with International countries such as Nepal (east), China (north), and Indian states Himachal Pradesh (west) and Uttar Pradesh (south). The population of Uttarakhand is increasing at a fast rate from 1.03 crores (2011) to 1.15 crores (2018) (Census, 2011). Therefore it is very crucial to estimate the available means of renewable sources i.e. solar energy for the means of agriculture, industry and institute usage.

3. Methodology

In this study, the SPV feasibility study has been performed to identify if the solar energy projects are appropriate or not. To analyze this energy requirement and accurate solar potential of the location are required. The methodology for the task has been described using the flow chart in Figure 1. This methodology has been divided into four subtasks such as energy demand analysis. In the first subtask, energy requirements analysis has been performed. To estimate the energy requirements of the location such as tehsil, city, and state, the per capita energy consumption is a very important factor in assessing the energy requirements. In this study, the energy consumption has been estimated with the help of the census 2011 data, per capita energy consumption, a number of fans, bulk, irrigation pumps, etc. (Census India, 2011; Kapoor and Garg, 2018a; Xiong et al., 2017). The other subtask of calculating the optimum tilt angle and tilted GHI has been performed using Perl script (beam irradiance (Hb), diffuse irradiance (Hd), tilt factor for beam irradiance (Rb), tilt factor for diffuse irradiance (Rd), and tilt factor for reflected irradiance (Rr)) in the Hadoop Cloud Computing environment. The optimum tilt angle has been obtained on getting the maximum irradiance value at the tilted surface. Satellite images of Landsat-8 and Sentinel has been used to classify the Uttarakhand area with the application of Classification And Regression Trees (CART) for Machine Learning (ML) in Google Earth Engine (javascript) (Chen et al., 2017; Dong et al., 2016; Gorelick et al., 2017; Huang et al., 2017; Johansen et al., 2015; Lee et al., 2016; Liss et al., 2017; Liu et al., 2018; Mutanga and Kumar, 2019; Padarian et al., 2015;

Patela et al., 2015; Shelestov et al., 2017; Shetty, 2019; Teluguntla et al., 2018; Xiong et al., 2017; Yang et al., 2018; Zurqani et al., 2018).

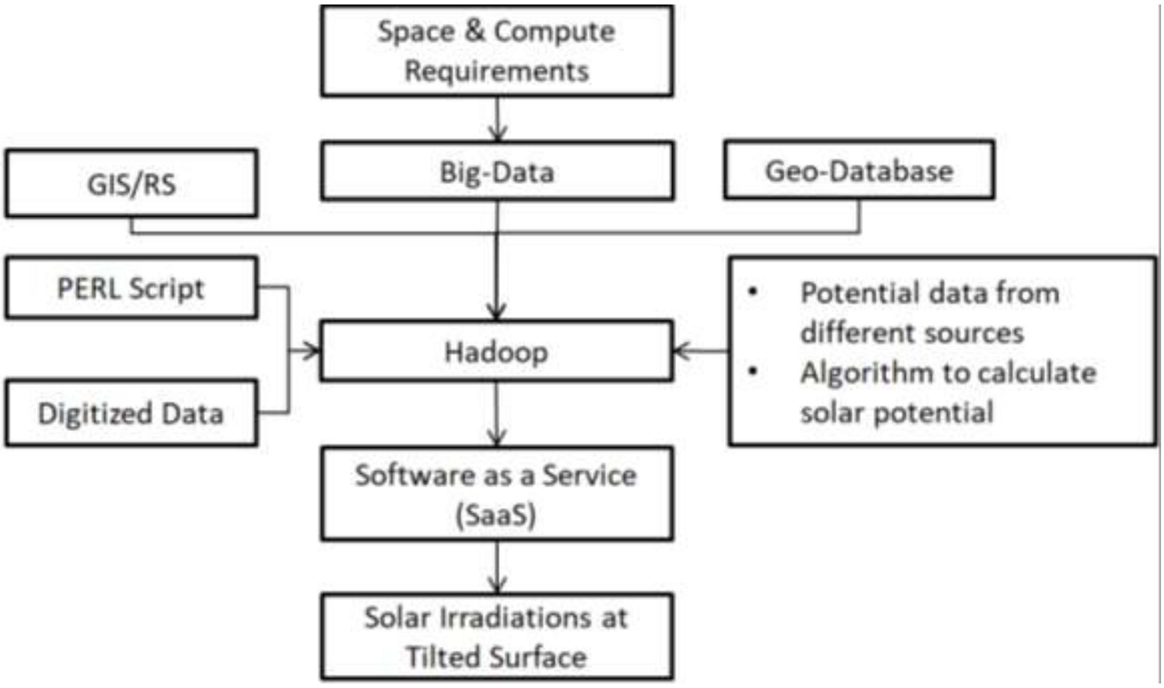
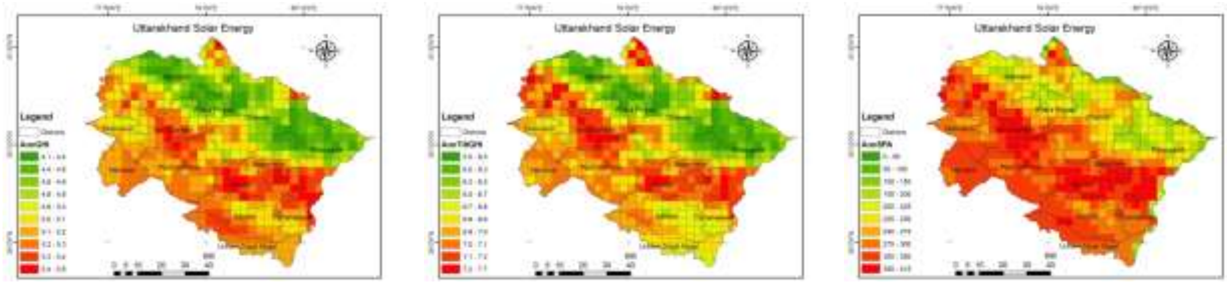


Figure 1. The methodology adopted for the study

India Census 2011, and socio economic data have been applied to estimate the energy requirements of the institute (Badenko et al., 2013a, 2013b; Kapoor and Garg, 2018a, 2018b; Xiong et al., 2017). These datasets have been best considered to be processed in the big data platform using Hadoop and solar potential has been estimated.

4. Results

The Perl programming script has been developed to calculate the tilted GHI at the tilt angles over Uttarakhand. The parameters such as a number of days, latitude, time of the day, tilt angle, and GHI have been used for converting GHI into tilted GHI. The outputs have been obtained on the console as well as text file containing all the calculated parameters. The output file shows the input and out parameters considered for this research obtained as a result of modified tilted GHI algorithm (Sukhatme and Nayak, 2008).



(a) (b) (c)

Figure 2. Uttarakhand annual average of (a) GHI (kWh/m2/day) (b) Tilted GHI (kWh/m2/day) (c) SPA (kWh/day)

5. Conclusions

The annual and monthly maps of GHI, tilted GHI, and SPA are the rich resource for the assessment of the individual and organizations for the feasibility of the small and huge solar projects. The average annual tilted GHI maps show the variation from the minimum of 5.523 to 7.633 kWh/m2/day. The optimum tilt angles for all the grids of 10 x 10 km vary from 18.8° to 21.5° for the selected study area. This tilt angle is an important parameter for the installations of the SPV panels to harness the solar energy. These maps are useful for the fast and quick analysis of the upcoming solar plants at the rooftops, water bodies, and land situated in Uttarakhand, India. These types of studies are the need of all the countries majorly in the African countries. In Africa, there is a lot of scopes available to harness the solar energy for daily and farming purposes.

The annual and monthly maps of GHI, tilted GHI, and solar potential are an excellent resource for the assessment of the individual and organizations for the feasibility of the small and large solar projects. The tilt angle is an essential parameter for the installations of the PV panels to harness the maximum quantum of solar energy. These maps are useful for the fast and quick analysis of the upcoming solar plants at the rooftops, water bodies, and land situated in Uttarakhand, India.

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