BJNRD

BJNRD (2022), 9(1): 74-78

Bhutan Journal of Natural Resources & Development

Short Communication

www.bjnrd.org

Open Access

ISSN 2409–2797 (Print)
ISSN 2409–5273 (Online)

DOI: https://doi.org/10.17102/cnr.2022.74

Exploring Solar Energy Potential using Solar Radiation GIS Toolset - A Case of College of Natural Resources, Lobesa, Punakha

Ugyen Thinley[1]

Abstract

The aim of this study was to explore solar energy potential on a small landscape (campus of the College of Natural Resources) using topography of fine spatial resolution that can detect number of rooftops feasible for harnessing solar energy. Digital elevation model was derived by extracting elevation values from the Google Earth Pro which was then used as input for solar radiation calculation. The total radiation that the campus received was 2,100 kWh over 259 days and the result was validated using power access viewer and global solar atlas databases. The monthly average radiation indicated that October, November, December and January are the radiation peaking months at the college campus. Twenty-two rooftops were identified to receive more than or equal to 3.08 kWh/m^2/day, while the remaining rooftops receiving less than or equal to 3.08 kWh/m^2/day. All in all, the study points out that the college has some potential of supplementing power shortage during lean hydro season using the rooftop solar panels.

Keywords: ArcGIS, energy, radiation, rooftops

Introduction

This short paper examines a potential for rooftop solar energy harnessing at the College of Natural Resources (CNR), located in a dry-subtropical region of chirpine forest in Bhutan. As such, CNR experiences cold-windy winters (12.8ºC) and hot-dry summers (35°C) leading to heavy utilization of electrical appliances for heating and cooling respectively as reported by Dorji *et al.* (2016). Such excessive use of power is not only expensive to the residents, but harmful to the environments (Ehrenfeld, 2005). Hydropower, the main source of energy in Bhutan, although is a renewable energy, its construction can affect land use, residences and wildlife habitats (Gracey *et al.*, 2016). Further, the sustainability of hydropower remains uncertain due to impending global warming and climate change (Hamududu and Killingtveit, 2012; Katopodis *et al.,* 2020). In Bhutan, recharge sources such as upstream glacial lakes are retreating at a rate of 30 to 60 metres per decade (UNDP, 2011) which was further corroborated by the retreat of Ganju la and Thana glacial lakes retreating at 11.4 m and 18.2 m annually (Wangmo, 2020). Moreover, every winter, residents in the country

[1]Department of Environment and Climate Studies,
College of Natural Resources.
*Corresponding Author: uthinley.cnr@rub.edu.bt
Received: September 30, 2021
Accepted: June 22, 2022
Published: June 28, 2022
Editor: Yogeeta Dahal, CNR

experience frequent power blackouts due to reduction in flow-volume to feed the turbines of hydropower plants (Yuden, 2020). Solar energy can, therefore, not only abate the environmental harms but supplement the power shortage during dry seasons. CNR is positioned in an area where there are no high and clustered buildings thereby warranting for the exploration of solar energy potential on the rooftops.

Materials and Method

The modelling of solar radiation was done using the following materials: Global Positioning, System (GPS), Digital elevation model (DEM), ArcGIS v10.8, Google Earth Pro, Power Data Access Viewer database, and Global Solar Atlas database.

For the small-scale landscapes, DEM of fine spatial resolution can be generated by extracting elevation values against each point in the google earth (GeoDelta Labs, 2020). In this study, conducted at the College of Natural Resources, clouds of points at 3 m interval were drawn on the Google Earth Pro imagery by using the add path tool. Every point is an elevation value. However, Google Earth elevation data created from such points can only be used for preliminary studies, not for high precision engineering (El-Ashmawy, 2016). The points were then saved as Keyhole Markup Language (KML) file format. KML file was then converted to GPX file in GPSVisualizer (online file format converter). GPX (GPS Exchange Format) file was then converted to feature file (shapefile) in ArcGIS. The elevation points coordinate system in decimal degrees was converted to a local planar coordinate system of Bhutan called PCS DRUKREF03.

To generate the DEM, Kriging interpolation was used with the cell size of 3.27 m as defaulted by the software. The DEM was then cut (masked) to defined area of CNR, created by GPS tracking using the Garmin GPSMAP60Cs. The area of CNR was extracted from Google Earth Pro imagery of year 2020, and georeferenced it in ArcGIS from which foot prints of all building polygons were created to represent their rooftop area.

Solar radiation analysis tools in ArcGIS Spatial Analyst extension can analyse the effects of sun over a landscape for a particular period (Gastli and Charabi, 2010; Kausika and van Sark, 2021). In calculations it accounts for mean latitude at the site, elevation, slope, aspect, seasonal/daily shifts of the sun angle and shadows of surrounding topography. To generate estimated solar power potential, Area Solar Radiation tool was used following the procedures below:

- Input raster = DEM- generated from the elevation points
- Output global radiation raster = sum of direct and diffused radiations in watt hours per square metres.
- Latitude = mean latitude of the study area in decimal degrees
- Sky size = kept at default size (200 by 200 cells)
- Time configuration = multiple days in the year 2021, January 2 to September 16 totalling to 259 days.
- Topographic parameters: Day interval = biweekly; hour interval = half an hour; slope and aspect were generated from DEM with calculation direction of 32 since topography of the site is complex.
- Radiation parameters: sky sectors (zenith divisions) = 8; azimuth divisions = 8; diffuse model type = standard_overcast_sky; and the rest kept at default.
- The resultant global radiation was outputted by the tool as the sum_{total} of $direct_{total}$ and $diffused_{total}$ radiations.
- ArcGIS Radiation model Validation: To validate results from the solar radiation model of ArcGIS, Power Access Viewer and Global Solar Atlas were referred to from where daily mean radiation at the study site could be calculated by supplying the location coordinates (latitude and longitude) approximately in the centre of the campus.
- Rooftop solar radiation estimation: The

footprints of the rooftops were digitized using google earth imagery to extract the solar radiation values with the help of raster tool called extract by mask.

Results and Discussion

The total radiation within 259 days (01 January-16 September 2021) at the CNR campus accounted to 2,100 kWh, with 56.447% of the total area (acre) receiving more than 800 kWh (high), 31.338% receiving 600 to 700 kWh (medium) and 12.215% receiving less than or equal to 600 kWh (low) as shown in Figure 1a. The mean daily radiation within the campus accounted for 5.27±0.22 kWh, with the minimum radiation reception at 4.68 and the maximum at 5.55 kWh per square metre over 259 days. Twenty-two rooftops (red) were found to receive high radiation values (>=3.08 kWh/m^2/day) with the remaining rooftops (yellow) receiving less than or equal 3.08 kWh/m^2/day (Figure 1b).

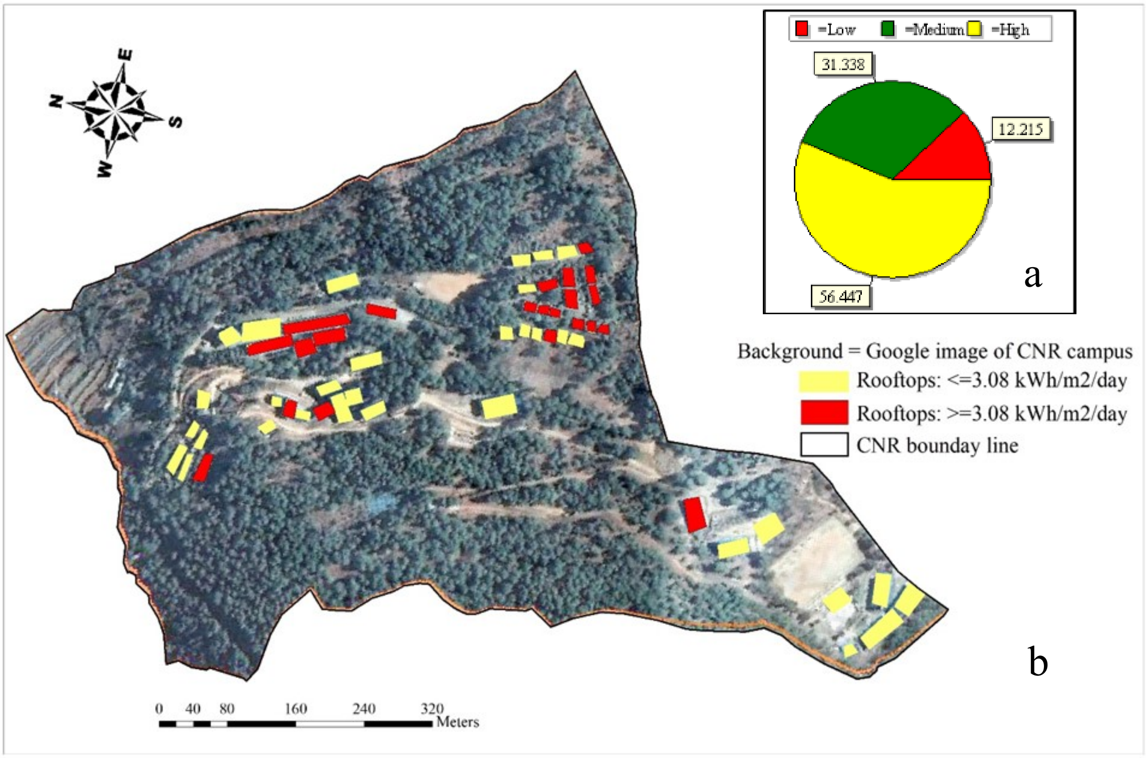

Figure 1: a) Chart showing radiation levels (kWh) by percent of total area (acre) and b) Map showing solar radiation reception by rooftops at the CNR campus

The result of solar radiation model of ArcGIS was validated using the daily prediction of global energy resource by National Aeronautics and Space Administration (NASA) and Global Solar Atlas. The spatial resolution of energy prediction by NASA uses 0.5 by 0.5-degreespatial resolution (approximately 55 km) while Global Solar Atlas uses spatial resolution of 3 by 3 arc-seconds (approximately 90 m). The mean daily energy of NASA and Global Solar Atlas at the study site were 4.23 kWh/m^2 and 4.49 kWh/m^2 per day respectively, compared with Area Solar Radiation model with 5.27 kWh/m^2 per day. The solar energy peaking months are October (133.3 kWh/m^2), November (121.2 kWh/m^2), December (120.8 kWh/m^2) and January (108.1 kWh/m^2) in descending order (Figure 2) according to the computation using global solar atlas database reporting system.

Conclusion

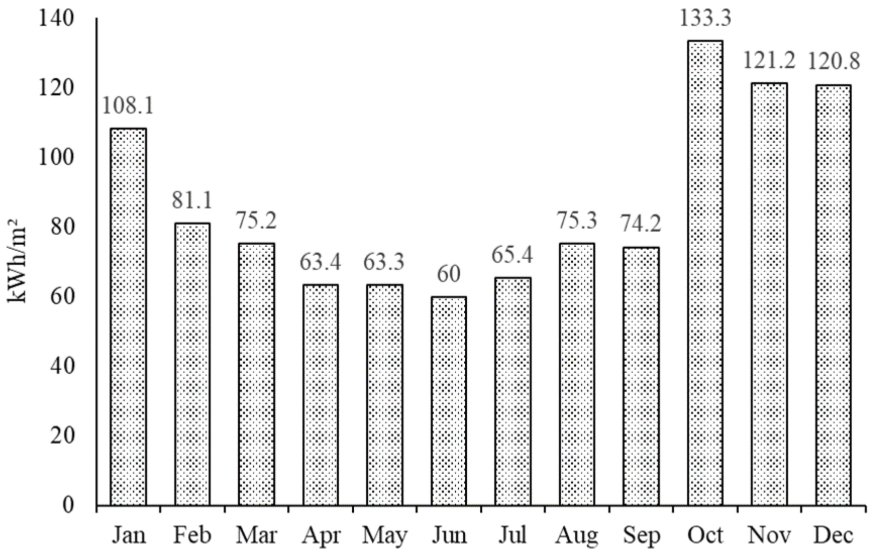

Figure 2: Monthly average of direct normal irradiance created from a single point in the middle of CNR campus

This study provides an insight on how to estimate solar radiation using the GIS techniques, which are now becoming powerful tools to plan from the desktop rather than physically being on the ground, which is cumbersome and laborious. Moreover, in the digital age, there are ubiquitous data online that can be mined and wrangled to suit the objectives of the study or plan. The result indicates that CNR campus is feasible for investing on solar energy harnessing with the use of some existing building rooftops, thereby avoiding the construction cost of new solar panel installation infrastructure. The study also indicates that installation of solar panels on rooftops in the college can mitigate the power supply shortage during lean hydro season (October, November, December and January) during which Bhutan imports additional electricity from India (Ministry of Power, 2020). However, the use of default settings of the ArcGIS tool for calculating solar radiation was found to underestimate the amount of radiation (Carl, 2014). As such, to achieve the better fit of the model, it is recommended that the model be calibrated using the meteorological stations if radiation data are recorded by the stations to reduce the errors of prediction (Amillo *et al.*, 2018; Kausika and van Sark, 2021). Moreover, the use of topographic data (e.g., DEM) in the GIS model is designed as a preliminary basis to assess solar power potential. Consequently, the study does not provide an in-depth analysis of photovoltaic magnitude of rooftop.

References

Amillo, A.G., Ntsangwane, L., Huld, T., &Trentmann, J. (2018). Comparison of satellite-retrieved high-resolution solar radiation datasets for South Africa. Journal of Energy in Southern Africa, 29(2), 63-76.

Carl, C. (2014). *Calculating Solar Photovoltaic Potential on Residential Rooftops in Kailua Kona, Hawaii* [Master's Thesis, University of Southern California]. https://spatial.usc.edu/wp-content/uploads/formidable/12/Caroline-Carl.pdf

Dorji, U., Olesen, J. E., Bøcher, P. K., &Seidenkrantz, M. S. (2016). Spatial variation of temperature and precipitation in Bhutan and links to vegetation and land cover. *Mountain Research and Development*, 36(1), 66-79.

Ehrenfeld, D. (2005). The environmental limits to globalization. *Conservation Biology*, 19(2), 318-326.

El-Ashmawy, K.L. (2016). Investigation of the accuracy of google earth elevation data. *Artificial Satellites*, 51 (3), 89.

Gastli, A., & Charabi, Y. (2010). Solar electricity prospects in Oman using GIS-based solar radiation maps. Renewable and Sustainable Energy Reviews, 14(2), 790-797.

GeoDelta Labs. (2020, September 11). Extracting Elevation Data from Google Earth [video] https://

www.youtube.com/watch?v=isDop9WKdjk
Gracey, E. O., & Verones, F. (2016). Impacts from hydropower production on biodiversity in an LCA framework—review and recommendations. *The International Journal of Life Cycle Assessment*, 21(3), 412-428.
Hamududu, B., & Killingtveit, A. (2012). Assessing climate change impacts on global hydropower. *Energies*, 5(2), 305-322.
Katopodis, T., Markantonis, I., Politi, N., Vlachogiannis, D., & Sfetsos, A. (2020). High-Resolution Solar Climate Atlas for Greece under Climate Change Using the Weather Research and Forecasting (WRF) Model. *Atmosphere*, 11(7), 761.
Kausika, B. B., & van Sark, W. G. (2021). Calibration and Validation of ArcGIS Solar Radiation Tool for Photovoltaic Potential Determination in the Netherlands. *Energies*, 14(7), 1865.
Ministry of Power. (2020, March 19). *Trade in Electricity* [Press release]. https://pib.gov.in/PressReleasePage.aspx?PRID=1607177
Wangmo, C., (2020, November 14). *Glaciers retreating at an alarming rate.* Kuenselonline.com.
UNDP. (2011). Climate Change Adaptation. <https://www.adaptation-undp.org/explore/bhutan>. Accessed 3 June 2022.),
Yuden, K. (2020, September 11). *Frequent power outages leave residents in the capital frustrated.* The Bhutanese.