Semi-Automatic Feature Extraction to Assess Solar Potential for Rural India

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Abstract

The over-exploitation of non-renewable resources for energy demands is a serious issue. Convergence towards renewable resources such as solar energy is need of the day. Solar energy is the cleanest form of energy available on Earth. The objective of this research is to extract the building rooftop from the satellite images using a k-means clustering algorithm to identify the usable area for solar potential assessment. The scenes of WorldView-3 and Google Earth are segmented into nine parts and the algorithm implemented in Matlab is applied to the individual parts for better utilization of computing resources. This approach has been applied to the parts of northern states of India for solar potential assessment in a fast and accurate manner. The Global Horizontal Irradiance (GHI) data obtained from the database of National Renewable Energy Laboratory (NREL), United States have been used in the solar potential assessment. For the validation purpose, the above-mentioned algorithm has been compared with the digitization in QGIS software. The results obtained from the above-mentioned algorithm developed have extracted 85% to 90% of the features in the satellite image. The developed algorithm has given best results with the WorldView-3 (high-resolution image) than the other coarser resolution scenes. The developed approach is helpful in evaluating the feasibility of the large areas for solar potential assessment. This methodology is useful for the implementation of different government's solar energy generation schemes for rural and hilly areas. It helped in estimating the solar potential of the large hilly area for electricity generation. This approach is useful for a larger area as it computes the usable area by dividing the scenes into smaller parts and applies the algorithm individually to each part of the scene. Keywords: k-means clustering, GHI, rooftop, solar potential, Google Earth, WorldView-3

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Abstract

The over-exploitation of non-renewable resources for energy demands is a serious issue. Convergence towards renewable resources such as solar energy is need of the day. Solar energy is the cleanest form of energy available on Earth. The objective of this research is to extract the building rooftop from the satellite images using a k-means clustering algorithm to identify the usable area for solar potential assessment. The scenes of WorldView-3 and Google Earth are segmented into nine parts and the algorithm implemented in Matlab is applied to the individual parts for better utilization of computing resources. This approach has been applied to the parts of northern states of India for solar potential assessment in a fast and accurate manner. The Global Horizontal Irradiance (GHI) data obtained from the database of National Renewable Energy Laboratory (NREL), United States have been used in the solar potential assessment. For the validation purpose, the above-mentioned algorithm has been compared with the digitization in QGIS software. The results obtained from the above-mentioned algorithm developed have extracted 85% to 90% of the features in the satellite image. The developed algorithm has given best results with the WorldView-3 (high-resolution image) than the other coarser resolution scenes. The developed approach is helpful in evaluating the feasibility of the large areas for solar potential assessment. This methodology is useful for the implementation of different government's solar energy generation schemes for rural and hilly areas. It helped in estimating the solar potential of the large hilly area for electricity generation. This approach is useful for a larger area as it computes the usable area by dividing the scenes into smaller parts and applies the algorithm individually to each part of the scene.

Keywords: k-means clustering, GHI, rooftop, solar potential, Google Earth, WorldView-3

Objectives

Unavailability of electricity for agricultural purposes is a major problem in the rural areas of India.

The study has been performed to cater this problem by evaluating the feasibility of solar energy for the farmers at an optimum tilt angle.

In this research work, the solar potential of the Salhapur village has been assessed for the sustainable development of this village.

Our study finds an optimum tilt angle to get the maximum quantum of the solar energy falling on the Solar Photovoltaic (SPV).

Geo big data and cloud computing have been used in assessing and digitizing the required area of interest.

The Global Horizontal Irradiance (GHI), data have been downloaded from the website of the National Renewable Energy Laboratory (NREL), United States.

Study Area

The study area selected for this study is Salhapur village located in Haridwar district of Uttarakhand, India (Fig. 1).

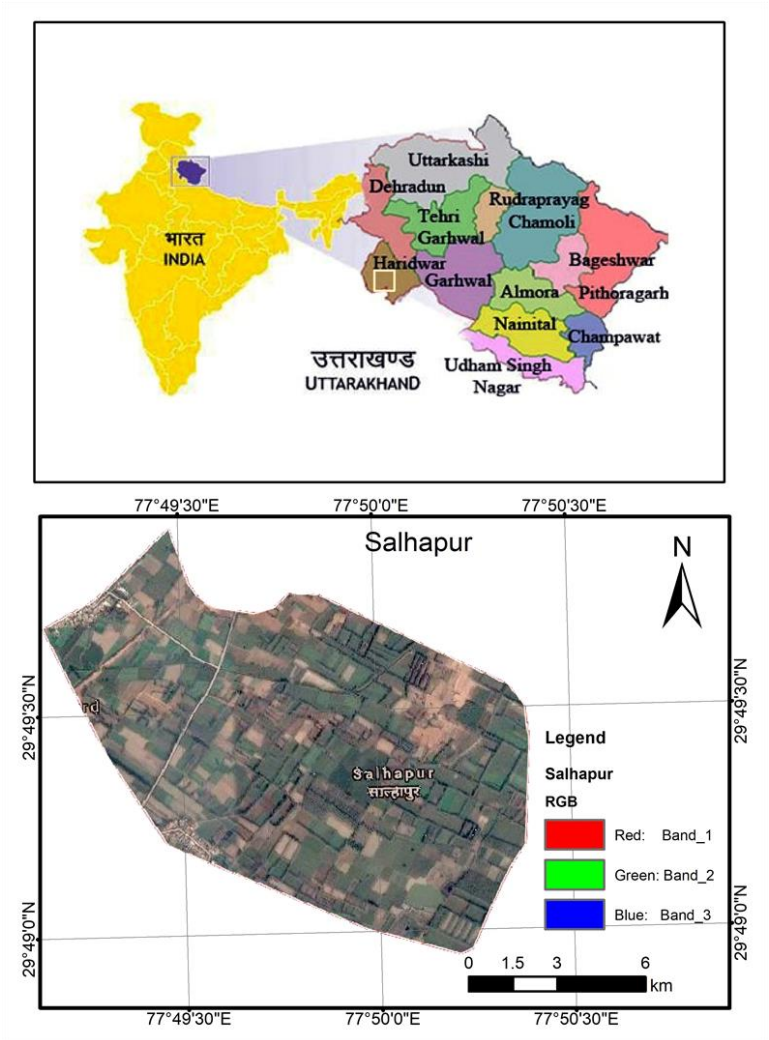

Fig. 1 Study area selected for this study

The Salhapur has been selected for this study since it is located near the hilly terrain. The occupation of most of the families living here is agriculture. Therefore solar energy can help them in agricultural needs i.e. well pump for irrigation and their daily needs.

Methodology

A methodology has been proposed to quickly estimate the solar potential of the location (Fig. 2). This methodology can be applied to any location such as building's rooftop, barren land, water bodies, etc. This methodology has been divided into two phases.

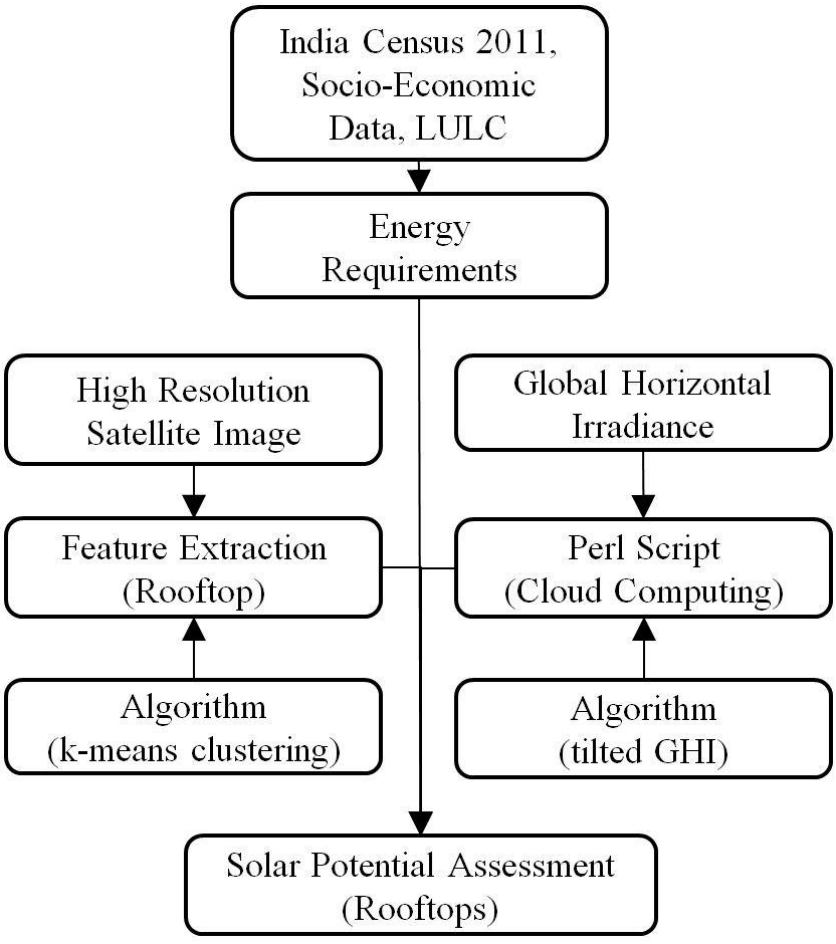

Fig.2 Proposed methodology applied in this research work

The first phase deals with the estimation of the usable area for SPV installation and the second phase deals with the calculation of the tilted GHI at that location. In the first phase, an approach has been devised to extract the rooftops of the buildings using a semi-automatic approach. In this approach, the study area has been segmented into smaller parts. K-means clustering algorithm has been applied to each segmented part to extract the rooftop information. This rooftop information has been used to estimate the usable area for SPV installations.

The second phase deals with the energy requirements and solar potential assessment. The energy requirements have been calculated using India Census data 2011, socioeconomic information, and energy consumption per capita. The solar potential has been calculated using tilted GHI. This tilted GHI has been calculated using an algorithm implemented in the Perl programming language. To process this large set of values, the processing of these values have been performed using cloud computing. Finally, the feasibility of the solar potential assessment has been made using energy requirements and predicted solar potential.

Results

The values of annual tilted GHI and assessed solar potential using average tilted GHI data from 2002-2008 at Salhapur village are 6.97 kWh/m2/day and 165 MWh respectively.

The averaged solar potential assessed of the 15 years i.e. from 2000 to 2014 is 148 GWh.

Fig.3 Google Earth image of the house in a Salhapur village

Fig.4 Rooftop extracted using semi-automatic rooftop extraction algorithm

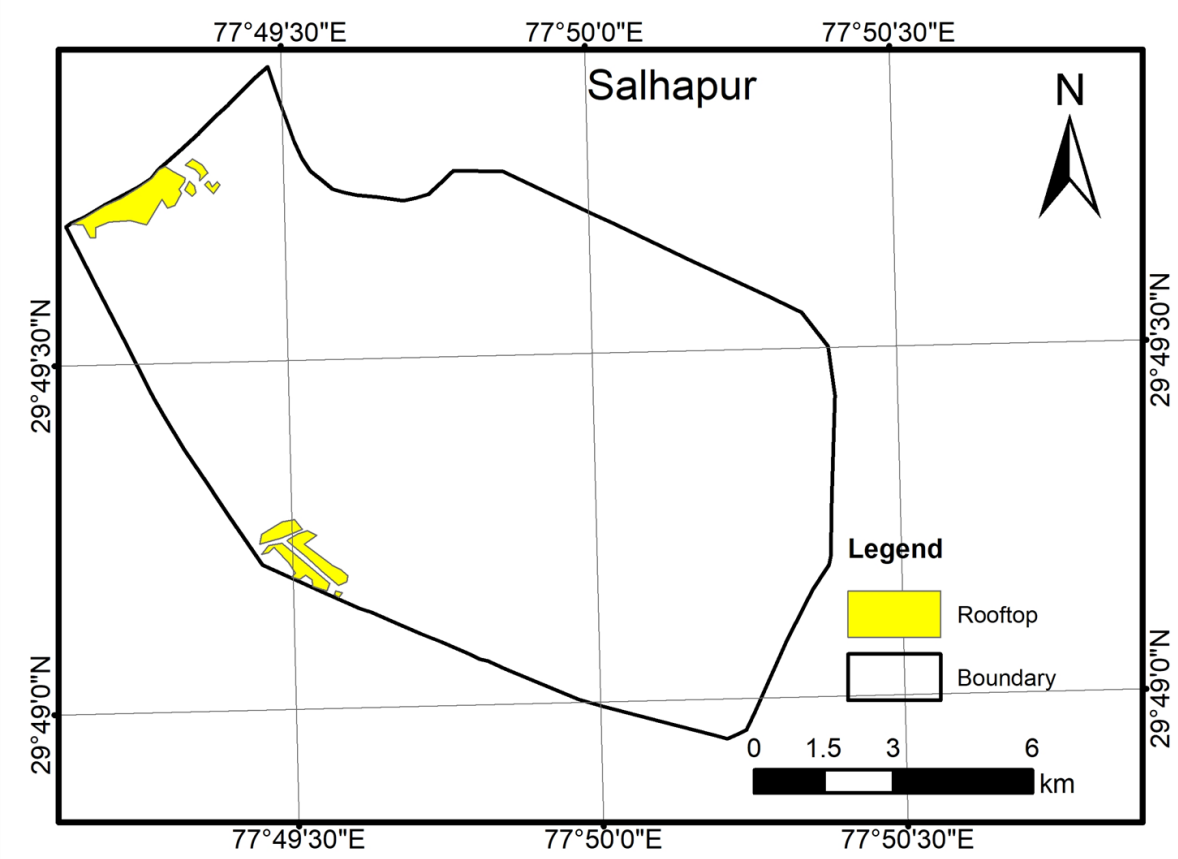

Fig.5 Rooftops of the Salhapur for Solar Potential Assessment

It has been found from this study that enough solar potential is available to feed the requirements of all the households in the Salhapur village.

Conclusions

The proposed methodology i.e. semi-automatic feature extraction to assess solar potential has been implemented of the study area and solar potential assessment has been carried out.

The implemented semi-automated approached saved a lot of time in extracted usable rooftop area for solar potential assessment.

This is the pilot study conducted in this village. The proposed methodology in this study can be replicated at other locations such as hilly terrain, remote and rural areas, etc.

This methodology is useful for the government bodies in policy making and subsidies for solar plants at the country level.

Disclosures

This study has been carried out as a part of the Ph.D. programme. The first author of this study is also thankful to the Ministry of Human Resources and Development, GoI for providing financial support during the Ph.D. programme. The authors also like to thank Mr. Shray Pathak for his help during the eLightening presentation. The authors would also like to thank AGU-2018 fall meeting for accepting work to be presented during the meeting.

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References

[1] A. A. F. Husain, W. Z. W. Hasan, S. Shafie, M. N. Hamidon, and S. S. Pandey, "A review of transparent solar photovoltaic technologies," *Renew. Sustain. Energy Rev.*, vol. 94, no. July, pp. 779–791, 2018.

[2] M. Ghanea, P. Moallem, and M. Momeni, "Automatic building extraction in dense urban areas through GeoEye multispectral imagery," *Int. J. Remote Sens.*, vol. 35, no. 13, pp. 5094–5119, 2014.

[3] G.- Data, *GIScience Remote Sensing Retrieval of High Resolution Land Surface Temperature Using Landsat 5 TM and*. 2017.

[4] I. Gherboudj and H. Ghedira, "Assessment of solar energy potential over the United Arab Emirates using remote sensing and weather forecast data," *Renew. Sustain. Energy Rev.*, vol. 55, pp. 1210–1224, 2016.

[5] R. M. Moharil and P. S. Kulkarni, "A case study of solar photovoltaic power system at Sagardeep Island, India," *Renew. Sustain. Energy Rev.*, vol. 13, no. 3, pp. 673–681, 2009.

[6] O. Sharma, D. Mioc, and F. Anton, "Polygon feature extraction from satellite imagery based on colour image segmentation and medial axis," *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.*, vol. 37, no. B3a, pp. 235–240, 2008.

[7] B. Liss, M. D. Howland, and T. E. Levy, "Testing Google Earth Engine for the automatic identification and vectorization of archaeological features: A case study from Faynan, Jordan," *J. Archaeol. Sci. Reports*, vol. 15, no. September, pp. 299–304, 2017.

[8] A. Kazantzidis, E. Nikitidou, V. Salamalikis, P. Tzoumanikas, and A. Zagouras, "New challenges in solar energy resource and forecasting in Greece," *Int. J. Sustain. Energy*, vol. 37, no. 5, pp. 428–435, 2018.

[9] Z. Qu *et al.*, "Fast radiative transfer parameterisation for assessing the surface solar irradiance: The Heliosat-4 method," *Meteorol. Zeitschrift*, vol. 26, no. 1, pp. 33–57, 2017.

[10] M. Taylor, P. G. Kosmopoulos, S. Kazadzis, I. Keramitsoglou, and C. T. Kiranoudis, "Neural network radiative transfer solvers for the generation of high resolution solar irradiance spectra parameterized by cloud and aerosol parameters," *J. Quant. Spectrosc. Radiat. Transf.*, vol. 168, pp. 176–192, 2016.

[11] X. Zhou, J. Yang, F. Wang, and B. Xiao, "Economic analysis of power generation from floating solar chimney power plant," *Renew. Sustain. Energy Rev.*, vol. 13, no. 4, pp. 736–749, 2009.

[12] I. Kougias *et al.*, "The potential of water infrastructure to accommodate solar PV systems in Mediterranean islands," *Sol. Energy*, vol. 136, pp. 174–182, 2016.

[13] C. A. Bode, M. P. Limm, M. E. Power, and J. C. Finlay, "Subcanopy Solar Radiation model: Predicting solar radiation across a heavily vegetated landscape using LiDAR and GIS solar radiation models," *Remote Sens. Environ.*, vol. 154, pp. 387–397, 2014.

[14] M. A. Martínez, J. M. Andújar, and J. M. Enrique, "A new and inexpensive pyranometer for the visible spectral range," *Sensors (Switzerland)*, vol. 9, no. 6, pp. 4615–4634, 2009.

[15] C. F. Peruchena and A. F. Amores, "Uncertainty in monthly GHI due to daily data gaps," *Sol. Energy*, vol. 157, no. August, pp. 827–829, 2017.

[16] Y. Su, "A Comparative Analysis of the Performance of a Grid-Connected Photovoltaic System Based on Low-and High-Frequency Solar Data," *Int. J. Green Energy*, vol. 12, no. 12, pp. 1206–1214, 2015.

[17] NREL, “Inventory of Solar Radiation / Solar Energy Systems Estimators, Models, Site-Specific Data, and Publications,” 2016.

[18] J. R. Janke, “Multicriteria GIS modeling of wind and solar farms in Colorado,” *Renew. Energy*, vol. 35, no. 10, pp. 2228–2234, 2010.

[19] M. Sengupta, P. Gotseff, M. Sengupta, and P. Gotseff, “Evaluation of Clear Sky Models for Satellite-Based Irradiance Estimates Evaluation of Clear Sky Models for Satellite-Based Irradiance Estimates,” no. December, 2013.

[20] M. Kapoor and D. Bassir, “Climate change for agriculture, forest cover and 3D Urban models,” in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences -ISPRS Archives*, 2014, vol. 40, no. 8, pp. 787–791.

[21] Newport, “Introduction to Solar Radiation,” *Newport Corporation*, 2018. [Online]. Available: https://www.newport.com/t/introduction-to-solar-radiation. [Accessed: 01-Sep-2018].

[22] Wikipedia, *Har Ki Pauri*. Haridwar, 2018.

[23] Google Earth, “Google Earth,” 2018. [Online]. Available: https://earth.google.com/web/. [Accessed: 30-Jan-2018].

[24] Census Population Data, “Haridwar District Population Census 2011, Uttarakhand literacy sex ratio and density,” *Census Population Data*, 2015. [Online]. Available: https://www.census2011.co.in/census/district/586-haridwar.html. [Accessed: 02-Sep-2018].

[25] Elshayal, “Elshayal Smart GIS 18.022,” 2018. [Online]. Available: https://freesmartgis.blogspot.com/.

[26] Mathworks, “Deep Learning with Matlab,” *Introd. Deep Learn. with MATLAB*, p. 15, 2017.

[27] MathsWorks, “Color-Based Segmentation Using K-Means Clustering - MATLAB & Simulink Example - MathWorks India,” *MathsWorks*, 2018. [Online]. Available: http://in.mathworks.com/help/images/color-based-segmentation-using-k-means-clustering.html;jsessionid=274172036a725ca7bc89020ded9e. [Accessed: 16-Aug-2018].

[28] Esri, “ArcGIS 10.3.1 for Desktop quick start guide—Help | ArcGIS Desktop,” 2018. [Online]. Available: http://desktop.arcgis.com/en/arcmap/10.3/get-started/quick-start-guides/arcgis-desktop-quick-start-guide.htm. [Accessed: 01-Sep-2018].

[29] S. P. Sukhatme and J. K. Nayak, *Solar Energy: Principles of Thermal Collection and Storage*, Third. New Delhi: Tata McGraw-Hill Education, 2008.

[30] PV-Tech, “The art and science of pyranometers,” *PV-Tech*, pp. 48–51, 2015.

[31] T. Muneer, X. Zhang, and J. Wood, “Evaluation of an innovative sensor for measuring global and diffuse irradiance, and sunshine duration,” *Int. J. Sol. Energy*, vol. 22, no. 3–4, pp. 115–122, 2002.

[32] DeltaOHM, “LP PYRA 03 - Datasheet.” pp. 1–12, 2007.

[33] M. Kapoor and R. D. Garg, “Cloud computing for energy requirement and solar potential assessment,” *Spat. Inf. Res.*, vol. 26, no. 4, pp. 369–379, 2018.