Nationwide Assessment of Solar PV Power Potential Using Geospatial Data and Collaborative Research with Higher Education Institutions: Case of the Philippines

Jeark A. Principe[1], Ma. Divina Angela I. Bauzon[2], Marielle E. Sotto[2,3], Jayson M. Cañete[2]

[1] Department of Geodetic Engineering, University of the Philippines Diliman, Quezon City, Philippines - japrincipe@up.edu.ph
[2] National Engineering Center, University of the Philippines Diliman, Quezon City, Philippines – (mibauzon, jmcanete)@up.edu.ph
[3] Energy Engineering Program, University of the Philippines Diliman, Quezon City, Philippines – mesotto@up.edu.ph

Keywords: solar PV power potential assessment, WebGIS, IEC, research collaboration

Abstract

Geospatial technologies present a significant opportunity to assess solar photovoltaic (PV) power potential through remote sensing techniques and geospatial analysis. This aligns with the goal of ensuring access to affordable, reliable, and sustainable energy, one of the Sustainable Development Goals (SDG) that the Philippine National Economic and Development Authority (NEDA) aims to achieve. In support of the said SDG, a research project, called Project SINAG, has developed a method for estimating solar PV power resources utilizing high-temporal remotely-sensed data. The primary objectives of this study are twofold: first, to develop a webGIS platform for solar energy resource information access and decision support; second, to conduct information dissemination and capacity-building activities for various stakeholders in the solar energy sector. The localized assessment of solar PV power potential incorporates meteorological and geomorphological factors such as high temperature, dust deposition, and slope. Collaboration with academic institutions, government agencies, and the solar energy industry has been instrumental in providing capacity-building through training workshops, internships, and on-the-job training. Moreover, the project has produced information, education, and communication (IEC) materials, launched a webGIS portal, and supported data requests and student research. The webGIS platform serves as the primary information dissemination tool for the project, enabling rapid sharing of research outputs with end-users. To enhance the platform, future developments may include additional functionalities such as community forums, client feedback mechanisms, mobile application development, and the integration of real-time data for map layers and forecasting tools.

1. Introduction

1.1 Solar PV Output Potential Assessment

Solar irradiance refers to the amount of light energy per unit area received by the Earth’s surface from the sun (Garner, 2015). Values of this meteorological parameter can be affected by several factors such as solar and panel tilt angles, time of day, season, geographical location and atmospheric conditions (Wald, 2015; Rathod, Mittal & Kumar, 2016). Remote sensing methods can be used to estimate the solar PV resource potential of an entire country without or with limited onsite data gathering. Solar irradiance can be remotely measured by satellites and is available for access as derived products. These products include Shortwave Radiation (SWR) and Surface Solar Irradiance (SSI) (JAXA, 2015; Kramer, 2016; NSMC 2013) which can further be processed to account for effects of cloud cover and atmospheric scattering and absorption, which may have an impact on solar radiation values (Jia et al, 2021; Benitez et al, 2022).

In solar PV power (PPV) output potential assessment using geospatial technologies, previous studies accounted for meteorological and geomorphological factors where high temperature, dust deposition, and slope were considered affecting the solar energy reaching the surface. High temperature and dust deposition which limit the maximum solar potential power (PPV) (Principe & Takeuchi, 2019; Meneses et al, 2005; Goossens, Offer & Zangvil, 1993; Zorrilla-Casanova, 2011). A more localized or city-level PPV assessment should consider additional factors, such as slope which affects the amount of solar energy received on the surface. It is therefore necessary to also account for the effects of solar panel’s tilt angle on PPV. For instance, the PPV potential in Davao City, Philippines was assessed using global horizontal irradiance (GHI) and digital surface model (DSM) in GRASS GIS (Teves et al, 2016) which shows the latter’s impact on the estimated PPV. Finally, more factors should be considered when selecting sites for solar PV installations which include, but not limited to, slope, typhoon frequency and intensity, proximity to the grid, road network, water bodies, land cover/use, tree cover density, and protected areas (ESMAP, 2020; Levosada et al, 2022).

1.2 Project SINAG

Solar is undoubtedly one of the most utilized renewable energy resources. A comprehensive solar PV resource map will therefore guide both private individuals and key government organizations, such as the Department of Energy, on the optimal locations for rooftop and large-scale solar farm installations (Yao & Zhu, 2023). With this, research that focuses on providing accurate and up-to-date information on the potential output power of solar PV systems is highly significant.

Project SINAG is a research project under the auspices of the joint research program between the Philippine Department of Science and Technology (DOST) and China’s Ministry of Science and Technology (MOST). The research project aims to develop a forecasting model and an accurate assessment of PPV using remotely sensed data using remotely-sensed data of high spatial and temporal resolution. The project consists of three components: OutSolar, SolarPot and WebGIS components. The OutSolar component aims to develop a locally-adapted forecasting model which predicts output power of solar PV installations in the Philippines. The SolarPot component will assess the solar PV resource potential in the Philippines considering meteorological and geomorphological aspects. Lastly, the WebGIS will host the outputs of the OutSolar and SolarPot components so that relevant stakeholders can view and

https://doi.org/10.5194/isprs-annals-X-5-2024-135-2024

access these outputs as digital maps.

1.3 Project SINAG’s web-based GIS (WebGIS)

Geographic data presentation and visualization have undergone significant changes in the digital age, with the advent of Geographic Information Systems (GIS) representing a major advancement in geographical data analysis. (Cañete et al., 2023). These changes comprise cloud-hosted spatial data and features, web services, and software applications that improve accessibility from any place or device, increasing user engagement and audience reach. The project uses the Project SINAG Web Portal to make its outputs available online. The outputs from solar PV output forecasting of OutSolar component and potential mapping of SolarPot component are made available online via the user-friendly Project SINAG Web Portal, allowing interested parties and stakeholders in solar PV systems to utilize graphical user interfaces (GUI) and digital maps (Cañete et al., 2023). The online portal features a well-organized database schema, a strong backend system, and effective cloud storage. The processed spatial data, graphical model summaries, historical data exploration tools, data request and download capability, and mapping tools are among the outputs that are stored on a different cloud server (Cañete et al., 2023). It is projected that Project SINAG Web Portal will be crucial to the assessment and selection of appropriate locations for solar PV installations across the Philippine archipelago (Cañete et al., 2023).

1.4 Scope and Limitations of the Study

This study utilized remotely-sensed geospatial data to calculate the solar PV power potential of the country. Moreover, this study assumed that results of the solar PV power potential assessment would be mainly used in residential areas where solar PV panels are installed parallel to the surface (i.e., rooftop PV installations). This study did not consider other criteria in PPV potential assessment except for meteorological and geomorphological factors.

1.5 Objectives of the Study

The main objectives of this study are to develop a webGIS for solar energy resource information access and decision support and to conduct information dissemination and capacity-building activities for various stakeholders of solar energy.

2. Methodology

One of the main objectives of Project SINAG is to conduct Information, Education and Communication (IECs) and capacity-building activities for various stakeholders of solar energy. With this, the project has implemented activities including internships, training workshops on solar PV potential assessment and forecasting, and technical support through data requests and consultations.

2.1 Internship and Trainings

The project aims to provide an opportunity for high school and undergraduate students to expose them in the geospatial research in the form of internship and on-the-job training. The students were able to participate in the project’s output generation and presentation by doing presentations, research papers, and IEC materials. The project also provided training workshops to institutions (HEIs) and SUCs which aim to develop skills on introductory GIS analysis. Participants were able to do collaborative studies with the project on solar energy assessment and forecasting through this capacity-building activity involving faculty and students. All trainings, whether internship, OJT, or workshop, provided by the project aim to enable participants to have a firsthand experience in using GIS data, tools, and software in the assessment of solar energy potential in the Philippines.

2.2 Data requests

The project also aims to provide technical support through data accessibility for its users, specifically academic institutions, government bodies and other stakeholders in the solar PV industry. The primary target users of the project are researchers and solar industry policy makers conducting research and development on solar PV technology, feasibility assessment, site selection, and project implementation.

Data request was done through Project SINAG’s online request form published in the project’s official website (https://www.sinag.nec.upd.edu.ph). The following documents are required to be submitted as attachments to the said request form: (1) Formal letter of request: in pdf file format and with endorsement from immediate supervisor or research adviser and (2) Area of interest: in coordinates or in shapefile (.*shp). Processing of data took at least 3-4 weeks, depending on the amount and type of data to be processed. Different types of dataset were made available for researchers including (but not limited to): solar radiation data (e.g. shortwave radiation, surface solar irradiance), meteorological data (e.g. dew point temperature, 10m u-component of wind, 10m v-component of wind, 2m temperature, forecast albedo, low cloud cover, high cloud cover, medium cloud cover, surface solar radiation downwards, total cloud cover, total precipitation), aerosol properties and cloud property.

2.3 Sharing of Outputs via the WebGIS

To facilitate the automated distribution of research outputs, the project aims to develop a WebGIS platform to host its products. The said outputs are mainly from its PPV potential assessment.

The process of developing WebGIS involves two separate systems: the client-side frontend and the server-side backend as shown in Fig. 1. The portion of the system that operates on the user's device—such as a computer or smartphone—is referred to as the frontend. The frontend, on one hand, oversees presenting the user interface and enabling user interaction with WebGIS. The backend, on the other hand, manages the background functions. All endpoint queries and replies are supported by this set of advanced web services, which also includes cloud storage, databases, APIs, and other related technologies (Cañete et al., 2023).

React and *Node.js* (Node.js, 2014/2023) are used in the construction of the Project SINAG WebGIS's frontend, and *Netlify* (Netlify, 2023)—a cloud-based platform that simplifies web development procedures—hosts it as shown in Fig. 2. It makes use of numerous technologies to enhance both its features and user experience. React is a Javascript framework (ReactJS, 2023) that is used as a main component of web development. The preferred map package for mapping features is React Leaflet (React Leaflet, 2023), while Recharts is incorporated for data visualization.

The web application's backend architecture (Fig. 3) was made up of multiple parts that worked together to deliver a flawless user experience, and it was hosted on the Google cloud platform. Between the client and the application, it has a *nginx* server that serves as a mediator. The application was developed using

Django (Django, 2012/2023), a popular Python web framework that used Object-Relational Mapping (ORM) to communicate with the PostgreSQL database (PostgreSQL 16, 2023) that held project and user data. PostgreSQL was used to reference media files like CSV sheets and GeoTIFF photos, which were also stored in a cloud storage database. Docker (2023) was used to containerize each of these microservices.

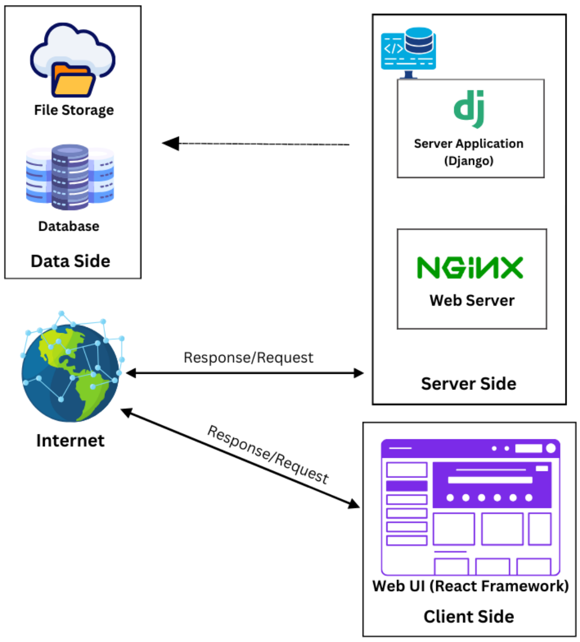

Figure 1. The full schematic of Project SINAG WebGIS architecture.

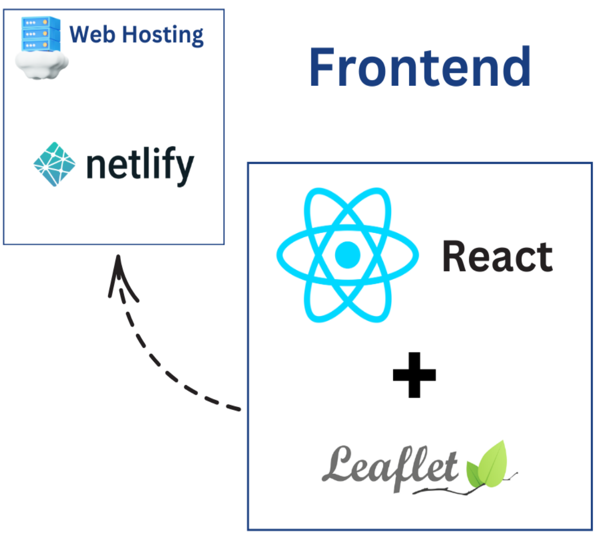

Figure 2. The frontend frameworks and libraries used on the web development.

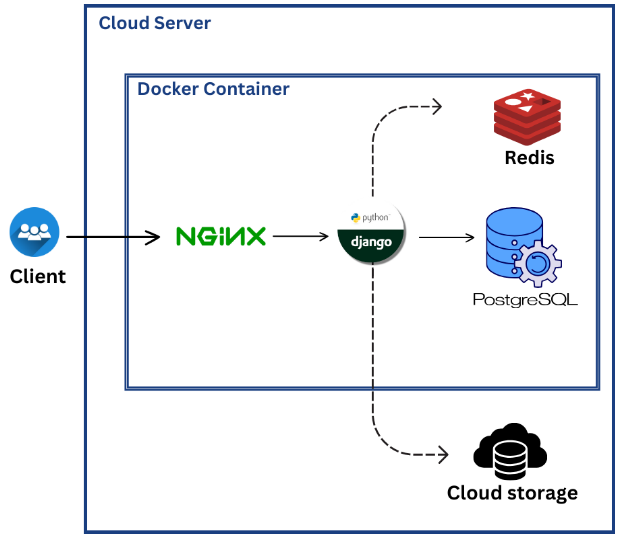

Figure 3. The backend architecture of Project SINAG WebGIS.

2.3.1 WebGIS Map Layers

One of the critical components of webGIS is the Map Layer page which houses data on various products in raster files related to solar PV potential evaluation. This data consists of six different layers of raster files in the *.tiff format as shown in Table 1.

Layers	Spatial Resolution	Temporal Resolution
Shortwave Radiation	5 km	Monthly
Adjusted Shortwave Radiation	5 km	Monthly
Cell Temperature	5 km	Monthly
Dust Effects	5 km	Monthly
Temperature Effects	5 km	Monthly
Solar PV Power Resource Potential	30 m (Low) 1 m (High)	Monthly

Table 1. Output Product of SolarPot Component.

The Shortwave Radiation (SWR) was extracted from the Advanced Himawari Imager-8/9 (AHI-8/9)'s Level 2 Photosynthetically Available Radiation (PAR) product. To determine the highest possible solar PV radiation that a unit area can receive, the Adjusted Shortwave Radiation (RSWR') of Project SINAG has been adjusted using the cloud optical thickness product from AHI-8/9 (EORC & JAXA, 2022; Sotto et al., 2023). The temperature of the solar PV panel determined using remotely sensed shortwave radiation, ambient temperature, and wind speed data is called the cell temperature, and it is used to evaluate the efficiency loss due to temperature impacts (Principe et al., 2023; Principe & Takeuchi, 2019). Using the AirRGB decomposition method, which requires values of Aerosol Optical Depth (AOD) and Angstrom Exponent (AE), the combined impacts of dust and precipitation were estimated. The *R* component of AirRGB is predominantly linked to high AE and high AOD in the Philippines (Bauzon et al., 2022). The resulting solar PV power (PPV) resource potential maps were then utilised in the WebGIS Layers. PPV considered the effects of meteorological and geomorphological, and using the adjusted shortwave radiation as the input product (Principe et al., 2023).

2.3.1.1 Adjusted Shortwave Radiation Layer

Correction factor for solar radiation (*CFSR*) is applied to a certain pixel to account for the correction due to cloudiness of a certain pixel. Cloud optical thickness (CLOT) defines the cloudiness of a certain pixel wherein CLOT > 1.0 indicates cloudy skies while CLOT < 1.0 implies clear or relatively clear skies (Sotto et al, 2023a; Principe & Takeuchi, 2019). For clear skies, *CFSR* is equivalent to zero while it is computed as Eq. (1) for cloudy or hazy skies (Sotto et al, 2023a; Principe & Takeuchi, 2019). The nearest cloud-free day, ΔR, is used as a correction factor. Lastly, CFSR is applied per day of observation and Eq. (2) is used to calculate the adjusted radiation.

$$CFSR = \frac{\Delta R \times R_i}{R_{ave}} \quad (1)$$

$$R_i' = \frac{R_i}{1 - CFSR} \quad (2)$$

2.3.1.2 Meteorological Effects Layers

A study by Bauzon et al. (2022) characterized the localized aerosol property distribution in the Philippines using R_{RGB} values derived from the AirRGB decomposition method by Misra et al. (2017). The *R* scenario describes high Angstrom Exponent (AE) indicating small particles and low Aerosol Optical Depth which is more relevant in solar PV installations in the Philippines. Areas with higher R_{RGB} values indicate areas with higher likelihood of dust accumulation (Principe & Takeuchi, 2019; Bauzon et al, 2022). Eq. (3) was used to calculate the combined effects of dust and precipitation (Principe & Takeuchi, 2019).

$$\Delta\eta_d = \frac{\sum_{i=1}^{n} x_{d_i} x_{r_i}}{n} \quad (3)$$

where x_d accounts for dust effects and x_r accounts for the cleaning effect of precipitation.

In a solar PV module, cell efficiency decreases as cell temperature increases. The effect of high temperature on solar cell efficiency can be defined as the difference between cell operating temperature and standard temperature at test conditions over the evaluation period as defined in Eq. (4) (Principe et al., 2023). The temperature coefficients and rated cell module efficiency used in this study are data from project collaborators with actual solar PV installations in St. Louis University (SLU) and University of the Philippines Diliman (UPD EEE).

$$\Delta\eta_t = \eta \frac{dP}{dT} (T_c - T_s) \quad (4)$$

where η is defined as the rated cell module efficiency, $\frac{dP}{dT}$ as the temperature coefficient, T_c as the cell operating temperature, and T_s as the temperature at standard test conditions (Principe & Takeuchi, 2019).

2.3.2 Solar PV Power Resource Potential Layer

Solar PV output power potential (PPV) accounts for the output power considering the combined effects of high temperature, dust, precipitation and tilt angle of the panel. PPV is computed using Eq. (5) (Principe & Takeuchi, 2019; Bauzon et al, 2022; Sotto el al, 2023).

$$PPV = A_{cell}\eta R(1 - \Delta\eta_t - \Delta\eta_d) \quad (5)$$

where A_{cell} is defined as the effective PV installable area (assumed to be 70% of the pixel resolution), η is the capacity factor of the solar panel and $R_{surface}$ is used as *R* (Liu et al, 2017, Principe & Takeuchi, 2019).

3. Results and Discussion

3.1 Information, Education and Communication (IEC) Activities

3.1.1 Lectures and Training Workshops

In its efforts to build strong collaborations with state universities and colleges (SUCs) and HEIs, Project SINAG conducted site visits and training with different institutions as listed in Table 2. Training workshop sessions conducted between April 2022 to August 2023 were attended by 102 faculty members and 121 students. The training consists of lectures on the *Introduction to Solar Energy and Geographic Information System*, and a two-part training workshop on *GIS Training Workshop on Solar Energy Resource Assessment* and *Introduction to Solar PV Output Forecasting* with hands-on laboratory exercises.

Institution	Location	No. of Trainees
Saint Louis University	Baguio City	12
Mindanao State University General Santos	General Santos City, South Cotabato	10
University of Southeastern Philippines	Davao City	125
UP Diliman & Philippine Science High School	Quezon City	8
Mariano Marcos State University	City of Batac, Ilocos Norte	17
Institute of Science and Technology University	Iloilo City	16
Institute of Science and Technology University	Iloilo City	16
Cavite State University	Indang, Cavite	8
Cavite State University	Indang, Cavite	8
University of the Philippines Diliman	Quezon City	3

Table 2. Trainings conducted by Project SINAG.

3.1.2 Internships and On-the-Job Training

A total of five (5) students from Philippine Science High School (PSHS) attended their Science Immersion Program (SIP) with Project SINAG at the National Engineering Center. The SIP became a venue to introduce remote sensing and GIS field among the students and exposed them to the world of science and technology through internship and mentorship under different Project SINAG research components. The SIP interns analyzed data of SolarEdge Plant, examined PAGASA AWS, Agromet, and Synoptic Stations, and mapped different plant locations. Interns have also evaluated the data quality of solar power plants and PAGASA Plant Stations used in model forecasting. Project SINAG has also hosted six (6) on-the-job trainees (OJTs), five BS Geodetic Engineering students of UP Diliman and one BS Electrical Engineering Student from Pamantasan ng Lungsod ng Maynila. Each trainee was assigned to a Project SINAG component.

3.1.3 Data Request

Multiple data requests have been fulfilled by Project SINAG since the start of the project. The data requests were from students in undergraduate (18) and masters (4) degree programs. About 45% of the data requested were accommodated to support the thesis requirements and the remaining 55% for course research projects.

Through data requests, Project SINAG has supported research and thesis dissertations from different institutions (Table 3).

Institution	Student Type*	Purpose	Data Request
UPHS DALTA	BS	Thesis	Solar Potential
LPC	BS	Thesis	Solar Potential
UP Los Baños	BS	Thesis	Meteorological Properties
UP Los Baños	BS	Thesis Simulation	Meteorological Properties, Solar Potential
CSU	BS	Thesis	Solar Potential, Shapefiles
UP Diliman	MS	Thesis	Solar Potential, Slope
UP Diliman	MS	Research Project	Solar Potential
UP Diliman	MS	Thesis	Solar Potential, Aerosol & Meteorological Properties
UP Diliman	BS	Research	Cloud, Aerosol & Solar Potential
USEP	BS	Research	Solar Potential
UP Diliman	BS	Thesis	Solar Potential, Aerosol & Meteorological Properties
USEP	BS	Research	Meteorological Properties
CVSU	BS	Research	Meteorological Properties
CVSU	BS	Research	Meteorological Properties
MSU - GSC	BS	Research	Solar Potential
VSU - Main	BS	Research	Solar Potential
USEP	BS	Research	Meteorological Properties
USEP	BS	Research	Meteorological Properties
PSU	BS	Research	Solar Potential
CvSU	BS	Research	Meteorological Properties
UPD	MS	Thesis	Cloud Property
MMC - Mindanao	BS	Thesis	Solar Potential, Aerosol & Meteorological Properties

**BS (Bachelor of Science), MS (Master of Science)*

Table 3. Data requests fulfilled by Project SINAG.

The said institutions include the University of Perpetual Help System DALTA (UPHS DALTA), Lyceum of the Philippines - Cavite (LPC), University of the Philippines (UP) Los Baños, Caraga State University (CSU), University of the Philippines Diliman, University of Southeastern Philippines (USEP), Mindanao State University General Santos City (MSU GSC), Cavite State University (CvSU), Visayas State University Main Campus (VSU), Palawan State University (PSU), and Mapúa Malayan Colleges (MMC) Mindanao.

3.2 Collaborative Research

The project has also conducted annual colloquia to showcase research studies that utilized Project SINAG’s outputs, and gather stakeholders in the industry, academe and government. Each colloquium featured presentations and discussions by by resource persons from DOST-Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD), Philippine Space Agency and Renewable Energy Management Bureau – Department of Energy, providing valuable opportunities to engage with research and advances in the field of solar energy.

Project SINAG Colloquium 2022 with the theme, “Geomatics for Solar PV Research in the Philippines: Accomplishments and Opportunities,” was attended by 118 participants, 3 speakers and 11 presentors from the academe and industries in Luzon, Visayas, and Mindanao. The project’s 2023 colloquium, with a theme “Solar PV Research and Applications: Achievements and Challenges,” was attended by a total of 65 participants, 3 speakers and 8 presentors. The event also served as a culminating activity to formally close Project SINAG’s project implementation.

The 19 presentors in Project SINAG Colloquia were students and researchers who were supported by the project though data requests and internship programs. To conclude their on-the-job training in Project SINAG, interns and OJT’s presented outputs of their research to different conferences (Table 4).

Research Study	Conference
Preliminary Analysis of Himawari 8 and AERONET Data	Project SINAG Colloquium 2022
Incorporating Fifth Generation ECMWF Reanalysis (ERA5) Data For Solar PV Output Forecasting In The Philippines: A Comparative Study of Solar Irradiance With And Without Weather Parameters	Philippine Geomatics Symposium 2023
Slope Analysis of CLOT-Adjusted SSI-FY4A Data for Solar PV Data for Solar PV Power Potential Assessment in the Philippines	Philippine Geomatics Symposium 2023

Table 4. Research output of On-the-Job Trainees hosted by Project SINAG.

3.3 WebGIS of Project SINAG

With Project SINAG webGIS, interested users can access geographic information and services from any location or device that has internet access. Registered users can explore maps, analyze data, and make informed decisions when it comes to the study of solar PV potential maps and forecasting data without being constrained by physical boundaries.

https://doi.org/10.5194/isprs-annals-X-5-2024-135-2024 | © Author(s) 2024. CC BY 4.0 License.

A map, as shown in Fig. 4, can be displayed on the Layers page, which can be used to visualize any Project SINAG layer data more efficiently. It includes information on numerous raster products associated with solar PV potential assessment, which is a crucial component of the webGIS

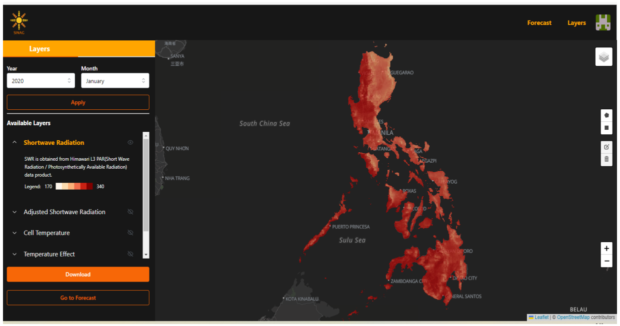

Figure 4. The map layer page.

4. Conclusion

Collaborative efforts with academic institutions, government agencies, and solar energy industries provided capacity-building activities through the conduct of training workshops, internships, and on-the-job trainings, development of IEC materials and webGIS portal, and support for data requests and research studies. The project trained a total of 102 faculty members and 121 students in different lecture and training workshops conducted in Luzon, Visayas and Mindanao. Through the project's data sharing, 22 research studies from 43 students in undergraduate and graduate programs were supported by providing data products gathered and developed by the project. Colloquia hosted by Project SINAG also gathered 183 participants, 6 resource speakers, and 19 presentors from the academe, industry and government institutions.

The Project SINAG webGIS platform offers dynamic visualizations and real-time data to relevant stakeholders. The platform can aid in making more informed decisions on planning and management of any solar energy projects. Through its publicly accessible online platform, webGIS enables citizens to take part in decision-making processes by having access to open maps and interactive forecasting tools to promote public participation.

Researchers and policymakers can collaborate on solar energy initiatives using shared spatial data. With these shared services and APIs, it enables collaboration across organizations and sectors. It helps them also to collaborate on projects without geographical constraints. There are still limitations on the current design of the Project SINAG webGIS platform such as flexibility on the use of APIs services, handling big data for spatial rendering, and real-time forecasting.

The webGIS platform will be used as the main information dissemination tool of the project to facilitate a faster sharing of research products to its users. To further improve the webGIS, the project may add functionalities for community forum and client feedback, mobile applications development, integrations of real-time data for both map layers and forecasting tools.

Acknowledgments

This study was implemented under the SolarPot and WebGIS components of Project SINAG (Solar PV Resource and Installation Assessment Using Geospatial Technologies). The authors would also like to acknowledge the Department of Science and Technology (DOST) as the funding agency of Project SINAG.

References

Bauzon, M. D. A., Sotto, M., Cañete, J., Principe, J., Masa, J. L. 2022. Spatial Analysis and Characterization of Dust Particles using Remotely-Sensed Data and its Effects on Solar PV Power Production: Case of the Philippines. 43rd Asian Conference on Remote Sensing 2022, Ulaanbaatar, Mongolia.

Benitez, I., Sotto, M., Bauzon, M. D. A., Santos, J. A., Principe, J. 2022. Preliminary Analysis on the Difference Between Solar PV Power Output Forecasts Derived from Remotely Sensed and In-Situ Solar Radiation Data. 30th IIS Forum, Tokyo, Japan.

Cañete, J., Benitez, I., Bauzon, M. D. A., Sotto, M., Ibañez, J., Principe, J. 2023. Development of a WebGIS for Solar PV Resource and Installation Assessment Using Geospatial Technologies. ISPRS ICWG IV/III - Philippine Geomatics Symposium (PhilGEOS) 2023.

Dizon, A., Escosio, J., Sotto, M.,. Bauzon, M., Cañete, J., Principe, J. 2023. Slope Analysis of CLOT-Adjusted SSI-FY4A Data for Solar PV Power Potential Assessment in the Philippines. ISPRS ICWG IV/III - Philippine Geomatics Symposium (PhilGEOS) 2023.

Django Software Foundation, Django, 3.2.9, https://www.djangoproject.com/, 2023, https://github.com/django/django

Docker, Docker Documentation, https://docs.docker.com/, 2023

ESMAP. 2020. Global Photovoltaic Power Potential by Country. World Bank: Washington D.C., United States of America.

Garner, R. 2015. Solar Irradiance National Aeronautics and Space Administration. NASA. Retrieved from http://www.nasa.gov/mission_pages/sdo/science/solar-irradiance.html (accessed on 06 July 2023)

Goossens, D., Offer, Z. Y., Zangvil, A. 1993. Wind tunnel experiments and field investigations of eolian dust deposition on photovoltaic solar collectors. Solar Energy, 50(1), 75-84. https://doi.org/10.1016/0038-092X(93)90009-D.

Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J-N. 2023. ERA5 hourly data on single levels from 1940 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), DOI: 10.24381/cds.adbb2d47

JAXA. 2015. Japan Aerospace Exploration Agency. JAXA Himawari Monitor. Available online: https://www.eorc.jaxa.jp/ptree/userguide.html (accessed on 06 July 2023)

Jia, D., Hua, J., Wang, L., Guo, Y., Guo, H., Wu, P., Liu, M., Yang, L. 2021. Estimations of Global Horizontal Irradiance and Direct Normal Irradiance by Using Fengyun-4A Satellite Data in Northern China. Remote Sensing 2021, 13(4), Article 4. https://doi.org/10.3390/rs13040790.

Kramer, H. 2016. Earth Observations Missions Portal. Available online: https://www.eoportal.org/satellite- missions/fy-4#references (accessed on 06 July 2023)

Levosada, A. T. A.; Ogena, R. P. T.; Santos, J. R. V.; Danao, L. A. M. Mapping of Suitable Sites for Concentrated Solar Power Plants in the Philippines Using Geographic Information System and Analytic Hierarchy Process. Sustainability 2022, 14 (19), 12260. https://doi.org/10.3390/su141912260.

Liu, B., Li, K., Niu, D. D., Jin, Y. A., & Liu, Y. 2017. The characteristic analysis of the solar energy photovoltaic power generation system. IOP Conference Series: Materials Science and Engineering, 164, 012018. https://doi.org/10.1088/1757-899X/164/1/012018

Meneses Rodriguez, D., Horley, P., González-Hernández, J., Vorobiev, Y., Gorley, P. 2005.Photovoltaic solar cells performance at elevated temperatures. Solar Energy 2005, 78, 243-250. 10.1016/j.solener.2004.05.016.

Misra, P., Fujikawa, A., Takeuchi, W. 2017. Novel Decomposition Scheme for Characterizing Urban Air Quality with MODIS. Remote Sensing 2017, 9 (8), 812. https://doi.org/10.3390/rs9080812.

National Satellite Meteorological Center (National Center for Space Weather). 2023. FY-4 Series. Available online: https://fy4.nsmc.org.cn/nsmc/en/satellite/FY4.html (accessed on 06 July 2023).

Netlify, Netlify Manual and Documentation, https://docs.netlify.com/, 2023

Node.js Foundation, Node.js, 16.13.0, https://nodejs.org/, 2023, https://github.com/nodejs/node

PostgreSQL Global Development Group. 2023. PostgreSQL, 16, https://www.postgresql.org.

Principe, J., Bauzon, M. D. A., Sotto, M., Cañete, J. 2023. Remote-sensing based estimation of potential solar PV power output considering the effects of high temperature, dust and precipitation: Case of the Philippines. IEEE I&CPS Asia 2023, Chongqing, China.

Principe, J. A., Takeuchi, W. 2019. Assessment of Solar PV Power Potential in the Asia Pacific Region with Remote Sensing Considering the Effects of High Temperature, Dust and Snow. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. 2019, XLII-4/W19, 339–346. https://doi.org/10.5194/isprs-archives-XLII-4-W19-339-2019.

React Leaflet, Introduction to React Leaflet, https://react-leaflet.js.org/, 2023 React, Quick Start – React, https://react.dev/, 2023

Rathod, A. P. S., Mittal, P., & Kumar, B. 2016. Analysis of factors affecting the solar radiation received by any region. International Conference on Emerging Trends in Communication Technologies (ETCT) 2016 (pp. 1–4). Dehradun, India: IEEE Xplore.

Sotto, M., Bauzon, M. D. A., Cañete, J., Principe, J. 2023a. AHI-8 SWR Adjustment using CLOT-derived Correction Factor for Solar PV Power Potential Assessment in the Philippines. 31st IIS Forum, Tokyo, Japan.

Sotto, M., Ibañez, J., Benitez, I., Principe, J. 2023b. Assessment of Potential Solar PV Output Derived from Remotely-sensed Solar Irradiance Data and Different Tilt Angles. Asian Conference on Remote Sensing (44th ACRS). Taipei, Taiwan.

Teves, J., Sola, E. F., Pintor, B.H., Ang, M. R. C. 2016. Assessing the urban solar energy resource potential of Davao City, Philippines, using LiDAR Digital Surface Model (DSM) and GRASS GIS. In Proceedings of the SPIE Remote Sensing, Edinburgh, United Kingdom.

Wald, L. 2018. Basics in Solar Radiation at Earth Surface. HAL Science. Observation, Impacts, Energy Center, MINES ParisTech, PSL Research University.

Yao, H., & Zhou, Q. 2023. Research status and application of rooftop photovoltaic Generation Systems. Cleaner Energy Systems, 5, 100065. https://doi.org/10.1016/j.cles.2023.100065

Zorrilla-Casanova, J., Piliougine, M., Rubio, J.Bernaola-Galvan, P., Carpena, P. López, L., Sidrach-de-Cardona, M. 2011. Analysis of Dust Losses in Photovoltaic Modules. World Renewable Energy Congress 2011. Linköping, Sweden. 2985-2992. 10.3384/ecp110572985.