Solar suitability map for office buildings using integration of remote sensing and Geographical Information System (GIS)

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Abstract The rapid growth and urbanization of metropolitan regions has resulted to greenhouse gasses and global warming [1]. Infrared radiation emitted by the Earth’s surface, atmosphere and clouds which absorbed by greenhouse gasses would otherwise be emitted to space. The absorption and re-emission of infrared radiation by greenhouse gases warms the Earth’s lower atmosphere and surface, a process known as the “Greenhouse Effect”. The main anthropogenic greenhouse gas emissions are in the form of carbon dioxide (CO₂), which is emitted by human activities such as cement production [2], deforestation and burning of fossil fuels [3], are enhancing the Greenhouse Effect and it is the primary cause of climate change. The changes in climate could have large, harmful impacts on human wellbeing. The IPCC 5th Assessment Report culminated that urban areas trigger the majority of carbon emissions from final energy use [4].

Over the past two hundred years, there is an increasing of carbon dioxide emissions, caused by industrialization, electricity demands rise, and the associated fossil fuel burning. Demands of energy are expected to rise up by a factor of 1.5 to 3 by 2050, which will lead to a continually increasing trend in carbon dioxide emissions [5]. Currently, the world’s cities emit 70 percent of the world’s carbon dioxide. Rising carbon emissions have become an increasing problem, which makes it necessary to do the mitigation of carbon emissions, even many governments are adopting policies that promote this. Many...
countries in the world are focusing at the increased use of renewable energies and improving energy efficiency in urban and rural areas while utilizing the potential of economic growth from the low-carbon sector [5].

Several European Directives, including the Energy Efficiency Directive 2012/27/EU (2012), highlighted that big effort must be done by all Member States to optimize the use of energy sources. EU is targeting for a 27% cut in Europe's annual consumption for primary energy by 2030. This can be achieved in several ways, such as implementing efficient way of energy efficiency plans, greenhouse gas (GHG) emissions reduction [6], reduce carbon emissions by mitigating the production of fossil fuel electricity by using renewable energy instead [5], increasing the consumption and production of renewable resources and so on [6]. Renewable energy is a kind of energy which generated from natural resources such as wind, sun radiation, tides, rain, and geothermal heat which are renewable (naturally replenished) [7]. Amongst all renewable resources, solar energy produces promising results.

Solar irradiation can be defined as an amount of sun power per square meter that reaches the Earth [8]. Part of the solar irradiation can be converted to electricity as an application in solar energy. In contrast to conventional power sources such as gas or coal, solar irradiation is uncontrollable and volatile by the user [9].

It is essential for the accurate information of the solar radiation intensity at a given location to the development of solar energy-based projects and in the solar energy conversion systems performances for long-term evaluation. This information is used in the project plan, in cost analysis, and the calculations of a project efficiency. Malaysia has the opportunity to effectively utilizing solar energy, promoting a clean environment, and developing technologies for renewable energy in the country [10]. Malaysia is located close to the equator, between 1 and 7 degrees north and between 100 and 120 degrees east, thus having a high level of irradiance. The annual solar irradiation in Malaysia is 1643 kWh/m² [11].

Over years, numerous methods for estimating solar radiation on a horizontal plane have been developed. In this study, the satellite dataset with the aid of GIS technology was used to generate solar energy potential map of the urban area throughout the year.

With the integration of satellite images, spatial dataset and GIS tools, the best location to set up solar collectors such as photovoltaic and concentrated solar power can be determined. With the improvement of energy efficiency, developing new energy, and establishing a method of clean energy, the carbon emission can be reduced.

1.1 Study Area
In this research, one type of office building has been chosen as the study area. The office building located at Jalan Bangsar, 59200 Kuala Lumpur, Malaysia. The study area is shown in Figure 1.

![Figure 1. One type of office building](image-url)
2. Methodology

The methodology portrays the procedures used to collect the dataset, discussion on the data processing phase and to document the procedures used in the data analysis. The methodology of this research is divided into two main phases as shown in Figure 2.

In this study, two types of data involved are AW3D from the ALOS satellite image provided by NTT Group, and spatial information including sun azimuth and sun altitude of the study area.

An AW3D dataset was processed and the polygon of each building (rooftop) was extracted as well as the height of each building. These data, along with the sun azimuth and altitude (Refer Table 1) were used to perform the hill shade analysis of the study area (using ArcGIS 3D Analyst Tool) from 8 am to 7 pm (hourly) as shown as Figure 2.

Apart from hill shade analysis, the process to determine the suitable area to locate the solar collectors (photovoltaic and concentrated solar power) also involves the reclassification of the hill shade
results, overlay (using weighted sum method), reclassification of the overlay results, vectorization and the area calculation using Calculate Geometry Tool to calculate the area of unshaded rooftop. For daily solar suitability map, hourly solar map (8 am to 7 pm) were used in the weighted sum operation. The analysis was performed for every month starting from January 2018 to January 2019. The results have been compared hourly and monthly.

3. Results and Analysis
Hill shade analyses have been performed on office buildings for every month starting from January 2018 to January 2019 at a 1-hour interval (8:00 am to 7:00 pm). These analyses were used to generate solar suitability maps that contain information about suitable areas to set up the solar collector. The solar suitability maps generated are shown as follows;

3.1 Hourly
Figure 4 shows the solar suitability maps for January 1st 2019 for each hour starting from 8:00 am to 7:00 pm.

![Unshaded Area](image)

![Shaded Area](image)

Figure 4. Hourly Solar Suitability Maps

As refer to Figure 4, the yellow polygons represent the unshaded rooftop (area exposed to sunlight) whereas the grey polygons show the shaded rooftop (area sheltered from the sunlight). From the results, it can be seen on January 1st, 2019, the office building rooftop receives the highest amount of sunlight is from 12:00 noon to 4:00 pm.

3.2 Daily
The hill shade analyses have also been performed daily from January 1st, 2018 until January 7th 2018 at a 1-hour interval for each day. The solar suitability map from 8:00 am to 7:00 pm were overlaid to produce the daily solar suitability map. The results of overlaid are shown and compared in Figure 5.
Figure 5 shows the solar suitability maps for 1st January 2018 to January 7th, 2018. From the figure, it can be seen that the office building rooftop receives the highest amount of sunlight (area exposed to sunlight) on January 4th, 2018. This indicates that the amount of sunlight received by the building varies in a week although the azimuth and altitude used to produce the hill shade analysis are almost the same for that month.

3.3 Monthly
The hill shade analyses have also been performed monthly. The monthly solar suitability maps are based on the sun azimuth and altitude of the first day of each month i.e. January 1st, February 1st, March 1st, etc. The monthly solar suitability maps, as well as its attribute data, are shown in Figure 6 and Table 1, respectively.
Figure 6 represents the solar suitability maps for January 2018 to December 2018. From the figure, it can be seen that in February, March, May, and October, the area of rooftop that was exposed to the sunlight is higher as compared to the other months. These are supported by Table 1 where it is shown that February, March, May, and October recorded a high percentage of area that is exposed to the sunlight. Among these four months, February shows the highest percentage which is 95% (6330.700 m²) exposure of the total area. Followed by October, 94.2% exposure area. April shows the lowest percentage (59.1%) of sunlight exposure to the rooftop. From these results, it can be seen that the amount of area exposed to sunlight varies from month to month. This result has yet to take into account the cloudy and rainy factors which, if any, affect the amount of the exposed area.

### 4. Conclusion
This study focused on generating the solar suitability map for the study area. Remote sensing and GIS technology were implemented to determine the best location or suitable area to set up a solar collector such as photovoltaic and concentrated solar power. The data and information such as rooftop information from AW3D, sun azimuth, and sun altitude were used in performing the hillshade analysis of the study area. From the results, it can be concluded that the integration of remote sensing data and GIS software can assist the users to map the suitable location of the solar panel as well as in decision making.

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