Implementation of a Building Integrated Photovoltaic in Urban Lands Using the Geospatial Technology

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SUMMARY

Solar energy remains the largest source of potential clean and renewable energy. Since the oil shock in the early 70s' the solar energy market has grown on average 25 to 30% per year Although environment and energy security are the main reasons for the global trend of adopting alternative energy, however the main incentive is the potential of this kind of energy to stimulate economical growth. Indeed, the economical impact of implementing and adopting alternative energy is highly considered by various stakeholders and lawmakers at both international and national levels. Here in Malaysia, there is no daily solar energy map diffused online and adapted to PV users, which is not enough to encourage and to response the needs of the large public as well as concerned authorities. However, even though GIS technologies and other Geomatic disciplines as Remote Sensing, cartography… etc. have a proven and well known potential to address this issue in an effective and efficient manner, but still no effort has been made. In fact, there is a lack of appropriate geospatial based tools to offer and integrated solution to inform, optimize, and manage actual and future PV network in Malaysia. This project aims to offer to various users including government bodies, local authorities, and general public a geospatial tool to access useful information related to solar energy and PV implementation and management. Thus in this study we created a website to automatically generate and publish daily solar radiation maps of peninsular Malaysia from NOAA-AHVRR Satellite Images, and to inform on the eco-friendly locations to implement the photovoltaic solar panel based on a combination of LANDSAT TM and QUICKBIRD images in urban areas, case of Johor Bahru City. Only 48.8% of the whole JB city center area can be used to install 100% PV without having a negative effect in the Urban Heat Island. The MapServer tool was used to develop a webapplication potentially offering information to various PV users. Thus, we could produce a solution to localize the PV users and get all the information depending on their PV installations. Also, the website gives the access of daily reports about received and produced energy for each user. The user of this tool can be a current PV user, future one or even the government in order to quantify the produced energy in the whole peninsular Malaysia and forecast energy demand on short-term basis, towards a sustainable use of photovoltaic solar energy for green cities.

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1. INTRODUCTION

In line with the global trend for developing renewable energy, the national energy policy (NEP) in Malaysia was formulated in 1979, after suffering two international oil crises in 1973 and 1979 ((Mohamed, et al., 2005)). has announced that the main objectives of Malaysia' s energy policy are: I) supply, II) utilization and iii) environmental objectives , the first one is based on reducing its independence from oil and by developing and utilizing alternative sources of energy, whereas the second one is aimed at promoting and encouraging the efficient utilization of energy and discouraging wasteful and non-productive patterns of energy consumption within the given socio-cultural and economic parameters, and lastly, the environmental objective seeks to ensure that factors pertaining to the environment are not neglected in pursuing the supply and utilization objectives. In Malaysia, there is no daily solar energy map diffused online and adapted to PV users, which is not enough to encourage and to response the needs of the large public as well as concerned authorities. In fact, current or an expected user of PV needs detailed information allowing him prompt access to (i) the real received solar energy in his specific location and (ii) quantity produced of energy depending on the type of PV technology used. So, all PV users need to know before buying or installing solar panel, if the location suitable and receives optimal solar radiation, if the efficiency is enough for his daily demand of energy, and a monitoring and tracking tool such as a daily report about received and produced energy. This study aims to offer to various users including government bodies, local authorities, and general public a geospatial tool to have access to useful information related to solar energy and PV implementation and management. Thus, the main objectives have been set up for this project as (i) To create an application to automatically generate solar radiation maps of peninsular Malaysia from NOAA Satellite Images, (ii) To determine the eco-friendly locations to implement the photovoltaic solar panel based on a combination of LANDSAT TM and QUICKBIRD images and finally (iii) To create a website to integrate and diffuse the results of the previous two objectives through a web-mapping application using MapServer and offering useful information to various PV users

2. METHODOLOGY

To achieve objective #1, 18 images AVHRR-NOAA from the FKSG-UTM receiving station have been acquired. (Tovar, et al., 2001) algorithm is used to extract surface solar radiation as this algorithm has been successfully calibrated and used in Malaysia. The whole Malaysian peninsula is covered by this objective as a good spatial and temporal coverage is allowed by AVHRR images. PCI Geomatica10.0.3 and ENVI4.5 as well as Matlab7 have been used for the processing. The main concern was to to automate the process to generate solar radiation maps based on (Tovar, et al., 2001)'s algorithm and thus generate daily solar energy maps from NOAA AVHRR satellite images. A special focus was put on the direct estimation of photovoltaic installation output in the term of electricity and market monetary value. In the satellite images, the visible and infrared channels are utilized in cloud detection, while the visible channel only was used in determining the albedo of both the surface and clouds. In equation 1, The minimum value for each pixel giving the information related to the clear-sky planetary albedo for every pixel α toa,min (i,j). While in the same way, the maximum value for each pixel I the series corresponded to the planetary albedo of the overcast cloudy sky including cloud top and the atmosphere above the cloud α toa,max (i,j). The αt toa (i,j) is determine as the instantaneous planetary albedo. Later, the cloudiness can be express

$$n^t(i,j) = \frac{[\propto^t_{TOA}(i,j) - \propto_{TOA,min}(i,j)]}{[\propto^t_{TOA,max}(i,j) - \propto_{TOA,min}(i,j)]} \quad \textbf{Eq 1}$$

Through the cloud-cover index nt(i,j) at a given point (i,j) and in a given time t by the following cloud-cover index formula (D., et al., 1986).

Objective #2 involves a high spatial resolution image and has been limited to Johor Bahru City Center using one QUICKBIRD and one LANDSAT7 TM Images. PCI Geomatica10.0.3 and ENVI4.5 as well as Matlab7 have been used for the processing. Urban land cover of Johor Bahru City has been classified using very high resolution (Quickbird) image. Then, temperature for each land cover classes through combination of Landsat-5 TM land surface temperature image, Quickbird land cover classified image in Johor Bahru was determined (see figure 1). Thus eco-friendly locations to implement photovoltaic solar panel in Johor Bahru City was achieved but choosing only pixels that they do not overpass a certain threshold. This process was allowed to be done automatically

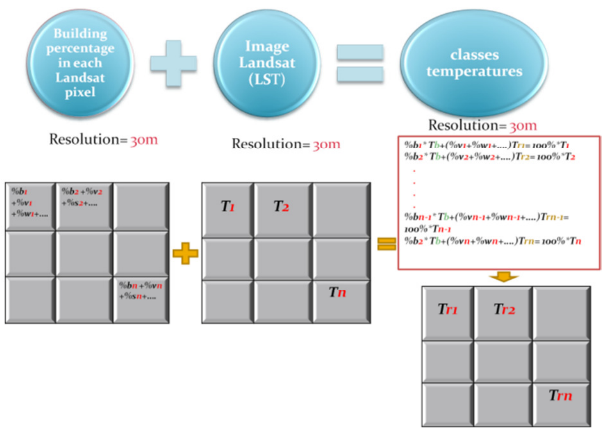

Figure 1: Combination of LANDSAT LST image and QUICKBIRD Classification to extract individual land cover LST

Finally, to achieve objective #3, Web Mapping Technique has been used by the utilization of MapServer environment; this final product includes the results of the 2 last objectives in order to diffuse the information for a large public and to management the utilization of Photovoltaic in peninsular Malaysia. Allowing (i) to visualize location in Peninsular Malaysia map in order to quantify solar energy received per day; (ii) Simulate electrical energy produced based on

Solar cell type, solar energy received, PV area, and other parameters using an energy calculator; (iii) Forecast of electrical energy produced for next days from existing PV users' network; (iv)Allow Government and local authorities to Manage and Control the implantation of PV in eco-friendly locations; (v) Receive monthly average report about the summation of energy producing by using PV in the hall of Peninsular Malaysia and (vi) Encourage general public to adopt PV by allowing them to consult monthly. Figure 2 summarize the website developed and its various components

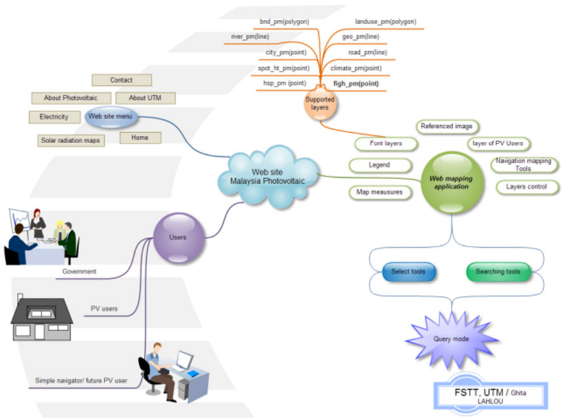

Figure 2: Relationships between web site components

3. RESULTS AND DISCUSSION

After retrieve the LST for the whole area of study, the masking process can be use to masked out another class except the building class. This is done as the purpose to see the distribution of temperature on building feature. This masked image was been combined with LST in order to extract a general view about land surface temperature of building. The range of temperature remains the same as LST map. The minimum temperature is about 22°C and the maximum temperature is 27°C. The different of temperature for the building features due to the different surrounding area. Building that surrounded with vegetation area is colder than the building that is hotter when it is surrounded by other buildings. The result can be show in Figure below:

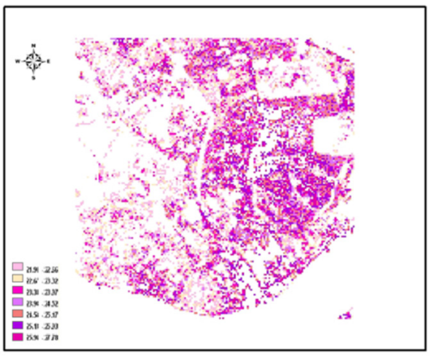

Figure 3 : Land surface temperature map (Building) of Johor Bahru city, 2005

As we can see in the legend, the temperature is between 20 et 43 ˚C, and as we defined before the threshold that we determined is 32 ˚C, as a maximal temperature of eco-friendly location, whereas in this image we have pixels which their temperatures are more than 32˚C. so the next objective of this part will arrange this problem by modifying a new percentage of roofs where we can implement BIPV without overtaking the threshold.

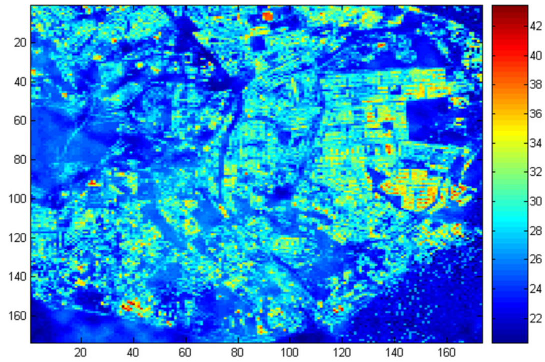

Figure 4: the map of BIPV LST average, 60 w

The extraterrestrial solar radiation assumed was taken from the solar constant which is 118.1088 MJ/m² per day. However the value was estimated for a whole day solar radiation. Since the study area of Peninsular Malaysia receives only 12 hours of solar radiation every day, the values of extraterrestrial solar radiation used in this study is 59.0544 MJ/m². The final output of the monthly solar radiation map covering the eighteen days by using the previous created program are shown below:

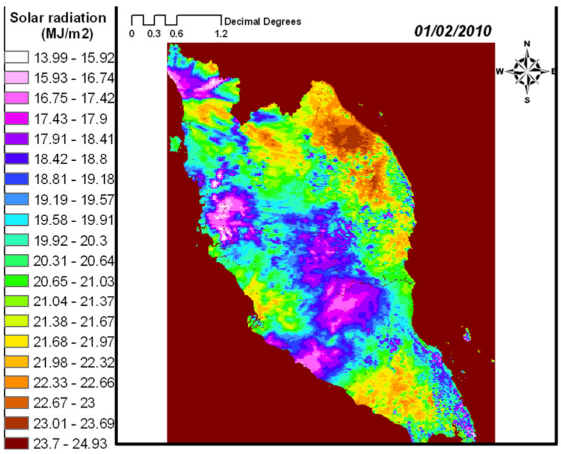

Figure 5: Example of estimated daily solar radiation maps

The 18 images used in this study have been used to produce a monthly average that can be modified automatically as new images are added (figure 6)

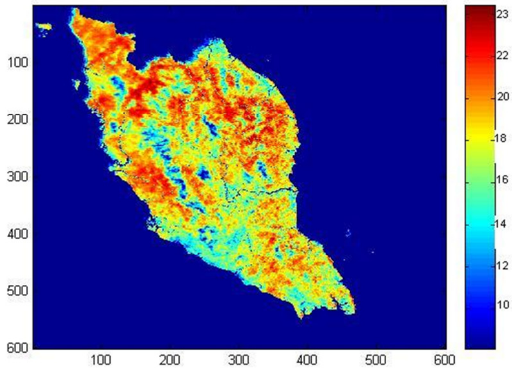

Figure 6: Solar Radiation Average in the first eighteenth days of February 2010 over Peninsular Malaysia

The last step of this project is to make the access of the last results easier, for that we choose the web mapping as a tool to achieve this goal.
Bellow we can see the main page in this web site, the page which contains all the component of the web mapping application and navigation options

Navigation mode

- Map layers:
- Tools navigation mapping
  - Zoom in to the map;
  - Zoom out to the map;
  - A pan;
  - Full extent;
  - Define a zoom size.
  - Legend
- Layers control
- Map measures
  - The scale of map;
  - The geographical coordinates (X, Y);

The dynamic extent that is changed when we zoom the map;

- Referenced image

Query mode

- Searching tool
- Select tool
  - The cost of this installation;
  - Energy received in this location;

Visualizing the statistical graphs of solar energy and PV gain.

- Web site menu
  - Home
  - Solar radiation maps
  - About photovoltaic
  - About UTM and Electricity

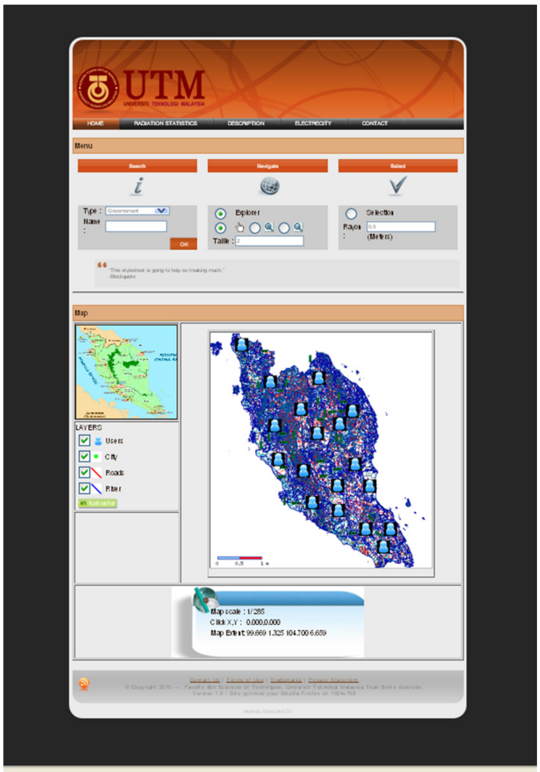

Figure 1: Main page of the web site

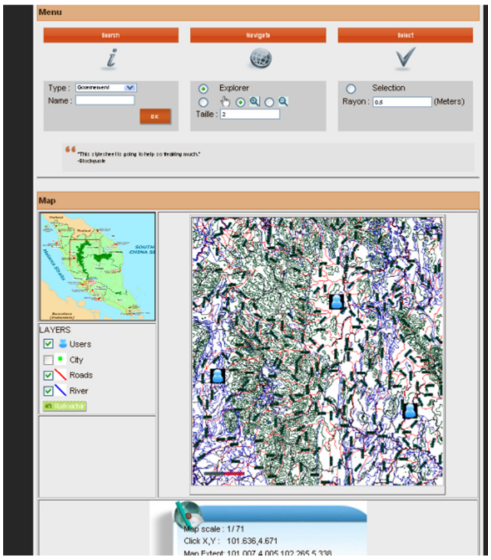

Figure 8: Component of Web mapping application

We can see in the next printed screen, haw the map changes when we make some modification as zoom in, zoom out or activate or deactivate a layer:

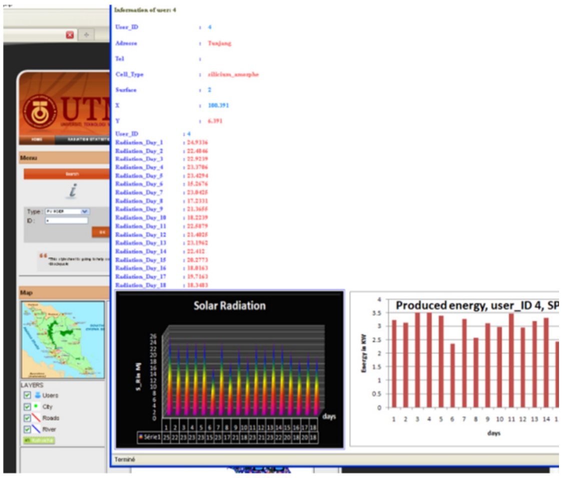

Figure 9: Report of a specific PV user

When the user click in his location of installed PV or choose from the list his ID, the mape makes a zoom in this location and create a new web page which contains the report of his received and consumed energy per day, figure :

This page contains also, some information about his address, his phone, his geographic coordinates, and the most important information about his installation of PV, the area of the panel the type of PV cell that he uses. And bellow this he can see the graphics about the statistics of produced and received energy. If the user is considered by knowing the total of energy value produced b all pv users in peninsular Malaysia, he can get a report from this web site which presents the quantity of produced energy and the locations of all these users and all the information related for each one about his installation, figure 10:

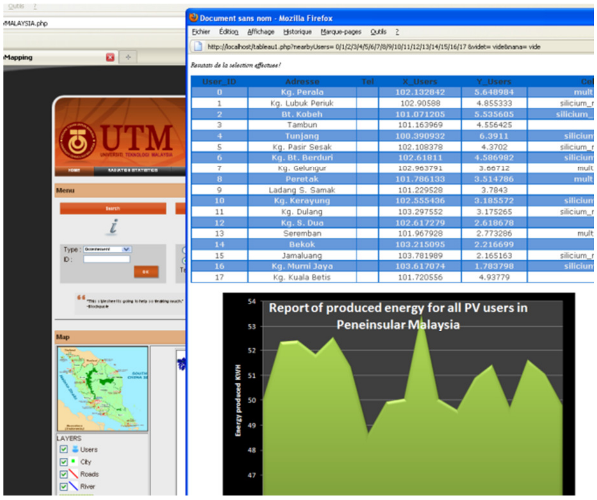

Figure 10: General report of all Users PV in Peninsular Malaysia

Also any user of this web site can get the information about received energy solar in the whole of peninsular Malaysia which allows him to have an idea about the energy that he can produce in his roof and decide if it will be benefic for him. All the created maps of solar energy are in one catalogue and the user can get the access on this easily (figure 11).

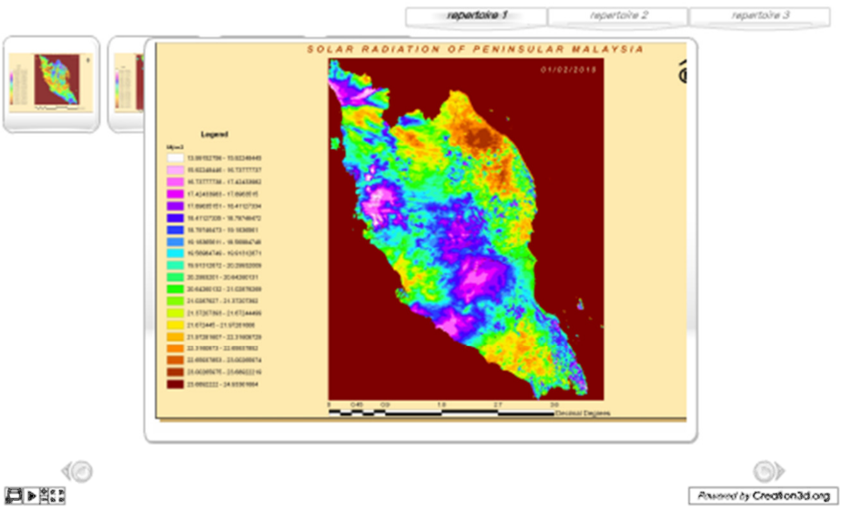

Figure 11: Map of monthly solar energy over peninsular Malaysia

4. CONCLUSION

The ultimate outcome of this study is a tool allowing easy access to resourceful Photovoltaic information. This website contains a dynamic web mapping application to serve a current or a potential PV user, the government or even a simple web navigator. It provides an access to crucial information about the installation of photovoltaic in the Malaysian peninsula based on Mapserver as web mapping, a dynamic map with different layers that are generated and displayed with daily up-dates. The use of Mapserver allowed more fluid and easy navigation in the website with a high quality of maps' visualization.
Users of this web site can get a preview on the number, location, technology, etc., of installed PV panels in Peninsular Malaysia, using the local coordinates system; WGS 1984 as a projection -reference datum Kertau 1948. They might use the standard navigation mode to browse the map, by zooming in or out, choose specific layers to display and knowing the scale of the map and extent which change interactively. The request mode allows users by a simple click in the map, in a specific location with a specific radius, to get a report about all installed PV in this area. This report is in the form of two tables and 2 graphs, the first one is about personal information of the owner of this installation, it contains also, the area of this installation and the used type-technology of solar cell. The second table contains the information about historical and actual daily received energy. The two graph show the same information as the tables but in more convivial and user-friendly manner. Also in the request mode, a general report of all PV users in the Malaysian peninsula and the quantity of electrical energy produced can be obtained. Thus, for current PV users, future ones, government or any web navigator, this web site can provide the access to valuable information about photovoltaic in Peninsular Malaysia

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