SIMULATION OF SOLAR PANELS EFFECT ON THE MICROCLIMATE IN ARID AREAS USING REMOTE SENSING TECHNOLOGY

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A project report submitted in fulfillment of the
requirements for the award of the degree of
Master of Science (Remote Sensing)

Faculty of Geoinformation Science and Engineering
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May 2009

To My beloved Parents, Brothers,,,

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude to my supervisor, Dr. Ali EL BATTAY for being a dedicated mentor as well as for his valuable and constructive suggestions that enabled this project to run smoothly.

Also, not forgetting Omar Molki and Ahmad Jabr, Dr. Salem M.Zaki and Dr. AbdulGaffar, I convey my full appreciation for their on-going support and contributions toward this project, whether directly or indirectly especially.

Last but not least, I am forever indebted to all my family members for their constant support throughout the entire duration of this project. Their words of encouragement never failed to keep me going even through the hardest time and it is here that I express my sincerest gratitude to them.

ABSTRACT

Using renewable energy sources become more significant than nonrenewable energy sources since it can reduces fossil energy consumption in an eco-friendly manner. Building solar panels in large area and use it as alternative energy may have significant effect on the microclimate. In this study, on some microclimate parameters effect have been studied extensively by measuring solar panels in field and laboratory experiments and integrating the results of these experiments through simulating in LANDSAT 7 ETM+ images of Riyadh - Saudi Arabia. The focus was on four microclimate parameters which are land surface albedo, land surface temperature, relative humidity, and atmospheric pressure. This study showed a clear impact when land cover changes to solar panel. In fact, the solar panel's albedo in the shortwave part of Electro Magnetic Spectrum (EMS) is around 0.13, compared to the dominant landcover class in arid area, sand which is 0.30. Furthermore, by implementing solar panels over a vast arid area, the surface temperature might increase by 20 – 30 % passing from an average of 45 °C to 62 °C. Thus, the relative humidity in the time of image has dropped from 13% standardize to only 3% in the case of solar panels. The fourth studied microclimate parameter, air pressure showed no significant change before and after simulation and seen more related to altitude.

ABSTRAK

Menggunakan sumber-sumber tenaga boleh diperbaharui menjadi lebih signifikan daripada sumber-sumber tenaga tidak boleh diperbaharui sejak ia boleh mengurangkan fosil penggunaan tenaga dalam satu eko mesra cara. Suria bangunan berpanel dalam kawasan luas dan menggunakan ia sebagai tenaga alternatif mungkin kesan pada mikroiklim. Microclimatic kesan-kesan telah dipelajari dengan meluas dengan mengukur panel suria di lapangan dan eksperimen makmal dan keputusan eksperimen-eksperimen ini adalah kemudiannya tersimulasi dengan LANDSAT 7 ETM imej-imej Riyadh - Arab Saudi dalam empat parameter mikroiklim termasuk permukaan tanah albedo, suhu permukaan tanah, kelembapan relatif, dan tekanan atmosfera. Rantau kajian ini menunjuk yang iaitu litupan tanah bertukar menjadi panel suria mempunyai kesan-kesan negatif pada mikroiklim. Albedo panel suria 0.13 terlibat atas kawasan kajian dengan bertambah suhu permukaan untuk 20 - 30 %, dan kesan suhu pada kelembapan relatif dengan berkurangnya nisbah daripada 13% untuk 3%, dan kesan itu juga pada tekanan udara tetapi adalah kesan rendah 2%.

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LIST OF SYMBOLS

°C	Calicoes degree.
°K	Kelvin degree.
3×10^{8} m s^{-1}	Light speed.
Ee	Emitted Energy.
ε	Emissivity.
σ	Steve Boltzmann $=5.67\times10^{-8}$ W m^{-2} K^{-4}
R	Net radiation.
µm	Micrometer.
α	Surface albedo.
$I\uparrow$	Outgoing long wave radiation from the surface.
$I\downarrow$	The absorbed downwelling long wave radiation.
ψ_{λ}	The transmissivity.
α_{λ}	The reflectivity.
ζ_{λ}	The absorptivity.
L	The latent heat of evapouration.
E	The evapouration or condensation rate.
H	The sensible heat exchange between the ground and the atmosphere.
G	The sensible heat exchange between the surface and the substrate.
W/m^{2}	Watt per square meter.
PV	Photovoltaic.
LEDs	Light-Emitting Diodes.
UHI	Urban Heat Island.
ET	Evapotranspiration.
SVF	Sky view factor.

SRTM	The Shuttle Radar Topography Mission.
ETM+	Enhanced Thematic Mapper plus.
NASA	National Aeronautics and Space Administration.
ATCOR	Atmospheric Correction.
LST	Land Surface Temperature.
TIR	Thermal Infrared.
K_1	666.09 W/m^2 sr µm.
K_2	1282.71 K.
AT.P	Atmospheric pressure.
DLR	GERMAN AEROSPACE CENTER.
Envi. dbase	Riyadh Environmental Data Base.
FKE	*Fakulti Kejuruteraan Elektrik – Faculty of Electric Engineering*

CHAPTER 1

INTRODUCTION

1.1 Background

The world is facing a global energetic crisis due to the overuse of Earth's non-renewable sources of energy such as fossil energy. Besides the scarcity of these resources, their use since the industrialized era has led to significant enhancement of the atmospheric greenhouse effect. Combined with other anthropogenic kinds of pollutions, it is obvious that the global warming phenomenon and the global climate change is a result of such blindly and uncontrolled overuse of Earth's fossil energy (Ferilli, 2009). the major problem of using fossil based energy is (i) it is not renewable, which means that after a certain time it will finish, and (ii) the global warming has reach an alarming level which shows a real danger to the future of all kind of life on the earth, including human being.

During hundreds of years, mankind has found a way to use fuel as a powerful energy source to produce electrical energy. Figure 1.1 indicates that the fossil fuels become highly significant. Heavy oils, oil sands and oil shale will increase the static lifetime to 62 years. Natural gas will last for approximately another 64 years, whereas the reserves of coal will be available for about another 200 years (DLR, 2005). Uranium, another finite source of energy, will only last for another 40 years, using light-water reactors without conditioning the nuclear fuel. It would appear that there are considerable amounts of resources still available which in principal can also be used such as water and sun resources.

The distribution of energy resources among present and future generations is not ensured (DLR, 2005). Even if today's generation were to come to the conclusion that an appropriate basis for acting shall be left for future generations despite the exploitation of the reserves of fossil and nuclear energy carriers, then in the light of the long time needed to develop and introduce new energy technologies, the minimum requirement has to be to begin now to introduce forcefully these new technologies not dependent on using fossil or nuclear fuels and not to lay down any structures today which might make future changes impossible or impede changes significantly in this context.

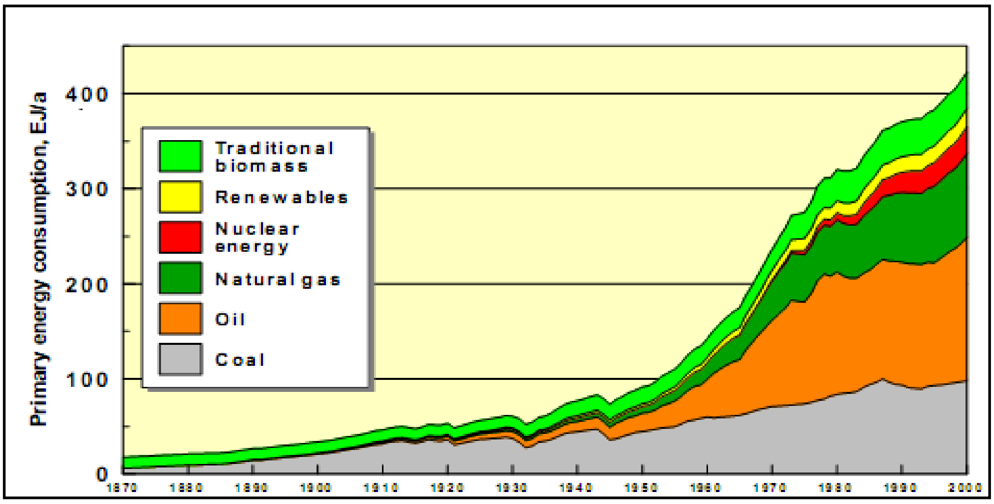

Figure 1.1 The fossil fuels become very vast and important (DLR, 2005).

To overcome this manmade dilemma, many alternative sources of energy have been studied, the main objective is to find an energy source which is renewable and Earth's friendly. Nuclear power, even if it is highly reliable, is no more a trend because of its heating potential as well as the many political and geostrategic implications. In the last decade, a special attention has been given to other kind of energy's source, such as the hydropower, wind power, bio-fuel, geothermal energy, and last and not least, the solar power. In fact, it is proved that if adequate technology is developed and adopted, solar energy is enough to cover all modern societies' needs of energy (DLR, 2005).

In this study, the focus is on the solar energy issue and its impact on local and regional scale if exploited at a very wide level. Remote sensing capability is used to quantify the impact of the implementation of large solar plant, big enough to supply a modern megacity.

1.2 Solar Energy, potential and challenges

The solar energy is giving the earth heat through the atmosphere which absorbs the disadvantageous radiance (e.g. UV-C). It is the renewable source per excellence, because it is coming continuously from the sun. Wind energy origins from a non-homogeneous and variable warming up of the earth's surface by the sun (high and low pressure difference). Water energy, is the energy released by water in motion, again water cycle is made possible due to sun energy. The biomass energy is nothing else than solar energy, stored thanks to photosynthesis, in the plants green (vegetable) tissues (Ferilli, 2009). So, most of renewable and Earth's friendly sources of energy are related to the solar energy. However, solar technology means generally any kind of tool that allows the direct transformation of solar energy into forms of energy that are useful to man: heating, electricity, combustible. A famous solar technology is solar panels which are used to (I) transform directly solar radiance to electric energy, the so called photovoltaic solar panels, or (II) to convert sun light into heat which produce hot water and indirectly electricity, in this case it is called thermal solar panel.

Although the world now is talking about how to concentrate solar power to heat the water by technology called parabolic (thermal solar panel). Europe-Middle East & North Africa (EU-MENA) completed a study about the feasibility of Concentrating Solar Power to supply the Mediterranean Region (MED-CSP, 2005). This study confirmed the considerable potential of solar power, both photovoltaic and thermal, to produce the electricity and water supply of the whole region and all countries around the Mediterranean and the Arabian Peninsula. This project will reduce the CO_2 emissions and obviously contributes to decrease the global warming problem. Intergovernmental Panel for Climate Change (IPCC) recommends reducing CO_2 by 30% in 2050. MED-CSP summarized the study in the following statements (DLR, 2005):

- Environmental, economic and social sustainability in the energy sector can only be achieved with renewable energies. Present measures are insufficient to achieve that goal.
- A well balanced mix of renewable energy technologies can displace conventional peak-, intermediate and base load electricity and thus prolongs the global availability of fossil fuels for future generations in an environmentally compatible way.
- Renewable energy resources are plentiful and can cope with the growing demand of the EU-MENA region. The available resources are so vast that an additional supply of renewable energy to Central and Northern Europe is feasible.
- Renewable energies are the least cost option for energy and water security in EU-MENA.
- Renewable energies are the key for socio-economic development and for sustainable wealth in MENA, as they address both environmental and economical needs in a compatible way.
- Renewable energies and energy efficiency are the main pillars of environmental com-patibility. They need initial public start-up investments but no long-term subsidies like fossil or nuclear energies.

- An adequate set of policy instruments must be established immediately to accelerate renewable energy deployment in the EU and MENA.

There are many suitable places which receive high amount of sun's energy over the world. For example, the Great Sahara in Africa is the largest area 9,064,960 km^2 and the yearly irradiance is around 260 W/m^2, the Empty Quarter in Middle East is the second larger area 2,589,910 km^2 where the irradiance is 270 W/m^2, while Takla Makan in china is the smaller area, 271,950 km^2, and a yealry irradiance of 210 W/m^2 (Bishop, 1991).

1.3 Problem statement

It is known; that any urban or rural area has its own microclimate which is a local atmospheric zone extending from 0.1m to 5 km, where the climate differs from the surrounding area. Many factors could affect the climate in local area such as water sites which are cooler than surrounding, the concrete or the asphalt which absorb sun's energy making the area hotter. The weather variables in a microclimate such as rainfall, wind, humidity or temperature, the natural surface like soil and vegetation and the local topography, all of these factors make the difference in the climate in local area.

The widely use of solar panel is related to the many advantages of this technology which has become one of the important element to produce economically electrical energy with no more pollution. However, installing solar panels in very vast area near to urban or rural sites could have a significant effect on human life and environment by modifying microclimate. For instance, considering a water vapour content of 5 grams per kg of dry air at 30°C, the relative humidity is around 16%, rising the air temperature by and additional 5°C, the RH become only 12% (Tetens, 1930). In fact, in arid and semiarid regions, adding a few centigrade degrees to a surface and/or air temperature which is at the top limit of tolerability (more than 50°C), that have a catastrophic impact on both flora and fauna.

1.4 Objectives

This project aims to simulate the impact of installing vast Photovoltaic solar panels plantation in arid areas and study the effect on the microclimate. The simulated site was selected near to Riyadh city in Kingdom of Saudi Arabia and the objectives of this project are as follows:

(1) To extract solar panel spectral signature and to compare its albedo with other prominent landcover change in arid areas.

(2) To use satellite imagery to choose the appropriated location to install imposing photovoltaic solar panels near Riyadh city.

(3) To produce maps using satellite image of four microclimate's parameters, land surface albedo, land surface temperature, and relative humidity, before and after the simulated installation of photovoltaic solar plant.

1.5 Scope of the study

This study will focus on photovoltaic monocrystalline solar panels. The field study concerns two types of photovoltaics, the first produce 60W/h and the second produce 80W/h. For the simulation purpose, the desert and arid area near Riyadh city in Saudi Arabia has been chosen. LANDSAT 7 ETM+ images are used in this project because of its adequate spatial resolution, appropriate spectral coverage ranging from visible to thermal infrared and wide availability of free images covering many years. This project focuses only on four microclimates related parameters; land surface temperature, relative humidity pressure and albedo. SRTM images were used to extract elevation values of study area and Meteorological data to develop and validate the methodology. Spectroradiometer, Goniometer and other field instruments are used to extract solar panel spectral signature and PCI Geomatica, ERDAS imagine and ArcGIS are used to handle satellite images.

1.6 Structure of the document study

This report is divided into five chapters including this one. Next chapter is covering literature review of key elements addressed in this study, namely: Desert microclimate, Photovoltaic solar panel and urban heat island. In chapter three it is described the data sets (both images and ancillary), mainframe of the methodology to achieve the objectives and various processing models. Chapter 4 presents the results and discussion. Finally, the last chapter 5 presents the main conclusions and achievement of this study and some recommendation for future work.

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