Prioritizing Locations for Distributed Generation: From Cities to Rooftops

Faculty of Environment
GEOG 471 Remote Sensing Project Winter 2018

Zhihao Wang
Jiachen Wei
Yunhong Tian

INTRODUCTION

United Nation Sustainable Development Goal 7, affordable and clean energy, is experiencing slow progress due to inadequate policy commitment and limited acceptance of new technologies [1]. Distributed photovoltaic (PV) technology harvests the sun's energy as a renewable source of electricity, and it is cost-efficient in terms of land resources and transmission infrastructure. Taking a remote sensing approach, this project informs municipal administrations and local communities of the optimal locations for PV installations. It considers the impacts of air pollution on incoming solar radiation, temperature variation on solar cell efficiency, and roof complexity on available areas. The finding is likely to empower decision-makers to provide policy and financial incentives accordingly to facilitate the progress towards the sustainable development goal.

OBJECTIVES

To prioritize locations for PV installations, the project fulfills the following objectives:

1. On the provincial level, it quantifies the influence of air pollution on solar irradiance and identifies cities with abundant solar resources.
2. Within a significant city, it examines the spatial variation in land surface temperature and suggests thermal-efficient installation areas.
3. In a selected built environment, it determines the locations and areas of suitable roofs using LiDAR data.
4. It estimates daily power output based on ground-level solar radiation, solar cell efficiency, and available areas obtained from the steps above.

STUDY AREA & DATA

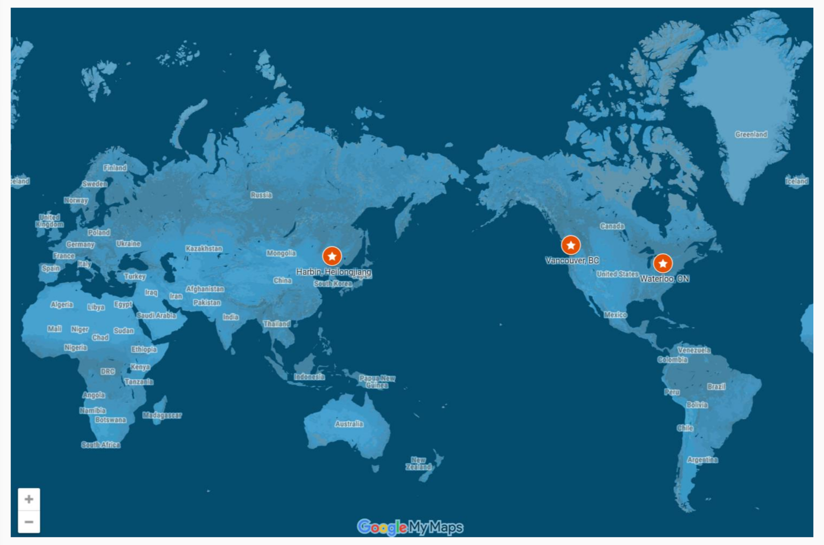
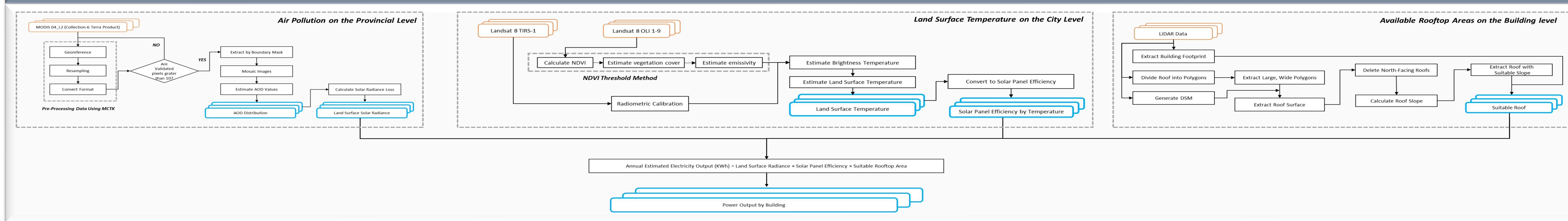


Figure 1. Study Area, Google My Maps (2018)

Study Area This project studies Waterloo and Vancouver in Canada, and Harbin in China. Referring to Figure 1, the three cities are in similar latitudinal positions to capture incoming solar radiation. Solar energy is the fastest growing renewable energy in Canada and one of the mandatory targets in China's 13th Five-Year Plan.

Data MODIS 04 Level 2 measures provincial air pollution; Landsat 8 TIRS and OLI retrieve city land surface temperature; LiDAR data examine available building rooftops. All data were collected from Jan, 2013 to Dec, 2014.

METHODOLOGY



RESULTS

Aerosol Optical Depth (AOD)

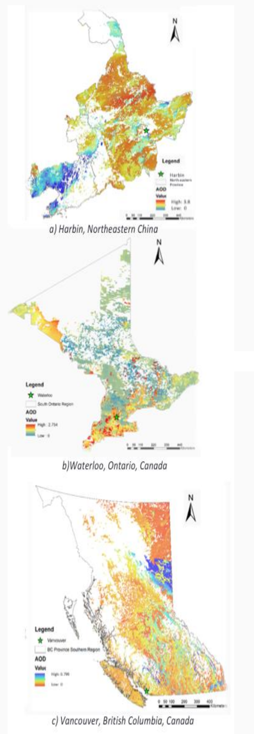


Figure 2. Annual AOD in Three Provinces

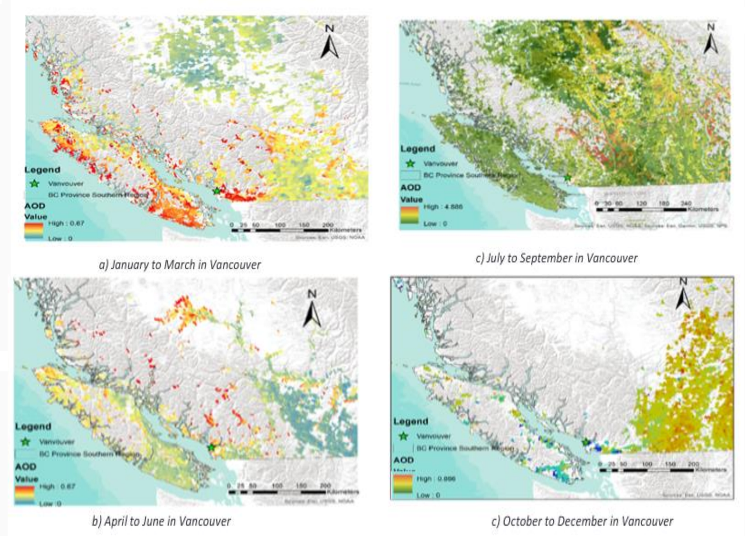


Figure 3. Seasonal AOD in Vancouver

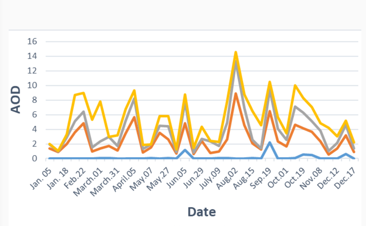


Figure 4. Ground vs. Estimated AOD

Figure 2 maps the annual AOD on the provincial level. Overall, the AOD in Southern BC is lower than the other two regions, which suggests the best air quality among the three regions. Figure 3 shows the seasonal AOD values. AOD is relatively high in spring and summer, causing greater losses in solar radiation received by the ground.

Using the Bird Model, an approximate 20% of the total irradiance loss is estimated in Vancouver, which reduces annual ground-level solar radiation to 3.45 KWh/m^2/day.

Land Surface Temperature (LST)

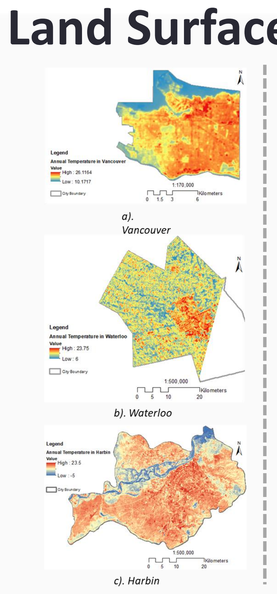


Figure 5. Annual LST in Three Cities

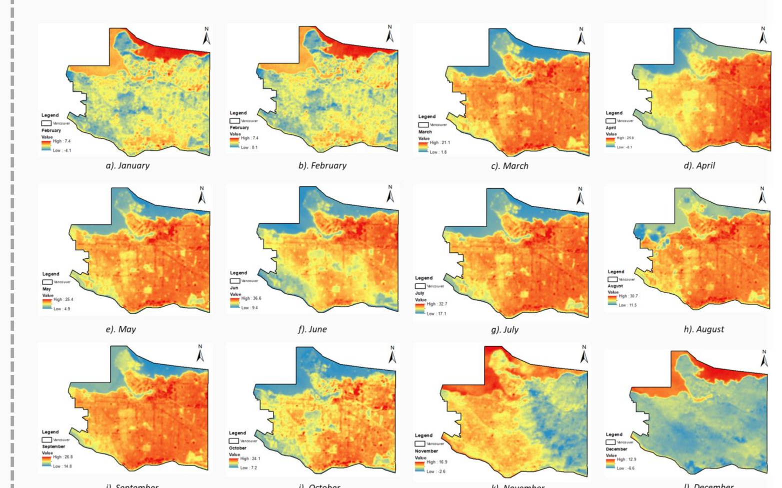


Figure 6. Monthly LST in Vancouver, BC

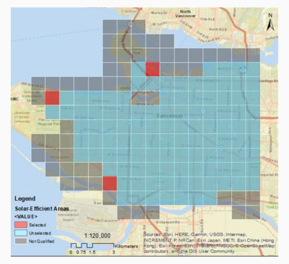


Figure 6. Three Solar-Efficient Areas in Vancouver

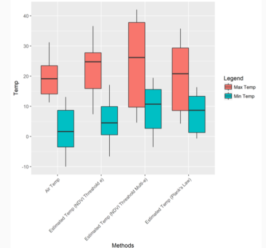


Figure 8. Ground Temp Vs. Three Methods Used to Estimate LST

Figure 5 shows the annual LST in three cities. Considering the cold temperature and snow accumulation, Vancouver is selected as the most suitable city. The monthly LST is shown in Figure 6, which reflects the effects of urban heat island. Figure 7 shows three solar-efficient areas within the city, overall 15.5% annual solar panel efficiency.

Suitable Roof Areas and Daily Output

Figure 9. Suitable Roofs

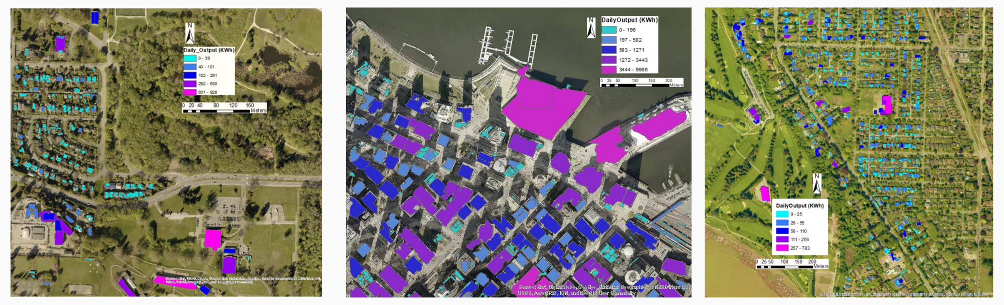


Figure 10. Daily Power Output on Suitable Roofs

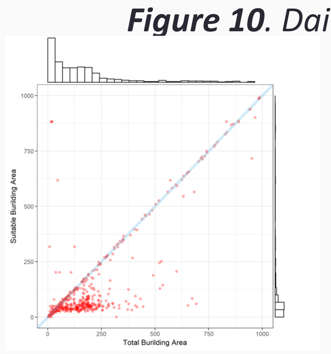


Figure 11. Suitable vs. Total Roof Area

Figure 9 shows the suitable roofs over the building footprints. These roof areas are relatively large in the area with appropriate aspect and slope values. Figure 10 illustrates the estimated daily output of each building. From left to right, each area is expected to generate 6.9 MWh, 60.8 MWh, and 9.8 MWh per day with a 50% solar panel coverage on the suitable roofs.

DISCUSSION

- AOD is retrieved from optical satellite images using the Deep Blue Algorithm [2], which is most accurate for forest and ocean as they show significantly low surface reflection in the blue band. In lack of opportunities for ground-truthing, this approach is selected as it does not require supplementary data.
- The project accounts for atmospheric and avoids using air temperature. However, when applying NDVI thresholds for land surface temperature measurement, the project considers homogeneous emissivity as ground measurement is not feasible during the limited time. A possible improvement is to utilize at-sensor earth radiance data.
- A small number of buildings were not recognized, and polygons converted from raster data are not accurate on the edges. There is a certain degree of subjectivity in the classification of aspect and slope values. Green roofs are not considered and a 50% solar panel coverage is assumed for daily output on the suitable roofs.

CONCLUSION

- Air pollution considerably impacts ground-level solar radiation. Vancouver tops the three cities in solar resources at 3.45 KWh/m^2/day.
- Spatial variation in surface temperature is significant within Vancouver. Annual solar cell efficiency is 15.5% in the coolest parts of the city.
- Suitable roofs abound in the city, with commercial area having much higher PV potential than residential neighborhoods.

REFERENCES

[1] United Nations. (2018). Sustainable Development Goal 7 [website]. Retrieved from https://sustainabledevelopment.un.org/sdg7.

[2] Shi, Y., Zhang, J., Reid, J. S., Holben, B., Hyer, E. J., & Curtis, C. (2011). An analysis of the collection 5 MODIS over-ocean aerosol optical depth product for its implication in aerosol assimilation. *Atmospheric Chemistry and Physics*, *11*(2), 557-565.

[3] Sobrino, J. A., Jiménez-Muñoz, J. C., Sòria, G., Romaguera, M., Guanter, L., Moreno, J., ... & Martínez, P. (2008). Land surface emissivity retrieval from different VNIR and TIR sensors. *IEEE Transactions on Geoscience and Remote Sensing*, *46*(2), 316-327.