The Data Collection and Monitoring Plan of Effect of Urban Heat Island on St George Rainway

EVSC 400 Environmental Science Capstone

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Executive Summary

Background

To become a water-sensitive city to meet Vancouver's challenges has never been more urgent. Strong economic, environmental and social imperatives are driving change. The Raincity strategy is a step in this transition, building on the actions and leadership around the green rainwater infrastructure over the past two decades. To achieve the Raincity strategy, the project group planned to construct Green Rainwater Infrastructure (GRI), highlighting an important opportunity to improve urban water management and improve the entire region through common interests. For coastal cities like Vancouver, proper management of freshwater resources and solving flood prevention problems are top priorities.

There are GRI implementations on St. George Rainway. The study site of the St. George Rainway is located in St. George from Kingsway to the False Creek Flats (Fig. 1 and Fig. 2). The goal of our group is to collect, monitor and analyze data of Urban Heat Island (UHI) effect on St. George Rainway. Based on our data planning, we hope we can help the project group decide the

Summary of Literature Review

Regarding human health, the research integrates tree canopy cover, urban surface temperatures, and population demographics as spatial measures to find a relationship between potential risks of heat exposure to humans and UHI (Venter et al., 2020). While another study focuses on how environmental characteristics such as thermal design, vegetation volume, and coverage are critical in affecting thermal discomfort, heat loads, physical and mental health problems (Baldwin et al., 2020). Heat data can be monitored by calculating average building height, density, and street width and establishing the building's albedo through satellite images (Touchaei & Wang, 2015). Evapotranspiration data can be collected based on a long-term scale of trees-monitoring plan to calculate how evapotranspiration will influence the surrounding temperature Zhou et al.'s (2014). Lastly, research suggests using a Landsat-8 thermal infrared band and the combination of at-sensor radiance, brightness temperature and the black body target temperature radiation to analyze land surface temperature (Wu & Zhang, 2019).

Overview of Data Collection, Analysis, and Monitoring Plan

Due to the global pandemic, field trips and data collection in the field have become difficult. This report will only provide a data collection and monitoring plan for the GRI's efficiency in reducing the UHI effect on St. George Rainway. Based on our acknowledgment and studies that have been successfully conducted in other cities, our monitoring plan suggests 4 main kinds of data need to be collected: *a.* collecting human heat data regarding heat-sensitive physiological illnesses and subjective mental sensation associated with the UHI effect; *b.* building data-based heat structure of a building (height, density, etc.) and its material through satellite images; *c.* building plants' evapotranspiration function through long-term monitoring of trees to mitigate UHI; and *d.* using thermal infrared remote sensing technology to analyze land surface data, which potentially affected by the water body and surrounding land cover. Combining all these aspects will provide a comprehensive study and monitoring plan for the GRI's efficiency to the UHI effect.

Our plan is multifaceted and covers the urban planning part (Building heat), human wellbeing (Human illness report), plant diversity (evaporation), and water condition (land surface temperature). Combining these aspects can provide a comprehensive study and monitoring plan for the GRI's efficiency to the UHI effect.

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2.2. Method

2.2.1. Human Health Data

Tan et al.'s (2010) research studied how UHI will affect human health in Shanghai. They used the temperature data and combined them with the death recordings provided by the Shanghai government. They found out that the human mortality rate is higher in the central city area than the suburban area when there is an increasing temperature situation by the UHI. Another study was done in Oslo, Norway, integrating tree canopy cover, urban surface temperatures, and population demographics as spatial measures to analyze potential risks of heat exposure to humans (Venter et al., 2020). The researchers indicated a relationship that each tree in the city would mitigate a heat-sensitive person getting potential risks of heat exposure by one day (Venter et al., 2020). A sim used to find out the UHI data before the GRI's implementation using the previous satellite images to find out the building's distribution. Then comparing the climate report with the data calculated by the BEM and SVF can find out how the UHI will affect temperature before the implementation of GRI. However, this method has some limitations. This method only studies the correlation between urban form factors and LST. The finding is that LST will decrease as the NDVI, SVF increase.

Moreover, by Allhaier, Flerchinger & Su(2012), the surface temperature is a state variable, which is continuously adjusted to adapt to changes in hydraulic and meteorological forcing in a way that always maintains an energy balance (Equation 1): Rn = LE + H + G, where Rn is net radiation (W*m^-2), LE is latent heat used for evaporation(W*m^-2), H is the heat exchange between surface and air(W*m^-2)) and G represent the ground heat flux(W*m^-2). Allhaier et al. (2012) also found that less energy can be used to heat the land surface if the evaporation process used more energy.

2.3. Conclusion and Discussion

In this literature review, we found three methodologies to collect and monitor UHI effects. The first method is to collect data on human health from direct ways and indirect ways. For direct ways, human health has a relationship with temperature change, including death rate, heart attacks, asthma, skin, subcutaneous tissue disorders and other potential risks. Indirectly, a friendly green infrastructure should fully consider walking and cycling areas, density, connectivity of a street, neighborhood safety, and satisfaction. Under the UHI effect, these indicators would change. It is a difficult, complex, time-consuming method to collect all the data. It can be a long-term method to monitor UHI effects. The second method is to analyze how the UHI can be affected by the green plant's evapotranspiration rate. Based on Saaroni et al. (2018) and Zhou et al. 's (2014) research, this method is good for small area analysis. The last method is to test a water body with a cooling effect on LST as an ecosystem service. Water cooling effects significantly impact the relationship between LST and land cover, such as building height, SVF. By analyzing the previous surface temperature data, and current LST, the GRI efficiency on reducing UHI effect can be monitored. We chose these three methods because they are from different aspects to collect and monitor UHI effect, including human, ecosystem and physical properties of urban material. Through these three aspects, we can monitor UHI effects in multi-directions.

3. Data Collection, Analysis, and Monitoring Plan

3.1. Method 1: Collecting the Building Heat Data

For collecting the temperature and UHI effect data before the GRI implementation, we can use

3.3. Method 3: Collecting Evapotranspiration Data

For collecting the plant's evapotranspiration data, the most common method is to collect the plant's density and type on St George Rainway. The temperature data should be directly collected at each corresponding evapotranspiration data collection site by using thermometers. The method by Peters et al. (2011) can be used to test the evapotranspiration data. The gas analyzer should be set in our study site to measure the air's water vapor amount. The water vapor amount near the GRI can be seen as the plant's transpiration rate (TT). Since the total plant's evapotranspiration (ET) is the sum of the TT amount and the rainfall interception loss through the plant's canopy (IT). The Rutter canopy interception model can monitor the IT (Rutter et al., 1971). To be specific, water storage in the canopy should be collected every hour since the major source of water storage in the canopy is through precipitation. The canopy water storage losing can be seen as the transpiration of plants. Using the data collected after precipitation minus the data collected before precipitation to get the rainfall loss through the plant's canopy. After all the needed data is collected, add the water vapor amount and the rainfall loss to get the plant's evapotranspiration data.

3.4. Method 4: Collect surface temperature data

By observing from the satellite map, there is no water body exposed under the sunlight, instead, the St George Stream was hidden under the road surface. However, it still sees a pool and a lot of manhole cover on the road, which means that most of the water finally flows to the underground creek surface. It is suggested to collect the LST map from USGS, which provides an overall thermal preview of the entire study area. In addition to testing water quality, it is also necessary to set up surface temperature testing facilities along the St. George Rainway after the introduction of the GRI. The St. George Rainway project mainly focuses on a small area, only including the rainway and its surrounding communities (*The St. George Rainway, n.d.*). Therefore, it is possible to build up some small weather stations and use calibrated/electronic thermometers, pyranometers and hygrometers to test land surface temperature, solar radiation and humidity. At the same time, it is suggested that these weather stations need to be equipped with solar energy and information transmission devices. The benefits include no need for manual measurement, saving time and reducing energy consumption on the road; real-time data transmission to the database, easy to organize and save, suitable for long-term research.

3.5. Setting: Importing the Plan to Study Site

After ensuring what types of data need to be collected, the next step is to import our plan on the St. George Rainway. The Figure 3 below shows the data collection site. Firstly, the blue area represents where the building density, height, and street width data should be collected for a short time, and in the long term, the building density area can be enlarged to study how the building density far away from the St. George Rainway can influence the UHI effects. Secondly, the green pins represent where the plants and total evapotranspiration data should be collected. Thirdly, the yellow pins represent the land surface temperature data that should be collected since all three sites have different surroundings: 1. trees and grassland surround the first site; 2. surrounded by grassland and houses; 3. houses and few trees surround the third site. Lastly, the temperature data can be collected from the previous climate report for the temperature data before the GI implementation. For the current temperature data, people can retrieve it from the Landsat thermal infrared band from the USGS.

Then, using the temperature data as the dependent variable to build the graphs to show how the building density can influence the temperature, how the plant's evaporation rate can influence the temperature and what is the water's potential cooling effect on UHI. Temperature data can also be another dependent variable, and human illness conditions can be another independent variable. Find the relationship between them by graphs. Morever, the LST in three different sites are expected to be different as their different land surface cover, it includes the SVF and NDVI.

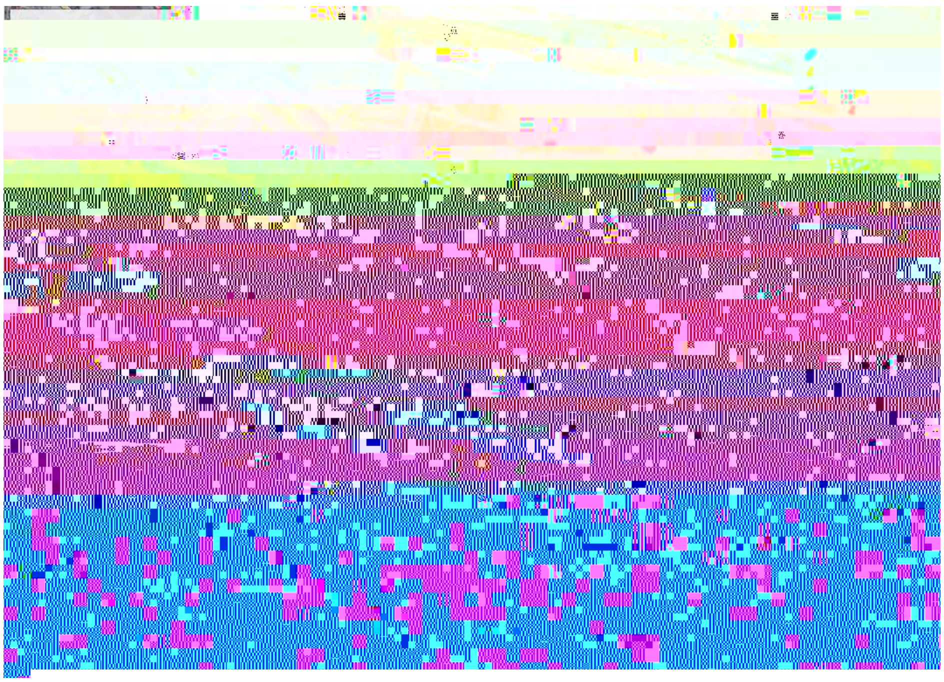

Figure 3: The data collection sites selection on St. George Rainway

4. Limitations

1. After collecting the SVF data and finding the relationship between the radiation absorbed by the roof and temperature, it only considers the flux of radiation in the cloud but does not include the GRI. The weathering prediction forecasting cannot predict the correct cloud amount and the radiation flux in the cloud precisely during the cloudy weather, as mentioned in Touchaei & Wang'

5. Next Steps

1.The difference between building heat data's trend before and after the GRI implementation to identify the GRI implementation's efficiency. The GRI can be shown as effective if the trend of building heat data increasing rate after the GRI implementation is smoother than the data before GRI implementation.

2.The next step for the plant's evapotranspiration data analysis is similar to the building heat data. The evapotranspiration data's trends should be analyzed. Also, each different site will have a different evapotranspiration efficiency. Comparing all the data to determine which surrounding environment and GRI setting can have the highest evapotranspiration rate, also, the water resource consumption by plants should be considered. Then, for the future, a similar GRI setting can be added in St. George Rainway to enhance its effect on reducing the UHI effect.

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