University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

The Cooling Effects of Campus Greenery at the University of British Columbia Campus

How has urban greenery coverage affected Land Surface Temperature and Air Temperature?

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SEEDS Sustainability Program

UBC sustainability

The Cooling Effects of Campus Greenery at the University of British Columbia Campus:

How has urban greenery coverage affected Land Surface Temperature and Air Temperature?

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Bachelor of Urban Forestry (Honours)

Abstract

Heat waves have threatened many people’s health and affected people’s thermal comfort on the West Coast of Canada in recent years. Urban greenery is crucial in mitigating climate change issues by influencing the temperature in cities. Land surface temperature is a metric to understand energy change at a landscape scale, while the air temperature is not representative of its surroundings. Land surface temperature can be measured and calculated by using remote sensing technology. This technology can capture surface temperature data from satellite imagery, allowing for accurate measurements of temperature changes over time. The paper studied how urban greenery coverage affected land surface temperature and air temperature respectively at the University of British Columbia in July and August 2022. The study calculated land surface temperature from Landsat images and collected air temperature data from available sensors. Two linear regression models were built to illustrate relationships between urban greenery coverage and land surface temperature and air temperature respectively. The results revealed that with the increasing percentage of urban greenery coverage, the land surface temperature reduced. Deciduous trees showed the strongest ability to reduce land surface temperature, followed by modified grass-herb and coniferous trees. Areas that are classified as barren had the highest land surface temperature. However, there was no significant relationship between urban greenery coverage and air temperature. This study provides valuable information for urban planners and policymakers to design and implement effective green space strategies that can address climate change and human thermal comfort issues.

Keywords: Land surface temperature, climate change, heat waves, cooling effects, urban forestry, land cover types.

Introduction

Green infrastructure is an integral part of urban design, it plays an essential role in maintaining the ecosystem equilibrium in cities. Due to the rapid expansion of cities, more land has been used to build infrastructures and houses, leaving fewer and fewer areas for forests (Lin et al., 2019). It is no longer in line with modern social development thinking to consider forests and cities as separate elements (Pregitzer, Charlop-Powers & Bradford, 2021). We do not have enough land to preserve large areas of forests on top of expanding cities, nor can we abandon the great benefits that forests bring to humans, both physically and psychologically (Lin et al., 2019). The benefits of forests include minimizing air pollution, purifying water resources, mitigating climate change, and improving human psychological health (Bernath & Roschewitz, 2008). Green infrastructure is a hybrid urban design concept that generally refers to the combination of greenery and urban architecture to provide more ecological functions for urban residents (Ahern, 2007). With green infrastructures, people enjoy the dual benefits of urbanization and greenery.

This paper will focus on analyzing the impact of green infrastructures at the landscape level and measuring how land surface temperature (LST) and air temperature are being impacted in the summer of 2022. LST is an important metric for understanding and analyzing energy change on the planet, while the air temperature is more easily to be influenced by external factors (Mutiibwa et al., 2015). However, air temperature is an essential indicator to assess human thermal comfort (Chen & Ng, 2012). Thus, measuring the impacts of both LST and air temperature can assess the resilience of UBC comprehensively during hot days in summer.

Green infrastructures mitigate the climate change crisis, a benefit that is particularly evident in urban settings. The urban heat island effect is one of the most serious climate crises facing humanity today. The urban heat island effect is a result of the nature of urban buildings that generate large amounts of heat that cannot be removed quickly enough, making cities often much warmer than their surroundings (Runnalls, 1995). Many papers have been conducted to study how greenery can mitigate the urban heat island crisis and the conclusions are positive (Runnalls, 1995; Bernath & Roschewitz, 2008).

Many studies on the role of greenery on the urban heat island effect have been done at the University of British Columbia Vancouver campus, but most of these studies have only looked at the impact of trees or focused on the microclimate extent (chen, 2022; Ng, 2022; Shao, 2021). Green infrastructure is a very broad component, and trees are an important part of it, but definitely not all of it. For example, shrubs and grass are part of green infrastructures and should be covered when we study the impact of green infrastructures. The University of British Columbia has a large number of students, faculty and staff, and their health and thermal comfort are the top concern for the University of British Columbia. (University of British Columbia., n.d.). There are still research gaps regarding green infrastructures at UBC Vancouver Campus, including what is included in green infrastructure at UBC and how green infrastructures affect the climate crisis. These questions have not been addressed yet.

Heat waves on the West Coast of Canada in recent years have exceeded many of the highest temperatures recorded in history, dramatically increasing the number of illnesses caused by heat waves (Philip et al., 2021). Vancouver has also faced a severe climate crisis in the past two years, especially the annual summer heat wave that affects the quality of life and learning experience of UBC residents (Stewart et al., 2017). The objective of this study is to :
1. Find the relationship between the land surface temperature and the coverage of campus greenery in July and August 2022.
2. Find the relationship between the air temperature around campus buildings and the coverage of campus greenery in July and August 2022.

It is hypothesized that the land surface temperature will decrease as the campus greenery coverage increases. It is also hypothesized that the air temperature will experience a minor decrease when the campus greenery coverage increases.

Study Area Description

The study area is the University of British Columbia Vancouver Campus. Figure 1 shows the whole study area. The UBC Vancouver campus (see figure 1), located on the point grey peninsula, with an extent of 49.279647 degrees on the north, 49.235109 degrees on the south, -123.263915 degrees on the west, and -123.196713 degrees on the east based on WGS 1984 coordinate system. The University of British Columbia has over 58,000 students and approximately 17,00 faculty and staff (University of British Columbia., n.d.). The Vancouver Campus is located in the City of Vancouver, British Columbia, Canada. The Vancouver campus is approximately 400 hectares in size, surrounded by around 90 hectares of dense forest which is the Pacific Spirit Regional Park (UBC Campus+Community PLanning, 2015). There are several green places on the campus, including various parks, a farm, and a large botanical garden. The campus land use type is corporated with both natural and academic types (Sutherland, 2012).

According to the Biogeoclimatic Classification Zone (BEC), Vancouver is classified into Coastal Western Hemlock Zone, with a XM subzone, indicating it has a moderate climate and also highly productive and structurally complex coniferous forests (Feller, 2003). This zone is dominated by Western Hemlock (*Tsuga heterophylla*) and Western Redcedar (*Thuja plicata*) (Feller, 2003). UBC Vancouver campus has a wide diversity of tree species such as *Acer* genus, *Thuja* genus, and *Quercus* genus, with over 8,000 planted trees (UBC Campus+Community PLanning, 2015). The dominant tree species on campus (see figure 2) are reported as western red cedar (*Thuja plicata*), red alder (*Alnus rubra*), Douglas fir (*Pseudotsuga menziesii*), black cherry (*Prunus serotina*), and Norway maple (*Acer platanoides*) (Burton & Wiersma, 2016). About half of the total campus land now consists of vegetative features including grass, planting beds, and trees, including the UBC Botanical Gardens and UBC Farm (Burton & Wiersma, 2016).

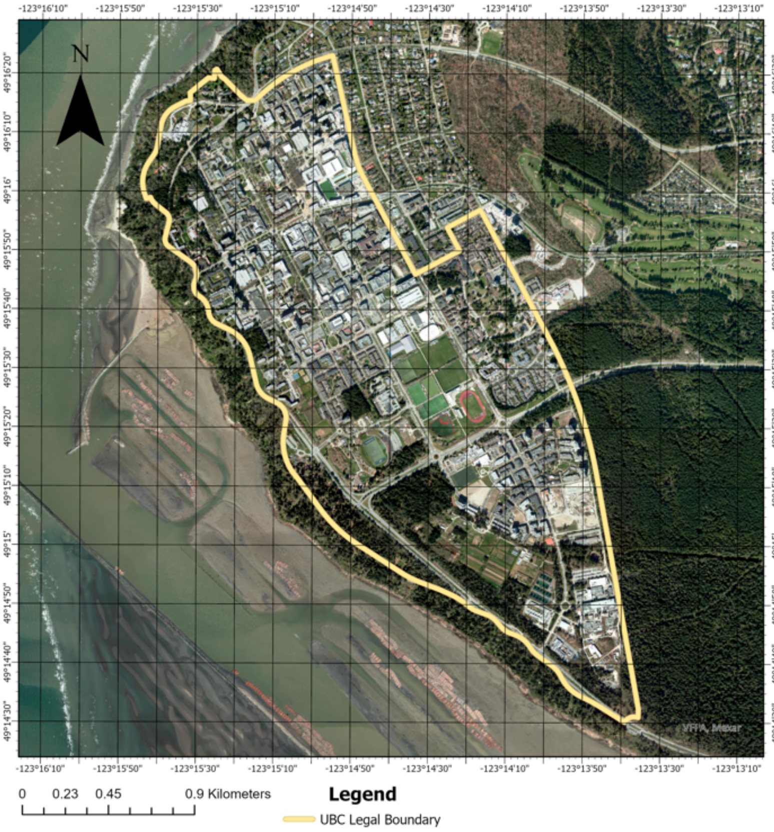

Figure 1. The University of British Columbia boundary. The basemap is projected in WGS 1984 and source from ESRI.

Data Summary

Metro Vancouver Land Cover Classification Data

From the MetroVancouver Open Data Portal, land cover classification data can be retrieved as a raster dataset (https://gisportal.metrovancouver.org/portal/apps/sites/#/open-data-portal/datasets/eaa66d9a3042460aab8f3157e922010a/about). It is public data and does not have any limitations to downloading. It is a continuously updated data and its latest updated time is December, 2022. This land cover classification dataset contains four level-1 classes which are built-up areas, bare areas, vegetation areas, and water/shadow/clouds. The vegetation class contains coniferous trees class, deciduous trees class, shrub class, modified grass-herb class, natural grass-herb class and non-photosynthetic vegetation class. This data was generated by using RapidEye 5m multi-spectral satellite imagery and full feature LiDAR data. The imagery was collected on August 2014. This data contains land cover classification for Metro Vancouver area, Abbotsford area and a 5km buffer.

UBC Geospatial Open Data

This is a complete UBC campus geospatial data package that contains five main feature dataset which are context, landscape, locations, planning and transportation. These dataset have to be downloaded together as a geoJSON package from the UBC open geospatial repository on GitHub (ubc-geospatial-opendata/ubcv at master ·

UBCGeodata/ubc-geospatial-opendata · GitHub). All people can access to this open date package without any limitation. All these data are projected in WGS84 coordinate system as shown in Figure 4. Every feature dataset has its own metadata description that explains what feature classes are included in this dataset. However, there is no accuracy assessment for this data as well, which potentially impact the accuracy of the final result of this paper. No update frequency record can be found, but the latest update was done on November 22th, 2022. According to its data description, it is the single repository that will host UBC's operational geospatial data.

Landsat 8 Collection 2 Level-2 Series Products

The eighth satellite in the Landsat series, Landsat 8, was launched by NASA and the U.S. Geological Survey (USGS) (USGS, n.d.). Landsat satellites provide the optimal ground resolution and spectral bands to effectively track land use and land change brought on by factors such as climate change or urbanization (USGS, n.d.). The Landsat 8 has eight spectral bands at a resolution of 30 meters (USGS, n.d.). The data is derived from Landsat 8 database, which provides data detecting on the Summer of 2020, which is the time explained in this paper. Level-2 products include both surface reflectance and surface temperature. Level 2 science products are created with Collection 2 Level-1 inputs that satisfy the 76 degree Solar Zenith Angle constraint and contain the auxiliary data inputs necessary to create a product that may be used in science (cite). All products can be download from USGS Earth Explorer (https://earthexplorer.usgs.gov/). Images are free and in 30 meters resolution.

SkysPark

Skyspark is a platform from Skyfoundry that includes heating, ventilation and air conditioning (HVAC) and energy data on campus. It records individual building's air temperature, as well as each room's air temperature. The HVAC systems in the UBC Building are managed by a Building Management System (BMS) from three different vendors, which relies on sensor feedback to maintain thermal comfort and ventilate spaces. The sensors collect information every 15 minutes and report back to the backend of SkysPark, and all temperature information will be updated automatically. On the BMS panels dispersed throughout the campus, all of the sensor data is momentarily stored. All data can be accessed and download through SkysPark (https://skyspark.energy.ubc.ca/ui/), whereas it only available for UBC staffs and students. Skyspark is the only air temperature source for the UBC Vancouver campus, and is managed by the Energy & Water Service Department.

Data Summary Figures and Tables

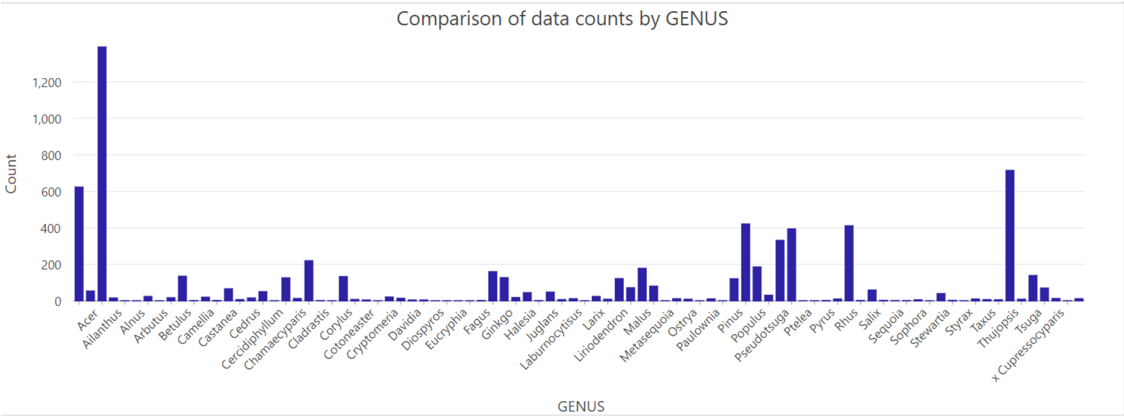

Figure 2. The bar chart of the number of genera from campus trees. Some genus names are missing. Acer is the most dominant genus.

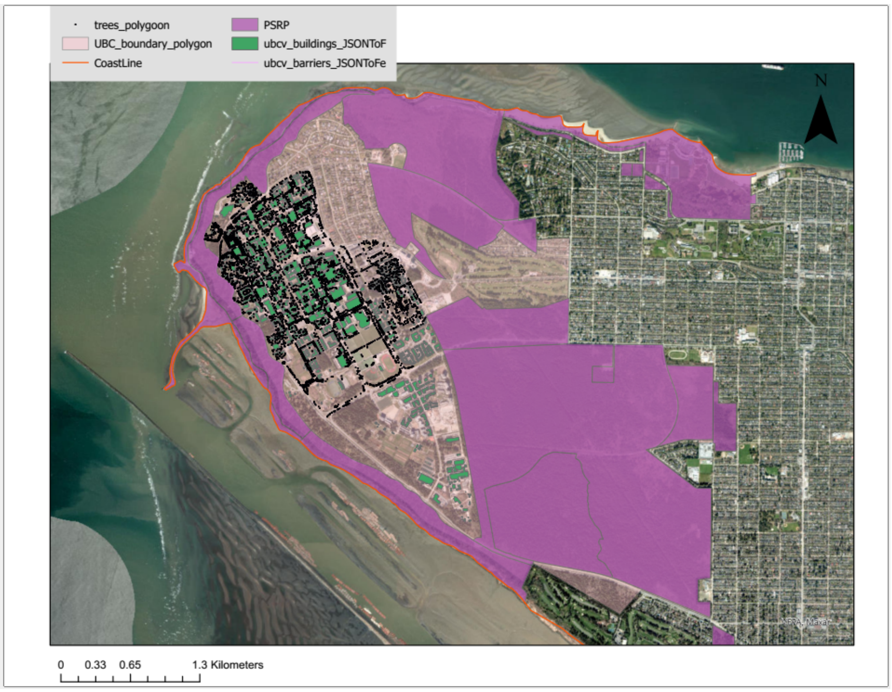

Figure 3. The UBC Vancouver Map with different landscape features. All landscape features were derived from UBC Geospatialdat package.

Methods

Overview

This study is to investigate and quantify the impacts of urban forest coverage rates in reducing both Land Surface Temperature and Air temperature during hot days in the July and August of 2022 on the UBC Vancouver campus. To investigate the impacts of urban forests, it is necessary to first understand the urban forest compositions and coverage rate on the campus. Buffers will be created around each building to measure urban greenery coverage within each buffer. Second, to investigate these impacts, we will derive the mean Land

Surface Temperature in the July and August of 2022 on the UBC Vancouver campus. Next, a model is needed to illustrate how the Land Surface Temperature changes with the urban forests coverage rate.

The relationship between the Land Surface Temperature and urban forests coverage rate can be expressed through a linear regression model and will be investigated here. The last step is to build another linear regression model to see if any relation exists between urban forests coverage rate and air temperature, and if so, what kind of relation exists. Figure 5 showed the complete workflow of this study.

Land Surface Temperature Calculation

LST is an important metric for understanding and analyzing energy change on the planet, which can be calculated by

$$LST = (BT / 1) + W * (BT / 14380) * \ln(E)$$

(Mutiibwa et al., 2015)

(Mutiibwa et al., 2015), where BT is top of atmosphere brightness temperature in Celsius degrees, W is the wavelength of emitted radiance, and E is land surface emissivity. Band 4, Band 5 and thermal band from each Lansat imagery were required to get all variables from the LST equation (Mutiibwa et al., 2015). The temperature unit was converted from Kelvin to Celsius degrees to make it consistent with further air temperature analysis. Air temperature data are in Celsius degrees. In order to get Land Surface Temperature data, Landsat Images from Landsat 8-9 Collection2 Level1 are required to calculate Land Surface Temperature. Top Of Atmosphere (TOA) Reflectance, Brightness Temperature, and NDVI are all required to calculate Land Surface Temperature (Reddy & Manikiam, 2017). This study will focus on the hottest days in the summer of 2022 which are July and August, so the Landsat Images from July 2022 to August 2022 on the extent of the UBC Vancouver campus are required. The study aims to finding the cooling effects of campus trees, thus hottest days would maximize the cooling effects of campus trees. The final LST map would be in a resolution of 30m due to the size of the Landsat image. However, it will be resampled into 5m to match the spatial resolution of the campus greenery coverage data in order to do further data processing such as extraction. 10 meters buffers were created around each building. Changing the cell size of the final LST map to make it have the same spatial resolution as campus greenery coverage data would allow data extraction within each buffer.

Building Model between LST and Greenery Coverage

After calculating both LST data and greenery coverage rate on the UBC Vancouver Campus extent, it is necessary to build a linear regression model to examine the relationship between LST data and greenery coverage. Since the paper aims to find how greenery coverage rate would affect LST, a simple linear regression with one variable would be enough for this study. The greenery coverage is the independent variable while the LST is the dependent variable. All data from the population will be used to test the significance of each variable. The null hypothesis would be greenery coverage class is not significant, $\beta_1=0$, given other X variables in the model. The output generated by RStudio would give the test statistics values and p-values so the significance and coefficient of each variable can be verified. By comparing p-value with the alpha value, whether the null hypothesis is rejected or not can be determined.

Building Model between Greenery and building air temperature

A simple linear regression model was applied to air temperature at the same time by using the same method. The only difference between building this model and the model between LST and Greenery Coverage is that the dependent variable will change from LST to air temperature. Though LST is an important metric for understanding and analyzing energy change on the planet (Mutiibwa et al., 2015), air temperature is a better metric to monitor the thermal comfort of humans because it directly affects the rate of heat transfer between the human body and the environment. (Nikolopoulou & Lykoudis, 2006). The model between greenery coverage and air temperature can help UBC planning department to understand how human thermal comfort varied in July and August in 2022, and implement more regulations later to improve UBC residents' thermal comfort during summer days.

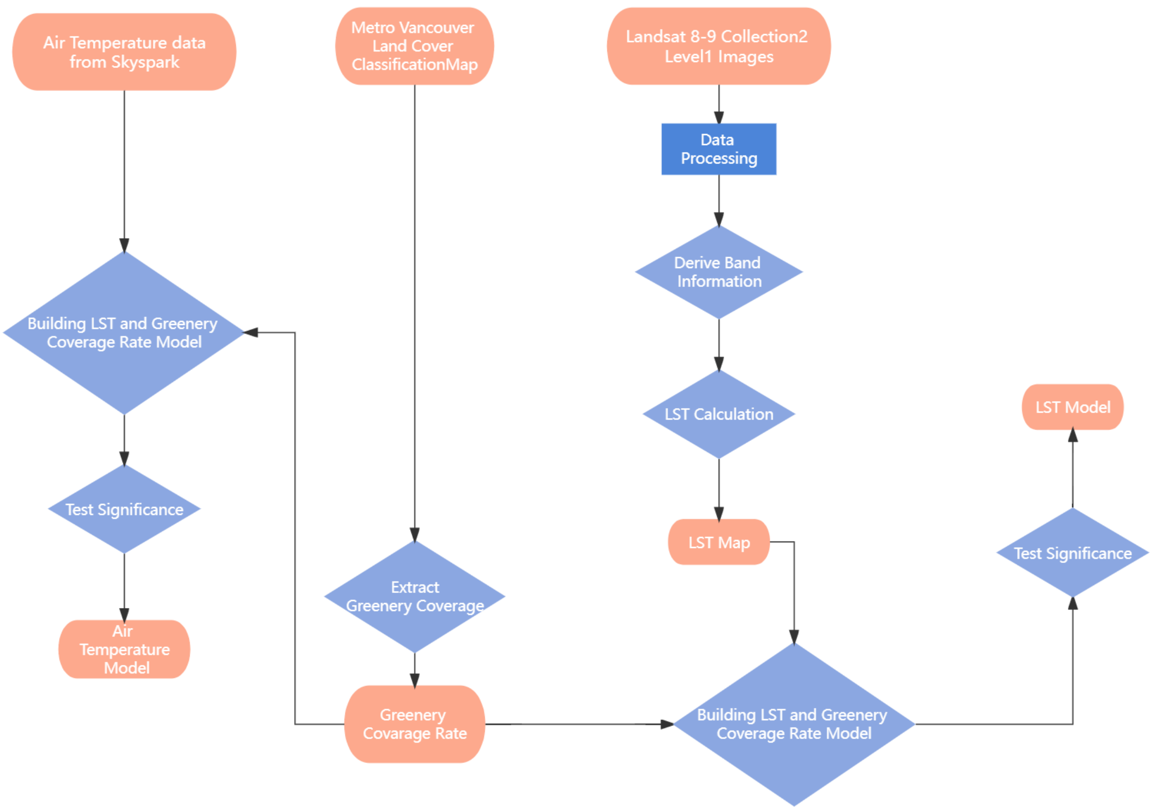

Figure 4. The workflow of the proposed method. Same level products or steps were colored in the same color and shape.

Results

Land Surface Temperature Distribution

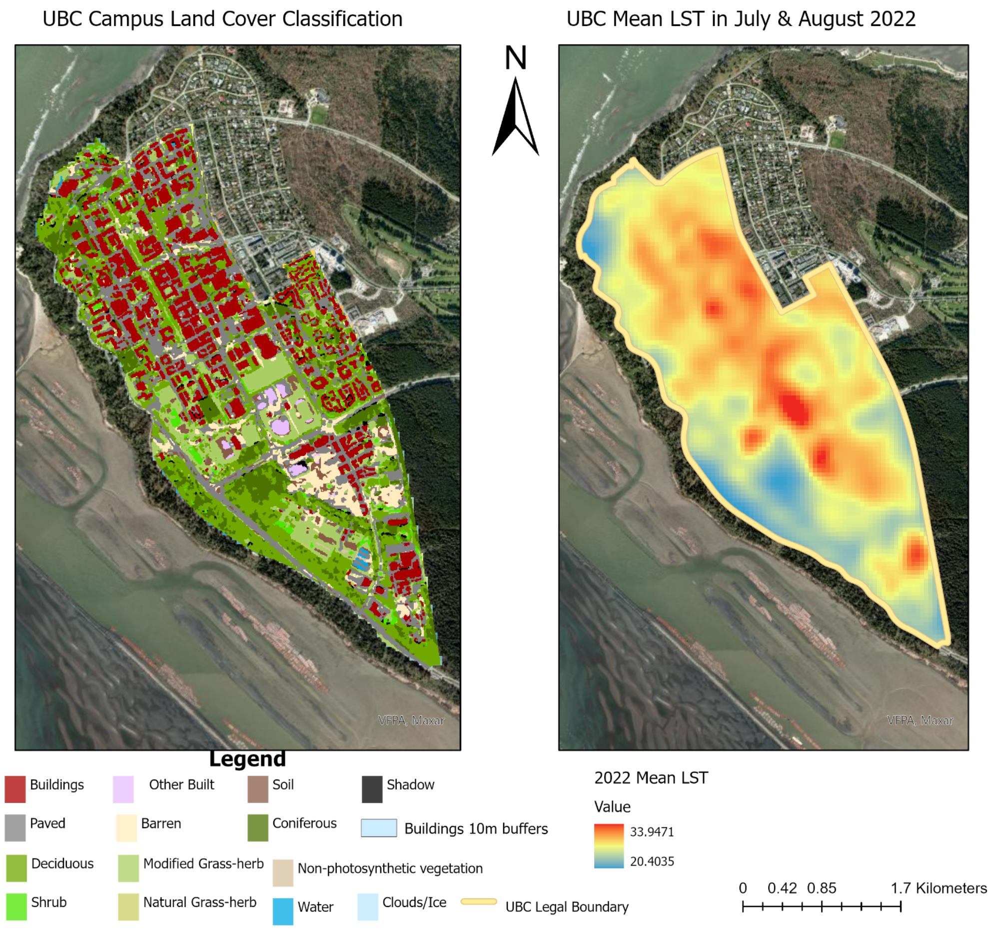

Figure 5. The Land surface temperature map and land cover classification map for the UBC Vancouver Campus. This is the average Land surface temperature that were calculated from all available Landsat data from July and August, 2022. The land cover classification data was derived from MetroVancouver Open Data Portal (MetroVancouver, 2022).

By calculating the average land surface temperature from July 2022 and August 2022, the average land surface temperature ranged from 20.4035 ℃ to 33.9471 ℃. Areas with greenery components such as coniferous areas, and deciduous areas had lower land surface temperature compared with artificial-built areas such as paved areas and buildings. The area with a combination of paved, buildings, other built and barren had the highest land surface temperature, which is located in the middle of the campus. Coniferous forests and deciduous forests areas had lower land surface temperatures, and were mainly located on the edge of the campus.

Figure 6. The 10 meters buffers were created in every building on campus to make further analysis between urban greenery coverage within each buffer and land surface temperature.

In the present study, 10-meter buffers were established around campus buildings to evaluate the proportion of all greenery classes within each buffer. The results indicate that the total greenery coverage proportion ranged widely from 0 to 100%, with a median coverage rate of approximately 20.37%. These outcomes demonstrate the marked variability in greenery presence surrounding campus buildings, with some areas featuring scarce vegetation and others displaying a significant abundance.

The further analysis revealed that the three coolest areas within the buffers had varying greenery components. Deciduous trees were the most prominent greenery component in the top three coolest areas, occupying 59.10%, 47.62%, and 48.65% of the areas, respectively. Modified grass-herb and coniferous trees were the second and third most prevalent greenery components. The top three hottest areas were mainly comprised of barrens and paved surfaces, accounting for 100%, 61.32%, and 57.85% of the total coverage, respectively.

Linear Regression Model Results

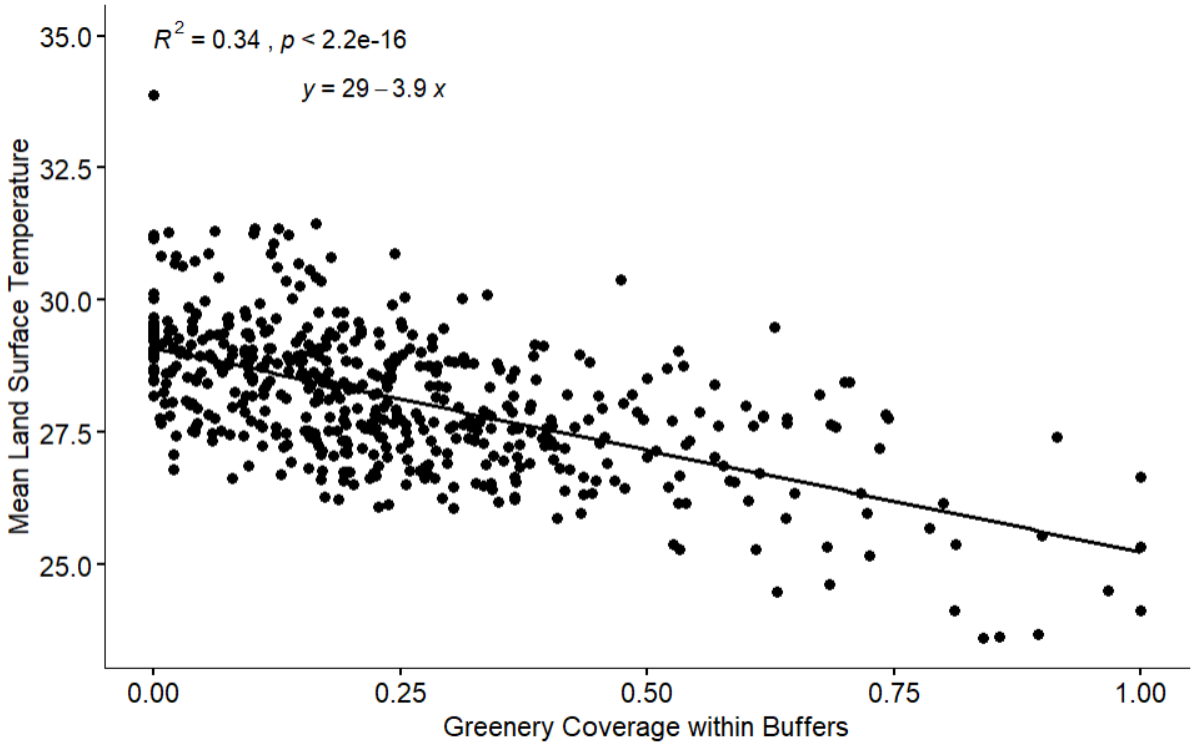

Figure 7. The linear regression model. The independent variable is urban greenery coverage and the dependent variable is the mean land surface temperature.

Figure 7 showed a linear regression model between greenery coverage within buffers and mean land surface temperature demonstrating a negative relationship. The scatter plot revealed that the majority of points followed the trend line, with some outliers present. The majority of points were concentrated between the greenery coverage of 0 to 50%, with a decrease in mean land surface temperature as greenery coverage increased. These results suggest that the presence of greenery within buffers may play a critical role in reducing land surface temperature.

There is only one variable in this model, the p-value is smaller than 2e-16, which is smaller than the alpha value (0.05), so the variable is significant. The p-value for the model is also smaller than 2e-16, also smaller than 0.05 so the regression is significant. The model can be written as $y_i = 29.09214 - 3.85428x_i + e_i$. The multiple R^2 value is 0.3406, indicating data are scattered-distributed pattern, the data did not fit the model very well.

The hypothesis that an increase in campus greenery coverage would lead to a decrease in land surface temperature is supported by the model results, indicating a significant correlation between the two variables.

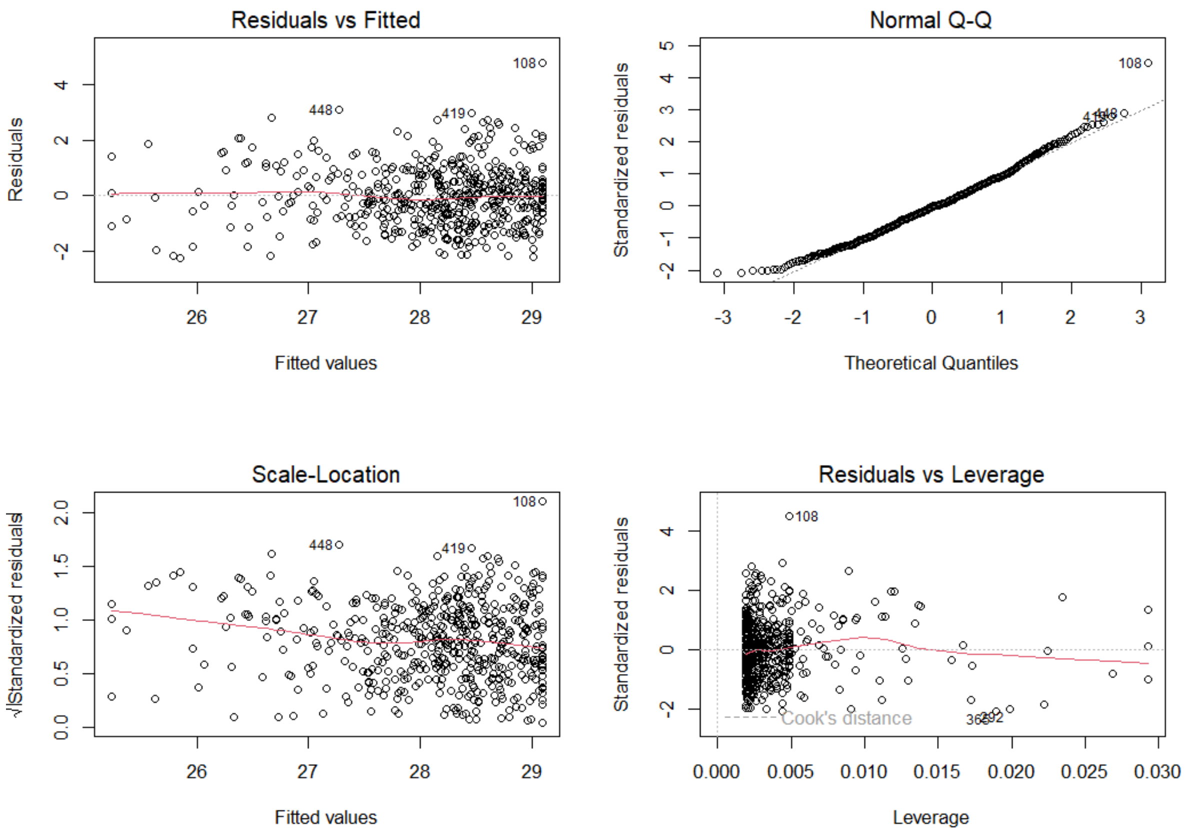

Figure 8. Residual plots, Normal Q-Q plot, Scale-Location plot and Residuals vs Leverage plot from the land surface temperature model, which were used to check model assumptions and identify influential observations.

According to the normal Q-Q plot from figure 8, no skews in both upper and lower tails, so the normality assumption was met, the y values are normally distributed for each of the x values. According to the residual plots, the spread around the line is not identically equal, especially for some outliners, so the variance of the y values is not the same for every one of the x values. According to the residual vs leverage plot, there are many points fall outside of the dashed line. This means all those points are influential points in our regression model.

Air Temperature Distribution

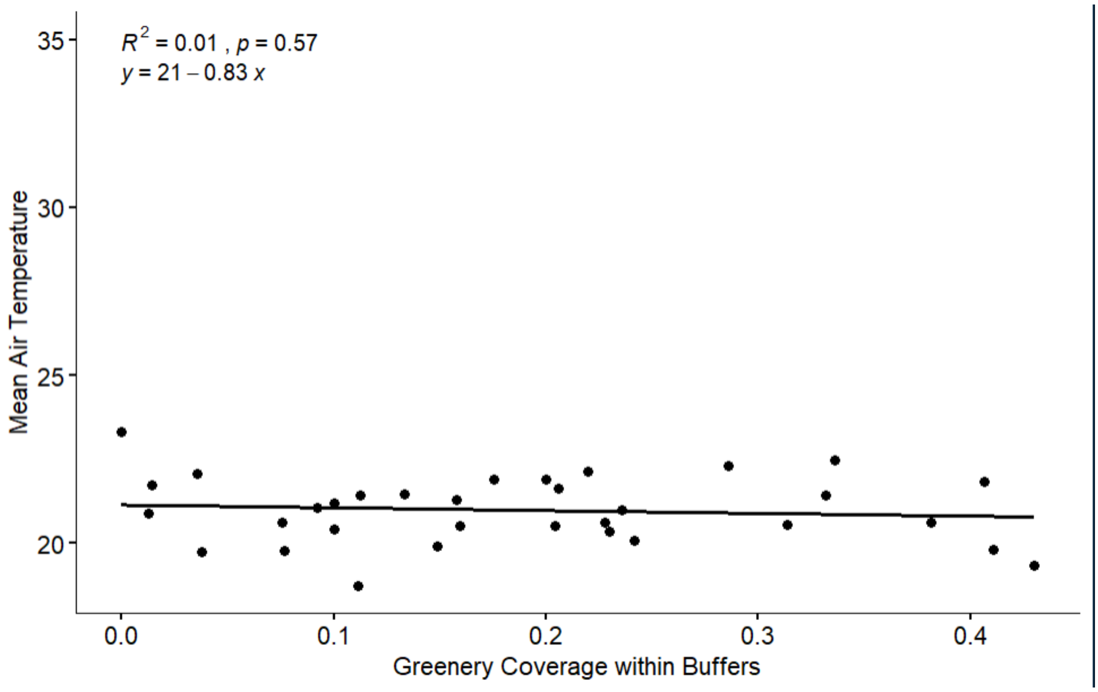

Figure 9. The linear regression model. The independent variable is urban greenery coverage within buffers and the dependent variable is the mean air temperature around each building.

Figure 9 shows the linear regression model between greenery coverage within buffers and mean air temperature. The model did not reveal any significant relationship. The trending line is almost flat, indicating that there is no discernible pattern between the two variables. In addition, the p-value for the mean air temperature variable in the linear regression model is 0.572, which is smaller than the alpha value of 0.05 commonly used for statistical significance. This result indicates that the mean air temperature variable is not statistically significant and cannot be used to predict greenery coverage within buffers.

The x-axis represents greenery coverage within buffers, while the y-axis represents mean air temperature, which ranged from 18.73 to 23.30. This range is much lower than the land surface temperature distribution.

The R2 value for this model is only 0.01. This value represents the proportion of variation in the dependent variable (in this case, mean air temperature) that is explained by the independent variable (greenery coverage within buffers). In other words, the R2 value measures how well the regression model fits the data. A value of 0.01 suggests that only 1% of the variation in mean air temperature can be explained by greenery coverage within buffers. This indicates that other factors besides greenery coverage within buffers are likely influencing mean air temperature in the study area.

Thus, The hypothesis that increasing campus greenery coverage would cause a minor decrease in air temperature has been rejected, as no significant correlation was found between the mean air temperature and the level of greenery coverage.

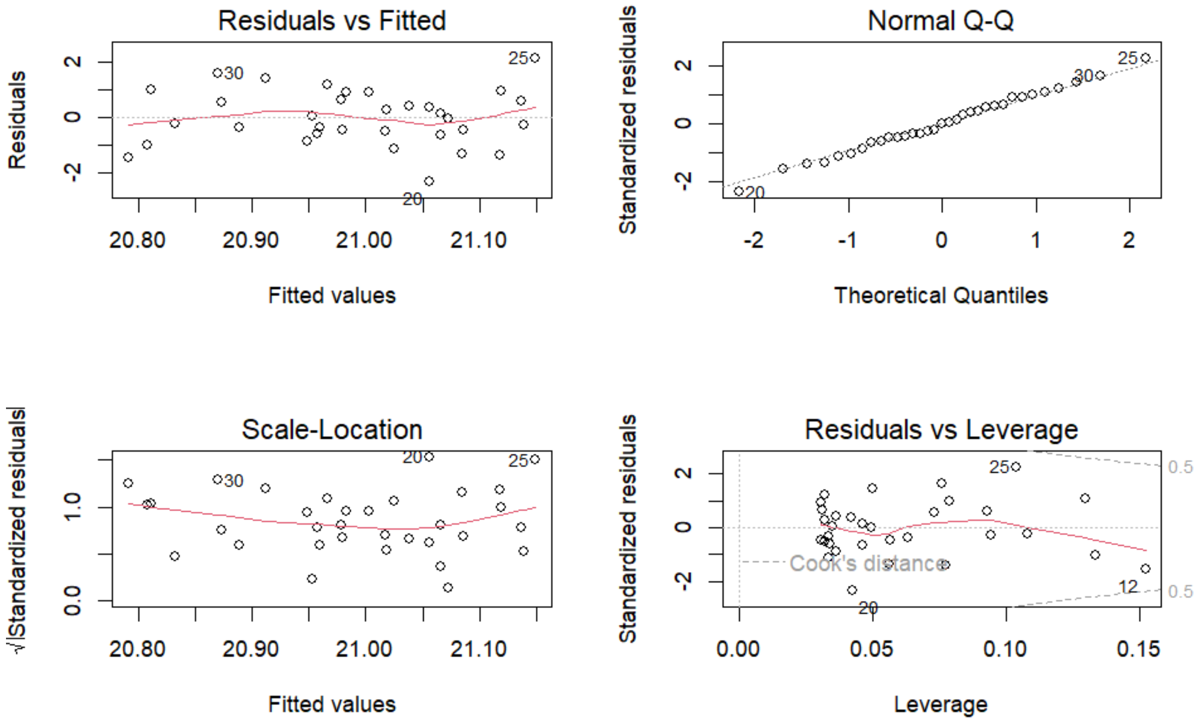

Figure 10. Residual plots, Normal Q-Q plot, Scale-Location plot and Residuals vs Leverage plot from the mean air temperature model, which were used to check model assumptions and identify influential observations.

According to the normal Q-Q plot from figure 10, there are some skews in lower tails, so the normality assumption was not met, the y values are not normally distributed for each of the x values. According to the residual plots, the spread around the line is not identically equal, the points were distributed sparsely, especially for some outliners, so the variance of the y values is not the same for every one of the x values. According to the residual vs leverage plot, though there are some observations close to the border of cook's distance, they do not fall outside of the dashed line. This means there are not any influential points in our regression model.

Discussion

The effect of campus greenery on mitigating land surface temperature

This study aims to study how campus greenery coverage affects the land surface temperature in July and August 2022, and the linear regression model that was used to predict the impacts of urban greenery coverage on mean land surface temperature demonstrated that with the increase of urban greenery coverage, the mean land surface temperature decreased (See Figure 7). The statistical result indicated that the urban greenery coverage is significant, but the urban greenery coverage in the model does not explain much of the variation in land surface temperature due to the low value of R^2. Land surface temperature is an indicator of heat flux, and its variation can be influenced mainly by urban physical properties, such as urban structure (Oke, 2004). Urban structure represents the arrangement of land use in urban areas, and street canyons are result of different urban structures (Kusaka & Kimura, 2004). Urban canyons create shaded areas between buildings and avoid direct solar radiance on surfaces thus resulting in lower land surface temperature (Bourbia & Awbi, 2004) Urban greenery coverage is a type of land cover, and it is urban composition instead of urban configuration. Both urban composition and urban configuration impact in variations of land surface temperature. However, we only consider urban composition in this model, thus the R^2 value is not high.

The land surface temperature was calculated from the Landsat 9 satellite images, and the final land surface temperature map has a 30 meters spatial resolution restriction. 30 meters spatial resolution is relatively large to a campus extent since this size allows various land covers to exist in the same cell, and all these land covers affect land surface temperature. Thus, the LST within each cell is not representative considering its cell size. A stronger relationship between greenery coverage and LST is expected to see if the spatial resolution gets finer.

The study contained six different types of urban greenery which are deciduous trees, coniferous trees, shrub, modified grass-herb, natural grass-herb, and non-photosynthetic vegetation. These six types of greenery have different abilities in lowering surrounding temperature. According to the dominant greenery in the coolest areas, deciduous trees showed the strongest cooling ability, followed by modified grass-herb and coniferous trees. Deciduous trees have larger and denser canopy compared with other types of greenery, they provide more shades and reduce the direct sun radiation significantly (Massetti et al., 2019). Additionally, the transpiration process helps to lower surrounding temperature by evaporating water from leaf surfaces, while high temperature increases the rate of transpiration (Winbourne et al., 2020). The two main leaf-related factors explain why deciduous tree have the strongest cooling effect.

The findings of this study have significant implications for both climate change and human thermal comfort. Land surface temperature is closely related to heat flux, and it is a critical factor in understanding the urban heat island effect (Deilami, Kamruzzaman & Liu, 2018). By demonstrating that increasing urban greenery coverage can decrease mean land surface temperature, this study offers a practical solution to mitigating the urban heat island effect and potentially reducing energy consumption related to air conditioning for UBC Community. Furthermore, the study highlights the importance of considering the type of greenery when designing urban green spaces. Deciduous trees have been found to be the most effective in lowering surrounding temperature due to their larger and denser canopy and the transpiration process. Thus, it is crucial for the urban planning department to take these cooling effect differences into consideration when designing green spaces in different areas of the city. For instance, in areas with dense high buildings, greenery with high aesthetical values but weaker cooling effects may be more appropriate due to the presence of urban canyons that can lower land surface temperature. On the other hand, in open areas, greenery with stronger cooling effects may be needed to counter the higher land surface temperature. Taking these factors into account can result in more effective green space strategies that can mitigate the urban heat island effect and enhance the overall livability of the city. As urbanization continues to rapidly expand worldwide, implementing green infrastructure in urban areas can be an effective tool for reducing energy consumption and improving human thermal comfort.

The effect of campus greenery on mitigating air temperature

The second goal of this study is to find out how greenery coverage affects air temperature, and the linear regression model that was used to predict the impacts of urban greenery coverages on mean air temperature demonstrated there is no relationship between urban greenery coverage and air temperature. According to the statistical results, the second hypothesis is not supported. The hypothesis was made based on shades provide urban greenery, transpiration process and high albedo (Sailor, 1995; Tan et al., 2018).

All air temperature data were derived from Skyspark. Every building on the campus has attached Outside Air Temperature sensors that are used to record the temperature. Sensors have different locations. Some are the outdoor air inlets to air handling units, and some are sensors outside the building, mounted to the exterior wall. These sensors have a shade and weather cover, but can still be influenced by the sun heating up the roof. These sensors also lack of metadata, such as sensors' azimuth or elevation. The elevation or azimuth of sensors have potential impacts on air temperature they detected, but the missing information makes it impossible to verify.

In addition, some of UBC's buildings are equipped with air conditioners, which are turned on during the summer months to bring indoor temperatures up to a comfortable level. Sensors that are set into the exterior walls or placed in the outdoor air inlets of the air handling units can be affected by the cooling of the air conditioners and affect the accuracy of the temperature detection. The inaccuracy of air temperature data and missing metadata of sensors are the main reasons for model failure.

Towards Climate-Resilient Summer Planning: Recommendations for the UBC Planning Department

UBC Campus + Community Planning is the UBC Planning department that seeks to reshape the campus as it changes by fostering communities that are active and resilient in both academic and residential settings (UBC Campus + Community Planning, n.d.). The UBC Campus + Community Planning is proposing UBC Vision 2050, a comprehensive guideline which will determine how UBC Vancouver's physical campus develops and changes in the next 30 years. Here are some target goals that can be added into UBC Vision 2050 based on study's results and discussions.

1. The overall deciduous trees occupation is approximately 22.88% among all land covers on the UBC campus. Deciduous trees have shown a strong ability in lowering surrounding land surface temperature and improving huma thermal comfort during hot days. Thus, the overall deciduous trees coverage is recommended to increase to 30% by 2050 in order to build a more resilient campus. It is also recommended that more deciduous trees can be planted on the center of the campus, especially the Main Mall, the East Mall and the West Mall. Most buildings and infrastructures are located on the center of the campus, and those areas have a huge flow of people.

2. Barren areas contributed to the high land surface temperature, and it occupies approximately 5.12% of all land covers on the UBC Campus. Unlike buildings which provide teaching activities or vegetation which provides aesthetical values, campus barren areas do not have significant functions. It is recommended to reassess the status of the campus's barren area. For barren areas that do not have any specific functions, other vegetation can replace and planted on those areas to provide more cultural value.

3. The missing metadata information of sensors from Skyspark is a big barrier for this study. It is recommended to do a field survey and go to every building to record each sensor’s detailed information for future study.

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