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Student Research Report

Urban Green Space Analysis on UBC Vancouver Campus

Integrating virtual gaming technology to map cultural use and biodiversity value of urban green space

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Abstract

Rapid growth in urbanization has transformed natural landscapes into built-environments. Consequently, species biodiversity is threatened, while the innate relationship between humans and nature begins to fade gradually. Urban green spaces play a vital role in reconnecting human and urbanized landscape with its unique characteristics. Meanwhile, virtual gaming technology with applied geographic information has made a spectacular process to promote interactions between humans and their surroundings. A novel approach of combining Light Detection and Ranging (LiDAR) data, ground-based inventory data, geographic information system (GIS) data, and geocoordinates derived from reality game Pokémon GO was applied to explore geospatial gaming technology's application in mapping cultural use and biodiversity hotspots at a university campus. Five types of green space were identified: lawn, planting bed, planting bed on structure, athletic field, and urban forest. In order to capture a relatively complete understanding of cultural perception and vegetation biodiversity value, two green space assessments were conducted with a combination of factors: namely native species ratio, species richness, canopy cover and cultural interest. Both assessments highlighted the importance of urban forest. This green space type achieved 0.396 in the first assessment and 0.501 for the second assessment of cultural and biodiversity values. This research provided a primary resource that emphasized the preservation of urban forests needs to be prioritized in future campus planning and development.

Key words: LiDAR, GIS, Gaming technology, Green Space, Cultural value, Biodiversity

Story Map: https://storymaps.arcgis.com/stories/cd16f2520dc44744b5e68bdf0915d8a1

1. Introduction

Importance of Urban Green Space

Rapid growth in urbanization has transformed natural landscapes into built-environments due to human intervention (Xian et al., 2005). Consequently, the species biodiversity is threatened, while the innate relationship between humans and nature that biophilia hypothesis discussed begins to fade gradually (Kellert & Wilson, 1993). Urban green spaces play a vital role in reconnecting human and urbanized landscape with its unique characteristics. Urban green spaces act/serve as nature-based solutions in climate change adaptation, biodiversity, and air pollution are frequently discussed by ecological researchers and institutions (Vierikko et al., 2020). In addition to the ecological services that green spaces provide, they also enrich citizens' quality of life by providing social gatherings and recreational opportunities to facilitate natural environment experiences (Rafiee et al., 2009).

Trees and understory vegetation in green spaces offer both tangible and intangible benefits to the local environment and visitors, and these values refer to ecosystem services. This framework introduces provisioning services, supportive services, regulating services, and cultural services (Daily, 1997). The cultural services in urban green spaces are widely perceived by citizens (Camps-Calvet, Langemeyer, Calvet-Mir & & Gómez-Baggethun, 2016), but these immaterial benefits are often forgotten and only recognized when we face severe environmental challenges to lose them. Although the ecosystem services framework explains the fundamental benefits that humans receive from nature, the approach fails to interpret the complexity of reciprocal human-nature interaction (Buizer et al., 2016). For example, the fruits and vegetables extracted directly from nature are considered provisioning services, and the provision of wildlife habitats refers to supportive services (Camps-Calvet et al., 2016). Air purification is a benefit of regulating services, and cultural services indicate that nature provides opportunities for social cohesion and cultural recognition (Camps-Calvet et al., 2016). This concept only proposes a positive and one-directional relationship, and the importance of reciprocal interaction need to be addressed in order to provide a guideline for planning and management in landscapes and green spaces.

Virtual Gaming Technology to Promote Interaction with Nature

Virtual gaming technology with applied geographic information has made a spectacular process to promote interactions between humans and their surroundings. Pokémon GO has become the first location-based augmented reality game. It is also one of the most successful mobile games, which peaked at 28.5 million daily unique platers in the United States alone a week after its launch (Lella & Lipsman, 2017). Recent research has proposed that game-based learning has a high potential to educate people about ecosystem services because of the essential learning concepts in game design and the inspiring intrinsic motivation in players (Dieleman & Huisingh, 2016; De Freitas, 2016; Foster, 2008). Alha et al. (2019) conducted an online survey to understand why people play this game. The result highlighted that 12.6% of participants started it with outdoor exploration interests and nature connection. Dorward et al. (2016) also explained Pokémon GO is a conservation opportunity that could increase awareness in wildlife protection and assist in engagement activities with real-world nature. Moreover, a project utilized citizen science to explore how public involvement complements traditional ways of scientific data collection and knowledge generation in hydrological sciences and water resources management (Buytaert et al., 2014).

Integrate Virtual Gaming Technology in Urban Green Space Analysis

Real-time virtual gaming technology has proven its unprecedented possibilities to promote two-way interaction with nature. Van Berkel et al. (2019) collected photos with geographic coordinates from social media to test the ecosystem service perception and landscape characteristics. However, little research utilized the location-based function, Global Position System (GPS), to conduct green space analysis for urban green space on a local scale. This research applied a novel approach of combining Light Detection and Ranging (LiDAR) data, ground-based inventory data, geographic information system (GIS) data, and geocoordinates derived from the reality game Pokémon GO to explore geospatial gaming technology’s application in mapping cultural use and biodiversity hotspots at a university campus. This information would help preserve green spaces with socio-cultural values during continuous urban development and direct decision-making in landscape planning and university campus management. The main objectives of this research are:

1) How to identify cultural use and biodiversity hotspots?

2) What aspects of an urban green space hold both cultural and biodiversity values?

3) How different green space types contribute to cultural and biodiversity perspectives?

4) What is the composition and configuration of the high-valued green space in the study area?

2. Study Area

The University of British Columbia (UBC) was established in 1908, the oldest university in British Columbia (The University of British Columbia, 2020). The Vancouver campus surrounded by forests and ocean is situated on the traditional, ancestral, and unceded territory of the Musqueam people in the University Endowment Lands (The University of British Columbia, 2020). The UBC Vancouver campus, with 402 hectares in size, is located at 49.265°N and 123°W, which belongs to Coastal Western Hemlock biogeoclimatic (CWH BEC) zone, the wettest climates and most productive forest areas (Centre for Forest Conservation Genetics, 2020). Western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*) are most common species in the CWH BEZ zone (Pojar, Klinka & Demarchi, 1984).

Vancouver is a well-known coastal city with its multiculturalism, and the UBC Vancouver campus is the home of 55990 students (The University of British Columbia, 2020). UBC highly values staff and students' cultural diversity while maintaining its high academic reputation and achievement. According to the 2019 student enrollment statistic, Aboriginal students and international students make up to 30 percent of current UBC students (The University of British Columbia, 2020). The concept of social inclusion and culture recognition is well demonstrated in UBC.

Since 1925, the UBC Campus and Community Planning department have worked with multiple disciplines to take proactive actions to steward green spaces in the UBC Vancouver campus (Figure 1). Approximately 8000 trees planted and over 10000 native trees in natural settings, where western redcedar (*Thuja plicata)*, pin oak (*Quercus palustris)*, and red maple (*Acer rubrum)* are dominant species on campus (UBC Campus and Community Planning, 2020). The landscape management of green spaces also resonates with the city's biodiversity strategy to support biodiversity and enhance the quality and access to nature (Vancouver Board of Parks and Recreation, 2016).

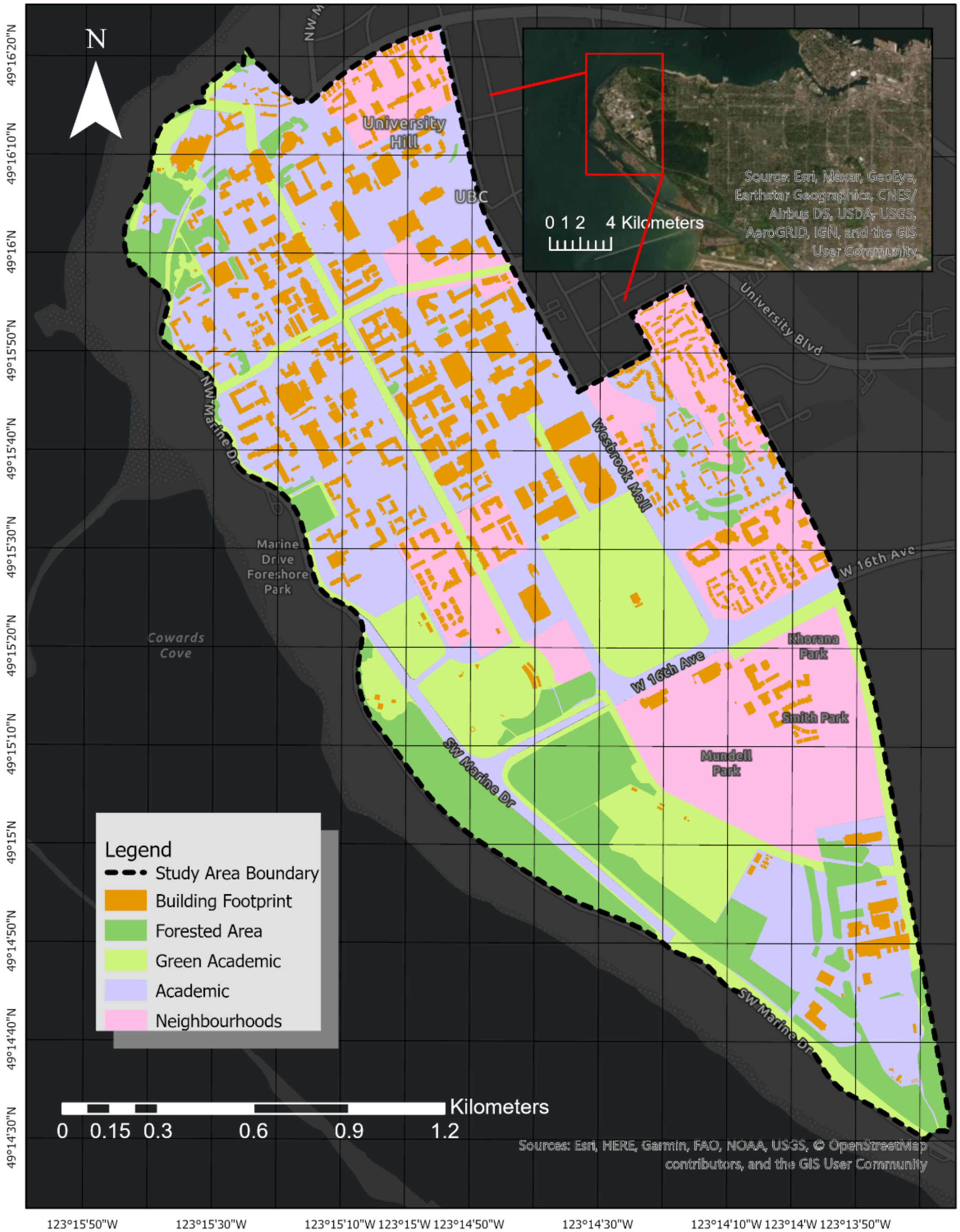

Figure 1: Map of the University of British Columbia Vancouver campus planning. The UBC Vancouver campus is composed with Academic area, green space (Forested area & Green academic), and neighbourhoods. Green Academic land use designation identifies spaces are open areas to support land-based teaching, research and community engagement (UBC Campus and Community Planning, 2020). The map projection is NAD 1983 UTM Zone 10N. Data source: University of British Columbia Vancouver Campus. Campus and Community Planning data. (2015). Retrieved from: https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/ETO8IU

3. Methods

Methodology Overview

Data derivation and validation, data normalization, and green space capability analyses were three main steps in the project's methods. These processes were conducted by ArcGIS Pro (version 2.7.1.; Esri Inc., 2020) and R Studio (version 4.3.0; RStudio Team, 2020), and the ModelBuilder extension in ArcGIS to edit, manage, and visualize geospatial data for this project.

Tree Crown Delineation and Validation

The raw LiDAR point cloud was filtered in ArcGIS Pro (version 2.7.1.; Esri Inc., 2020), and then classified, and denoised in R Studio (version 4.3.0.; RStudio Team, 2020) by normalize_height and lasfilternoise function of 'lidR' package. The first returns refered to the canopy of upper vegetation layers, once they were classified, these points were interpolated to a digital surface model (DSM). The last returns represented the last detectable signal when a pulse was intercepted by ground. A digital terrain model (DTM) and a digital elevation model (DEM) were derived as these points were classified (Ben-Arie et al., 2009). The subtraction of LiDAR-derived DTM and DSM produced a canopy height model (CHM). Watershed segmentation method was applied to delineate 2D individual tree crown in R with 'ForestTools' package (Yang et al., 2014).

Manually interpreted tree crowns were delineated based on the true color composite aerial imagery. A set of high spatial resolution orthophoto (spatial resolution of 10 cm) was used to create a subset of crown delineations. The total of 445 trees were manually identified and the centroids of the trees are located at the bottom of the tree to minimize the distortion effect of aerial photo. As the tree centroids were defined, I created the tree crowns based on the location of centroid and the radius of tree crowns.

The validation of tree crown delineation by LiDAR and aerial photos utilized the ground-based tree inventory data that collected by Urban Forestry UFOR 101 students in 2019 to assess the positional accuracy of tree crown area. The field tree inventory data provided 729 tree centroids with a specific crown radius for each tree. Two scatterplots were computed in R to represent the relationship between crown area differences and ground-based tree size.

Data Normalization

Species richness, canopy cover, native species ratio and cultural features were four indicators to determine the green spaces' cultural and biodiverse values for this research. The data normalization process of four indicators were completed in ArcGIS Pro using different geoprocessing tools. The normalized data ranged from 0 to 1, where 0 represented low and 1 presented high value.

Species Richness

The campus tree inventory point data was used to spatial join with campus green space polygon shapefile by the intersect, and 'one to many' method was applied to produce information of species richness. As the species counts calculated per each green space, I have normalized the species richness ranges from 0 to 1(Equation 1).

Equation 1: Normalized Species Richness = Maximum count of species diversity / total count of species present per green space

Canopy Cover

As Ziter et al. (2019) highlighted in the research that positive temperature anomalies were reduced most strongly in areas with canopy cover ⩾ 40%, and the World Health Organization (WHO) concluded residential green spaces can reduce premature all-cause mortality. The LiDAR derived crown delineation were used with campus green space polygons, and I used ‘intersect’ geoprocessing tool as the geoprocessing tool to assign each individual tree to the associated green space. Two attribute tables were joined together to calculate canopy cover percentage (Equation 2), and the normalized canopy cover ranges from 0 to 1.

Equation 2: Normalized canopy cover = sum of tree crown area per green space / the area of green space

Native Species Ratio

Native species symbolized the history and spirit of local people. The species grown region were manually interpreted by two categories, native species and non-native species, where native species was classified as 1 and non-native species as 0. Then, the spatial join geoprocessing tool was used between campus green space shapefile and tree inventory point data to calculate the total species per green space and the number of native species per green space. Finally, native species ratio was normalized by equation 3.

Equation 3: Normalized native species ratio = number of native species per green space / the total number of species per green space.

Cultural Density Heat Map

The cultural heat map was created by the point of interest (POI) Pokémon Go Vancouver citizen science datasets. The point density analysis was carried on ArcGIS Pro (version 2.7.1.; Esri Inc., 2020) to produce the cultural heat map with the raster cell size of 2 meter and radius of 60 meter. Seven criteria were explained for users to nominate PokéStops (Zeroghan, 2019).

1. A location with a cool story, a place in history or educational value
2. An interesting piece of art or unique architecture
3. A hidden gem or hyper-local spot
4. Public parks
5. Public libraries
6. Public places of worship
7. Major transit stations hubs

Green Space Capability Analysis

Green Space Assessment 1

Once four indicators were normalized, I inputted them into a weighted overlay analysis on ArcGIS Pro to explore the cultural uses and biodiversity values of each green space. The assessment 1 included all four indicators, species richness, canopy cover, native species ratio and cultural point density, and the allocation of weight was applied differently on each of the indicator (Equation 4).

Equation 4: Cultural and Biodiversity Value = 0.45(cultural point density) + 0.2(canopy cover) + 0.2(species richness) + 0.15(native species ratio)

Green Space Assessment 2

To capture the full picture of the study area's green space, this assessment only included canopy cover and cultural point density as two indicators. The allocation of weight was applied equally for the two factors (Equation 5).

Equation 5: Cultural and Biodiversity Value = 0.5(canopy cover) + 0.5 (cultural point density)

Method Work Flow

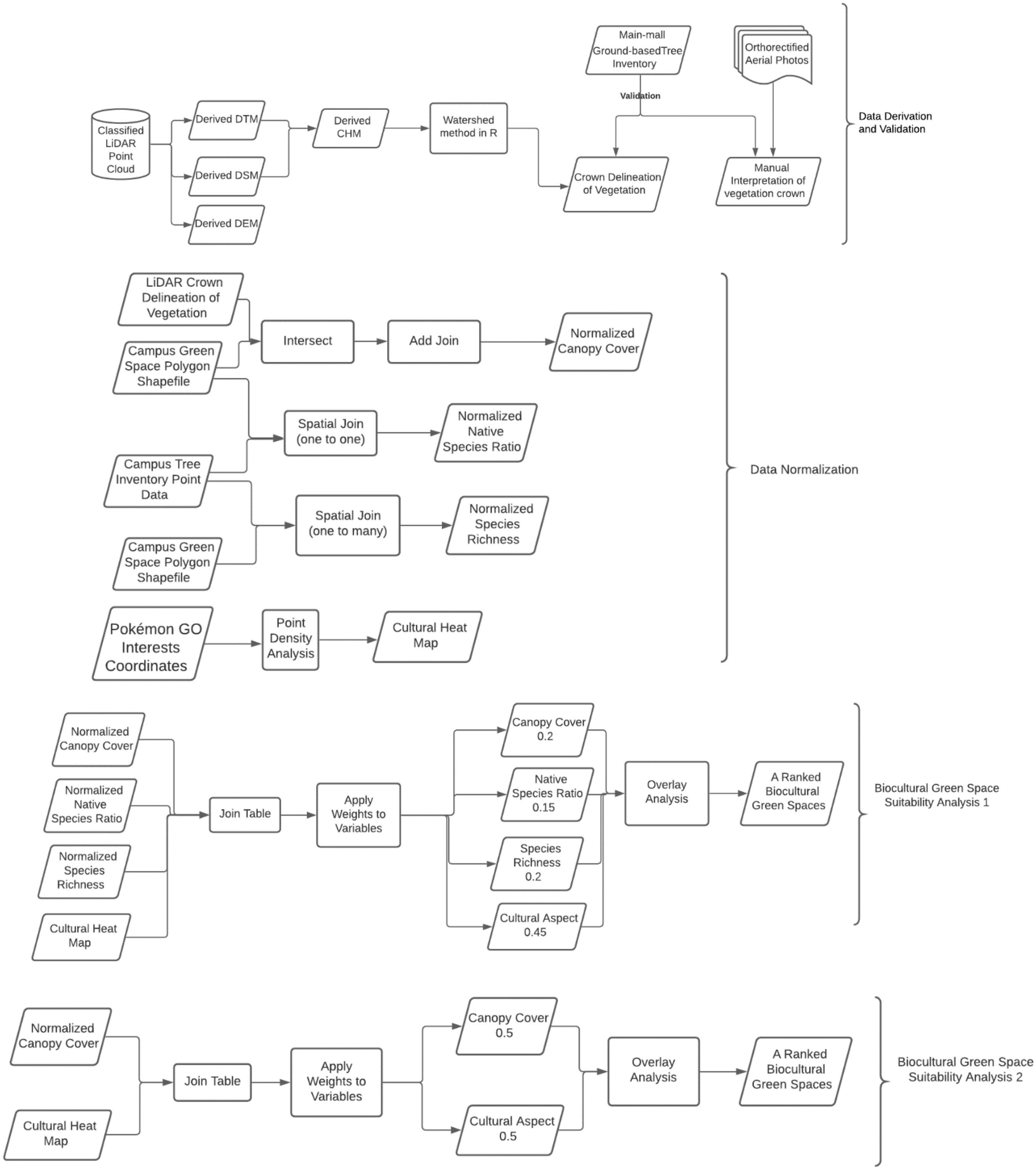

Figure 2: The general workflow of a ranked green space overlay analysis. The workflow was divided into four parts, respectively LiDAR data and orthophoto derivation and validation by ground-based tree inventory, data normalization, and two GIS-based cultural and biodiversity green space capability analysis. The rectangles in the flowchart represented the process/tools, and the parallelograms indicated the input data layers or the derived output data layers.

4. Results

Tree Crown Delineation Validation

LiDAR Crown Delineation

Raw LiDAR point cloud was normalized and classified in ArcGIS Pro (version 2.7.1.; Esri Inc., 2020) to produce its canopy height model (CHM). The process of individual tree crown delineation was computed in R studio (version 4.3.0.; RStudio Team, 2020) by using the watershed method (Figure 3). The class 4 and class 5 were categorized as medium and high vegetation, and they were captured as the main sources for individual tree crown delineation. The tree crowns were recognized and identified, while excluding the concrete buildings and other noises.

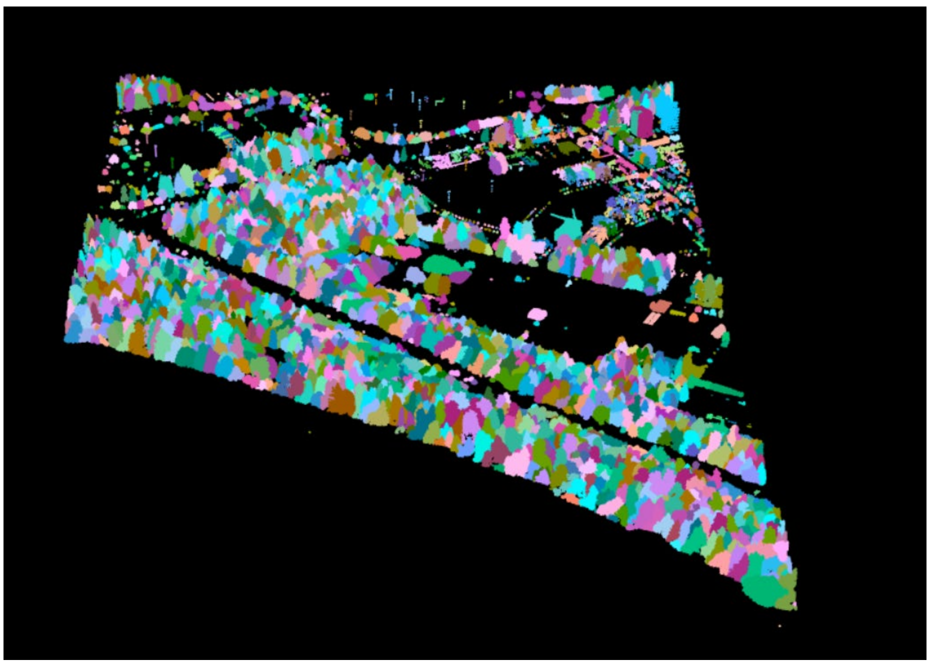

Figure 3: The 3-dimentional representation of a subset crown delineation of study area using LiDAR point cloud. The color represents individual tree ID.

Crown Delineation Validation and Crown Size Accuracy

The subset of ground-based tree inventory data was used as the reference level to compare the accuracy of LiDAR-delineation and aerial photo delineation (Figure 4). A set of high spatial resolution aerial photos was used to generate the crown area differences with the reference data, and the area differences in meter squared refer to the error. The ground-based tree inventory provided 729 trees with a specific crown radius for each tree, while 445 trees were manually delineated from the aerial photo. The aerial photos were captured at leaf-off condition; therefore, it was easier to delineate tree crowns by locating the centroid on the bottom of the tree stem. However, the leaf-off condition also made the crown size interpretation become challenging.

In order to determine the crown area accuracy of LiDAR-delineated tree crowns and aerial photo interpreted tree crowns, two scatterplots were created to compare the crown area differences with the ground-based tree crown size (Figure 5). The aerial photo delineation provided a relatively stable and gentle trend, where crown area differences located around zero line with a relative smaller variance range (Figure 5 a). More data of trees with smaller crown size were observed than the trees with large crown. The stable trend reflected that aerial photo would provide better crown area accuracy for small-sized trees. Instead of having a stable trend, LiDAR-derived tree delineation illustrated a negative trend between crown area differences and the size of tree (Figure 5 b). The variance range of LiDAR-derived tree delineation was much larger than aerial photo delineation. The positive crown area difference values indicated that overestimation occurred; and the negative differences represented the underestimation of LiDAR delineation (Figure 6). For trees with small crown area, LiDAR tended to overestimate the area by grouping small trees together; while underestimate the crown area of large trees.

Figure 4: The subset of tree crown delineation validation in UBC Vancouver campus by the ground-based tree inventory (light green) with LiDAR (dark green) and high resolution orthophoto (10 cm spatial resolution) outlined by black circles. The map projection is NAD 1983 UTM Zone 10N.

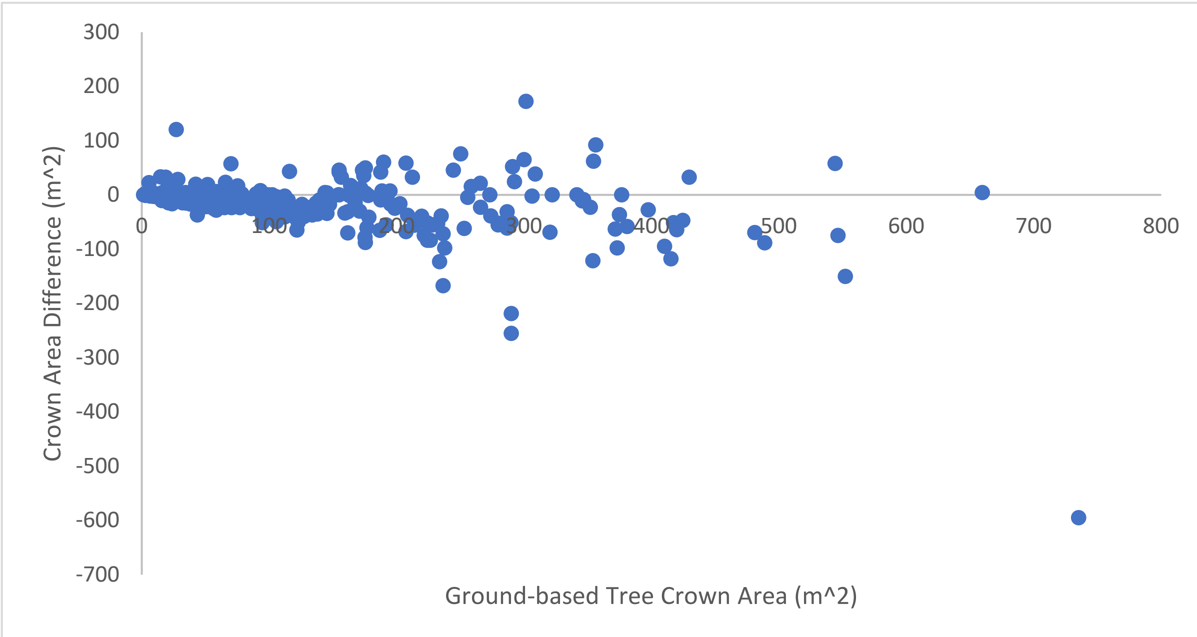

Figure 5 (a): The scatterplot represents the relationship between crown area differences and the reference tree size. The crown area differences refer to the difference between aerial photo delineation and ground-based tree inventory.

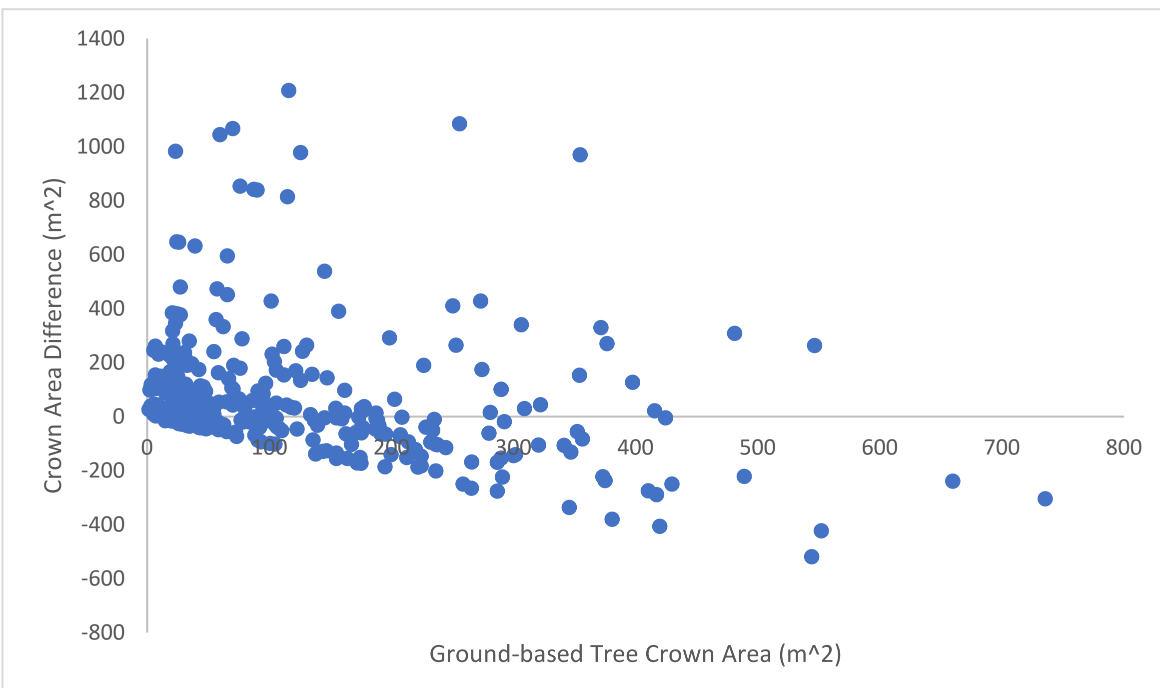

Figure 5 (b): The scatterplot represents the relationship between crown area differences and the reference tree size. The crown area differences refer to the difference between LiDAR delineation and ground-based tree inventory.

Figure 6: A comparison between LiDAR-delineated tree crowns and the real ground condition. Overestimation of tree crown occurred on top of the building. The map projection is NAD 1983 UTM Zone 10N.

Green Space Capability Analyses

Cultural Point Density Analysis

A heat map of cultural interest points was created to determine the cultural hotspot of the study area (Figure 7). The northern part of UBC Vancouver campus was considered the cultural hotspot, where dark purple color represented the high density of visiting. In contrast, the southern part of the study area with less interest points and lower point density illustrated fewer cultural values. UBC provides different cultural values for different group of people, therefore green spaces and some historical buildings and landmarks were captured in the heatmap.

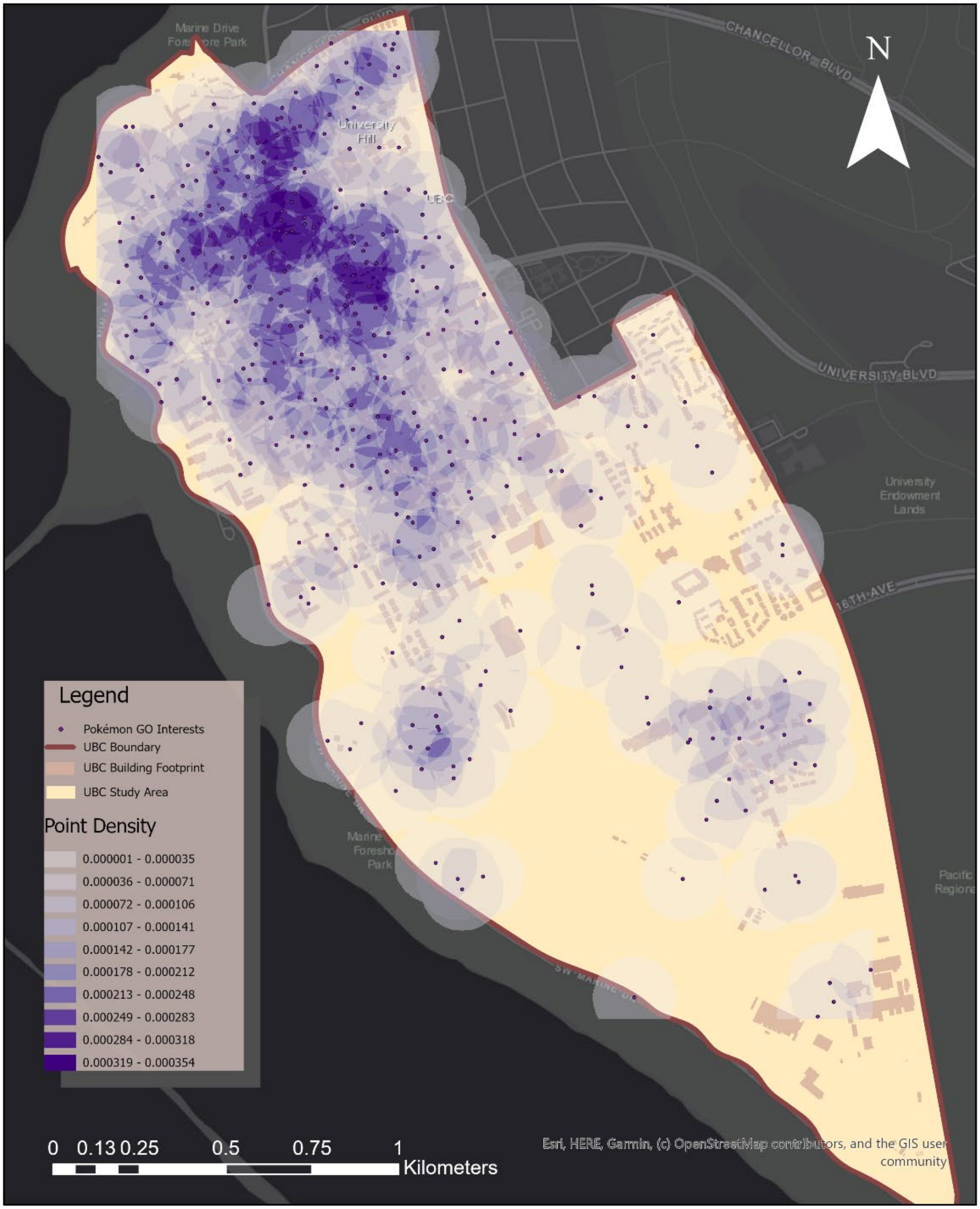

Figure 7: The heat map of cultural interests created based on the data of Pokémon GO Vancouver. The rasterized heat map has the cell size of 2 meters and radius of 60 meters. The map projection is NAD 1983 UTM Zone 10N.

Overall Green Space Cultural and Biodiversity Hotspots Assessments

Two green space assessments were generated based on two set of criteria. The first assessment illustrated the consideration of four categories namely canopy cover, native species ratio, species richness and cultural interest (Figure 8). However, due to the data limitation of ground-based inventory on natural forested area, the southern part of study area was excluded in this assessment by showing the grey color (Figure 8). As a result, botanical garden and the UBC farm were not included in this particular assessment. The green spaces with high cultural and biodiversity values (red polygons in the Figure 8) were identified collectively at the northern side of the study area, where the First Nation Longhouse and the Museum of Anthropology were located. The distribution of these cultural and biodiversity hot spots was not evenly distributed and they tend to be very fragmented over the study area.

Another green space assessment was conducted aimed to capture the full picture of the study area by only considering canopy coverage and the cultural aspect (Figure 9). As a result, botanical garden and the UBC farm were included in this assessment. Moreover, more small segmented areas were also included in this assessment, which contributed heavily to the composition and configuration of cultural and biodiversity green spaces in the study area. The sport field such as tennis courts and planning beds in the UBC farms shown in bright yellow were identified as the green spaces with very values. However, the green spaces with very high cultural and biodiverse values did not differ too much with the previous assessment (Figure 9). Moreover, a clear linear relationship was found between two assessments, with a R value of 0.7354, which revealed that 74% of the data fit the regression model (Figure 10).

Tow boxplots were created to further explore how would different types of greens space contribute into cultural and biodiversity values (Figure 11 & Figure 12). Lawn, planting bed and wild are three main green space types were included for green space assessment 1 (Figure 11). These three green space types contributed similarly into the assessment, where lawn and planting bed had larger variance ranges than the urban forest type. The green spaces within the wild category were naturally forested areas with more species richness and canopy coverage. As a result, the urban forest type contributed a little bit more than other two categories with less variance in both cultural and biodiversity value assessment considering four criteria. Similar trend was observed for assessment 2, where only canopy cover and cultural aspect were considered (Figure 12). Besides previous three types, the planting bed on structure (OS planting bed) was also included for this assessment. Lawn, planting bed and OS planting bed contributed similarly with a mean of 0.396 into the cultural and biodiversity values. The urban forest category remained the top green space type that contributed the most into cultural and biodiversity values with a mean of 0.501.

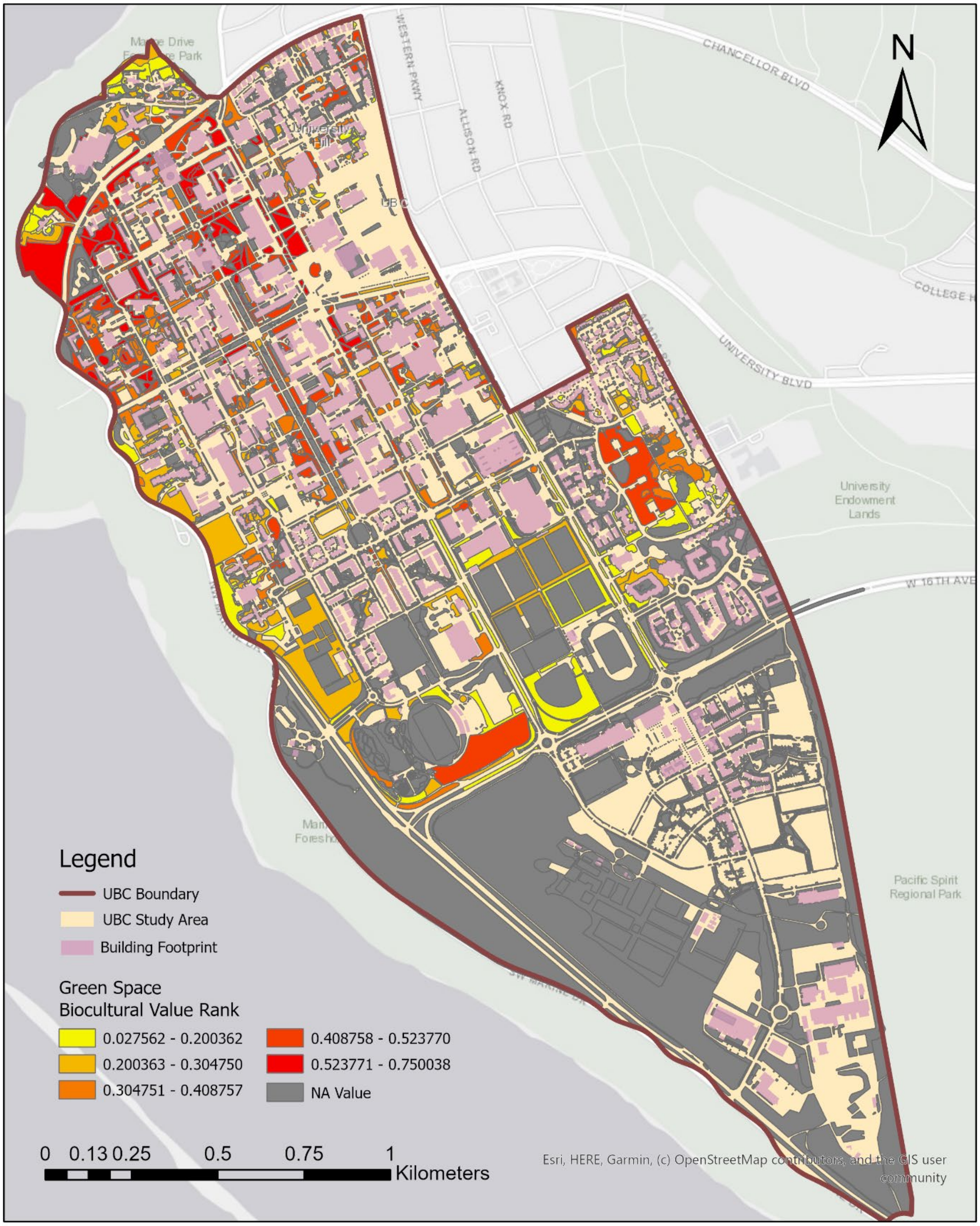

Figure 8: The map of a ranked cultural and biodiversity value of green space over the UBC Vancouver campus by considering four criteria. The suitability level ranges from 0 to 1, and five internals are defined on the map to represent the suitability of the identified green spaces. The map projection is NAD 1983 UTM Zone 10N.

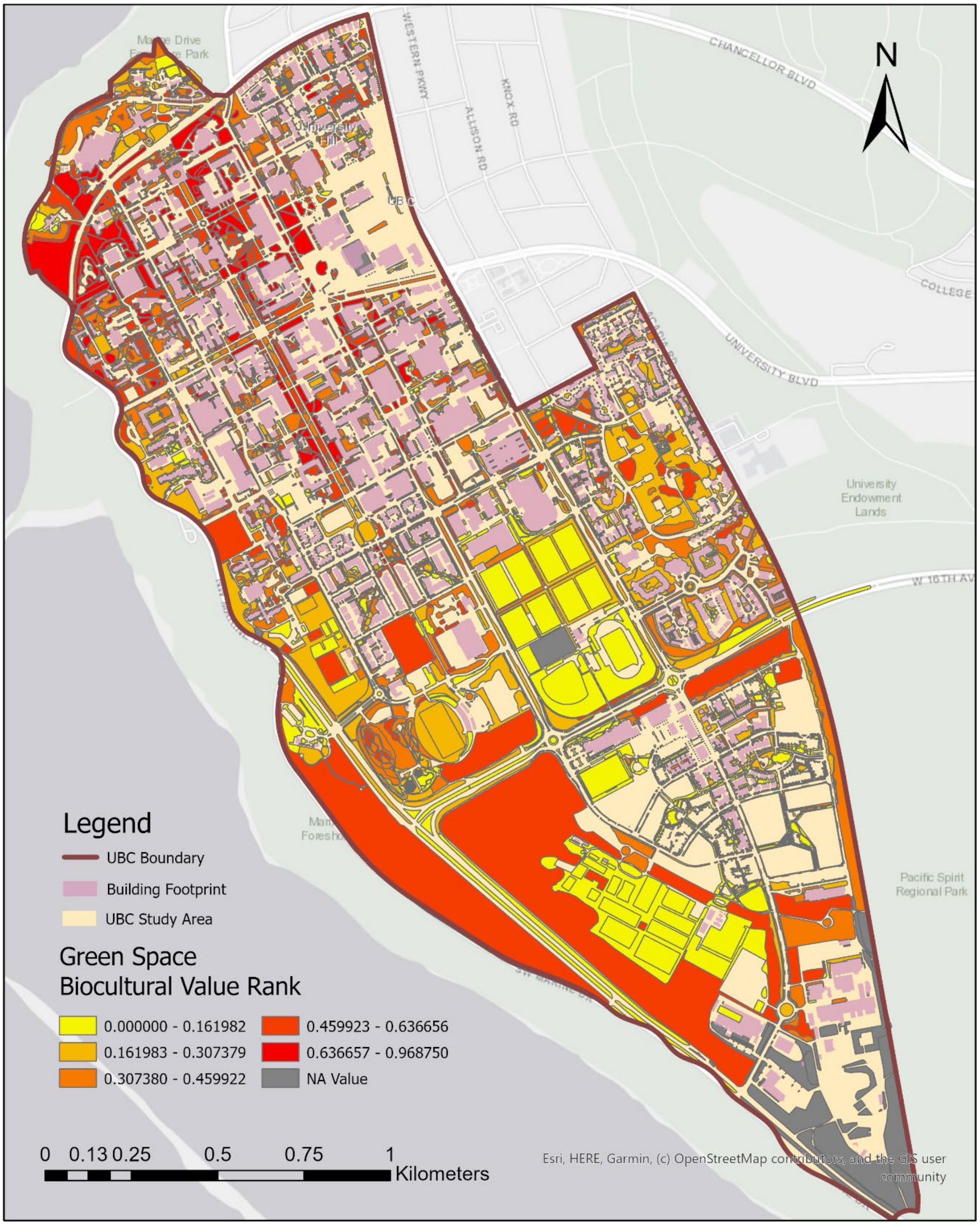

Figure 9: The map of a ranked cultural uses and biodiversity value green space over the UBC Vancouver campus by only considering two criteria. The suitability level ranges from 0 to 1, and five internals are defined on the map to represent the suitability of the identified green spaces. The map projection is NAD 1983 UTM Zone 10N.

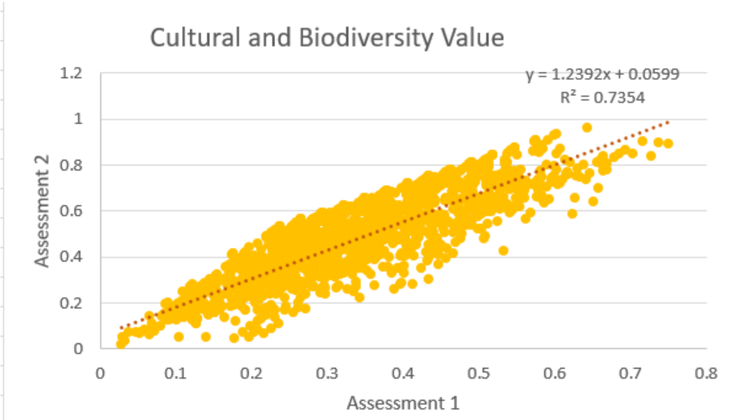

Figure 10: The linear relationship between two green space assessments.

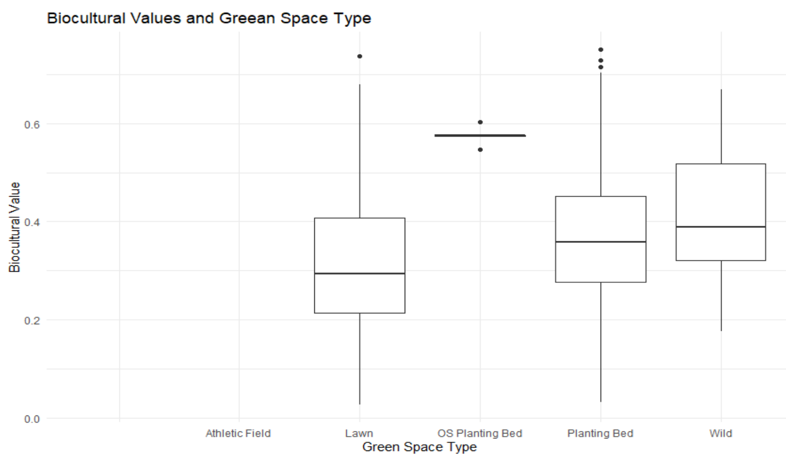

Figure 11: The boxplot of cultural and biodiversity values assessment 1, three main green space types are observed for cultural and biodiversity values.

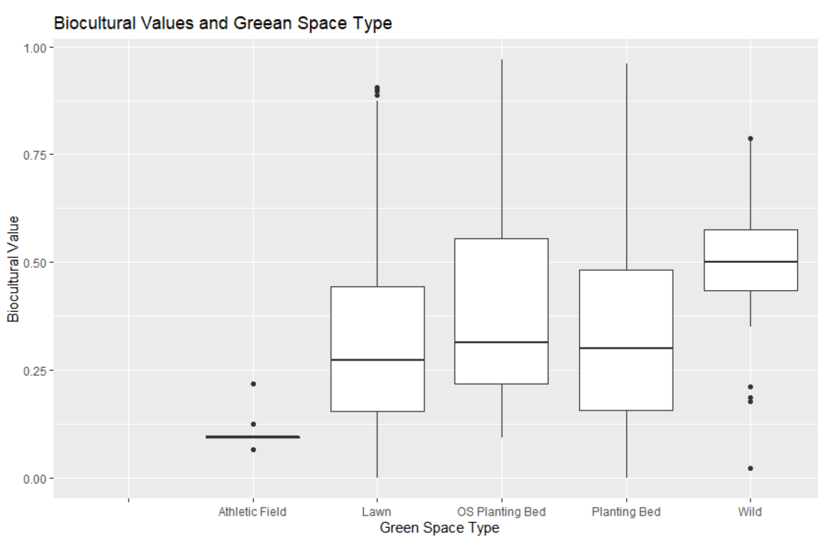

Figure 12: The boxplot of cultural and biodiversity values assessment 2, three main green space types are observed for cultural and biodiversity values.

5. Discussion

This research paper proposed a methodology by utilizing multiple data sources such as ground-based data, LiDAR-derived data, and citizen science to deliver an analysis on green space's cultural and biodiversity values in University of British Columbia Vancouver campus. The results have shown the significance of the urban forest green space type. The purpose of this research was to explore an appropriate method to integrate virtual gaming technology to capture green space's cultural and biodiversity value. Based on available geospatial data, providing assessments to prioritize the protection and conservation of significant green space types in campus planning and development.

Tree Crown Delineation Accuracy and Data Limitation

The accuracy of tree crown delineation was limited due to the inconsistency of data quantity for LiDAR delineation, ground-based tree inventory data and aerial photo delineated data. We set the ground-based data as the reference dataset to compare the crown area accuracy of LiDAR-derived crowns and manually aerial-photo delineated crowns. However, the ground-based data provided crown radius for 729 trees, while only 445 trees were manually delineated from the aerial photo. The crucial quantitative difference of the two datasets would impact the accuracy assessment.

The complex crown shapes have created some issues representing individual tree crowns (Gülçin & van den Bosch, 2020). Although there was a strong agreement between the aerial photo delineation and ground data, aerial photo distortion has made it difficult to accurately delineate tree crowns, especially for deciduous tree species. As for LiDAR data, there were some more overestimations observed than underestimations. LiDAR data tends to group multiple tree crowns into a large single crown. This grouping behavior on tree crown delineations also affected the canopy cover accuracy in the green space analysis. Individual crown delineation in this research applied watershed algorithm, which was proceeded by creating a model of the canopy height model (CHM). This method yields favorable results in stands of uniform crown shapes with distinct peaks (Ayrey et al., 2017). Therefore, watershed algorithm performed less well to complex and interlocking crowns (Ayrey et al., 2017). Besides, the accuracy represented the crown delineation for the subset area only.

The lack of information on species identification hindered the accuracy analysis from comparing among species types. The subset of ground base tree inventory excluded some of the tree's family name and genus name. Therefore, we could not compare the deciduous species and coniferous species' crown area accuracy in this research.

Urban Green Space Assessments

Identified green spaces tend to clustered at the northern part and the southern part of the study area, where these green space areas can offer social gatherings and events (Figure 8 & Figure 9). Since biocultural diversity was introduced to explain the interrelationships and interdependencies between people and their natural environment, we reckoned cultural interest and biological aspects for both green space assessments (Maffi, 2001). Two different assessments were demonstrated in this research. The cultural uses and biodiversity values of green spaces differs by considering different factors and weights.

Although assessment 1 considered more factors than assessment 2, the species data limitation of field inventory was the major constraint of this research. The dataset of ground-based tree inventory used in the assessment contained over 2000 data without tree identifications, which significantly affected native species ratio and species richness accuracy. Moreover, the inventory did not cover the southern part of the study area, where the botanical garden and UBC farm are located. Therefore, this assessment only demonstrated part of the study area. Assessment 2 aimed to cover the full extent of the UBC Vancouver campus by only considering cultural interest and canopy cover percentage as a representative of the biological aspect. However, canopy cover may not fully cover the biodiversity perspective in the biodiversity concept.

Based on the two green space assessments and associated boxplots, the urban forest category seemed to contribute the most to the cultural and biodiversity values than the other three categories. The ground data indicated there were more exotic species observed than native species. The native species tended to remain in the urban forest green space, located in the northern forested areas. Therefore, it is important to prioritize the urban forest green spaces to protect the native species community.

Suggestions on Future Green Space Researches

The result of this research was limited by the inconsistency of LiDAR data and ground-based tree inventory. The subset of the tree inventory dataset was collected in 2019 by Urban Forestry students, while the LiDAR data was acquired in 2015. The four years lag might contribute to the large variances when we calculate the crown area accuracy. The tree inventory data used for species richness and native species ratio analysis has not been updated since 2010, while new plantings and tree removals could frequently occur over ten years. Thus, the data collection time is a critical element to consider to make appropriate analysis in highly urbanized areas. Moreover, data availability and completeness contribute the most in any environmental assessment. The involvement of remote sensing multispectral imageries would help conduct normalized difference vegetation index (NDVI) analysis on vegetation greenness and infrastructure greyness in urban areas (Tischer et al., 2017). Moreover, complete data collection on tree species identification would help understand the different genera's contribution to green space types. Due to the data limitation, this research did not take understory species into account for green spaces analysis. However, the shrub and herb layers are essential to provide cultural values for local people (Gao et al., 2013).

LiDAR has shown strong potential in urban green spaces by producing individual tree crown delineation for canopy cover analysis and biomass estimation. With the combination of supplement ground inventory data, the green space biomass could be estimated. Many researches indicated the importance of vegetation biomass in the urban area. The higher the vegetation volume, the higher the sense of 'being away' from the urbanized areas (Lafortezza & Giannico, 2019; Nordh et al., 2009). Notably, the citizen science data offers great input in ecosystem service perceptions, and regularly integrating the remote data adds benefits in data collection (Van Berkel et al., 2018; Callaghan et al., 2019). This research utilized the Pokémon GO data to generate the cultural point density map. Indeed, scholars have proposed that games incorporate important learning concepts, because games promote active participation by setting clear goals and heightening curiosity by presenting uncertain outcomes and collaboration (De Freitas, 2006; Verutes & Rosenthal 2014). This way, virtual gaming technology has shown strong potentials to raise public awareness on natural environment, ecosystem services and wildlife conservation (Dorward et al., 2016). Future urban green space assessments should take advantage of geospatial coordinate function that provided in location-based virtual gaming technology to collect data of users' perception on cultural ecosystem services, educate and raise public awareness on surrounding landscapes, and promote two-way interaction between human and nature to alleviate health and well-being problems.

Acknowledgement

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Appendix

Data Summary

High Resolution Imagery

The high spatial resolution imagery of the University of British Columbia Vancouver campus had a map projection of UTM NAD 83 Zone 10 (Figure 13). The image was composed of 30 tiles with a tile size of 1km x 1km. A high-performance digital aerial camera, Zeiss DMC II 230 with a focal length of 92.014 mm, was used to produce high spatial resolution imageries of the UBC, and McElhanney Consulting Services Ltd collected the dataset on April 8th, 2015 (Orthophotos, University of British Columbia Vancouver Campus: https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/KIZZ4L). The raw pixel size was 9.5 cm ground sample distance, while the orthophotos were adjusted to a pixel size of 10 cm. The PAN/color ratio of 1:2.6 provides high radiometric quality images for RGB and Color-infrared (Z/I Imaging, 2020). A strong base-to-height ratio of 0.34 provides stereo measurement accuracy (Z/I Imaging, 2020). Manually delineated tree crowns were created based on this high spatial resolution imagery. This information was also used to compare tree crown area accuracy with LiDAR derived data.

Figure 13: The map is a high spatial resolution image of the University of British Columbia Vancouver campus in 2015, with a spatial resolution of 10 cm. The map projection is NAD 1983 UTM Zone 10N. Data source: McElhanney Consulting Services Ltd., (2015). Orthophotos, University of British Columbia Vancouver Campus. Retrieved from: [*https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/KIZZ4L*](https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/KIZZ4L).

Soft Landscape Dataset

The soft landscape shapefile included geospatial data information on UBC Vancouver campus's five green space types, namely lawn, planting bed, planting bed on structure, athletic field and the wild (urban forest) (Figure 14). The projected coordinate system of this dataset was NAD 1983 UTM Zone 10N. Each green space had associated green space planting bed ID. This information was used to complete the capability analysis for capturing cultural and biodiverse value of campus green spaces. UBC soft landscape dataset was derived from UBCGeodata in 2020. (UBCGeodata, 2020: https://github.com/UBCGeodata/ubc-geospatial-opendata/tree/master/ubcv/landscape).

Figure 14: The map of defined five green space types in University of British Columbia Vancouver campus. The map projection is NAD 1983 UTM Zone 10N. Data source: UBCGeo open data: https://github.com/UBCGeodata/ubc-geospatial-opendata/tree/master/ubcv/landscape

Campus Tree Inventory Dataset

The UBC Vancouver campus tree inventory shapefile was distributed by UBC Campus and Community Planning department in 2013 (Figure 15). The latest update of the dataset was in 2010. (https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/ETO8IU). The projected coordinate system of this dataset is NAD 1983 UTM Zone 10N. The tree inventory information with species' common names and scientific manes were used to calculate native species ratio and species richness for this research. Notably, this dataset only included part of the study area, with some tree species lacking specific tree identification information.

Figure 15: The map of ground-based tree inventory conducted in University of British Columbia Vancouver campus in 2013. The map projection is NAD 1983 UTM Zone 10N. Data source: https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/ETO8IU

LiDAR Point Cloud

The University of British Columbia Point Grey Campus Lidar was collected by UBC Campus and Community Planning department in 2015 (University of British Columbia Point Grey Campus Lidar, 2015: https://abacus.library.ubc.ca/dataset.xhtml?persistentId=hdl:11272.1/AB2/KET75X). The dataset covered the area of 8.87 km^2 with UBC Cliff, the Campus area and University Endowment Lands. The projection coordinate system of this LiDAR survey was NAD 1983 UTM Zone 10N. This LiDAR survey used to produce canopy height model and crown delineation (CHM), where classified point cloud data delivered in tiles (1 km x 1 km) and formatted in .LAS format (Campus and Community Planning, 2015).

Main-mall Tree Inventory Subset Data

The main-mall tree inventory dataset was collected by UBC Urban Forestry 110 class in 2019 and organized by Amy Blood into an excel file with corresponding longitude and latitude information (Figure 16). The projected coordinate system of this dataset was NAD 1983 UTM Zone 10N. The dataset included specific data of species names, diameter at breast height in meters (DBH), crown light exposure level and crown radius in meters. This dataset was used as the reference to assess the LiDAR and orthophoto delineated individual tree crown.

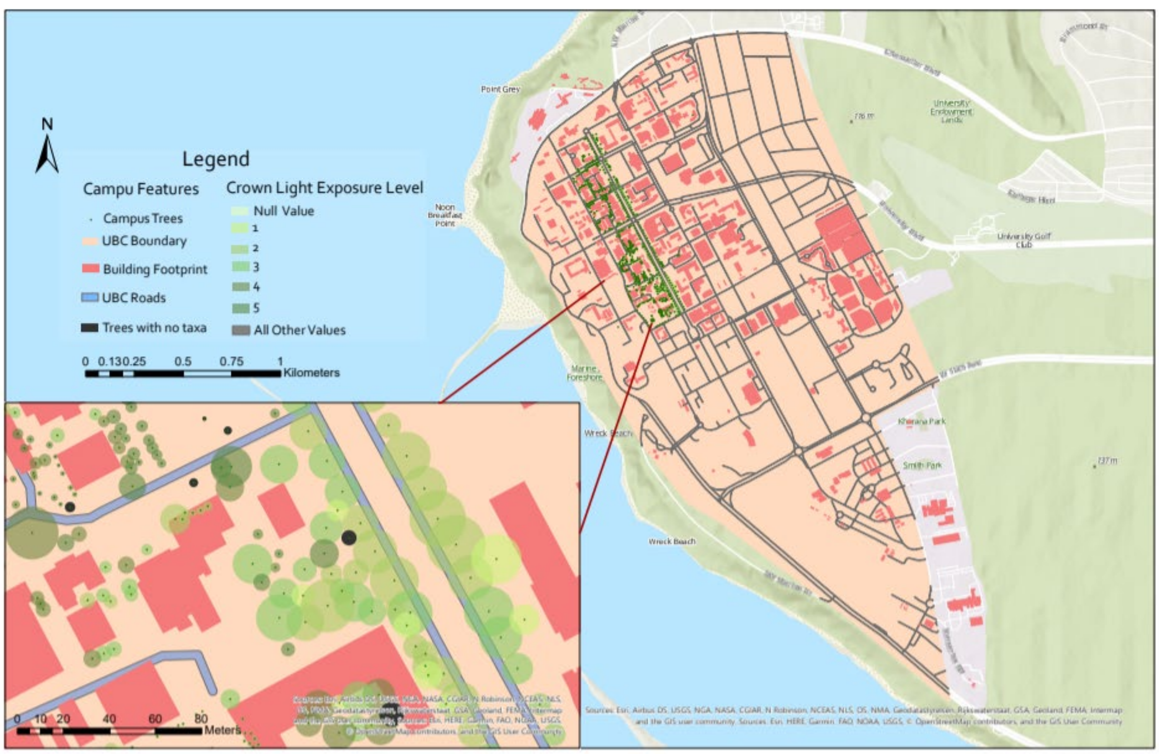

Figure 16: *The map of main-mall (UBC) ground truth tree inventory collected by Urban Forestry Program UFOR 110 class. The map projection is NAD 1983 UTM Zone 10N.The insert map shows the subsection of vegetation around the MacMillian Building, where six shades of green represent corresponding crown light exposure level from null value to level 5.*

UBC Pokémon GO PokéStop Geospatial Coordinates

The UBC PokéStop coordinates with associated longitudes and latitudes were provided by Pokémon GO company. The projected coordinate system of this dataset was NAD 1983 UTM Zone 10N. These geospatial coordinates were generated into point feature data in ArcGIS Pro to produce point density heat maps (Figure 17) and understand how virtual gaming technology contributes to capturing users' cultural interests in green spaces.

Figure 17: The map of Pokémon GO geospatial coordinates to capture cultural interests. The map projection is NAD 1983 UTM Zone 10N. The data source was provided by Pokémon GO company.

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