Quantifying Cigarette Butt Waste on Dalhousie University's Studley Campus: A Spatial Analysis of Hotspots via Location and Ground-Type Patterns

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April 7, 2025

ENVS3502

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Abstract

The abundance of cigarette butt litter present on Dalhousie University's Studley Campus, resulting from continued smoking creates a barrier to achieving the university's goal of maintaining a smoke-free campus. Physical counts of littered cigarette butts were conducted to quantify cigarette butt pollution on the two campuses and create a visual representation of the data using heatmaps generated using ArcGIS Pro. A total of 13,816 cigarette butts were recorded across 749 surveyed locations. Kruskal-Wallis and Post Hoc Dunn's tests were used to assess the significance of the distribution of cigarette butts, as well as their associated ground and location types. Cigarette butt accumulation varied by ground type: 65.77% of cigarette butts were found on natural surfaces, 17.44% on artificial surfaces, and 16.79% of cigarette butts were found in areas with both artificial and natural ground types. Additionally, accumulation of cigarette butts varied by location type: the largest quantities were recorded near sidewalks (25.11%), parking lots (21.56%), and educational buildings (21.06%). Notable high-density areas were observed: 676 outside of an administration building, 607 found outside of a library and 485 cigarette butts outside of a residence building, which are visible on the heatmap and illustrated in accompanying figures. The mean cigarette butt count per square meter was 18.45 with a standard deviation of 50.36. Results of the Kruskal-Wallis tests show a significant difference in cigarette butt counts across ground types ($p = 0.028$) and between location types ($p < 0.001$). The results of the Post Hoc Dunn's tests indicate a greater accumulation of cigarette butts on sidewalks and natural ground types. The findings of this study demonstrate that smoking persists despite campus guidelines. However, the results can be used to help inform Dalhousie's waste management practices and policy enforcement, contributing to a healthier and cleaner environment on Studley Campus.

Keywords

Cigarette Butt, Cellulose Acetate, University, Leaching, Second-Hand Smoke, Smoke-Free Policy, Hotspots, GIS (Geographic Information Systems), Litter Audit, Displacement Effect.

Table of Contents

Introduction

Cigarette butt (CB) pollution is one of the world's most common forms of litter, with estimates over the past decade suggesting that 4.5 trillion CBs are discarded into the environment globally each year (Novotny & Slaughter, 2014; Joly & Coulis, 2018; Valiente et al., 2020; Love et al., 2024; Conradi & Sánchez-Moyano, 2022). The filter is generally considered the "butt" of the cigarette, alongside the remaining paper, tobacco, and ashes (Araújo & Costa, 2019). The filter of the cigarette contains cellulose acetate, a polymer that hinders the biodegradability of CBs (Araújo & Costa, 2019). The exact length of CB biodegradation varies based on its composition, the conditions following its disposal, and by study (Joly & Coulis, 2018). For example, Parida et al. (2022) determined a rate of 92.1% biodegradation for cellulose acetate filters after 151 days, whereas Bonanomi et al. (2015) found a lower degradation rate of only 37.8% after two years. Contrarily, Joly and Coulis (2018) estimate that these filters take 7.5-14 years to entirely decompose—suggesting that CBs can persist as a form of physical pollution in the environment for up to 14 years.

Cigarettes also contain hundreds of highly toxic compounds, many of which are concentrated in the butt after smoking (Araújo & Costa, 2019). This includes heavy metals, polycyclic aromatic hydrocarbons (PAHs), microplastics, and numerous other toxic chemicals (Moriwaki et al., 2009; Chevalier et al., 2018; Dobaradaran et al., 2020; Torkashvand et al., 2021). Following improper disposal, CBs leach these harmful substances into the natural environment (Araújo & Costa, 2019). While limited studies have been done comparing the leaching differences of CB contaminants on different surface types, the leaching behaviour of these substances varies by substance type (Moerman & Potts, 2011) and environmental conditions (Kurmus & Mohajerani, 2020). For example, different heavy metals found in CBs exhibit different leaching behaviours: the concentration of Ba, Fe, Mn, and Sr leachate increases with time, whereas other metals such as Ni, Pb, Ti, and Zn fully leach within one day (Moerman & Potts, 2011). Additionally, Kurmus and Mohajerani (2020) found that CBs are more likely to leach these heavy metals during acidic rainfall as opposed to natural rain conditions. Toxic CB leachates, particularly nicotine, heavy metals, and PAHs, pose a threat to plants by affecting seed germination and plant growth (Ajibade et al., 2024). They also disrupt soil chemistry by significantly increasing soil pH and Na levels from the soils' natural baseline, impacting soil health, bacteria, and other soil dwelling organisms (Ajibade et al., 2024; Gill et al., 2018).

CB pollution also negatively affects wildlife. Birds in urban settings have been observed incorporating CBs into their nests, which can lead to increased genotoxicity by interfering with cell division in certain bird species following exposure to CB toxicants via physical contact (Suárez-Rodríguez et al., 2013; Suárez-Rodríguez & Macías Garcia, 2014). Wildlife is also vulnerable to risks associated with consuming discarded CBs (Novotny et al., 2011). When ingested, these toxins can increase mortality and alter behaviour, growth, and reproduction (Green et al., 2022). Similarly, domestic animals are at risk of consuming CBs and experience subsequent side effects such as vomiting, excess salivation, and respiratory failure (Novotny et al., 2011). The microplastics found in CBs allow for the leaching of up to 100 microfibers daily per cigarette (Conradi & Sánchez-Moyano, 2022). This too can have detrimental impacts on wildlife, as microplastics are often ingested leading to physical harm, chemical exposure, and alteration of behaviour (Jeong et al., 2024). Following consumption, these microplastics enter the food chain and can work their way up through trophic levels, ultimately impacting human health (Jeong et al., 2024).

Cigarette smoking and exposure to second-hand smoke can also lead to several known human health detriments, such as cancer, heart disease, and respiratory illness (Valiente et al., 2020). There are 70 known chemicals within a cigarette that are carcinogenic (Government of Canada, 2024). These carcinogens are the cause of many of the health implications associated with smoking (West, 2017). Smoking tobacco has significant effects on the genetic makeup of cells within the lungs which can lead to lung cancer (Government of Canada, 2024). West (2017) reveals that cigarette smoking can increase an individual's risk of stroke, osteoporosis, blindness, and peripheral vascular disease. Furthermore, over 6 million people face premature death from cigarette smoking annually (West, 2017).

To combat the negative health consequences associated with cigarette smoking, Dalhousie University has maintained a smoke-free policy since 2003, meaning the prohibition of all smoking on university property (Dalhousie University, n.d.-a). This decision is backed by many health organizations, such as the Lung Association of Nova Scotia, the Heart and Stroke Association of Nova Scotia, The Nova Scotia Provincial Health Council, and Smoke-free Nova Scotia (Dalhousie University, n.d.-a). Despite the university's efforts, CB pollution persists on Studley Campus. The absence of designated cigarette disposal bins following the smoking ban

may exacerbate the issue as smokers are left with limited disposal options. This is demonstrated in a study by Lakatos et al. (2024), who found that a lack of ashtrays and disposal bins was associated with increased CB littering behaviour. Enforcement of the smoking ban on Studley Campus also appears to be inconsistent and is not strictly upheld, with many students unaware of the policy and what it entails (Northam, 2010; Dehaas, 2013). Furthermore, studies have shown that smoking bans do not eliminate smoking behaviour, but may instead shift smoking locations to overlooked areas, thereby increasing localized littering (Novotny & Slaughter, 2014; Seo et al., 2011; Conradi & Sánchez-Moyano, 2022).

Numerous studies have been done to quantify CB pollution in natural environments, such as public beaches (Araújo & Costa, 2019; Araújo & Costa, 2021; Asensio-Montesinos et al., 2021; Díaz-Mendoza et al., 2023), and in recent years, more have emerged aiming to quantify CB litter in urban areas (Kaplan et al., 2019; Torkashvand et al., 2021; Valiente et al., 2020). Similar work has been done over the past decade (Beutel et al., 2021), however it is often missing the spatial aspect. Some research has been done on CB litter found on university campuses, such as that of Seitz et al. (2012) who quantified CB litter at an unnamed university campus in the Southeast region of the United States. However, few studies have been conducted within Canadian universities, and most research has focused on the qualitative aspects of CB pollution. For example, Smith et al. (2015) conducted a study on the main campus of the University of British Colombia (UBC) in which CB pollution was investigated qualitatively through student surveys and a literature review, to determine various disposal options as well as student behaviours and perceptions. UBC also performed an outdoor litter audit in March of 2024, which identified significant cigarette waste, though the audit was not explicitly focused on CB pollution (Love et al., 2024). These studies do not provide clear measurements of CB pollution, and no research has been conducted at Dalhousie University, highlighting an important research gap. This study aims to fill this gap by quantifying CB pollution on an urban campus at a Canadian university (Dalhousie University's Studley Campus) through conducting a physical count of CBs found on campus and mapping CB litter hotspots. The study will also identify ground and location types where CBs are most frequently littered, highlighting key areas that can be used as potential leverage points to address campus CB waste. Through this approach, the research will contribute valuable data to help inform Dalhousie's efforts to maintain a clean and smoke-free campus.

Methods

Site Description

Previous studies assessing CB waste distribution in urban environments were conducted in large metropolitan areas such as Madrid, Qazvin, Ankara, Izmir, and Istanbul, and as such, had the survey locations determined at random (Kaplan et al., 2019; Torkashvand et al., 2021; Valiente et al., 2020). The proposed research site is Dalhousie University's Studley Campus, which includes UKC, located in Halifax, Canada (Figure 1).

In its entirety, Studley Campus collectively occupy an area of approximately 0.3 km^2. To work effectively within the constraints of time and resource limitations, we defined a study site within the previously mentioned area and conducted an inspection of the entire grounds (Figure 2).

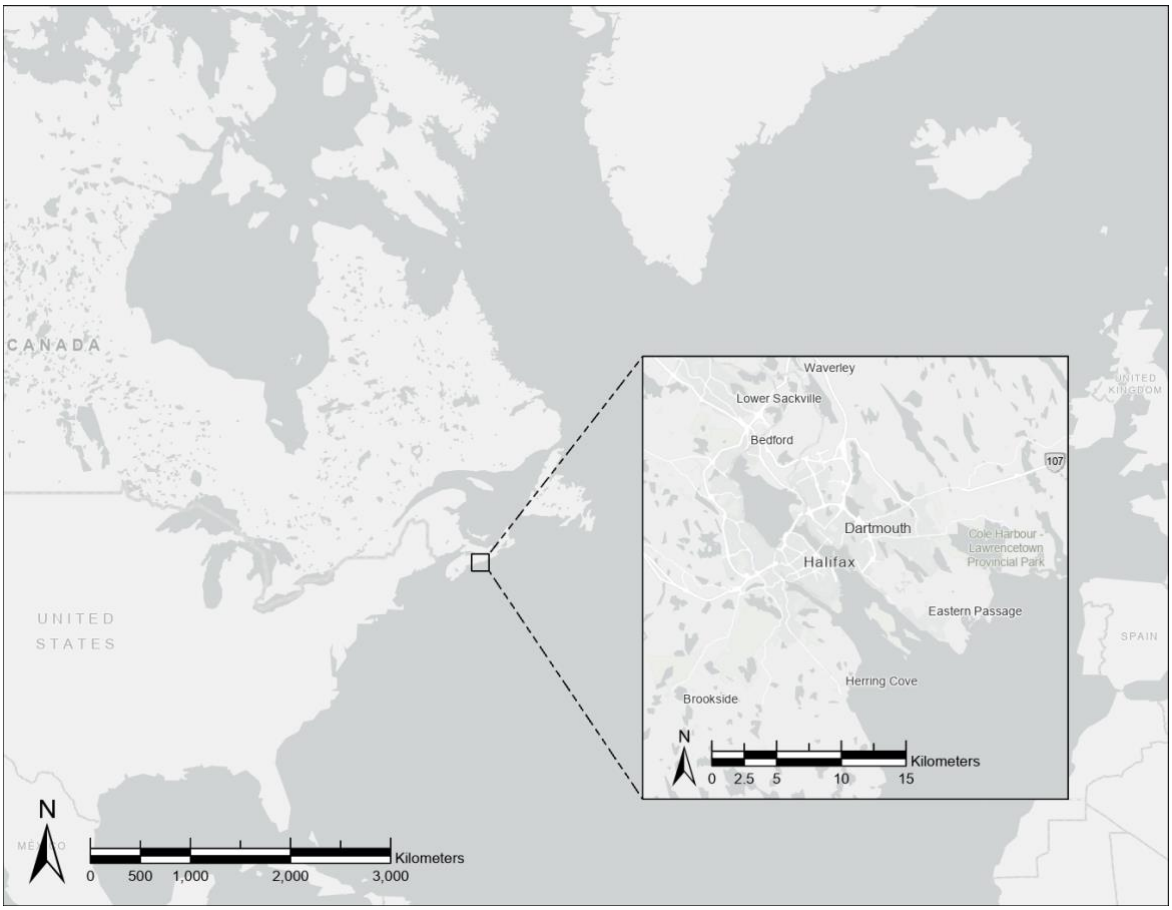

Figure 1. Inset map of area of interest, Studley Campus of Dalhousie University located in Halifax, NS.

The designated study area is located between the following intersections: Coburg Road, Oxford Street, South Street, and LeMarchant Street, encompassing an area that is approximately 0.19 km^2 (188,864 m^2) (Figure 2). Due to access restrictions, three areas were omitted, this included the National Research Council (NRC) and its associated parking lots, Wickwire Field, and the adjacent Oulton-Stanish Centre construction site taking place along South Street between Wickwire Field, and LeMarchant Place on 1246 LeMarchant Street (Figure 2). Accounting for all the building footprints, along with the previously mentioned exclusion zones, the survey area is approximately 101,000 m^2. Study site area estimations were conducted using the "Add a path or polygon" tool in Google Earth.

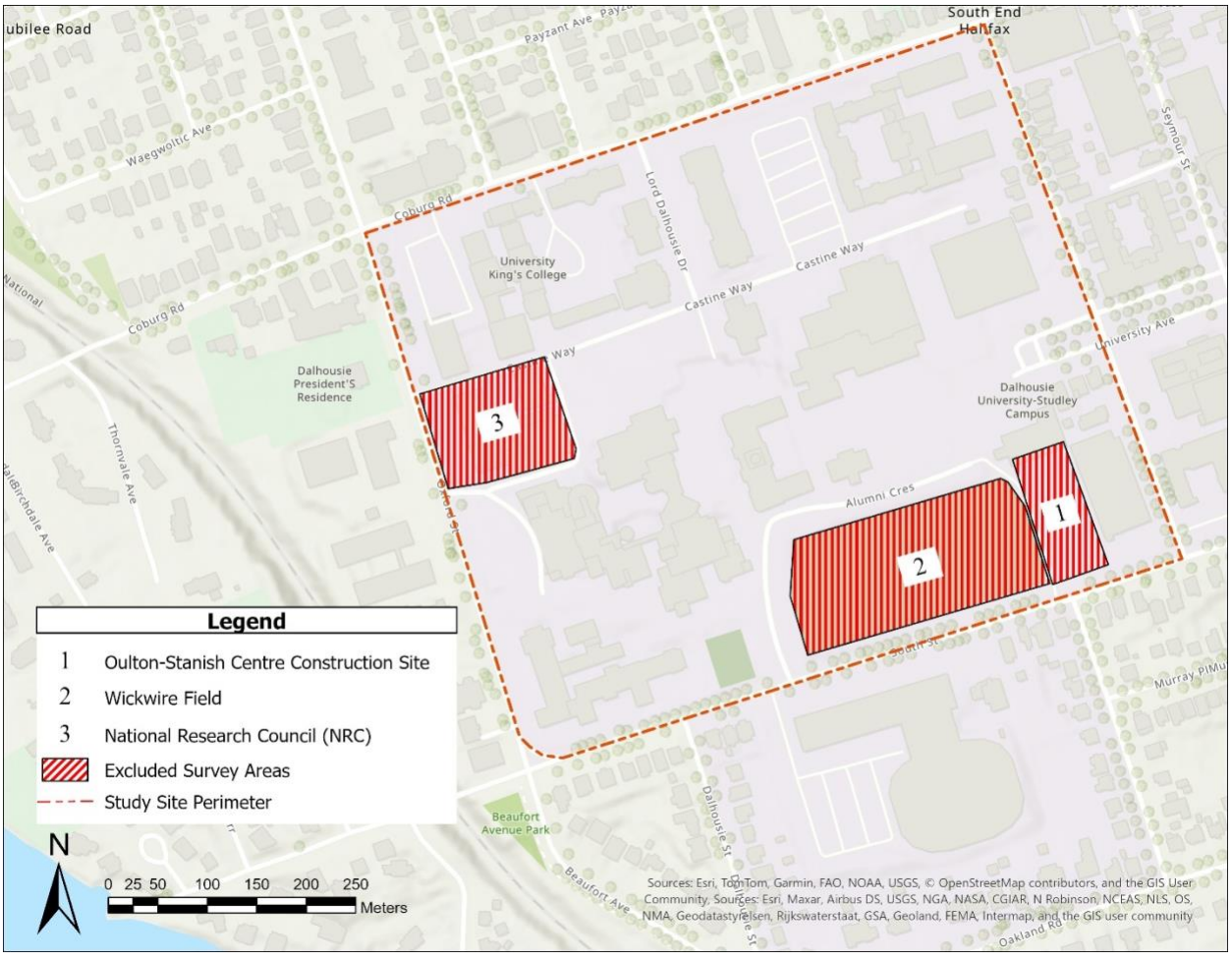

Figure 2. Map of the designated study area along with exclusion areas within Studley Campus of Dalhousie University, Halifax, NS.

This segment was chosen as it encompasses the highest variety of locations including administrative, residence, and professional buildings, along with libraries, parking lots, mixed use facilities, athletic/recreational areas, green spaces, as well as the UKC Campus (Figure 2). Additionally, it houses most of the educational buildings found within Studley Campus, and with a population of 21,000+ students and 6,000+ faculty and staff, the previously defined set of criteria and designated area of study will allow us to survey diverse, high-traffic areas (Dalhousie University, n.d.-b)

Table 1.

Summary of location type classifications of buildings and features found within the designated research site.

Location Type	Description
Education	any buildings with classrooms
Residence	student housing buildings
Courtyard	any green spaces
Recreation	buildings like gyms, theatres or clubhouses
Administration	buildings that held offices or administrative/custodial duties
Sidewalk	concrete walkways/pathways and stairs
Library	Killam Library, Wallace McCain Learning Commons, King's College Library

Data Collection

Data collection consisted of the following general steps:

1. Study site survey/walkthrough.
2. Establishment of 2m radius survey node upon CB waste discovery.
3. Coordinate logging (UTM 84GS) using Avenza Maps.
4. Counting and logging of CB quantity.
5. Logging surface type CB(s) were found on (natural, artificial, or both).
6. Logging nearest location type (sidewalk, parking, residence, library, recreational, administration, or education).

A thorough survey of the outdoor spaces within the designated study area was conducted by 5 researchers across a span of 5 days. Data collection occurred on the following dates and times in 2025:

- March 6 11:30-13:30.
- March 7 11:30-13:30.
- March 10 12:00-13:30 and 14:30-16:00.
- March 11 14:00-19:30.
- March 13 13:00-18:00.

Figure 3. Image of an open-reel tape measure used to establish a 2m radius survey node.

Each day, researchers would choose a portion of the designated survey site and conduct a walkthrough. Once CBs were discovered, a survey node was established by measuring a 2m radius encompassing the original CB and any other nearby CBs, using an open-reel tape measure (Figure 3). The radius used for all survey nodes remained constant to maintain consistency and

accuracy throughout the site. UTM 84GS coordinates were taken from the center of the node using Avenza Maps (ver. 5.4) and logged into a dataset for every node.

When CBs fell outside of the established circle, a subsequent circle was created using the nearest cluster of CBs and the same data collection methodology was employed. In the event only one single CB was found, with no others in a 2m radius, the single CB was the center point of the node. Upon the establishment of a survey node and logging of its coordinates, the CBs within it were then counted and logged alongside the coordinates.

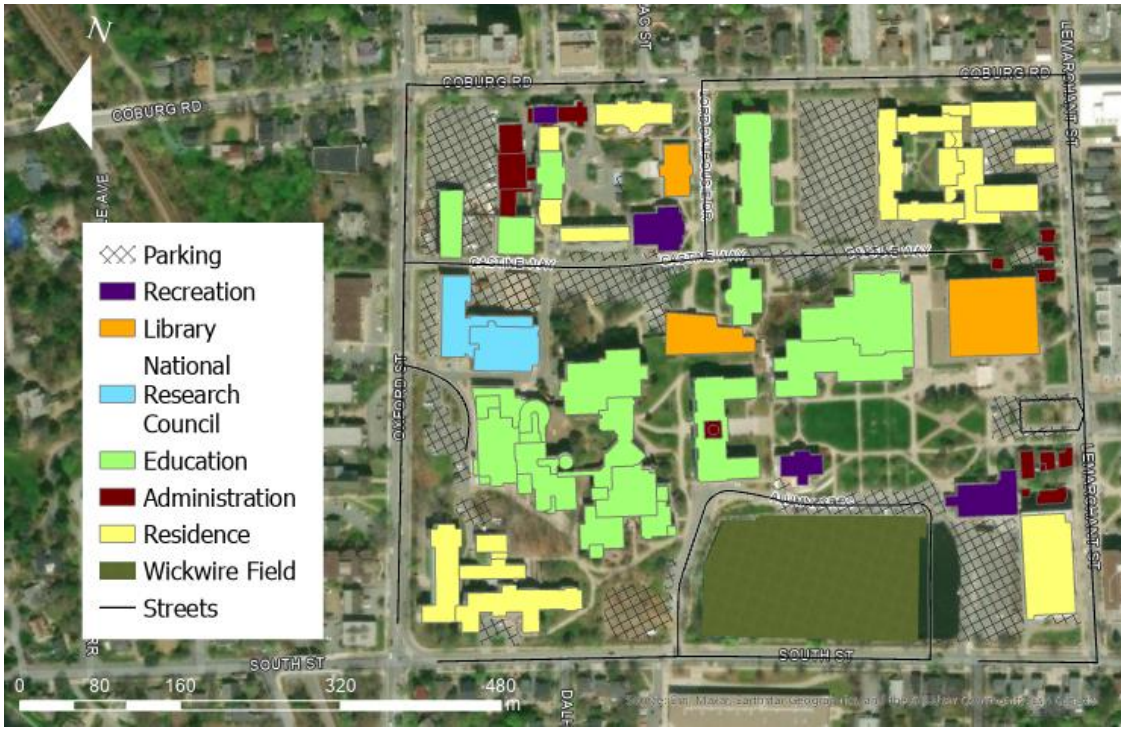

Figure 4. Map of the designated study area within Studley Campus of Dalhousie University, Halifax, NS.

Two types of data were also recorded with each node: ground type and location type. Ground type was classified as either artificial, natural or both. Artificial included any man-made ground coverage like concrete, asphalt, or turf. Natural included coverage such as grass, soil, mulch, and the both classification was used when CBs within the 2m radius were present across both natural and artificial ground type.

Location type was assigned using a pre-determined set of categorization and mapping guidelines (Figure 4; Table 1).

GIS & Spatial Analysis

Following the data collection stage, all UTM 84GS coordinate data as well as CB count, were imported into ArcGIS Pro (Ver. 3.4.3). Hot Spot Analysis (Getis-Ord Gi*), Optimized Hot Spot Analysis, and Heat Map tools were used for spatial visualization of the results and data.

Optimized Hot Spot Analysis was conducted to show statistical relevance among survey nodes. Using the data, this tool derives degree of automation (e.g. number of classes) and executes the Hot Spot Analysis (Getis-Ord Gi*) tool, in conjunction with the average and median nearest neighbour aggregation calculations. This generates a map visualizing statistically insignificant and significant hot spots and cold spots (Figure 11; Figure 12) (Esri, n.d.-b). Both the hot and cold spots include the number of survey nodes along with three classifications of 90%, 95%, and 99% statistical significance. These values are corrected using a False Discovery Rate (FDR) correction (Esri, n.d.-c) and are not weighted, meaning the resulting map indicates hot and cold spots based on occurrence and relative spatial displacement rather than CB count. A separate Hot Spot Analysis (Getis-Ord Gi*) tool generated map was created to visualize ranges of CB quantities found per node (Figure 12). Lastly, we generated a Heat Map weighted with the CB count to create a visual representation of CB waste distribution based on CB count as a function of Kernel Density (relative density) (Figure 12) (Esri, n.d. -a).

Statistical Analysis

Basic summary statistics were calculated using Microsoft Excel (mean, median, standard deviation). All other statistical analyses were performed using RStudio (version 2023.12.1). Dplyr and tidyr packages were used for data cleaning and manipulation, and ggplot2 was used for visualization (boxplots and bar charts). A Shapiro-Wilks test of normality was performed, and it was determined that the data were not normally distributed ($p < 0.05$). As such, we proceeded with non-parametric testing for further analysis. Kruskal-Wallis tests and post hoc Dunn's tests with Bonferroni corrections were used to determine statistical differences between categories (CB count and ground type, and CB count and location type).

Limitations

Surveying was time-intensive, which limited us to collecting data for only a few hours each day, over a period of 8 days. As a result, the entire study area was not surveyed simultaneously, introducing potential temporal bias in the results. Since CB waste accumulation

likely increases over time as people continue to smoke, areas surveyed later in the week, or even the same day, may have had higher counts of CBs solely based on the passing of time. To minimize this effect, we attempted to collect the data in as few days as possible.

Weather-related delays lengthened the data collection process; on Saturday, March 8, there was a snowfall the night before, interfering with visibility: Since most CBs are white, they likely would have been hidden by the snow, potentially resulting in undercounting. The following day, data collection was postponed due to temperatures below -14ºC, which created impractical and potentially unsafe conditions for surveying over long periods of time. This likely contributed to increased CB accumulation in areas that had not yet been surveyed.

The data collection process faced various limitations. There was an abundance of nicotine pouch litter found within the study area. Nicotine pouches are microfiber pouches with powdered nicotine inside that are used orally (CDC, 2025). We chose to exclude them in the CB waste data, because the investigation focused on Dalhousie University's smoke-free status, and nicotine pouches comply with these guidelines. However, when littered, especially when embedded into the soil and grass, they have a similar appearance to CBs. This may have led to them accidentally being counted as CBs or for CBs to be missed thinking they were nicotine pouches. Another limitation arose from the length of time CBs have been accumulating on campus. The CBs were often deeply embedded in the soil or grass which made them hard to count. Many CBs were also at various stages of biodegradation, making some susceptible to breaking when collecting and counting. This could have altered the count by either missing some that were too embedded or counting some twice if they had broken. Additionally, some CBs were found in snowbanks or ice patches, so we likely missed many that were deeply embedded.

There were some areas on campus that had obstacles which may have altered the count. For example, there were often cracks in sidewalks where CBs would be found so it was difficult to accurately determine the abundance. There were also garbage receptacles and parked cars that could not be avoided that may have led to some CBs being missed and excluded from the count.

We used Avenza Maps to determine and log the GPS coordinates. When a pinpoint was being placed to mark the location of CBs, often the marker continued to move, being unable to triangulate and determine the exact latitude and longitude at which we were standing. This created some error in where we found the CBs to where they display on the map. Avenza Maps

was used throughout the entire data collection process, so this error should be standard across all of the coordinates.

Results

Descriptive Statistics

A total of 13,816 CBs were recorded across 749 surveyed locations, with a mean of 18.45 CB count per survey node and a standard deviation of 50.36. The total surveyed area was 9,412.2 m^2. Across surface types 9,087 (65.77%) of CBs were found on natural surfaces 2,409 (17.44%) were found on artificial surfaces, and 2,320 (16.79%) were found in areas with both artificial and natural ground types (Figure 5; Table 2). For location type, the presence of CBs was highest around sidewalks (25.11%), parking lots (21.56%), and education buildings (21.06%), though significant amounts of CBs were found in each location category (Table 2; Figure 7).

CB counts deviating significantly from the mean were found in each ground and location type (Figure 8; Figure 9). The three highest CB counts were found at an administration location (n = 676), library (n = 607), and a residence location (n=485), with all being found on natural ground types.

Table 2

Summary of descriptive statistics of CBs collected on Dalhousie University's Studley Campus. Data collection was conducted from March 6 to March 17, 2025.

	N	*%*
Mean CB/node	*M* =18.45, SD = 50.36	-
Total CBs counted	13,816	-
Survey nodes	749	-
Ground Types		
Natural	9,087	65.77
Artificial	2,409	17.44
Both	2,320	16.79
Location Types		
Sidewalk	3469	25.11
Parking Lot	2979	21.56
Education	2910	21.06
Residence	2323	16.81
Administration	916	6.63
Library	890	6.44
Courtyard	240	1.74
Recreation	89	0.64

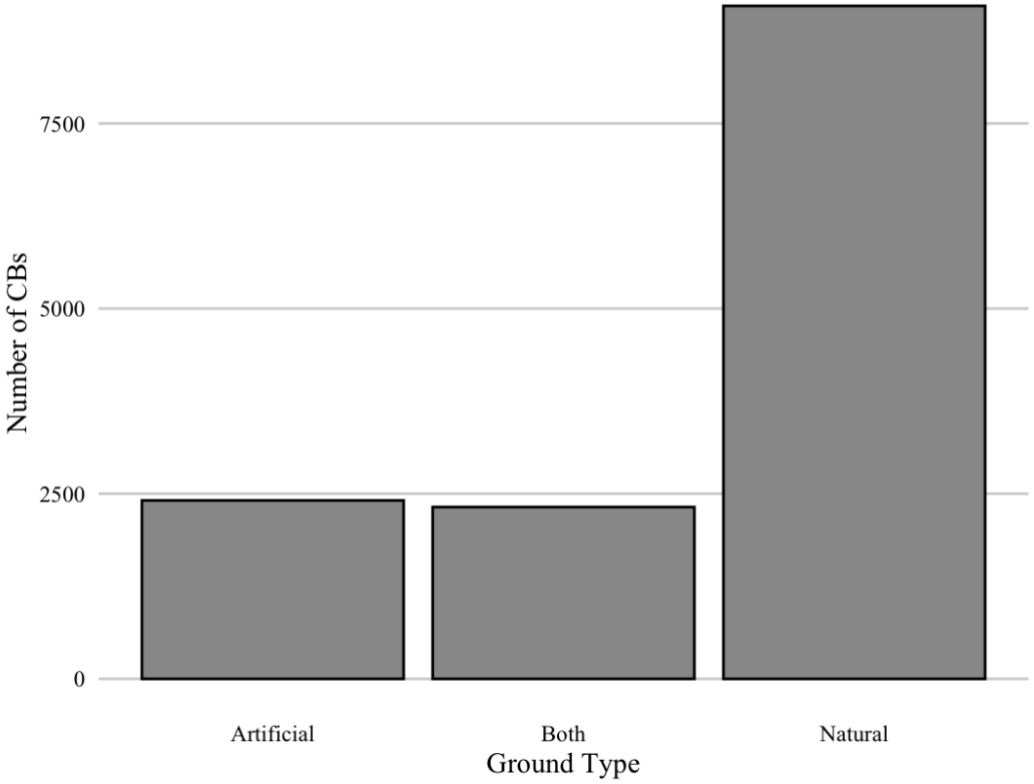

Figure 5. Quantity of CBs found within designated study site by ground type. Data collected from March 6 to March 17, 2025.

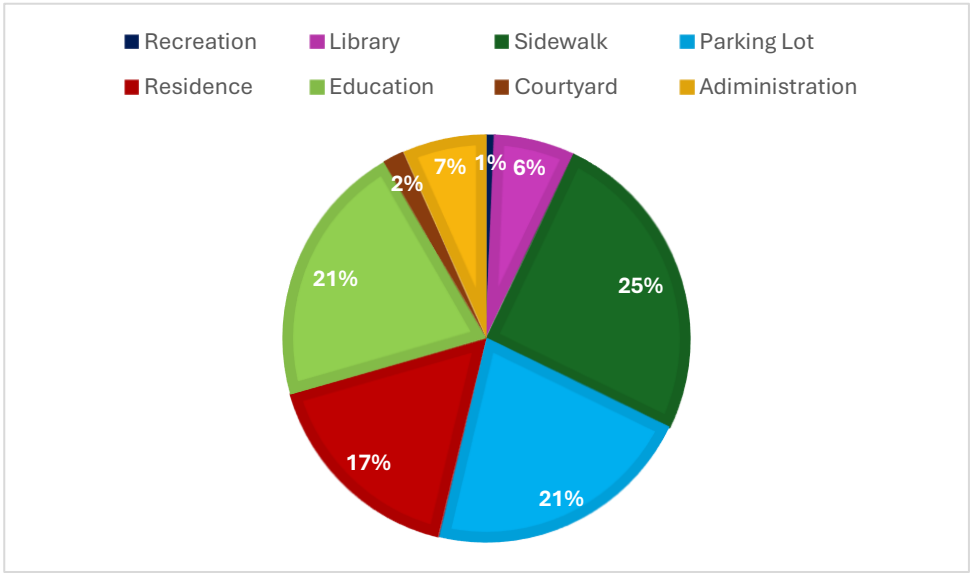

Figure 6. Location type frequency based on distribution of CBs during data collection conducted from March 6 to March 17, 2025.

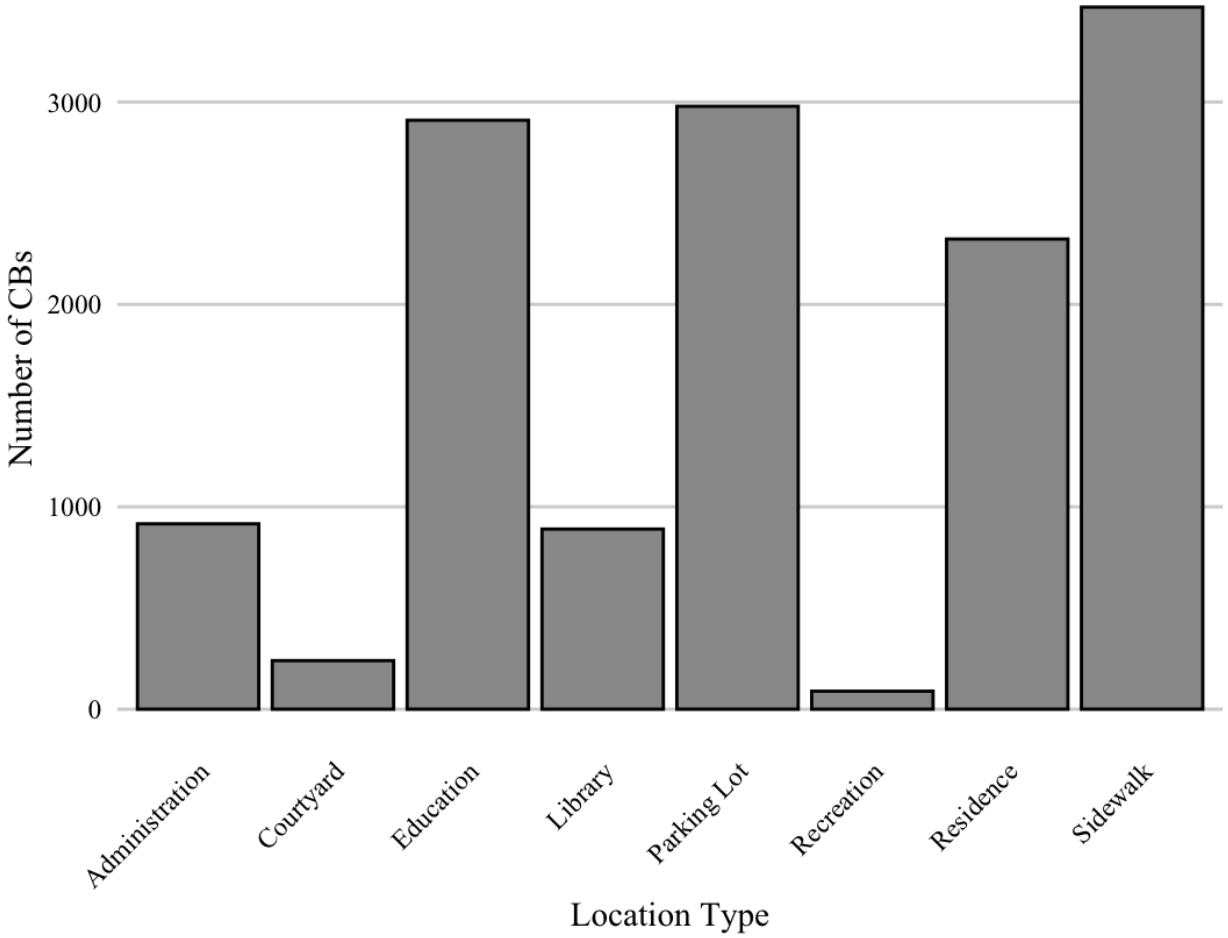

Figure 7. Number of CBs found on Studley Campus by location type during data collection conducted from March 6 to March 17.

Kruskal-Wallis Test Results

A Kruskal-Wallis test was conducted to compare CB counts across ground types and location types. There was a statistically significant difference in CB counts across three ground types ($\chi^2 = 7.14$, df = 2, $p = 0.028$) (Figure 8). There was also a statistically significant difference in CB counts between location types ($\chi^2 = 35.37$, df = 7, $p < 0.001$) (Figure 9).

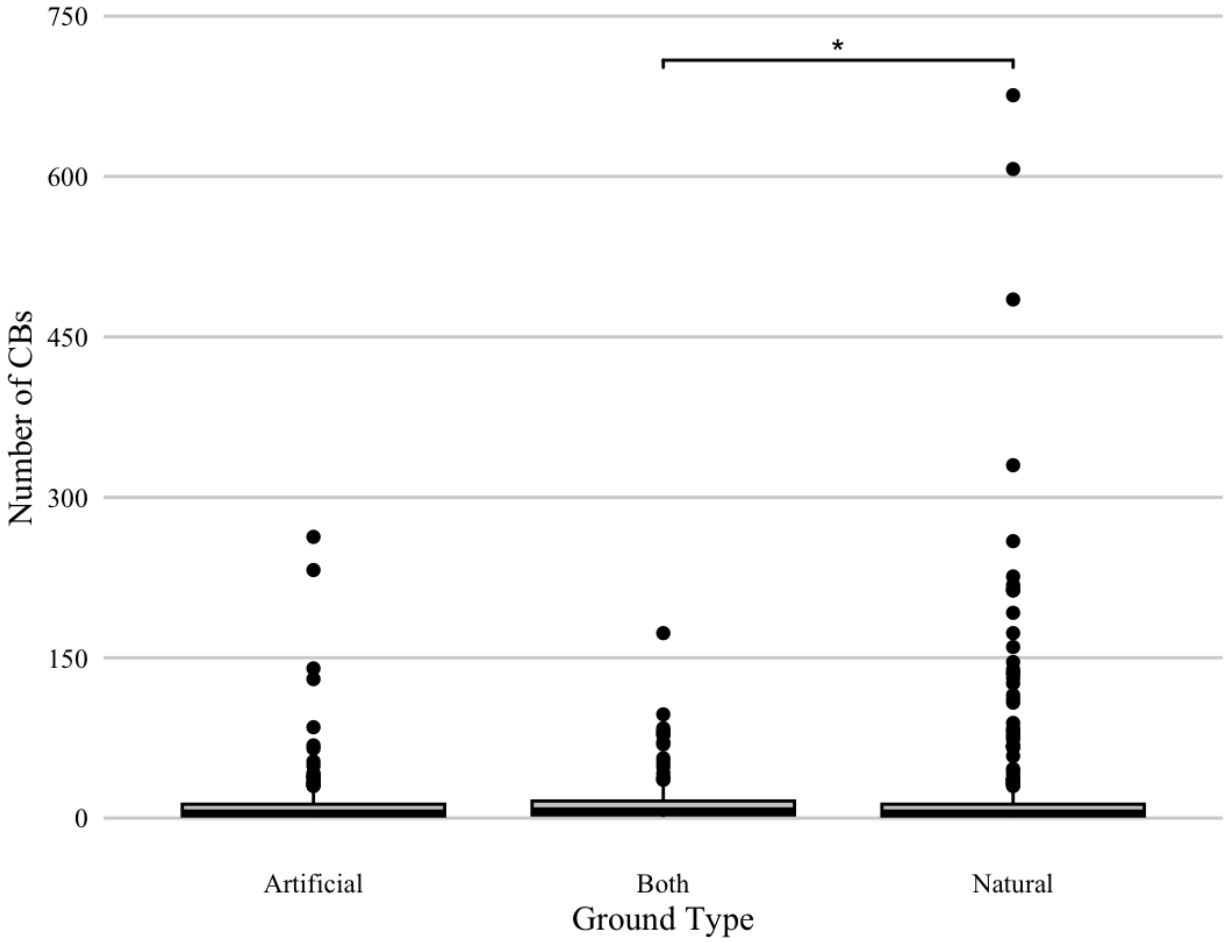

Figure 8. Box plot showing the distribution of CB counts by ground type. Asterisks indicate statistically significant differences in CB counts based on Dunns's test with Bonferroni correction ($p < 0.05$ = *). Significant differences were observed between natural and both ($p = 0.038$).

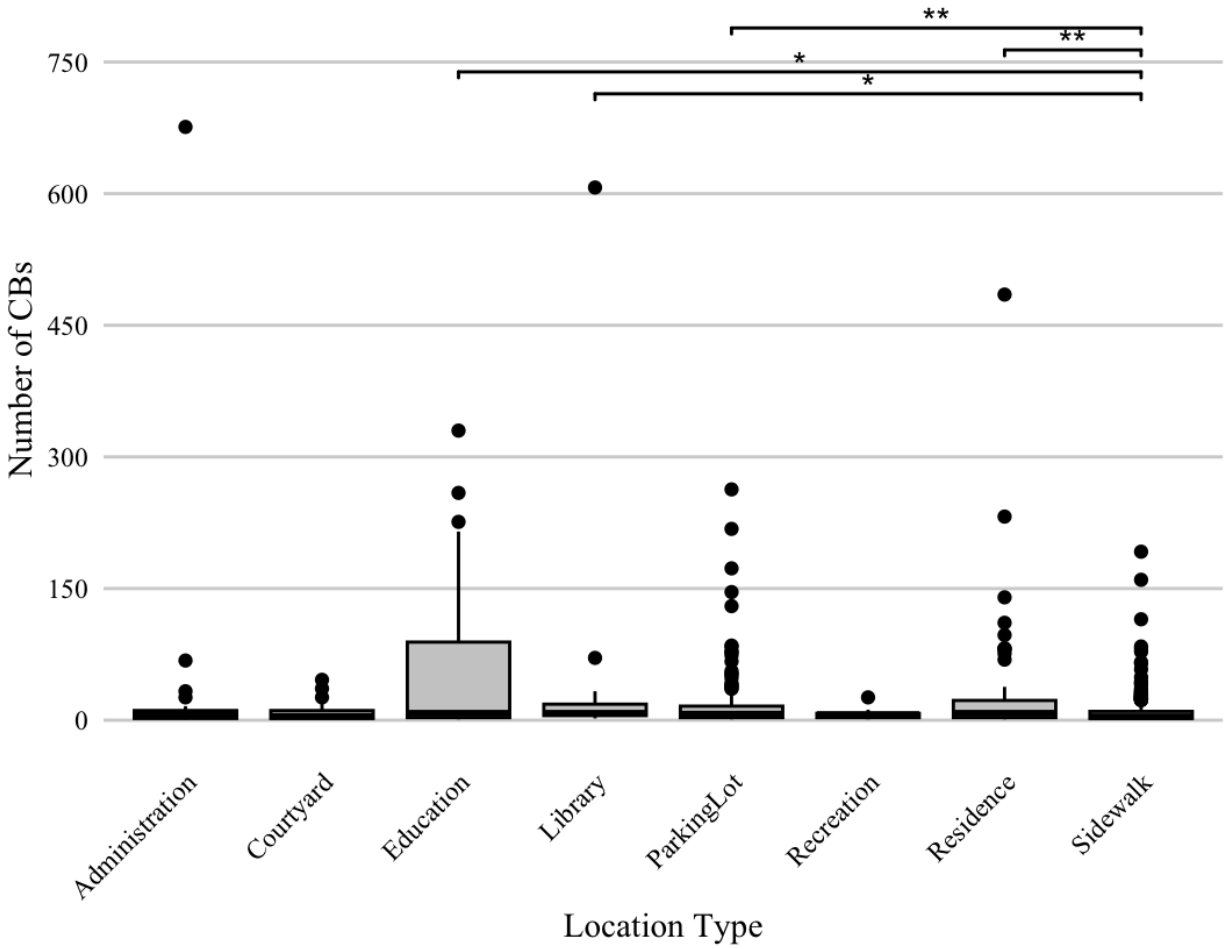

Figure 9. Box plot showing the distribution of CB counts by location type. Asterisks indicate statistically significant differences based on Dunn's test with Bonferroni correction ($p < 0.05$ = *, $p < 0.01$ = **). Significant differences were observed between sidewalk and education ($p = 0.015$), library ($p = 0.041$), parking lot ($p = 0.0034$), and residence ($p = 0.0036$).

Post Hoc Analysis Results (Dunn's Test)

Post hoc Dunn's tests with a Bonferroni correction were conducted following the Kruskal-Wallis tests to determine which groups were significantly different. For CB count by ground type, significantly more CBs were found on natural surfaces compared to mixed (both) ground types ($p = 0.038$) (Figure 5; Figure 8). No significant differences were found between artificial and natural ($p = 1.00$) or artificial and both ground types ($p = 0.066$) (). For CB count by location type, sidewalks had significantly more CBs than educational buildings ($p = 0.015$),

libraries (p = 0.041), parking lots (p = 0.0034), and residence buildings (p = 0.0036) (Figure 7; Figure 9). There were no significant differences in CB counts between other groupings. These results suggest that sidewalks accumulate more CBs than other location types on campus.

Spatial Analysis

Mapping the survey nodes reveals a relatively consistent canopy of CB waste found across the survey site (Figure 10). The densest cluster of nodes, with the majority of the highest CB counts, occurs along a sidewalk that is adjacent to a parking lot and is nestled between a UKC residence and education building. This data is consistent with the earlier statistical analysis, as it places the densest cluster of CBs in direct proximity to the four most frequently occurring location types (Figure 7; Table 2).

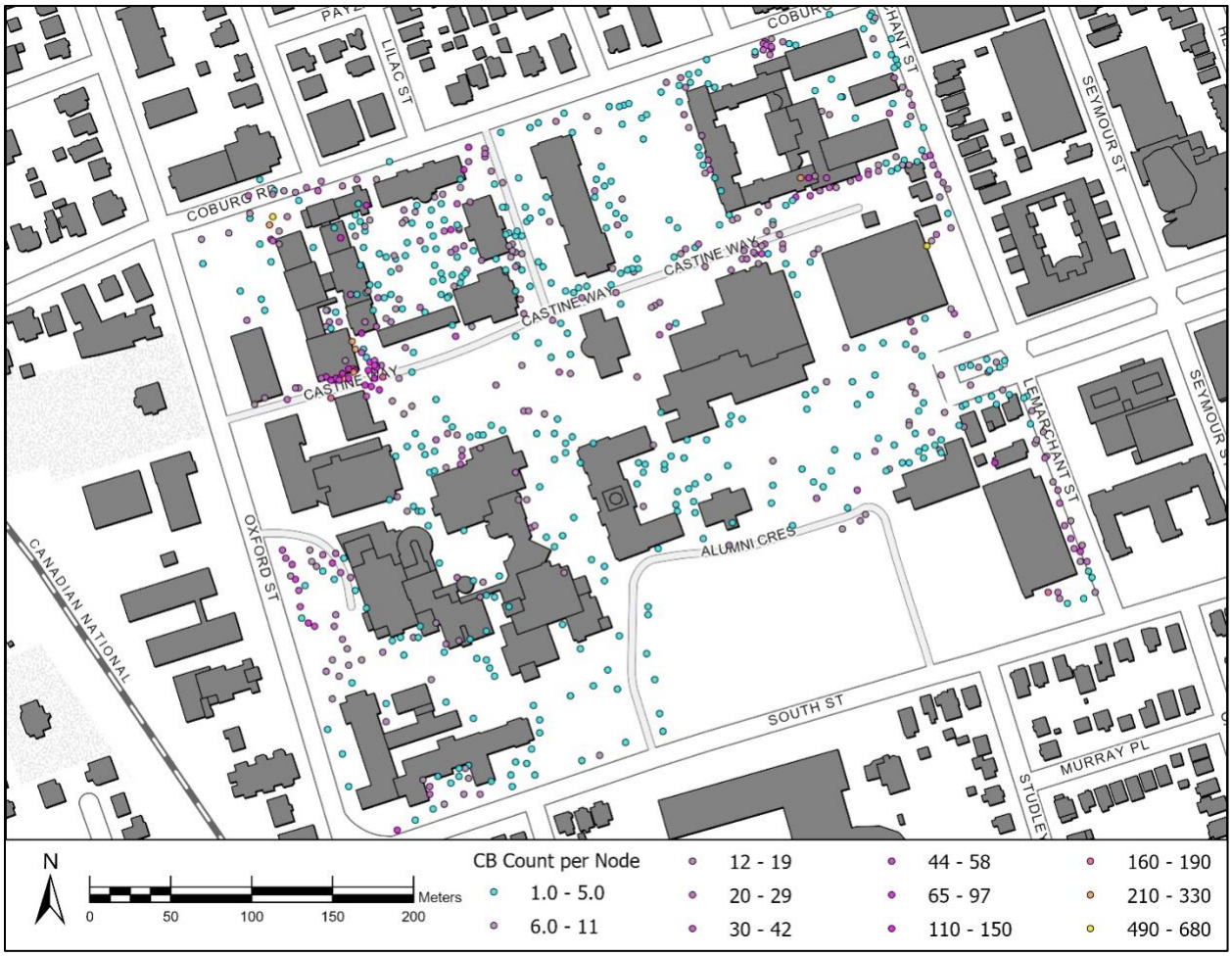

Figure 10. Hot Spot Analysis (Getis-Ord Gi*) map generated in ArcGIS Pro of the CB collection data across the designated study site within Dalhousie University's Studley Campus.

Figure 11. Statistical mapping analysis of CB nodes indicating hot & cold spots, confidence intervals, and node quantity. Mapping was done using Optimized Hot Spot Analysis tool in ArcGIS Pro.

Transforming the data using the Optimized Hot Spot Analysis tool, a distribution of hot and cold spots with varying degrees of statistical confidence (Figure 11) can be seen. Two distinct regions of hot spots are present: the first is along the northern portion of LeMarchant Street, running alongside some administration and residence buildings (Howe Hall and Studley House) (Figure 11; Figure 4). This cluster consists of nodes with 90% and 95% confidence levels. The second occupies a substantially larger area, encompassing a sizeable portion of UKC campus between Coburg Road and Castine Way, UKC's parking lots (both the courtyard one and the one on the NW corner of the study site). It stretches further south across the parking lot south of Castine Way, and up to the north entrances of the Wallace McCain Learning Commons and

Life Sciences Centre, both being educational buildings. Furthermore, most of these nodes are in the 99% confidence internal.

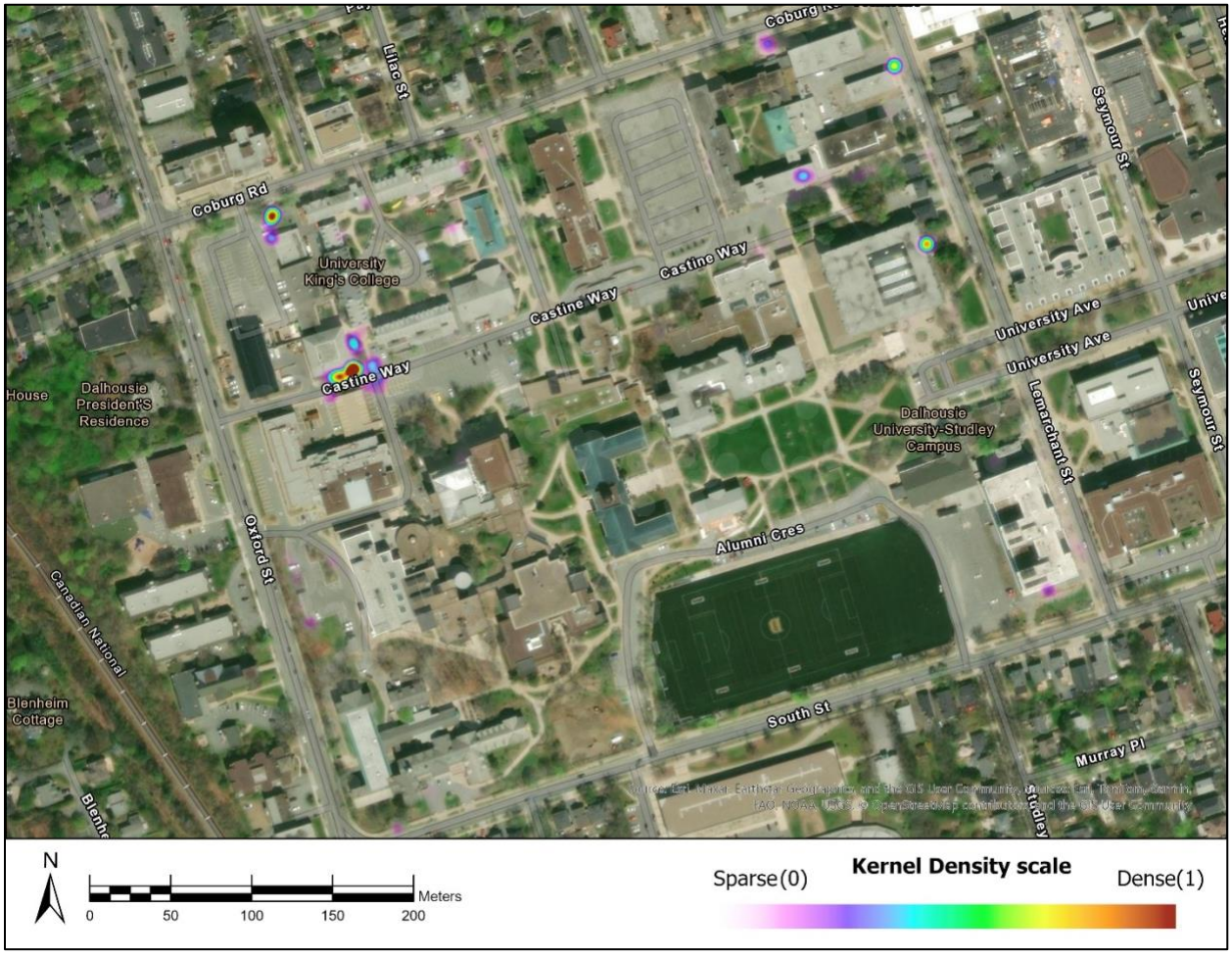

Figure 12. Heat map generated in ArcGIS Pro as a function of Kernel density, showing relative density on a scale of 0-1, weighted for CB per node count.

The heat map analysis, indicating the relative density of points (weighted with CB count values) reveals cross overs with the previous findings (Figure 12). It aligns with the statistical Optimized Hot Spot analysis in that the two densest locations (South portion of UKC along Castine Way and the Northwest corner of UKC, south of Coburg Road) coincide with hot spots of both 99% and 95% Confidence Intervals (Figure 11). In addition to that, the densest locations occur along Sidewalks and Parking Lots, once again remaining consistent with the previous findings (Figure 8; Table 2).

Discussion

The statistical results suggest that the distribution of CB waste on Studley Campus is influenced by both ground and location type, with natural ground types and sidewalks accumulating the most CB waste. This uneven distribution may reflect a pattern in where people tend to smoke or discard CB waste, possibly favouring surfaces that are more convenient (Breunis et al., 2021).

The analysis found that the mean CB count per square metre was 18.45, but several locations recorded exceptionally higher values: 676, 607, and 485 CBs, suggesting that certain locations experience substantially higher smoking activity or CB litter accumulation than others. Most of the extremely large values were found on natural ground types, though some were found on artificial (e.g., 263, 218) and both ground types (e.g. 173). A significant number of these hotspots were found on UKC. This suggests that UKC students may smoke more than Dalhousie students, or that smokers tend to aggregate in this area, despite UKC Campus also being a smoke-free campus (University of Kings College, 2015). Potential reasons for these high-density areas could be high foot traffic, proximity to "designated" smoking areas, or convenience (i.e., proximity to bus stops, education, administration, or residence buildings). These findings align with prior research on CB littering behaviour, which suggests that smokers tend to discard cigarette waste in high-traffic pedestrian areas, near building entrances, and in spaces where smoking restrictions are difficult to enforce (Breunis et al., 2021 Rath et al., 2012). The majority of the high CB counts in the administration category were present on UKC and around Castine Way.

Another high-density area (n = 607 CBs) was located around the entrance doors of Killam Library, shielded by trees. This location would not be ideal for socialized smoking or stress-relief from studying as it is in a hidden patch of greenery. This hotspot may reveal that people have shifted their behaviour to smoking in isolated locations, rather than eliminating smoking within a smoke-free space (Seo et al., 2011; Breunis et al., 2021; Rath et al., 2012).

The hotspot within the residence classification, 485 CBs, was located at a spot where service workers presumably smoke between shifts or on break. During the collection process there was a presence of staff from Howe Hall’s meal hall. This spot is located right on the sidewalk, where some could perceive this as off campus, which is what may be gravitating

people towards this spot. It was also noticed during collection that people often smoked in areas where there was already a smoking presence. During the field surveying, it was seen that service workers were smoking there, which may have enticed students to smoke here as well (Smokefree.gov, 2019). These findings align with prior research on CB littering behaviour, which suggests that smokers tend to discard cigarette waste in high-traffic pedestrian areas, near building entrances, and in spaces where smoking restrictions are difficult to enforce (Breunis et al., 2021; Rath et al., 2012).

The hotspot maps (Figure 11; Figure 12) provide a strong visual support for the statistical findings, fortifying the observed clustering of CB waste in specific high-traffic areas on Studley Campus. The highest concentrations of CBs are visible along the corner areas of Coburg Rd and LeMarchant St and near key social areas like the lawn and parking areas adjacent to UKC Campus along Castine Way. These findings not only align with the Kruskal-Wallis test results, but also with results found through other studies performed on smoke-free college campuses, all of which identified significant differences in CB accumulation across location types (Sawdey et al., 2011). The map highlights that CBs were particularly concentrated at campus entrances, bus stops, and sidewalks adjacent to academic buildings, suggesting that despite the smoke-free policy, individuals continue to smoke in areas where enforcement may be limited or where natural gathering points encourage smoking behaviour. Additionally, the high count of CBs near transit stops and pedestrian pathways indicates that CB litter is most prevalent in areas of waiting and social interaction.

From a practical standpoint, the high concentration of CB waste in certain areas highlights the inadequacy of policy enforcement and the necessity for complementary measures. The predominance of CB accumulation near educational buildings (21.06%), sidewalks (25.11%), and parking lots (21.56%) suggests that students and faculty members continue to engage in smoking near high-traffic zones, likely for convenience or socialization. This trend aligns with research indicating that smoking behaviours often persist in communal and accessible locations (Hammond et al., 2008). These findings highlight the need for universities to reassess their smoke-free policy enforcement and introduce targeted waste management interventions such as designated disposal bins. Furthermore, the high concentration of CBs near sidewalks, parking lots, and educational buildings reveal that smokers shift their behaviour rather than

discontinuing it, reinforcing the concept of displacement rather than elimination (Seo et al., 2011; Conradi & Sánchez-Moyano, 2022). Similar studies have shown that when smoking is banned in primary locations, smokers often migrate to peripheral areas where policy enforcement is weaker (Seo et al., 2011). Additionally, the relatively lower accumulations of CBs in recreational locations (0.64%) indicates that smokers may self-regulate their behaviour in aesthetically pleasing areas or areas of social gathering to avoid stigma or potential enforcement. For instance, a study by Bell et al. (2010) found that smokers in Vancouver experienced stigma that influenced them to avoid smoking in certain public spaces to maintain a considerate social identity. This self-regulation aligns with the concept that public sentiment and social norms can significantly impact individual smoking behaviors (Kim & Shanahan, 2003).

The initial hypothesis suggested that Dalhousie University's smoke-free policy would not prevent or reduce CB waste on Studley Campus. The hypothesis held true as the findings supported the prediction of high counts of CB waste throughout Studley Campus. Additionally, the high standard deviation of 50.36 in CB distribution highlights the variability in smoking behaviour across different campus locations. While some areas may have minimal cigarette waste accumulation, others exhibit disproportionately high counts. This inconsistency implies that enforcement efforts, clean-up methods or smoking alternatives may need to be location specific rather than campus wide.

Another unexpected finding relates to the distinction between natural and artificial environments. The data shows that 65.77% of CBs were found in natural locations, whereas only 17.44% were found in artificial environments. This suggests that smokers may prefer discrete areas, potentially to avoid detection or as a means of distancing themselves from high-visibility zones. This aligns with prior research indicating that smokers often adapt to policy constraints by seeking areas perceived as lower risk for confrontation or penalty (Smith & Novotony, 2011). The discrepancy between expected reductions in CB waste and the actual prevalence of CB hotspots exemplifies the limitations of smoke-free policies in the absence of comprehensive waste management strategies.

Recommendations for Action

Considering the abundance of CB waste, implementation of more signage around campus to remind people that Studley Campus is a smoke-free environment could help reduce cigarette waste (Novotny & Slaughter, 2014; Bowrey et al., 2020). It is crucial that the faculty, staff, and students at Dalhousie University are aware of the prohibition of smoking, and is communicated effectively (Cancer Council Western Australia, n.d.; Wynne et al., 2018). This could also be done through the distribution of mass emails or newsletters explaining in depth the reasoning behind the policy and the rules that must be followed. People are much more likely to comply with an increase in awareness on the ban, especially since people are often not aware of a smoke-free status (Wynne et al., 2018).

It could be beneficial for Dalhousie University to implement stricter enforcement on smoking on campus. There is some debate on whether this measure is effective, especially compared to increasing awareness, but typically stricter enforcement increases compliance. Stricter enforcement could involve employing people to patrol the area and provide information on the smoke-free status to first-time offenders and fines or even expulsion to people who are continuously caught (Wynne et al., 2018). The one limitation with this method is it could still encourage the behaviour shift of people to more discrete locations to smoke, rather than eliminate it (Seo et al., 2011; Conradi & Sánchez-Moyano, 2022).

Furthermore, Dalhousie University should implement educational outreach to provide information on the harms associated with CB waste as well as the goal of the smoke-free status. It is important for Dalhousie University to effectively communicate the reasoning behind the smoke-free status so that there is a common understanding among the staff, faculty, and students. This understanding can encourage people to respect the policy (Cancer Council Western Australia, n.d.). Education is also highly important because many people are not aware of the negative implications of littering CBs and are often unsure of whether or not CBs are considered litter. It is crucial that people who frequent Studley Campus are educated on the negative implications CBs have on the environmental as a behaviour shift may be the most effective way to prevent CB litter. Littering is often influenced by people's preconceived ideas surrounding trash disposal and the environment. Educating people on the negative environmental impacts can

help shift someone's attitude to desire a healthier and cleaner environment (Conradi & Sánchez-Moyano, 2022).

One additional method to aid in the clean-up of CB litter is community involvement. Although Dalhousie has not had any recent events targeting CB clean-up, Saint Mary's University partnered with A Greener Future Foundation to organize an "Unsmoke Butt Blitz" around the downtown Halifax area starting at the Halifax Central Library (A Greener Future, 2025). One of the primary recommendations for this research is the implementation of strategically placed cigarette disposal bins in high-density CB waste areas, particularly around educational buildings and sidewalks. While maintaining a smoke-free policy is important, that the reality of continued smoking behaviour necessitates pragmatic waste management solutions. Providing designated disposal units can prevent littering while upholding public health objectives. Similar approaches have been successfully adopted in other institutions, where properly placed receptacles have reduced cigarette litter without compromising policy goals (Novotny & Slaughter, 2014).

While this may go against Dalhousie University's smoke-free policy, it could be beneficial for Dalhousie University to implement smoking receptacles on campus. A litter audit performed by the city of Vancouver revealed that the implementation of receptacles reduced CB litter by 30% (Keliher, 2017). Implementation at each hotspot is encouraged, especially along Castine Way. 25.11% of CBs were found by sidewalks and therefore it would be beneficial to place receptacles along sidewalks found on Studley Campus. Additionally, 21.56% were found by parking lots and 21.06% by educational buildings and therefore would be beneficial to implement receptacles surrounding these.

TerraCycle, a CB recycling company, collects CB waste and then separates the components to dispose of them in a more sustainable manner. This process involves collecting cigarettes disposed of in cigarette specific receptacles. TerraCycle then separates the paper and leftover tobacco from the cellulose acetate. Cellulose acetate is then recycled and used for production of various other products, e.g. benches or industrial products (Smith et al. 2015). Various companies within Canada have partnered with TerraCycle to become involved in properly recycling CB waste. Dalhousie University currently does not have any relations with this company (Keliher, 2017). We recommend that Dalhousie University, after implementing

smoking receptacles, partners with TerraCycle to either establish their own recycling program or send their separated CB waste to this company.

Conclusion

This study revealed that there is a large abundance of CB waste, 13,816 CBs, on Dalhousie University's Studley Campus, despite its smoke-free status. The results determined that across all location types and ground coverage there was a presence of CB waste, with most concentrated near sidewalks (25.11%), parking lots (21.56%) and educational buildings (21.06%). Additionally, most were located on natural ground type (65.77%). The presence of CBs on campus indicates that action must be taken to address this problem, as the smoke-free status is not enough to prevent litter on campus.

Acknowledgements

Firstly, we would like to recognize and acknowledge that Dalhousie University is located on the unceded territories of Mi'kmaw, Wolastoquey, and Peskotomuhkati Peoples. Furthermore, we would like to express our sincere thanks to Dr. Caroline Franklin, for her guidance and expertise throughout the sampling and research process. Dr. Franklin also provided us with necessary equipment, like the measuring tape and latex gloves, which was helpful for the data collection process. Additionally, we would like to thank our TA Sarah for her constant feedback throughout this semester. We would not have been able to finish this report without their support. Finally, we would like to acknowledge the groundskeepers and waste management staff for pausing their work to allow us to collect accurate data, and for disposing of the CBs on a regular basis to keep the campus clean.

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