Mapping the Quality of Public Urban Green Spaces for Physical Activity in Paramaribo, Suriname

DRUTI GANGWAR
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ABSTRACT

Cities are growing demographically and economically leading to high work pressures on urban residents. Long working hours reduce outdoor recreational time thereby threatening residents' health and well-being. Sustainable Development Goal 11, Target 7 emphasized "providing universal access to safe, inclusive and accessible, green and public spaces". The COVID-19 pandemic has re-emphasized the importance of physical activities in maintaining a healthy lifestyle. Urban green spaces are providers of opportunities for recreation including opportunities for physical activities such as running and walking.

Existing research on public urban green spaces affirms that it is not just the quantity but also the quality of public urban green spaces that impact residents' use of the public urban green spaces. But it is difficult to carry out a quality assessment because of challenges in defining 'quality' and establishing their influence on the use of public urban green spaces. On the other hand, Paramaribo has seen uncontrolled urban growth in recent decades, and it has come at the cost of trees, and urban forests leaving the city with fragments of forest and green cover. This is further worsened due to a lack of knowledge on the benefits of public urban green and improper management of urban green spaces.

This study is an attempt to map the spatial distribution quality characteristics of public urban green spaces and empirically investigate its relation with physical activity in Paramaribo. A mixed-methods approach is used as the relationship between subjects is complex, making it difficult to investigate using traditional methods, i.e. qualitative and qualitative. The geospatial tools are used to study the spatial distribution of quality of public urban green spaces in Paramaribo. The qualitative interpretations of survey data and the author's first-hand experience in the study area aid in better understanding the statistical results of the physical activity estimation model.

Results from this study show that the quality characteristics of all public urban green spaces are not uniformly distributed across Paramaribo. It is also found that the quality of public urban green spaces is better explained when online spatial data is supplemented with survey/field data. Further investigation into the relationship between physical activity and the quality of public urban green spaces shows that the quality characteristics are weakly related to physical activity. There is also a possibility that there are other quality characteristics and external factors that could be influencing the relationship. This study also elaborates on the challenges and further recommendations for studying the 'quality' of public urban green spaces. In the end, the implication of this study for the urban management of public urban green space in Paramaribo is also described.

Keywords: Public urban green spaces, Physical activity, Quality characteristics, Tropical cities

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1. INTRODUCTION

1.1. Background

Ecosystems are providers of multiple goods and services to humans that directly or indirectly contribute to their well-being (Crossman et al., 2013). The concept of ecosystem services (ES) was first defined as "benefits people obtain from the ecosystem" (Millennium Ecosystem Assessment, 2005). Later this definition was elaborated by Burkhard and Maes (2017) as "the contributions of ecosystem structure and function to human well-being". The concept of ecosystem services serves as a bridge between human well-being and ecosystems (Neßhöver et al., 2007). The supply and demand of the ecosystem services vary geographically; hence mapping these ecosystem services helps in quantifying and documenting the supply-demand gaps (Bastian et al., 2012; Crossman et al., 2013; Fisher et al., 2009). These maps' spatial information helps communicate complex spatial details to people, including policy-makers (Burkhard and Maes, 2017).

Growing populations and economic development are driving land-use change that rapidly alters the structure and function of ecosystems in urban areas (Inostroza et al., 2013; Tratalos et al., 2007). Simultaneously, there are threats associated with the well-being of urban residents due to high work pressures leaving them little or no time to relax (Haaland and van den Bosch, 2015). The COVID-19 pandemic has also served as a reminder of the importance of physical activities in maintaining a healthy lifestyle. Urban green spaces are providers of multiple ecosystem services, including opportunities for recreation such as social gatherings, physical activities and leisure for urban residents (de La Barrera et al., 2016; Sandifer et al., 2015). The importance of urban green spaces has also been recognized worldwide under the Sustainable Development Goal 11, "Sustainable cities and communities". Target 11.7 emphasizes "providing universal access to safe, inclusive and accessible, green and public spaces, particularly for women and children, old persons and persons with disabilities"(UN, 2015). City planners are becoming increasingly conscious that citizens value public urban green spaces for their non-market features rather than the practical and monetary benefits (Owino et al., 2014). Therefore, it is necessary to inventory the benefits of different urban green spaces for urban residents (Hunter and Luck, 2015).

1.2. Public Urban Green Spaces

1.2.1. Definition, Types, Uses

The World Health Organization defines urban green spaces as natural surfaces/settings or other types of urban greenery such as tree lanes and blue spaces such as lakes and ponds(Nielsen and Bronwen Player, 2009). However, the definition of urban green spaces varies across the disciplines depending on the purpose of the study (McDonnell, 2011). Taylor and Hochuli (2017) reviewed 367 publications from 1975 to 2014 that used the term 'greenspace' and found similarities in definitions, but they remain complex and broad. Therefore, they emphasized the need to establish an operational definition, mainly if more than one characteristic of urban green spaces is being investigated (Taylor and Hochuli, 2017). The European Urban Atlas defines a 'Green Urban Area' as the public green area used predominantly for recreation. These may include parks, gardens, zoos, urban forests, and sub-urban areas managed as urban parks (European Commission, 2006). More examples of public urban green spaces may include lanes of trees, sports fields, children's playgrounds, and non-amenity areas such as roadside verges (de La Barrera et al., 2016; Nielsen and Bronwen Player, 2009).

1.2.2. Recreational uses of public urban green spaces

When discussing recreational uses associated with public urban green spaces, the most common are physical activities such as walking and playing, social activities such as group gatherings and meeting with friends, and interaction with nature in the form of bird watching or photography (Bertram and Rehdanz, 2015; Hunter and Luck, 2015). There may be other forms of recreation that an individual experiences (e.g. feeling calm, feeling relaxed) while visiting the urban green spaces. But they are unique and intangible and hence difficult to generalize (Adinolfi et al., 2014; Bertram and Rehdanz, 2015). Nonetheless, the most common recreational uses such as physical activity can be directly related to the quality of any public urban green space (Adinolfi et al., 2014). Therefore, it is worth investigating the characteristics that determine the quality of public urban green spaces thereby influencing their use for physical activity.

1.2.3. Quality Characteristics of public urban green spaces

The current literature on public urban green spaces showed an agreement among the researchers that the quality of public urban green spaces impacts residents' use of the public urban green spaces for recreational purposes (Adinolfi et al., 2014; Stessens et al., 2020; van Herzele and Wiedemann, 2003). However, a lack of a universally accepted definition of public urban green spaces makes it challenging to identify the characteristics that define the quality of public urban green spaces. On the other hand, de La Barrera et al. (2016) states that any meaningful assessment must consider the quantity and quality of public urban green spaces. Where 'quantity' indicates the amount of city area designated to be used as public urban green spaces; the 'quality' comprises characteristics that ensure a satisfactory level of services is delivered to its users (de La Barrera et al., 2016; Zhang et al., 2017).

A list of quality characteristics used in previous studies is given in Appendix 1. The most widely used quality characteristics of public urban green spaces include their size, type, and use functions (Annerstedt et al., 2012; de Vries et al., 2003; LR et al., 2015; White et al., 2013). Another range of assessments considers the level of maintenance, physical elements in the public urban green spaces, and activities performed as indicators of public urban green spaces quality (Brindley et al., 2019). Concerning the preconditions for public urban green spaces, Coeterier (2000) suggested that the distance of public urban green spaces from the user's house highly influences their choice of public urban green spaces. Furthermore, the perceptions of public urban green spaces users cannot be explained alone based on their features but also vary based on the surroundings of public urban green spaces (Coeterier, 2000).

Skärbäck (2007) analyzed the frequency of visits and the different qualities of urban parks and found a strong relationship between the two. The author claimed that the users look for multiple characteristics in a place that facilitates more activities in one public urban green space. Nielsen and Bronwen Player (2009) also stated that the usage of public urban green spaces is always associated with the quality characteristics of the urban green spaces. Additionally, the usage measures such as visitor counts and observed uses of the park reflect citizens' actual use of urban green space (Nielsen and Bronwen Player, 2009). Hunter and Luck (2015) also found that links between human perceptions and preferences were one of the two most frequently investigated links by researchers. The knowledge that the urban citizens acquire from their daily experiences may be more valuable than the experts hired to assess public urban green space's quality (Hur et al., 2010). An individual's experience in a public urban green space highly determines their frequency of visits, usage of the urban green spaces for recreation, and so on. However, only a few studies incorporate the perceived factors associated with public urban green spaces (Kothencz and Blaschke, 2017).

1.3. Mapping the quality characteristics of public urban green spaces

There is an emerging use of data-driven Geo-information system (GIS) modelling to resolve the conflict between urbanization and planning of public urban green spaces (Dobbs et al., 2019; Khan and Moulaert, 2014). The GIS datasets are often available through no-cost online platforms (e.g. Open street maps, Google earth engine) comprising repositories of spatial data of features such as buildings, road networks, and administrative boundaries. Some of these platforms are open-access, while others require authorization from the service provider to retrieve the data. The key challenge while assessing the quality of public urban green spaces by considering the user's perception is that it's difficult to model and scientifically map. Therefore, citizens' knowledge has a huge potential in accurately mapping ecosystem services such as recreational use of public urban green spaces (Priess and Kopperoinen, 2017). Another data source for assessing the popularity of public urban green spaces is the use of various social media platforms. Brindley et al. 2019 used Flickr photos as a proxy for the quality of public urban green spaces and compared them with the spatial indicator of public urban green spaces.

The study by van Herzele and Wiedemann (2003) developed an integrated indicator as a monitoring tool to provide attractive and accessible public urban green spaces. All public urban green spaces of more than 10 hectares size were selected for comparison across four cities in Belgium. An accessibility map showing the sizes of parks and the distance they service was prepared using the Spatial Analyst Toolbox. The inhabitants within the accessible range of public urban green spaces were asked to measure quality variables using a Likert scale (0-2, bad-good). The quality variables were derived from the literature and categorized into five groups- space, culture and history, nature, facilities, and quietness. Combining the survey responses with the accessibility map showed the areas with the lowest accessibility to public urban green spaces with at least one "good" quality characteristic. The key limitation of the monitoring tool was that (i) within a large public urban green space, there is a possibility of multiple uses that increases the subjectivity in the user preferences towards quality characteristics; (ii) in an attempt to keep the tool easy to communicate, it did not reflect many other aspects that could influence the attractiveness.

Kothencz and Blaschke (2017) investigated the role of public urban green spaces in quality of life by associating spatial indicators (objective factors) and visitors' perceptions (subjective factors). Unlike the city-scale comparison made by van Herzele and Wiedemann (2003), this study focused on a site-specific assessment of five urban parks in Szeged, Hungary. A mixed-methods approach was adopted for combining the subjective factors such as individual judgments of park greenness, facilities, and functions with the objective factors such as area of parks, percentage of vegetated surface, and percentage of built-up near parks. The subjective factors were ranked by visitors on a five-point Likert scale (1-5, best-worst), and objective factors were mapped using satellite imageries, area-weighted NDVI and other spatial (GIS) datasets. A Principal Component Analysis was used to reduce the number of indicators surveyed. Then multiple linear regression analysis was carried out to predict each of the three themes based on spatial (objective) indicators. The study showed that the relationship between objective and subjective factors was not as strong as anticipated. Nevertheless, the results ascertained that studying the objective factors alone does not provide insight into the essential quality characteristics of public urban green spaces.

In a more recent study, Stessens et al. (2020) assessed the overall quality of public urban green spaces using GIS-based spatial metrics comprising inherent characteristics (biodiversity and nature, quietness, and spaciousness) and use-related characteristics (maintenance, feeling of safety, and facilities). Only inherent qualities were used to develop a GIS-Based assessment for all public urban green spaces because the information on use-related characteristics was available only for ten public urban green spaces. But, the authors tried to combine the use-related characteristics for these ten public urban green spaces by surveying user preferences and perceptions of quality characteristics. The survey gave information on (i) the level of satisfaction for overall quality and individual quality characteristics using a Likert scale; (ii) the preference for individual quality as '0=not important, 1= somewhat important, and 2=important'. The GIS-based assessment for predicting the overall quality of all public urban green spaces used a weighted multiple linear regression model. On the other hand, for predicting the quality of ten public urban green spaces, the model included inherent qualities and a weighted sum of preference for individual quality characteristics and level of satisfaction for use-related quality characteristics. Stessens et al. (2020) concluded that the overall quality of the public urban green spaces was well-explained when the model included the inherent qualities. But the use-related characteristics were listed as 'important' in the survey. So the recommendation to include use-related characteristics would improve the accuracy of the GIS-based assessment. The shortcoming of the assessment was that it did not look into the actual usage. Thereby failing to confirm whether the user perceptions were based on their experience from visiting the public urban green spaces or personal reasons such as their disinterest in using public urban green spaces.

1.4. Problem Statement

This research is based on the understanding that, theoretically, certain characteristics define the 'quality' of public urban green spaces. Some quality characteristics can be measured from spatial data, while others require field investigation as they are use-related such as safety, cleanliness, and maintenance (Stessens et al., 2020). Previously, Hunter & Luck (2015) and Hur et al. (2010) found that the spatial data seldom represents a holistic overview of the quality of public urban green spaces and their use for physical activity. The above-discussed studies used a mixed-methods approach to investigate and ascertain that the quality characteristics of public urban green spaces influence the user's preference for public urban green spaces. However, a couple of challenges persist: identifying the most relevant quality characteristics and their influence on the use of public urban green spaces. Another takeaway from the existing literature is that the choice of statistical and geo-spatial analysis largely depends on the study area, sample size and data availability (Kothencz and Blaschke, 2017; Stessens et al., 2020; van Herzele and Wiedemann, 2003).

The study area for this research is located in Paramaribo, the capital city of Suriname, in South America. Paramaribo is undergoing rapid urbanization leading to the concretization of the city's public green spaces. The research project titled "Towards a greener and more Livable Paramaribo" (Groen Paramaribo), jointly led by Tropenbos Suriname and ITC- UT, aims to reduce the knowledge gap on the benefits of urban greenery in Paramaribo. As a part of this project's follow-up project, the condition and use of five public urban green spaces are being monitored by citizens through a digital survey questionnaire. The information gathered by citizen volunteers and interpreted using scientific research methods helps policymakers improve urban greenery. In the context of this research, the availability of in-situ data, through the Groen Paramaribo project, puts forth an opportunity to explore the relationship between the quality and use of public urban green spaces. Simultaneously, the online available spatial data and social media data enable investigation of this relationship for all public urban green spaces in Paramaribo.

This study considers that it is worth investigating how the citizen-monitored quality characteristics and physical activity estimates are different from the quality characteristics measured from online spatial data and physical activity estimates from social media data. Through this investigation, the aim is to address the challenges in identifying the quality characteristics of public urban green spaces and contribute to lack of knowledge of the relationship between quality and use of public urban green spaces, especially in tropical cities like Paramaribo.

1.5. Objectives and Research Questions

This study aimed to assess the quality of public urban green spaces in Paramaribo and their relationship with the physical activities of all public urban green spaces in Paramaribo. A total of 30 locations were identified as 'All Public urban green spaces' for which measurements were derived from online spatial data and social media data. 'All' public urban green spaces include the five locations being surveyed under the Groen Paramaribo Project. This research used geo-spatial tools to map the quality characteristics of public urban green spaces in Paramaribo and empirically identify their relationship with physical activity. The hypothesis, objectives and research questions designed to achieve this study are as follows:

Hypothesis: The quality of public urban green spaces influences their popularity for physical activity

Objective 1 - To map the quality characteristics of all public urban green spaces in Paramaribo

Q1. What is the spatial distribution of quality characteristics of all public urban green spaces mapped using online spatial data?
Q2. What is the spatial distribution of quality characteristics for public urban green spaces mapped using survey/field data?
Q3. How much does the quality profile of public urban green spaces differ when online spatial data is complemented with survey data?

Objective 2 – To identify the relationship between quality characteristics and physical activity in all public urban green spaces of Paramaribo

Q4. What is the relation between quality characteristics and the visitation rates based on social media data for all public urban green spaces in Paramaribo?
Q5. What is the relation between quality characteristics and visitor counts based on survey data available for five public urban green spaces of Paramaribo?
Q6. How much does the survey data complement/contradict the estimates from the physical activity model?

1.6. Study area

Latin America and the Caribbean are some of the world's most urbanized regions, and in the coming future, most of the world's population will reside in these countries (Dobbs et al., 2019). The study area for this research is Paramaribo, Suriname a country that has 93% forest, located in the north of South America. 30 public urban green spaces comprising public parks, street trees, green squares, and forest fragments **(Figure 1)** have been identified to carry out this study. Paramaribo is the largest city in Suriname, with about 70% of the total population of Suriname located in and surrounding areas of Paramaribo (Bharwani, 2011). It is one of the country's ten districts; each district is further divided into ressorts, the smallest administrative unit. Paramaribo comprises 12 ressorts spanning over 182 sq. km. with a population of 240,924 persons (as per Census 2012). The city has seen uncontrolled urban growth in recent decades, and it has come at the cost of trees, urban forests, and other vegetation, leaving the city with fragments of forest and green cover. The infrastructure development and rapid urbanization often come at the cost of public urban green spaces, which is further worsened due to a lack of knowledge on the benefits of public urban green spaces (Verrest, 2010). Furthermore, the lack of implementation of the Planning Act (1973) and the Urban Planning Act (1972) have led to unorganized urban development leading to ignored importance of urban green space quality (Tropenbos Suriname, 2019).

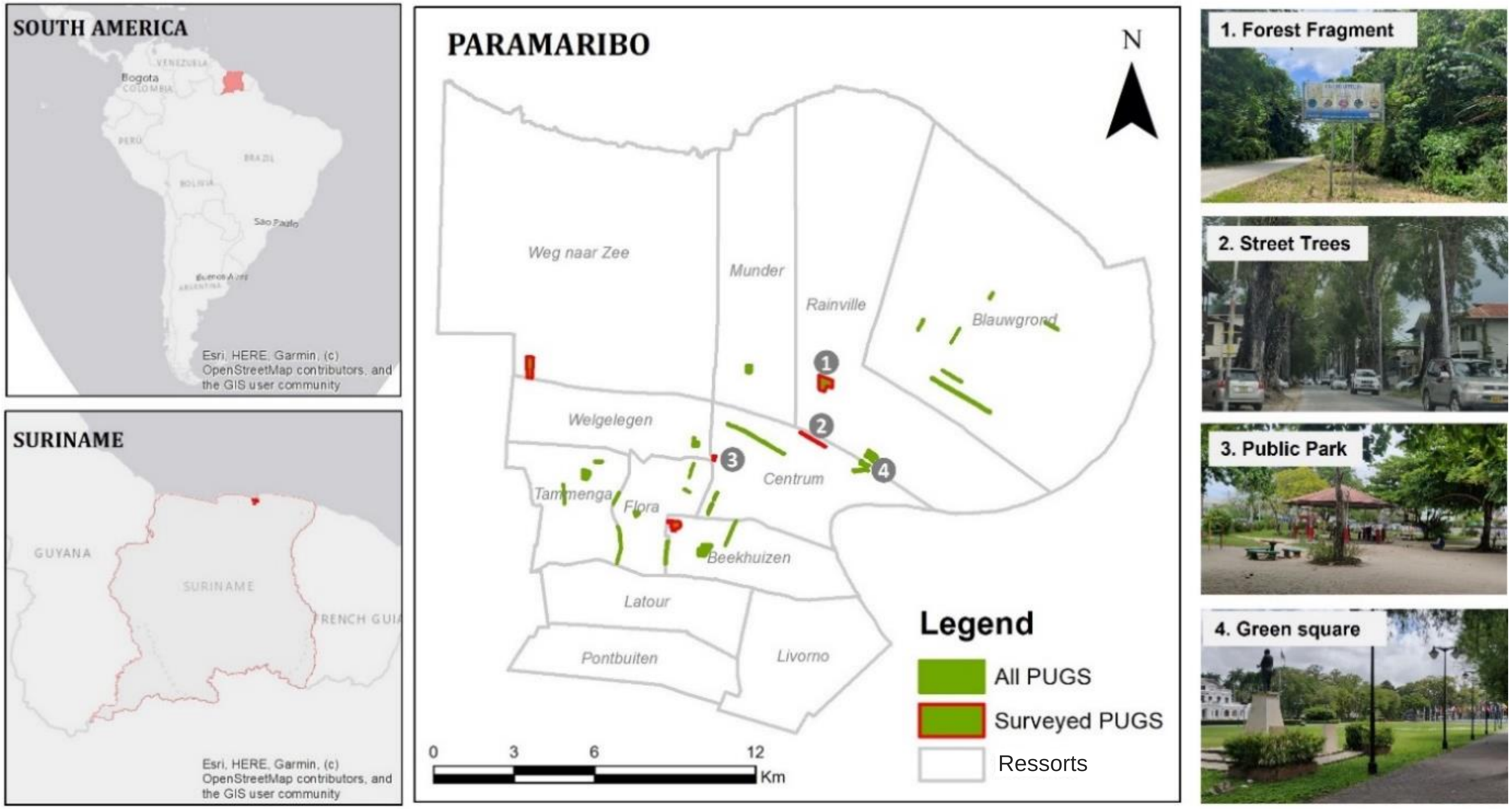

Figure 1 Location and types of Public Urban Green Spaces (PUGS) in Paramaribo

2. METHODOLOGY

2.1. Research Design

The socio-cultural, demographical and urban development history of Paramaribo indicates that the city experiences complex urban issues. In scientific research, a mixed-methods approach is better suited when the relationship between subjects of a study is complex, making it difficult to investigate using traditional methods, i.e. qualitative and qualitative (Johnson et al., 2007). So a, mixed-methods research would yield more meaningful and informative results for this study. Johnson et al. (2007) defined mixed-methods as an approach where "researcher(s) combines elements of qualitative and quantitative research approach for the broad purpose of breadth and depth of understanding and corroboration". The overall nature of this research was 'exploratory' as it is the first of its kind for Paramaribo.

This study's data were derived from online spatial platforms, social media, urban green space monitoring surveys and field measurements. **Figure 2** shows the methodology workflow for this study. A summary of data source, year of acquisition/ period, resolution and data collection method for each data is given in **Table 1** . The first objective pertains to mapping the quality characteristics of all public urban green spaces in Paramaribo. This was achieved by measuring and mapping quality characteristics from online spatial data for all public urban green spaces (RQ1), followed by zooming into quality characteristics maps and measurements from survey/field data for selected public urban green spaces (RQ2). The last part of this objective statistically analysed the quality characteristic measurements from online spatial data and survey/field data for five public urban green spaces (RQ3). The second objective investigated the relationship between physical activity and quality characteristics based on the statistical fitting of a Physical activity model for all public urban green spaces (RQ4) and in-depth inspection of five public urban green spaces based on survey data (RQ5). The end product for this objective and this study was a summary of statistical and survey/field data findings explaining the relationship between quality characteristics and physical activity in five locations (RQ6).

Table 1 Data used to measure quality characteristics and physical activity in public urban green spaces

Data	Source	Acquisition Year	Period	Scale/Resolution
Public Urban Green Spaces	Open street maps (OSM)	2021	01-2022	1:100,000
Buildings				
Roads				
Multispectral Satellite Imagery	Planet explorer (Planet SCOPE)	2021	06-09-2021	3m
Walking paths/Footpaths	Fieldwork by Author	2022	24-03-2022	1:100,000
Street lights				
Safety	Urban Green Space monitoring survey, Tropenbos Suriname & ITC-UT	2022	05- 2021 to 04- 2022	
Cleanliness				
Physical activity				
Physical activity	STRAVA Web	2022	01-02-2022 to 01-05-2022	

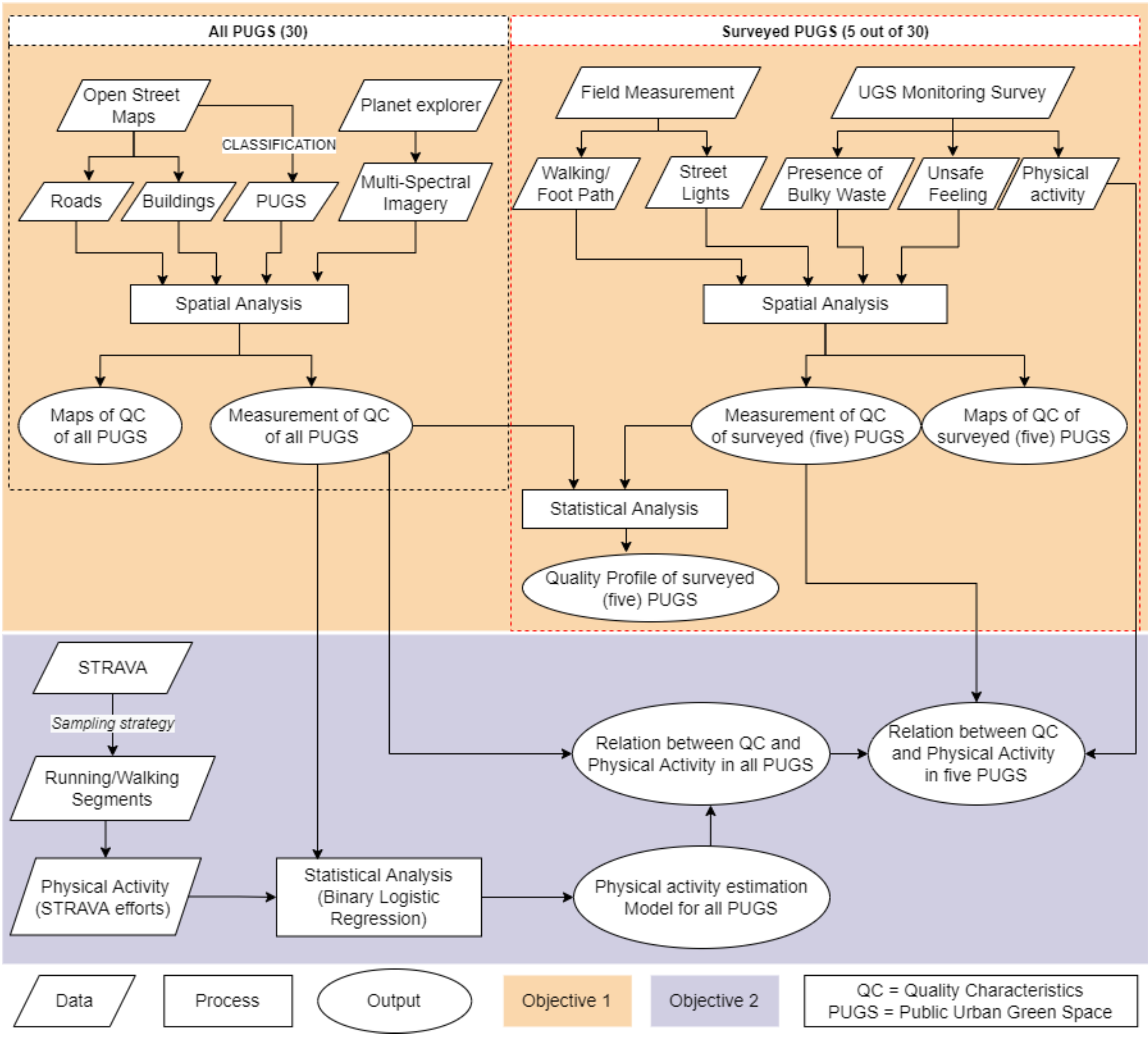

Figure 2 Research methodology workflow

2.2. Identifying and mapping 'all' public urban green spaces

The spatial data for urban green spaces in Paramaribo did not have information on the public or private character of the urban green spaces. So firstly, a decision tree-based visual interpretation from aerial images was performed to assign typologies to all urban green spaces (Appendix 2). This typology classification was done manually by the author and another MSc. Student (Bernice Bouhemaa) from the Faculty of ITC, University of Twente, who also worked on green spaces in Paramaribo. Secondly, the author extracted typologies thar can be associated with the 'public' character of urban green spaces. As a final step, the author used the criteria below to identify 30 locations used as 'all' urban green spaces in Paramaribo (**Figure 1**).

- Public parks and green squares of size >= 1 hectare, as the expert knowledge and field visit indicates that this is the average size of public parks and green squares in Paramaribo
- Fernandesplein, a public park sized <1 ha but being monitored under the Groen Paramaribo project as it is one of the five locations for which survey data is available
- Street trees extracted from step-wise criteria -

Step 1 - From the urban green spaces layer, extracted the polygons categorized as 'Green buffer' because it includes 'trees arranged in a row' and 'along the roads or roundabouts' (Appendix 2)

Step 2 – Among the Green buffer polygons, selected only those with an area/(perimeter)^2 ratio <= 0.007; this threshold was decided by calculating this ratio for already known street tree locations in Paramaribo
Step 3 – Remove all the polygon of length < 100m as this is a typical minimum distance for recording running/walking activity speed
For the polygons filtered from three steps, an on-ground investigation was carried out to check if, in reality, the location has a row of street trees or not. Those that did not have a row of street trees were removed.

2.3. Mapping the quality characteristics

2.3.1. Selecting quality characteristics

Previous studies emphasized that the quality characteristics for assessing the quality of public urban green spaces must be selected based on the purpose of the study to avoid the assessments being complex. A study on the "mindset" of residents towards the public urban green spaces in Paramaribo was conducted by S. Chote, an MSc. Student at Anton de Kom University, Suriname. A question in Chote's residential survey (2019) asked the respondents to select up to five (out of 21) 'basic characteristics that a public urban green space must have'. The results from 67 respondents showed that people think urban green spaces must have the presence of sufficient nature (~Greenness), quiet area (~Quietness), cleanliness and maintenance (~Cleanliness), safety, accessibility (~Accessibility to the location) and Facilities. Therefore, based on previous studies and discussions with experts and the literature review (Appendix 1), a set of quality characteristics was selected for this research (**Table 2)**.

Table 2 Characteristics assessing the quality of public urban green spaces in Paramaribo

Quality Characteristic	Description
Accessibility (to)	Having a public urban green space within walkable distance means it saves travel time and cost, which is one of the positive factors for users
Accessibility (within)	Access within a public urban green space using a walking/footpath makes them more attractive for walking/running
Spaciousness	The sizes of public urban green spaces define their functionality and also the space available for citizens to carry out various physical activities
Quietness	Public urban green spaces which have fewer noise levels due to road traffic are more attractive for running/walking
Greenness	Healthy vegetation enhances the quality of public urban green spaces by providing services such as aesthetic value and shades from tress
Safety	'Public' nature of the urban green spaces might compromise the safety of its user, thereby influencing their popularity for running/walking
Cleanliness	Users may be discouraged from visiting a public urban green space if it is unhygienic as it increases health risks
Facilities	The presence of street lights indicates its usability after daylight hours, also indicating it can be used for longer hours

2.3.2. Measuring the quality characteristics from online spatial data

The spatial data on the location and size of all (30) public urban green spaces, residential buildings, and road networks in Paramaribo was acquired from the OSM, an open-access platform containing a repository of crowdsourced spatial data. The shapefiles for the residential buildings were extracted by selecting only polygons labelled as 'houses' in the attribute field 'type' of the OSM buildings layer. The road networks were extracted by selecting the lengths of the roads falling within defined buffer distances (e.g. 50m for measuring quietness). The raster file for measuring greenness was extracted from the multi-spectral satellite imagery clipped to the extent of the public urban green spaces layer. After the datasets were acquired from online platforms, their quality characteristics were mapped and measured using geo-spatial tools in ArcMap 10.8.1. A summary of indicators, input data and spatial analysis are given in **Table 3.**

Firstly, accessibility to a public urban green space was measured by calculating residential density in an 800m buffer. Stessens et al. (2017) identified that for green spaces sized 1-2 ha, the maximum travel distance by foot ranges from 600-800m. Also, research on the outdoor walking speeds of adults suggests that an average adult can walk 800m in 10-15mins (Murtagh et al., 2021). Secondly, while measuring quietness, the density of the road network within 50 m was calculated from the centre of the public urban green space. Higher the road length per ha in a 50m buffer area, the lower the level of quietness. The buffer threshold was determined based on the study by Derkzen et al. (2015) which suggest that after 50m from a public urban green space, the traffic noise is blocked due to buildings in urban areas. Unlike the perceived sense of quietness, measuring noise from traffic ensures the indicator is not subject to vary from individual to individual (Coeterier, 2000; Stessens et al., 2020). Lastly, greenness was measured by calculating the Normalized Differential Vegetation Indices (NDVI) value, which measures vegetation's health (Kothencz and Blaschke, 2017). The nearer the value to 1 higher the proportion of green cover.

Table 3 Indicators for quality characteristics for all public urban green spaces

Quality Characteristic	Indicator	Measurable	Input data	ArcMap Tools
Spaciousness	Size of public urban green spaces	Area in ha	Public urban green spaces	Calculate geometry
Accessibility (to the location)	The density of Residential buildings around public urban green spaces	No. of residential buildings per ha in 800m buffer from edges	Buildings, Public urban green spaces	Proximity tools from the Analysis toolbox
Quietness	The density of roads around public urban green spaces	Road length per ha (polylines) in 50m buffer from centre	Roads, Public urban green spaces	Proximity tools from the Analysis toolbox
Greenness	The health of vegetation within the public urban green space	Mean NDVI value	Multispectral satellite imagery	Image Analysis; Zonal Statistics

2.3.3. Measuring the quality characteristics from survey data

In addition to the quality characteristics that were measurable from the online spatial data, four others could only be measured from fieldwork, such as surveys and field measurements. These characteristics are not measurable using the satellite/aerial data due to (i) limitations in spatial resolution and (ii) large tree canopies preventing visual interpretation of spatial features like walking paths/footpaths shaded with trees. A summary of indicators, input data and spatial analysis are given in **Table 4**. After the datasets were acquired, quality characteristics were mapped and measured using geo-spatial tools in ArcMap 10.8.

The Urban Green Spaces Monitoring survey provided data on the condition and uses of five public urban green spaces. One or more citizen volunteers visit the same location monthly to monitor the use and conditions. The total no. of survey records, i.e. no. of the months for which have been monitored, was not the same for all the locations. A couple of questions of this survey record Yes/No responses about the safety and cleanliness of a particular location (**Table 4**). Further, fieldwork was done to measure accessibility within the public urban green spaces and facilities in the form of street lights as there were no pre-existing open-access spatial data for measuring. The length of walking path/footpaths was recorded using LOCUS Map Mobile Application, which has an in-built GPS tracker that tracks the path and can later be exported to ArcMap. Facilities were measured by manually recording the number of street lights based on visual observations and were later added to the attribute table of the public urban green spaces layer. One of the urban green space survey questions collects information on the number of people engaged in physical activity (e.g. walking, exercising, walking the dog, playing) when the volunteer is in the location. In this question, the volunteer report "How many people are currently engaged in physical activity ?" by selecting one of the categories: none, 1-5, 6-15, and more than 15 persons. This study combined the monthly information to estimate the physical activity in five public urban green spaces.

Firstly, accessibility within the public urban green space was measured using field data on the length of any formal (paved) or informal (unpaved) path of >1m width within or adjoining the outside boundary of the public urban green space. Roads adjoining the outside boundaries of public urban green spaces were not measured under this variable as the variable 'accessibility to public UGS' already accounts for them (density of roads within 800m buffer). Secondly, facilities were measured based on no. of street lights per ha as it influences the quality and usability of public urban green spaces for walking/running. Lastly, the survey asks negative questions on cleanliness and safety (**Table 4**), meaning it is framed in a way that a 'no' indicates positive quality and 'yes' indicates a negative quality. So safety and cleanliness were measured by counting the no. of 'Yes' and 'No' received over months for each public urban green space.

Table 4 Indicators for quality characteristics of surveyed public urban green spaces

Quality Characteristic	Indicator	Measurable	Input data	ArcMap tool
Accessibility (within the location)	Walking paths/trails within/along the edges of the public urban green spaces	Walking path/footpath length in m/ ha	Public urban green spaces layer – each quality characteristic measurement added to the attribute table	Field calculator
Facilities	Number of street lights	No. of street lights/ ha		
Safety	Perceived sense of safety in public urban green spaces	Yes/No: Do you see anything that makes you feel less safe?		Charts (Symbology)
Cleanliness	Presence of waste within the public urban green spaces	Yes/No: Is there waste / bulky waste?		

2.3.4. Quality profile of public urban green spaces

The quality characteristics had different measurement units, so they were normalized for easy and direct comparison of quality profiles of each public urban green space. Min-Max normalization was followed to translate the measurements to a scale of 0 to 1. The formula used for calculating the normalized measurement was :

$$X_{new} = \frac{X - X_{min}}{X_{max.} - X_{min}}$$

The mean of four quality characteristics measured from survey/field data for five locations was calculated. The mean value was the sum of normalized measurements of four quality characteristics: accessibility within the public urban green space, facilities, safety, and cleanliness; over four (no. of survey/field data measured quality characteristics). The five public urban green spaces were ranked based on the mean quality characteristics to compare their relative quality performance. Secondly, the variations in quality characteristic measurements were represented using spider diagrams. These diagrams indicate the scores for each quality characteristic, i.e. from online spatial data and survey/field data. Lastly, for the surveyed public urban green spaces (n=5), the standard deviations of quality characteristics measured from online spatial data were compared with standard deviations of quality characteristics measured from survey/field data. The differences in standard deviation values indicate which quality is more varied than others across the five public urban green spaces.

2.4. Physical activity estimation

STRAVA is an internet-based fitness tracking app used for tracking physical exercise, mostly cycling and running, and it incorporates social network features using GPS data. Citizens can share their physical activity location, distance, and speed here. STRAVA segments are portions of roads or trails created by members where athletes can compare times. This data can indicate the popularity of public urban green spaces for running/walking. This is done by recording the 'efforts' associated with the running/walking 'segments' adjoining or passing through the public urban green spaces. Any running/walking activity whose start and end point cross the start and end of the segment is counted as an 'effort'. For each segment, 'effort' is a running/walking activity conducted along that segment. This means the segment is parts within the route/activity of a user. Therefore, this research uses STRAVA efforts to estimate physical activity by running/walking in a public urban green space. Among the 30 public urban green spaces, 9 locations had existing segments (47) passing through or adjoining the location. Overlap between multiple segments adjoining/passing through each location was reduced based on (i) length (selected only those >100m) and (ii) among all segments around/in a public urban green space; the longer ones were removed, and smaller segments were kept **(Figure 3)**. The principle is that the efforts for larger segments are already counted by counting the efforts associated with smaller segments.

Figure 3 Examples of sampling strategy of existing STRAVA Segments

For 21 locations, the segments were created during field work (74). Creating these segments included visiting the locations, recording running/walking activity on STRAVA mobile application and adding the activity to the author's STRAVA profile. When recording the running/walking activity, special attention was paid to the orientation, i.e. both clockwise and anti-clockwise activities were performed, and the GPS Drift (5m offset from start and endpoint) while running/walking along the edges of the public urban green space. After performing the STRAVA activity, the segments were created by selecting a portion of the activity performed around/within each public urban green space. Once the segment is created, STRAVA adds the efforts of users who have ever performed running/walking activity along that segment.

The challenge associated with acquiring data on efforts count was that segments and efforts count details (i) can not be downloaded automatically and (ii) cannot be filtered for a definite period. Therefore, the effort count had to be recorded manually using MS Excel. An inventory was made for efforts count on 01-Feb-2022 and 01-May-2022. Then no. of efforts recorded in these three months for each segment was calculated and associated with respective public urban green spaces. Further, only the most popular segment for each location was selected to minimize bias due to double counting efforts. The 'most popular' segment is the one which recorded the highest no. of efforts from 01-Feb to 01-May, i.e. highest running/walking activity was conducted along that segment. These efforts count for each public urban green space was used as a measure of physical activity.

2.4.1. Relation between Physical activity and Quality Characteristics

While building the physical activity estimation model, the response variable was physical activity measured from STRAVA. The explanatory variables were quality characteristics measured from online spatial data, i.e. Spaciousness, Accessibility, Quietness and Greenness. The statistical analysis was performed using SPSS. The first step was to check the normality of response variable data. It was found that the distribution is non-normal, and its relationship with explanatory variables is non-linear (Appendix 3). Log transformation of the response variable also did not reduce the skewness of the relationship. A Binary Logistic Regression method was used for modelling the relationship as the distribution of the response variable remained right-skewed even after log transforming. In principle, for a dichotomous response variable, the binary logistic regression model predicts it by creating its natural log of the odds ratio, also known as the logit function (Berger, n.d.). The advantage of this regression is that it does not presume that the response and explanatory variables have a linear relationship (Midi et al., 2010). Simultaneously, the correlation coefficients for the explanatory variables were < 0.5; hence a weak correlation was observed (Appendix 4). Further, there was no collinearity among explanatory variables as the VIF values range from 1-2 (Appendix 5), and it is concerning only if the value is more than 2.5 (Midi et al., 2010).

The response variable was translated to a binary variable where the '0' indicated that a location is not popular for running/walking and '1' indicated that the location is popular for running/walking. Based on the frequency distribution curve (Appendix 3), the public urban green spaces with no. of efforts < 51 were coded 0 and no. of efforts> 51 were coded 1. In the context of this study, the binary logistic regression equation for the physical activity estimation model is as follows:

$$\log\left(\frac{P_y}{1 - P_y}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$

Where, P_y = Probability of a location being popular for running/walking
x_1 = Accessibility to Public Urban Green Space, x_2 = Greenness, x_3 = Quietness, x_4 = Spaciousness

Further, a backward stepwise elimination method was followed to investigate the influence of the explanatory variable in predicting the response variable. A detailed summary of interpretations associated with the statistical outputs from the regression analysis is explained in Appendix 6. First, the significance of a quality characteristic in predicting physical activity was reported based on Significance values denoted as Sig. Second, the relation between explanatory and response variables was established using the Odds ratio (OR), and its reliability was checked using confidence interval (C.I.) (Bangdiwala, 2018). Third, the overall goodness-of-fit for four models was reported based on values of -2 LL, Nagelkerke R-squared, H-L Test (Chi-square test) test, Classification table and AUC (ROC). Field (2019) states that the lower the value of -2LL, the better is model fit. Negelkerke's R-squared is similar to the ordinary least square of multiple linear regression, so the nearer the value to 1, the better the model fit.

Similarly, the H-L test is said to be the most reliable method for checking the goodness-of-fit of the Binary logistic regression model (Bangdiwala, 2018). Lastly, AUC is an indicator of the ability of a model to distinguish between positive and negative classes; in other words, an indicator of the goodness-of-fit of the model (Aniruddha, 2020). Therefore, these three outputs were selected to investigate how well the quality characteristics predict the probability of popularity of the physical activity. Additionally, the classification table was used to comment on the model's accuracy in estimating the probability of popularity of a location for physical activity (Field, 2019).

3. RESULTS

3.1. Spatial Distribution of Quality Characteristics of all public urban green spaces

This section presents the results related to research question 1 on studying the spatial distribution of quality characteristics of all public urban green spaces. Based on the online spatial data available for all public urban green spaces, four quality characteristics, namely, spaciousness, greenness, accessibility (to the public urban green spaces), and quietness, were measured. The measurements for all the public urban green spaces are summarized in Appendix 7, and their spatial distribution is shown in **Figure 4.**

Figure 4 (a) indicates that most (22 out of 30) of the public urban green spaces are up to 2 ha in size and located in ressorts - Tammenga, Flora, Centrum, and Blauwgrond. The least spacious public urban green spaces are mostly street trees in ressorts – Blauwground, Centrum, Flora, and Tammenga. The most spacious public urban green spaces are Wolfertweg (7.34 ha), in Weg naar Zee, and Cultuurtuin (8.36 ha), in Rainville. Both are forest fragments, and Cultuurtuin is also the largest public park in the city.

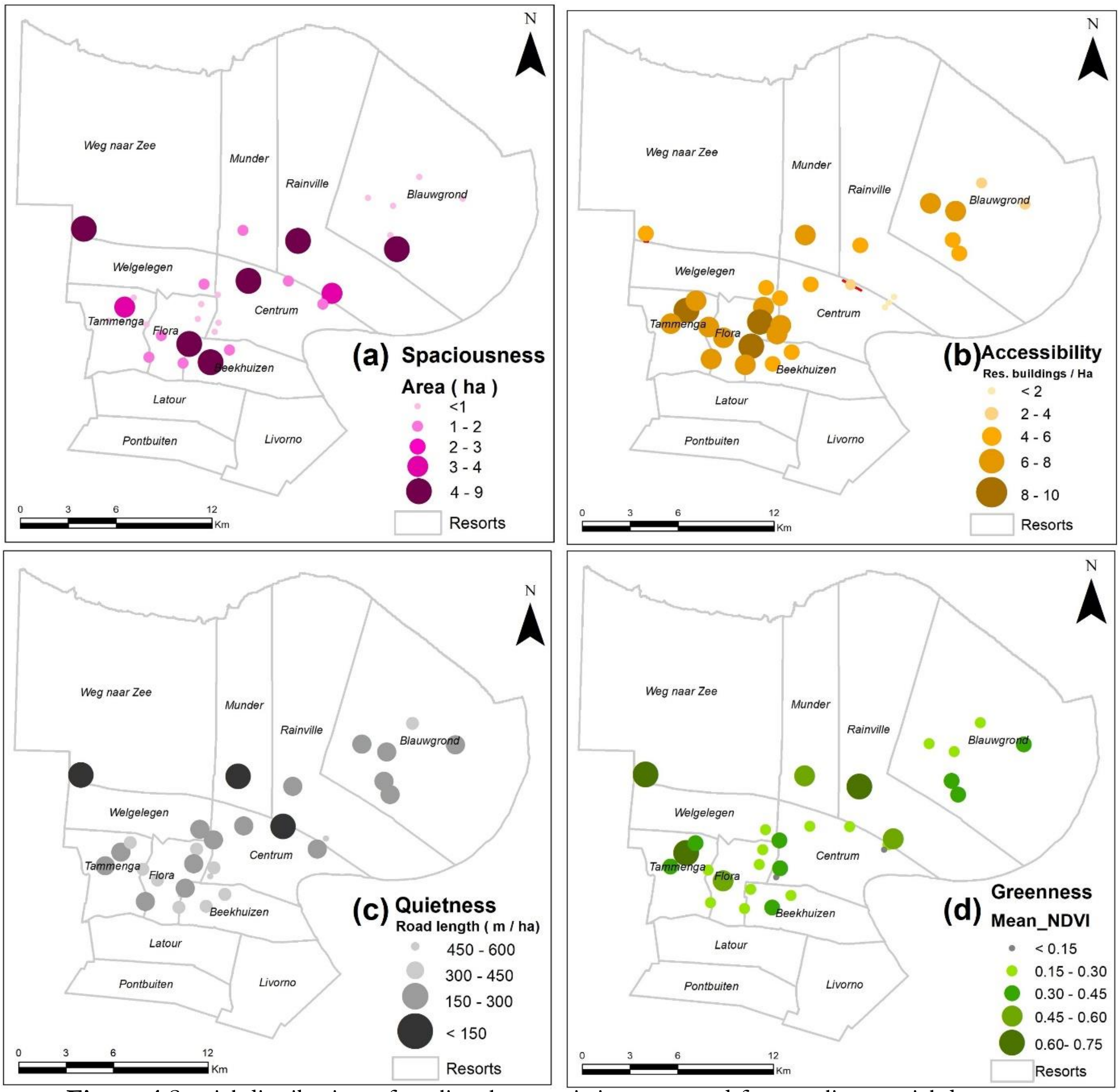

Figure 4 Spatial distribution of quality characteristics measured from online spatial data

Measurements of accessibility to the public urban green spaces, represented in **Figure 4 (b),** show that most of the public urban green spaces (12 out of 30) have high accessibility, with 6-8 houses per ha within 800m distance. The public urban green spaces with the lowest accessibility are located in Centrum resort. In contrast, the public urban green spaces in resort Tammenga, Flora, and Beekhuizen are highly accessible (4-8 residential buildings per Ha).

Quietness is least for public urban green spaces with 450-600 m road length per ha in 50m buffer around public urban green spaces. The higher the total road length, the less quietness in public urban green spaces and vice versa. Overall, **Figure 4 (c)** indicates that most of the public urban green spaces (15 out of 30) are quiet as they have 150-300m road length per ha. The least quiet public urban green spaces are in Centrum, and the quietest public urban green spaces are in Munder and Weg naar Zee.

The mean NDVI values, as shown in **Figure 4 (d)**, are used to measure the greenness of public urban green spaces. The least green public urban green space with a value of 0.04 is located in the Centrum. The greenest public urban green space with a value of 0.65 (Cultuurtuin) is located in Rainville. This is closely followed by public urban green spaces in Weg naar Zee (Wolfertweg, 0.62) and Tammenga (Priscillastraat, 0.60). These locations with higher NDVI values are forest fragments. Overall, most public urban green spaces locations (25 out of 30) have mean NDVI values of less than 0.5.

3.2. Spatial Distribution of Quality Characteristics of surveyed public urban green spaces

This section shows the results related to research question 2, where quality characteristics were measured using survey data and field measurements for five public urban green spaces. These characteristics include accessibility within the public urban green spaces, cleanliness, safety, and facilities. The measurements for these public urban green spaces are given in Appendix 8, and their spatial distribution in **Figure 5**.

Figure 5 (a) indicates the accessibility within the five surveyed public urban green spaces. It was found that 3 out of 5 locations do not have any form of walking paths within or along the edges of the public urban green spaces. Only Cultuurtuin and Fernandesplein have walking paths of lengths 98 m /ha and 696 m/ha, respectively. The Cultuurtuin has unpaved and informal walking paths to access the forest fragment (Appendix 12). The Fernandesplein has unpaved walking paths within the boundaries and a paved walking path on one of its outside boundaries (Appendix 12).

Figure 5 (b) indicates the facilities in the form of street lights. Cultuurtuin, Wolfertweg and Kinderdorpstraat have lowest no. of street lights/ Ha. Cultuurtuin is the city's largest public park but has poor lighting facilities. Wolfertweg is an impenetrable forest fragment hence poor lighting facility is not important for inaccessible public urban green spaces. Fernandesplein not only has a high no. of street lights but is well distributed along the edges and within the public urban green spaces. Nassylaan is a row of street trees along a major road with many street lights.

As reported during the urban green spaces monitoring surveys, Cleanliness and Safety were assessed based on a percentage of no. of responses for each category, i.e. 'Yes' / 'No' / 'Don't know' that indicates the presence/absence of bulky waste and unsafe feeling. The no. of responses per public urban green spaces varied such that Fernadesplein has 11, Wolfertweg has 10, Cultuurtuin has 9, Nassylaan had 8 and Kinderdorpstraat has 7. **Figure 5 (c)** shows the percentage of responses per public urban green space. Cultuurtuin and Nassylaan were the most unclean public urban green spaces as 6 out of 8 responses, and 5 out of 7 reported a presence of bulky waste for their respective location. The other three locations had mixed responses indicating that for some months, the respondents found them clean while other times they were unclean. Similarly, **Figure 5 (d)** provides an overview of perceived safety by survey respondents. All the five locations were reported to be safe by the respondents, only for Cultuurtuin 3 out of 9 responses listed that the respondents felt unsafe.

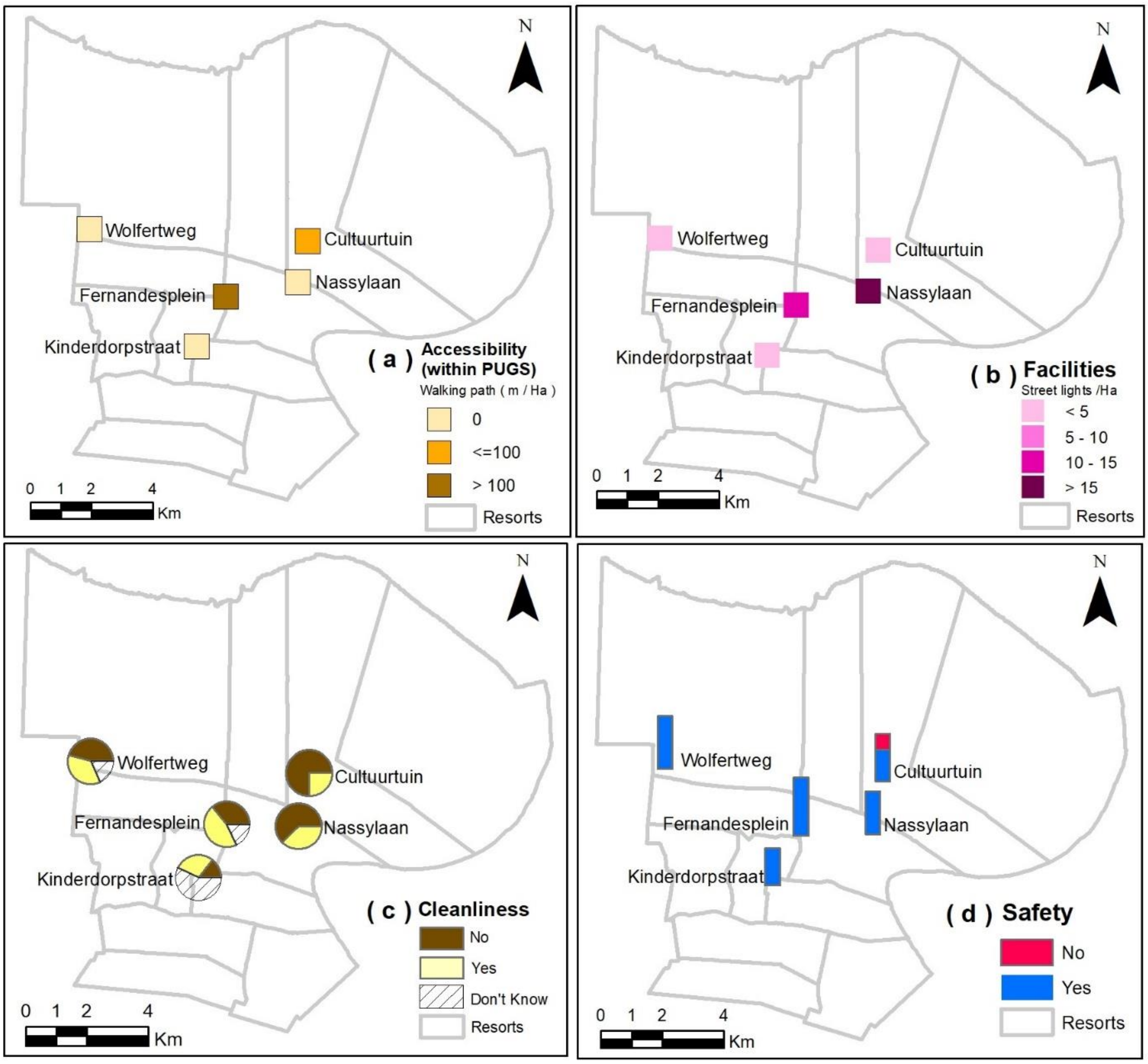

Figure 5 Spatial distribution of quality characteristics measured from survey/field data

3.3. Quality profile of surveyed public urban green spaces

This section reports results answering research question 3 by comparing the differences in measurements of quality characteristics for five public urban green spaces locations. **Table 5** shows the ranking of five locations based on survey/field data. The quality profile of each of the five surveyed public urban green spaces based on the normalized measurements (0 to 1, low to high) is shown in **Figure 6**. Further, the standard deviation in online spatial data measured characteristics for five locations is compared with survey/field measured quality characteristics.

Fernandesplein has the highest mean value of 0.93 and ranks 1 in terms of quality based on survey data. In comparison to this, the other locations have mean values much lower, with Cultuurtuin having the lowest mean of 0.08. Nassylaan and Wolfertweg have close mean values. When looking at the quality profiles of five public urban green spaces (**Figure 6**), it is evident that there is no uniform change in quality characteristic measurements for five locations. Fernandesplein seems to have medium to high scores (>0.50) for all quality characteristics except spaciousness, while Kinderdorpstraat scores extremely low (score <=0.30) on survey data measured quality characteristics which degraded the overall quality profile of this location. Similarly, for Cultuurtuin and Wolfertweg, the scores of greenness and spaciousness are high (score >0.90), while others indicate a low-quality profile (score <0.5). Nassylaan has a contrary case with a high score for facilities with a low-medium score (<=0.50) for other quality characteristics.

Table 5 Mean of quality characteristics measurements and ranking of surveyed public urban green spaces

Name	Mean (survey/field data)	Rank
Fernandesplein	0.93	1
Kinderdorpstraat	0.13	4
Cultuurtuin	0.08	5
Nassylaan	0.46	2
Wolfertweg	0.42	3

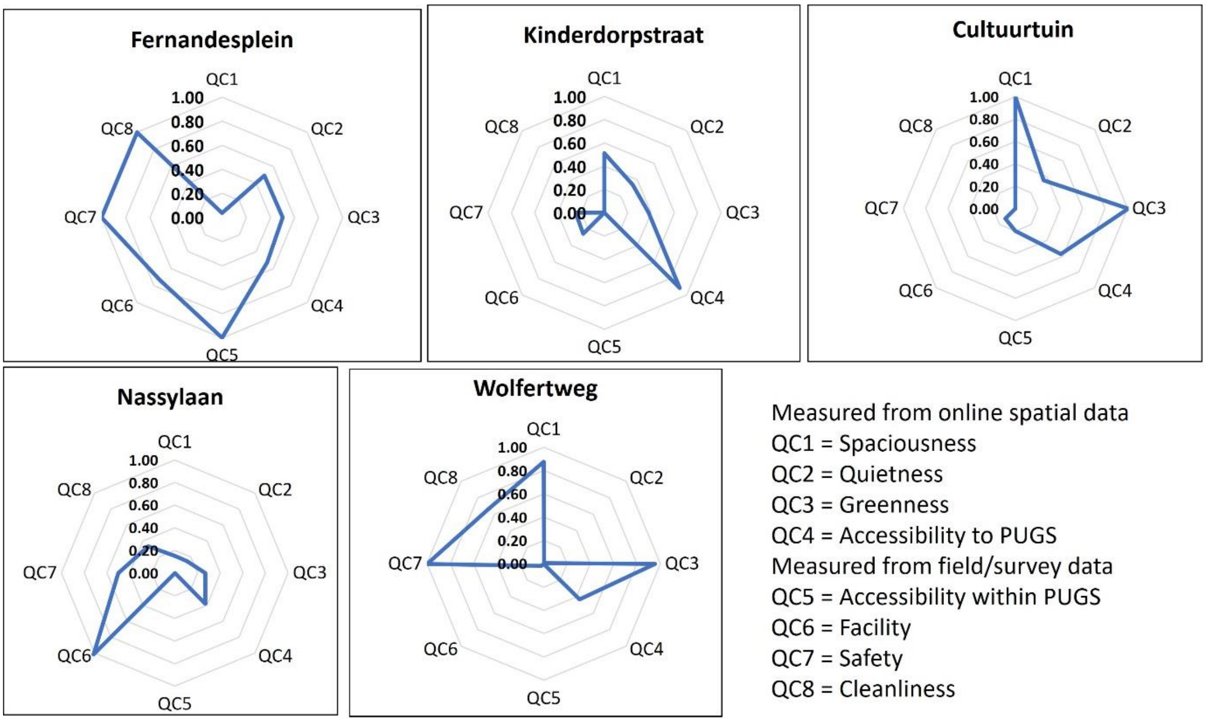

Figure 6 Quality profiles of public urban green spaces with online data and survey data

Further, the standard deviations in quality characteristic measurements for five locations based on surveyed data is higher (n= 5, Std. dev. values: QC5 = 0.44, QC6=0.42, QC7=0.45, QC8 =0.43) as compared to standard deviation of quality characteristics measured from online spatial data (n= 5, Std. dev : QC1=0.43,QC 0.19, QC3=0.34, QC4=0.21.) This also indicates that the quality based on survey data could vary more than the online spatial data. Therefore, the quality characteristics measurements from survey data might provide additional site-specific insights into the quality of the five public urban green spaces.

3.4. The physical activity estimation model

This section reports the model's results that answer research question 4 on the relation between quality and physical activity in public urban green spaces. Results for four models are summarized in **Table 6**, and the classification accuracy and AUC at each step are given in **Table 7**. Across the four models, all statistical significances of predictor variables are > 0.05, indicating their statistical non-significance in predicting physical activity. Although the significance values suggest that variables are insignificant, the reliability of this relation is checked from the odds ratio (OR) and its confidence interval. OR for Quietness in Model 1 (**Table 6**) has a value >1, indicating as this variable increases, the odds of physical activity in a public urban green spaces increases. Quietness is measured as road length per ha in the 50m buffer of the public urban green spaces, where a higher value of this variable indicates less quietness. As for other variables, having OR <1 indicating as Spaciousness, Accessibility, and Greenness increases, the probability of physical activity in public urban green spaces decreases. However, the observed relation may not be reliable as the lower bound of C.I. of OR is <1 and the upper bound includes 1. The -2LL values are low for all the models indicating the model has a good fit. For the first three models (**Table 6**), Nagelkerke's r-square is medium-sized (0.3 -0.4), while the last model, including only accessibility, has a low value. Additionally, the H-L test infers that H_0 (observed values significantly differ from predicted values) can be rejected as the Sig. of chi-square is >0.05. Therefore, the first three models indicate a goodness-of-fit for predicting physical activity. In contrast, the fourth model has a chi-square of 0.055, indicating that the observed physical activity categories could be significantly different from the predicted values for this model.

Table 6 Statistical summary of the physical activity estimation model

Model (Step)	**Variables**	**Sig.**	**OR**	**95% C.I. for OR**		**Model Summary**			**H-L Test**	
				Lower	**Upper**	**-2 Log-likelihood**	**Cox & Snell R Square**	**Nagelkerke R Square**	**Chi-square**	**Sig.**
1	Spaciousness	0.247	0.584	0.235	1.452	25.223	.273	.398	9.728	0.319
	Quietness	0.595	17.694	0.000	706349.736					
	Greenness	0.241	0.002	0.000	67.150					
	Accessibility	0.112	0.677	0.418	1.096					
2	Spaciousness	0.235	0.586	0.243	1.416	25.512	.266	.388	7.053	0.531
	Greenness	0.245	0.002	0.000	73.219					
	Accessibility	0.092	0.665	0.414	1.069					
3	Spaciousness	0.142	0.502	0.200	1.259	27.127	.226	.329	13.214	0.105
	Accessibility	0.054	0.651	0.421	1.008					
4	Accessibility	0.102	0.726	0.495	1.065	31.895	.092	.134	15.204	0.055

The model's classification accuracy (**Table 7**), at a probability threshold of 0.500, is highest when four quality characteristics predict physical activity. The model classifies 83.3 % of cases correctly. Consequently, spaciousness and accessibility predict 80 % of cases correctly, followed by the model using only accessibility (76.7%). Among four models, the prediction accuracy is least for the model using greenness, spaciousness and accessibility. Furthermore, all the models have more incorrect classifications for '1' values than '0'. This indicates that the quality characteristics underestimate the probability of physical activity in a public urban green space. All models' discrimination power is poor as the AUC values are near 0.6 as a value near 0.5 indicates a random model. Therefore, the physical activity estimation model(s) are close to giving a random prediction of the observed values.

Table 7 Classification Accuracy table (Threshold 0.500)

Step	**Observed**	**Predicted**		**Percentage Correct**	**Overall percentage**	**Likelihood under/overestimated**	**AUC of the ROC**
		0	**1**				
1	**0**	21	1	95.5	83.3	Likelihood Underestimated	0.665
	1	4	4	50.0			
2	**0**	19	3	86.4	73.3	Likelihood Underestimated	0.619
	1	5	3	37.5			
3	**0**	21	1	95.5	80.0	Likelihood Underestimated	0.665
	1	5	3	37.5			
4	**0**	21	1	95.5	76.7	Likelihood Underestimated	0.602
	1	6	2	25.0			

3.5. Physical activity and quality characteristics for surveyed (five) public urban green spaces

This section reports the result answering research questions 5 and 6. The physical activity based on the survey data and online spatial data, along with the normalized scores for quality characteristics, is summarized in **Table 8**. According to the survey data, Fernandesplein scores 0.7-1.0 for quality characteristics and either none, 1-5, 6-15, or >15 people perform physical activity. On the contrary, Cultuurtuin scores 0.0 -0.2 on the quality characteristic measurements but is most commonly used by >15 or 6-15 people for physical activity. Survey responses also indicate that none or 1-5 people do physical activity in Nassylaan, and it scores low on all quality characteristics except facilities. Only 1 out of 11 survey responses indicate 1-5 people doing physical activity in Wolfertweg; furthermore, it scores 0 on accessibility and facilities; 1.0 on safety, and 0.7 on cleanliness. Lastly, for Kinderdorpstraat, scores are low for all quality characteristics, and only 2 out of 7 responses report 1-5 people were doing physical activity. Further, looking at the quality characteristic measurement from online spatial data, physical activity from social media data, and estimated physical activity categories. **Table 8** places the results from survey/field data measurements in the context of online spatial data. To begin with, the physical activity model correctly predicted physical activity categories of all five public urban green spaces, i.e. not popular for running/walking.

Table 8 Summary of quality characteristic measurements and physical activity for five locations

Quality characteristics		**Fernandesplein**	**Cultuurtuin**	**Nassylaan**	**Wolfertweg**	**Kinderdorpstraat**
Survey/field data measured	**Accessibility (within)**	1.0	0.2	0.0	0.0	0.0
	Facilities	0.7	0.1	1.0	0.0	0.3
	Safety	1.0	0.0	0.5	1.0	0.3
	Cleanliness	1.0	0.0	0.3	0.7	0.0
Online spatial data measured	**Spaciousness**	0.04	1.00	0.15	0.87	0.51
	Quietness	0.49	0.35	0.15	0.01	0.34
	Greenness	0.50	1.00	0.27	0.95	038
	Accessibility (to)	0.53	0.57	0.38	0.43	0.91
People doing physical activity (survey responses)						
None		3	0	4	10	5
1-5		4	0	4	1	2
6-15		2	3	0	0	0
> 15		2	5	0	0	0
Physical Activity (category '0' = not popular for running/walking and '1' = popular for running/walking)						
STRAVA Efforts		9	51	1	2	3
Observed category		'0'	'0'	'0'	'0'	'0'
Predicted category		'0'	'0'	'0'	'0'	'0'

Across four characteristics measured from online spatial data, Nassylaan (0.15-0.38) and Fernandesplein (0.04-0.53) score low. Cultuurtuin and Wolfertweg have high measures of spaciousness, greenness and quietness among the five locations. Similar to survey data for physical activity, STRAVA effort counts indicate that Cultuurtuin is most popular for running/walking among the five. Regarding the relation between characteristics and use, Nassylaan scores low on three quality characteristics and has the lowest physical activity (STRAVA efforts). Similarly, Cultuurtuin scores high on two of four quality characteristics and has the highest physical activity (STRAVA efforts). Overall, there is no uniform relation between quality characteristics and physical activity for the five public urban green spaces. In the case of Fernandesplein, the survey/field data indicates high quality and 6-15 or >15 people use it for physical activity, while online spatial data/social media data indicates low quality and that not many people do running/walking activity. On the other hand, the survey/field data indicates that Cultuurtuin has low-quality characteristics and many people use it for physical activities. In contrast, the online spatial data indicates it has high-quality characteristics and is mostly used for physical activity (among the five locations).

4. DISCUSSION

This section discusses the results of the two objectives of this study. Section 4.1 discusses the results for research question 1,2,3, thereby achieving objective 1. Similarly, section 4.2 discusses the results for research question 4,5,6, thereby achieving objective 2. Further, section 4.3 reflects on the methods and material used, and section 4.4 discusses the implications of this study.

4.1. Spatial distribution of quality characteristics

This section discusses the spatial distribution of the quality characteristics of all public urban green spaces; and check if survey/field data provides additional information about quality characteristics for five public urban green spaces. The locations of public urban green spaces show that south western and northern ressorts comprise most public urban green spaces while there are no public urban green spaces in the southern ressorts. This could be because the southern part of Paramaribo has sparse urban development and mostly agricultural land.

Figure 4a and **Figure 4**d show that southwest ressorts comprise public urban green spaces that are small to medium-sized, i.e. <1 ha to 1-2 ha (Stessens et al., 2020) and have low to medium greenness (NDVI, 0.15-0.60). On the contrary, the most spacious (4-9 ha) and green (NDVI, 0.60-0.75) public urban green spaces are located on the city's outskirts. This could be due to (i) a rapid increase in built-up that leaves little to no land for public urban green spaces in the city centre (Verrest, 2010) and (ii) the outskirts of the city still are dominantly agricultural areas and forest fragments. Furthermore, public urban green spaces in southwest ressorts can be characterized by high accessibility (**Figure 4**b, 6-10 residential buildings/ha) and low quietness (**Figure 4**c, road length of 300-600 m/ha). This is because these ressorts comprise mostly residential areas, so (i) the public urban green spaces are easily accessible for the residents and (ii) the dense road network leads to traffic noise. On the other hand, the least accessible and least quiet public urban green spaces are located in the city centre, which comprises administrative and commercial buildings. Based on the author's experience in Paramaribo, it is evident that the city centre connects the north-south parts of the city and hence receives heavy vehicular movement leading to more traffic noise.

Therefore, land-use configurations can be suspected to influence the quality characteristics of public urban green spaces in Paramaribo. Overall spatial distribution of the quality characteristics of all public urban green spaces, shows that the quality characteristics are not uniformly distributed across Paramaribo. The city centre and southwest part have public urban green spaces with high accessibility, but spaciousness, quietness and greenness are higher in the city's outskirts. Interestingly, van Herzele and Wiedemann's (2003) study on urban green spaces in the Flemish cities of Ghent, Antwerp, Aalst and Kortrijk also found the qualities of urban green spaces are not uniformly spread in cities.

A synthesis of survey/field data measured quality characteristics for five public urban green spaces (**Figure 5**) suggests that Fernandesplein is the most accessible (within the public urban green space) and has the second-highest no. of street lights (facilities). This could mean that compared to other locations, Fernandesplein is more favourable for walking/running for most of the day (also in non-daylight hours). On the other hand, Cultuurtuin is accessible only through informal walking/footpaths and lacks street lights (facilities), cleanliness, and safety. These qualities are lacking because it is a forest fragment with overgrown grass that reduce accessibility within the location and dense trees/tall bushes that increase the possibility of dumping bulky waste. Furthermore, the absence of lighting can make it vulnerable to anti-social activities such as acts of violence, drug abuse, etc., that cause a sense of unsafety (Stessens et al., 2020).

Additionally, quality ranking based on survey/field data shows that Cultuurtuin ranks lowest (**Table 5**, mean=0.08) while Fernandesplein has the highest rank (**Table 5**, mean =0.93). The online spatial data measured quality characteristics of Cultuurtuin indicate that it has high 'quality' (**Figure 6**, QC1-QC4 scores >0.50), but the survey/field data suggest a 'low' quality (**Figure 6**, QC5-QC8 scores < 0.30). This shows that the online spatial data and survey/field data provide a contradictory quality profile of Cultuurtuin. On the other hand, for Fernandesplein, the online spatial data indicates a moderate 'quality' (**Figure 6**, QC 1 - QC4 scores near 0.50); and the survey/field data suggest that it has high 'quality' (**Figure 6**, QC 5 -QC8 scores > 0.60). So the online spatial data and survey/field data show a complementary quality profile of Fernandesplein. In conclusion, it can be said that the overall quality of public urban green spaces is better explained when online spatial data is supplemented with survey/field data. Looking at one or two quality characteristics from online spatial data or survey/field data does not provide an insight into the overall 'quality'.

4.2. Relation between physical activity and quality characteristics

This section discusses the results of the second objective, which aimed to identify the relationship between physical activity and quality characteristics of all public urban green spaces. The adjusted r-squared, -2LL and significance of chi-square of the H-L Test (**Table 6** and **Table 7**) indicate that Models 1, 2, and 3 are well-predicting the probability of popularity of a location for physical activity. The author checked for SPSS's over-accounting of a variable's predictive power by removing Spaciousness from Model 3 and re-running the model with Accessibility only. This model (Model 4) is the poorest fitting model (**Table 6**), indicating that the predicted values could be significantly different from the observed values. A closer look at the order of variable removal during the step-wise backward regression showed that Quietness was the first to be removed, followed by Greenness. So, although Model 1 has a high classification accuracy and has a good fit, the predictive power of Quietness and Greenness is unclear. Furthermore, the classification accuracy of Model 3 (80%) is almost the same as the Model 1 (83%), suggesting that Spaciousness and Accessibility are estimating physical activity almost to the same extent as the full model, i.e. Model 1.

However, the probability of popularity of a location for physical activity is underestimated by all four models (**Table 7**). It can be said that the quality characteristics almost randomly predict the observed physical activity (AUC values near 0.50). Also, the significance values (**Table 6**) of the quality characteristics suggest that they are statistically insignificant for predicting the probability of physical activity. Additionally, for all the models, the upper limit of C.I. of the odds ratio includes a value of 1 (**Table 6**), so it cannot be said with 95% confidence that the quality characteristics cannot predict physical activity. The possible explanation for these findings could be that the model was built using a small sample size (n=30), which might be insufficient to predict the relation. Second, the online spatial data measured quality characteristics might not be related to the physical activity measured on STRAVA; in reality, other factors may influence this relationship. As discussed in section 4.1, it is possible that land use characteristics could have a role in explaining citizens' choice of a public urban green space. Coeterier (2000) also indicated that the surrounding land use of urban green spaces influences the user's choice of a public urban green space. In this study, the author conducted an in-depth exploration of survey/field data measured quality characteristics to understand this gap.

So further, the author checked if the survey/field data could explain the findings from the physical activity estimation model (**Table 8**). When interpreting the survey data on physical activity, the author was aware that it takes into account no. of people doing physical activity in the form of walking, walking a dog, or playing. This is why the inferences are drawn about the relative popularity of the five public urban green spaces and not absolute physical activity per location. Survey data and STRAVA data both indicate that among the five locations, Cultuurtuin and Fernandesplein are the top two locations popular for physical activity. Based on the study by Akpinar (2016), the author expected to find that clean and maintained public urban green spaces are associated with a higher frequency of physical activity. In the case of Fernandesplein, survey data also shows it is the second most popular location for physical activity and has a high score of safety, cleanliness, facilities, and accessibility within the public urban green space. However, Cultuurtuin is the most popular location for physical activity but is unsafe, unclean, lack facilities, and has poor accessibility within the public urban green space. It could be due to (i) other characteristics that are very high such as spaciousness and greenness (Adinolfi et al., 2014) and (ii) sufficient parking space and good road connectivity making it easily accessible by motorized vehicles. When the five public urban green spaces are placed in the context of all (30) public urban green spaces (**Table 8**), the observed and predicted popularity for physical activity suggests that none of the five locations is very popular for running/walking.

Lastly, according to STRAVA data (Appendix 9), Nickeristraat is the most popular location for running/walking among all the public urban green spaces. This is a row of street trees situated in the ressort Beekhuizen, which lies in the central part of the city. Generally, the public urban green spaces with high STRAVA efforts count are rows of street trees and green squares. The spatial distribution of physical activity based on STRAVA (Appendix 10) shows that the most popular locations are situated in the central ressorts of the city. Combining this finding with the spatial distribution of quality characteristics (**Figure 4**), it can be said that the influence of the quality of public urban green space on its popularity for physical activity is not so strong. Hence, there might be other factors that better explain physical activity in combination with the quality characteristics or stand-alone. van Herzele and Wiedemann (2003) also indicate that while trying to keep a quality assessment easy to communicate, there is a risk of excluding some/many important quality characteristics. In conclusion to the findings of the two objectives of this study, it can be said that the hypothesis of this research that the quality characteristics of a public urban green space influence its popularity for physical activity cannot be fully accepted.

4.3. Reflection on methods and material

This study followed a mixed-methods approach by integrating binary logistic regression methods findings with survey/field data measurements to understand the profiles of five public urban green spaces. In this study, the qualitative interpretations of survey data and the author's first-hand experience from the study area helped to better understand the quantitative results. Simultaneously, the geospatial tools helped study the distribution of quality of public urban green spaces in Paramaribo.

McDonnell (2011) and Taylor & Hochuli (2017) suggest that the quality characteristics to be measured in any research must be selected based on the research subject. Therefore, only those characteristics that could potentially influence physical activity were included in this study. The selection of quality characteristics took multiple iterations because of an absence of prior knowledge/scientific research on the quality of urban green spaces in tropical cities. The quality characteristics were selected based on expert discussion, a residential survey (S. Chote, 2019) and the author's knowledge of the study area. The findings from this study highlight that other factors could be relevant for predicting physical activity, such as the surrounding land use of a public urban green space.

Given the vastness of physical activity data on STRAVA and the limited time available for this research, the plan was to use an API application to efficiently retrieve the physical activity data for 30 locations. The author followed the Strava developer's protocols and methods of acquiring data in bulk, but there were several reasons that it was unsuccessful. Firstly, there were several unresolvable errors while authenticating an API Application that exports the STRAVA data into R-Studio (several attempts made with the support of a big-data expert, Dr C. Paris at ITC-UT, and STRAVA expert, Luis Lopez). Second, STRAVA has a strict privacy policy prohibiting exporting bulk data regarding people's physical activity for a geographical area. Lastly, time limitations for this research could not afford the author to invest more time in finding innovative ways of combining web-based services with geospatial platforms. Therefore, manual data retrieval was adopted for gathering data on physical activity. Keeping this in mind and considering the size of STRAVA data on running/walking for 30 locations (61 existing segments), only running/walking activities were selected to measure 'physical activity'.

A structured criterion-based approach was followed to create new segments (e.g. considering the orientation of segments), while the criteria followed for creating the existing segments are unknown. This difference in segment creation could contribute to differences in 'effort' count, thereby introducing bias due to double counting or omission of data. As described earlier, 'efforts' are the cumulative sum of running/walking activity attempts along a segment. At the same time, 'users' are the unique number of people who ran/walked once or more than once along that segment. The decision to use 'efforts' instead of 'user' count is because this study aims to measure the popularity of a location for running/walking activities and not the size of the population served by a location. When exploring the STRAVA data on various physical activities, it was found that there was a higher no. of cycling segments than running/walking segments, indicating a possibility that cycling is a more popular physical activity than running/walking. An additional dimension to this research could have investigated the relation between quality characteristics of public urban green spaces and physical activity in the form of cycling.

The limitations of the physical activity estimation model are acknowledged in this paragraph. First, the sample size of 30 is often considered small for using statistical methods for modelling a larger population using a subset of it. However, in this study, 30 is the whole population meaning this research identifies that they are 'all' the public urban green space in Paramaribo. Also, the purpose of building this model was to test whether the relation between use and quality can be explained based on online spatial data or if there are certain gaps. The second limitation is the sensitivity of defining the threshold for binary coding of physical activity data. A sensitivity analysis was conducted to investigate the influence of the threshold value used to translate the data into a dichotomous variable. Such an analysis studies the influence of uncertainties associated with the response variable on the model performance (Chin and Lee, 2008). Results of the sensitivity analysis (Appendix 11) show that when locations with efforts <25 are categorized as '0', i.e. not popular for running/walking, the model has poorer goodness-of-fit as compared to the model used in this study (efforts <51 = '0', **Table 6**). This indicates that the discrimination power of the model reduces when locations with efforts ranging from 25-51 are categorized as '1', i.e. popular for running/walking. The threshold value of 25 divided the 30 locations into two sets with extremely varied ranges, e.g. '0' contained locations with efforts 1-25 while '1' contained locations with efforts 26 – 480. Therefore, a wide range of effort counts falls in '1', making it difficult for the model to predict physical activity based on such a variety.

This study's findings indicate that external factors may influence the quality of public urban green spaces and their use for physical activity. The first could be urban flooding, as Paramaribo is vulnerable due to its geographical location, poorly maintained drainage system, and increased construction in low-lying areas (Verrest, 2010). The flood risk mitigation model produced by McMeekin (2020) using InVEST Urban Flood Risk Mitigation Model indicates that ressorts of Centrum, Beezuiken, and Flora have a higher flood risk. This is because of the poor run-off retention capacity of these ressorts having dense built-up areas. Interestingly, these are also the ressorts where 50% of the public urban green spaces studied in this research are located. As the data on physical activity was recorded during the extended wet season in Paramaribo, it can be suspected that urban flooding could have discouraged the citizens from running/walking in/around public urban green spaces. The second external factor could be the urban heat island (UHI) effect discouraging the citizens from performing outdoor physical activity. Remijn (2020) suggests that the mean land surface temperature (LST) of the green feature group of 'streets with trees' is much higher than the 'large green area with trees' or 'large parks with trees' in Paramaribo. In this study, most public urban green spaces are small to medium-sized (1-2ha), and 18 out of 30 are street trees, so there could be high LST causing the UHI effect, especially in the dry season of Paramaribo.

4.4. Implication for management of public urban green spaces

After discussing the findings and methods used in this study, this section reflects on the possible implications for reducing the knowledge gap on public urban green space quality, thereby improving urban green space management in Paramaribo. These implications could be relevant for other tropical cities with a similar demographic, geographical, socio-political and cultural profile.

Firstly, Paramaribo lacks guidelines, policies, and acts recognising urban green spaces' 'public' status. A key challenge in this study was to identify which and where are the 'public' urban green spaces in Paramaribo. This study developed a criteria-based selection process that can be further extended and upscaled with the help of experts and citizen knowledge. Robust selection criteria could lead to the identification of green patches in the city that have the potential to serve as 'public urban green spaces' and thereby ensure better management that promotes the use of public urban green spaces.

Secondly, the available scientific knowledge focuses on public urban green spaces in cities located in temperate countries (Kothencz and Blaschke, 2017; Stessens et al., 2020). For a tropical city like Paramaribo this study could be seen as a first attempt to empirically identify the quality characteristics that influence the use of public urban green spaces for running/walking. For example, this study identifies that accessibility and spaciousness could be related to physical activity. Still, other quality indicators such as surrounding land use could better explain the use of public urban green spaces. Therefore, there is a pressing need to produce more knowledge that enables scientific research to contribute to the informed management of public urban green spaces. This knowledge cannot be generated using a silo approach but needs collaborations between government, civil sector, private sector, and educational institutions. The Groen Paramaribo project by Tropenbos Suriname and ITC-UT is one such collaboration that has harvested citizens' knowledge to keep track of changes in urban green spaces for healthy living in Paramaribo.

Thirdly, the fact that this research was conducted using crowdsourced data emphasizes the role of citizens in generating knowledge on this subject. Although the STRAVA data was very vast in the context of this study, it helped explore the popularity of certain parts of the city for certain activities. Despite the efforts to acquire and pre-process crowdsourced data, it is a good source of information, especially in geographies that are still underexplored. Therefore, government bodies can collaborate with crowdsourcing platforms and utilize the information derived from this data in decision-making. This could be an indirect but valuable use of citizens' knowledge in urban green spaces management.

Lastly, frequent studies on public urban green spaces in Paramaribo can help identify the urban green spaces needing better management and maintenance. For example, the STRAVA data used in this study found that street trees and green squares are more popular locations for running/walking than public parks like Fernandesplein, Cultuurtuin and Pamletuim. Given the role of physical activity in building a healthy lifestyle, it is important to maintain the quality of these locations. The Directorate of Public Green and Waste Management (Direktoraat Openbaar Groen en Afvalbeheer), responsible for managing public urban green spaces in Paramaribo, could use this finding to prioritize the maintenance and management of the most popular public urban green spaces.

5. CONCLUSION

More than 50% of Suriname's population lives in Paramaribo, which induces rapid urban development and it comes at the cost of green spaces (Verrest, 2010). Simultaneously, the urban residents must carry out outdoor physical activity to ensure a healthy lifestyle (Bertram and Rehdanz, 2015). Urban green spaces provide an opportunity for physical activity in an outdoor environment (de La Barrera et al., 2016; Neßhöver et al., 2007; Reid, 2005; Sandifer et al., 2015). Therefore, this study started with the realization of its societal relevance. As a scientific approach was followed, reviewing existing studies on the 'quality' of public urban green spaces was necessary. The author identified that most of the studies are focused on the 'quality' of public urban green spaces in developed cities (Kothencz and Blaschke, 2017; Stessens et al., 2020; van Herzele and Wiedemann, 2003). So, there is little knowledge of the 'quality' of public urban green spaces in tropical cities like Paramaribo. This study's novelty and scientific relevance is that it attempted to reduce the knowledge gap on the quality of public urban green spaces and investigate their relation to physical activity in Paramaribo.

Findings for the first objective show that the public urban green spaces in Paramaribo are distributed in the southwestern and central ressorts. The quality characteristics such as spaciousness, greenness, and quietness were higher for locations in the city's outskirts, while accessibility to the public urban green spaces locations in the residential areas. The survey/field data measurements showed that quality characteristics like safety, cleanliness, and facilities are essential to understanding the overall quality of a public urban green space. The author can confirm that survey/field data add a layer of information to the online spatial data.

Findings for the second objective show that spaciousness and accessibility to a public urban green space are related to physical activity. But the statistical outputs also suggest that the quality characteristics used to build the model are an underestimation of the likelihood meaning there may be other factors to predict physical activity. The author investigated the survey/field data to check if those can explain the gaps in the model. There was a relation between quality characteristics and physical activity at individual public urban green space levels. Still, the author cannot confirm if a relation exists for all the locations or not. Also, the five surveyed public urban green spaces were placed in the context of all public urban green spaces. It is observed that these locations are not popular for running/walking, suggesting that the research hypothesis, i.e. the quality characteristics of a public urban green space influence its popularity for physical activity cannot be fully accepted.

The study indicates that there may be other factors that could have a potential influence on the relation between quality and physical activity. A few suspected factors include surrounding land use of public urban green spaces, urban flooding, and the urban heat island effect in Paramaribo. The limitations of this study are also acknowledged to make the reader aware that this could have yielded different results if different methodological and data choices were made. In the end, the author elaborated on the urban management implications of this study. This research is the first of its kind hence opening wide avenues for future studies on the quality of public urban green spaces and physical activity in Paramaribo or similar tropical cities.

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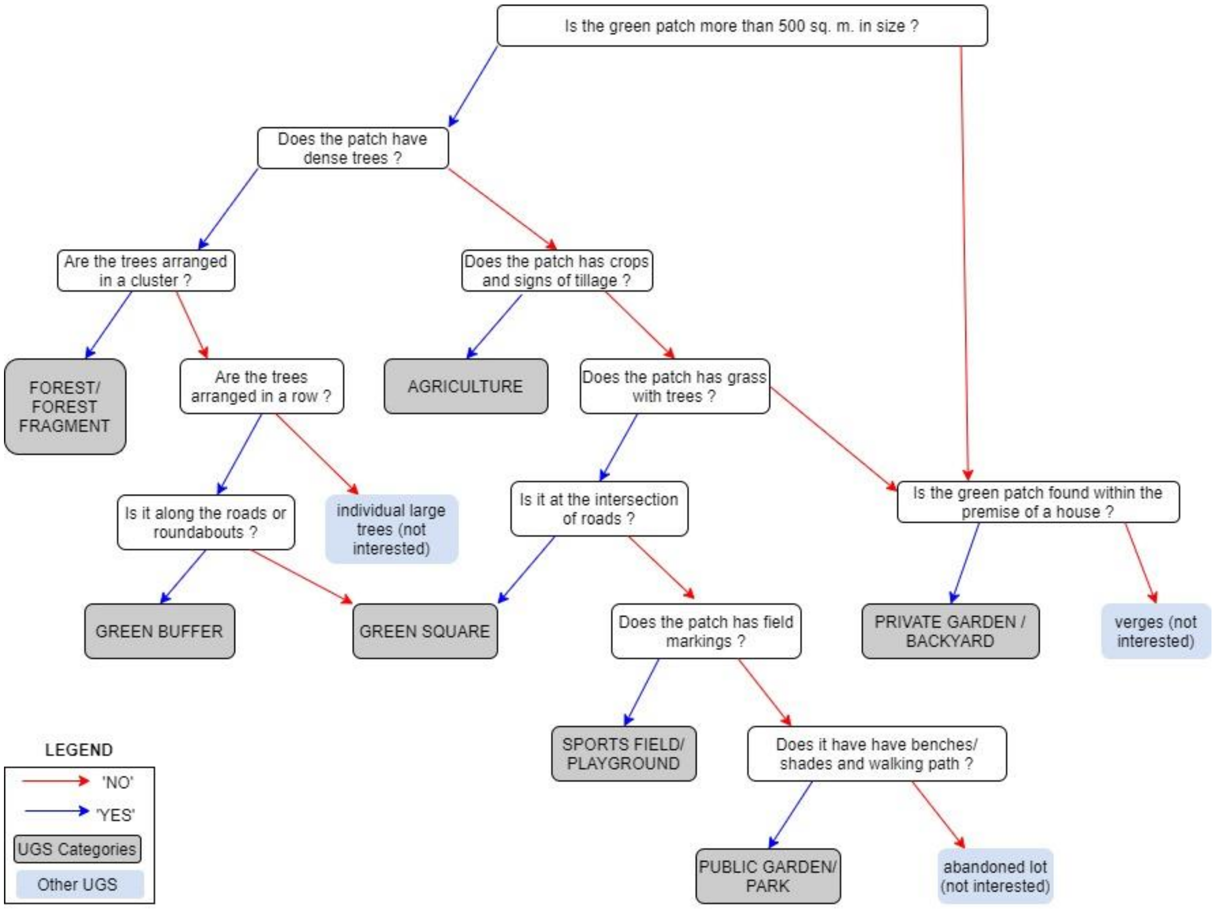
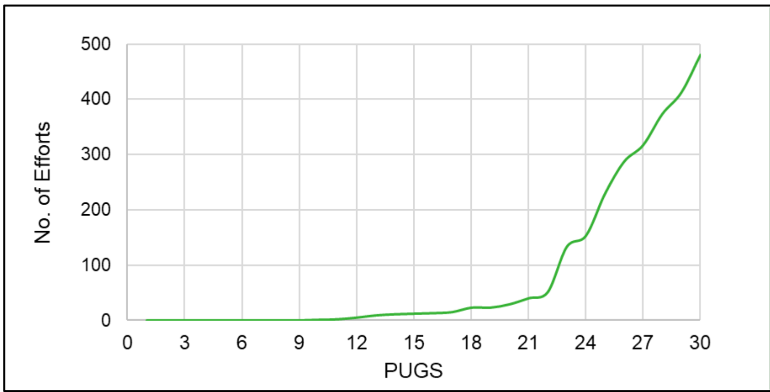
Appendix 1 : Quality characteristics used in previous studies

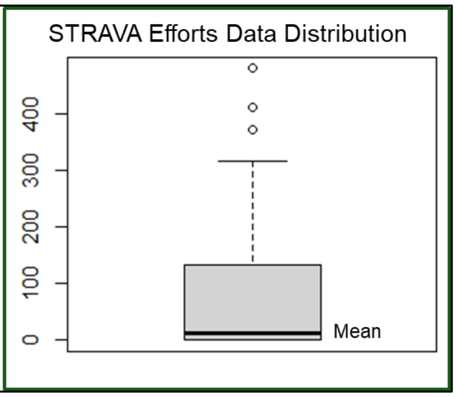
Quality Characteristics	Variable	References
Physical attributes	Location and size	(Coeterier, 2000; Stessens et al., 2017)
	Road network	(Coeterier, 2000)
	Surrounding land use	
Biodiversity/ Greenness/Naturalness	Trees canopy cover	(Ode Sang et al., 2016)
	Availability of water body/ fountain	(Daniels et al., 2018)
	Grass cover	(Daniels et al., 2018; Zhang et al., 2017)
	Shrubs/ Plant density	(Stessens et al., 2017)
Peacefulness/ Quietness	User's satisfaction level rated using Likert scale	(Stessens et al., 2020)
Spaciousness	Public green space per capita	
	User count	(Akpinar, 2016)
	Frequency of visits	(Skärbäck, 2007)
Cleanliness/ Maintenance	Instances of littering as reported by users	(Akpinar, 2016)
Facilities/Amenities	For leisure - seatings, walking paths	(Zhang et al., 2017)
	For physical activity – play area, running paths	(Akpinar, 2016)
Feeling of Safety	User's satisfaction level rated using Likert scale	(Stessens et al., 2020)

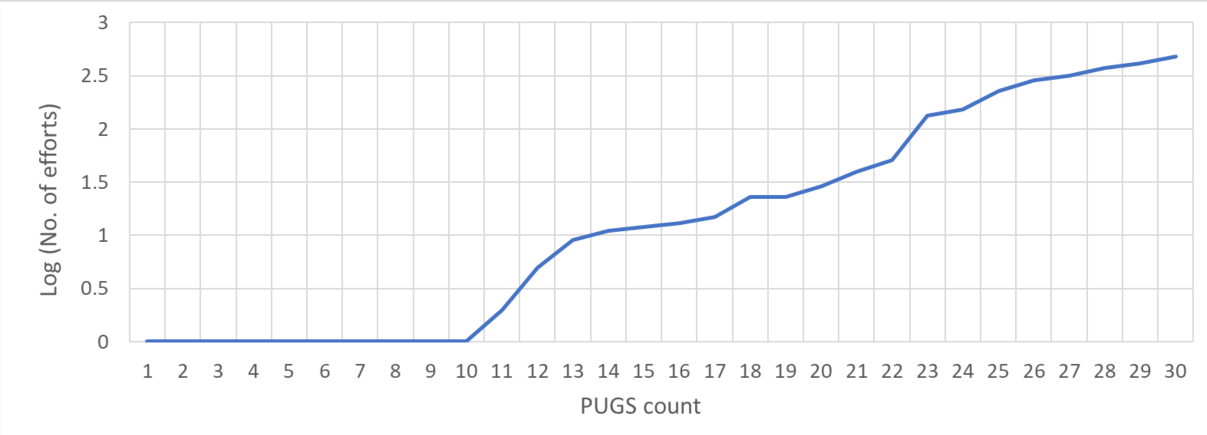
Appendix 2: Decision Tree used for UGS Classification

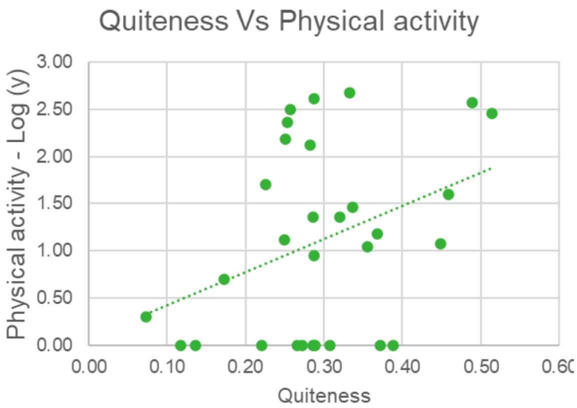


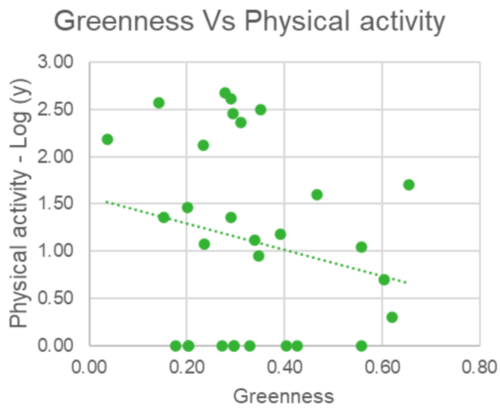
Appendix 3 : Physical activity and Quality Characteristics Data Distribution

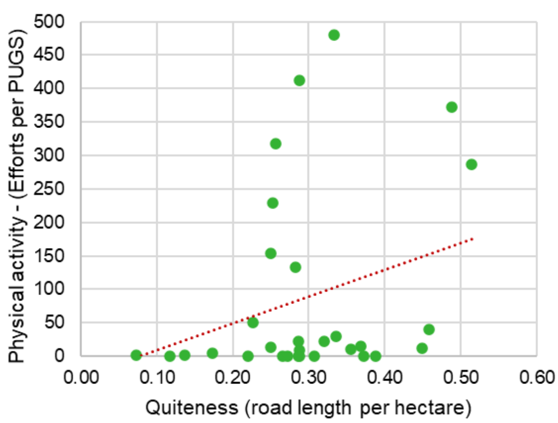


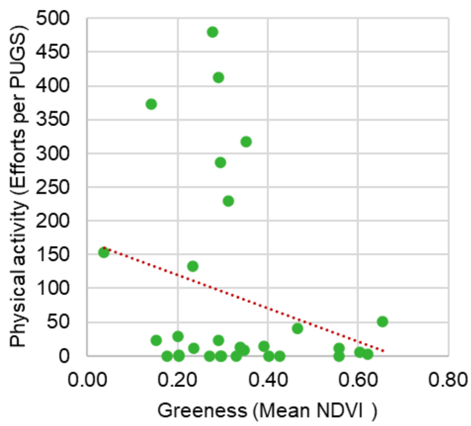


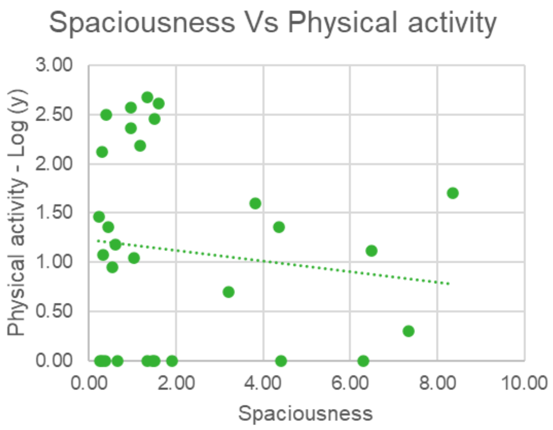


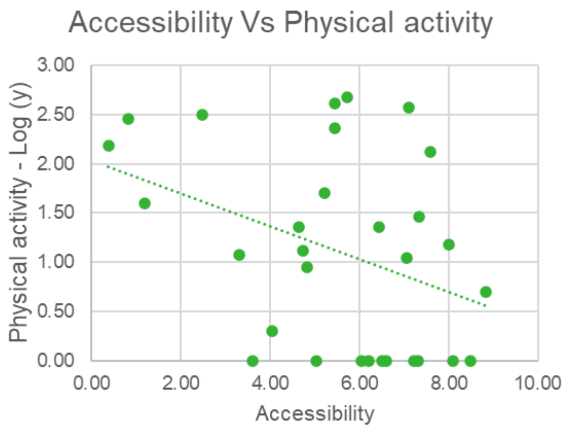


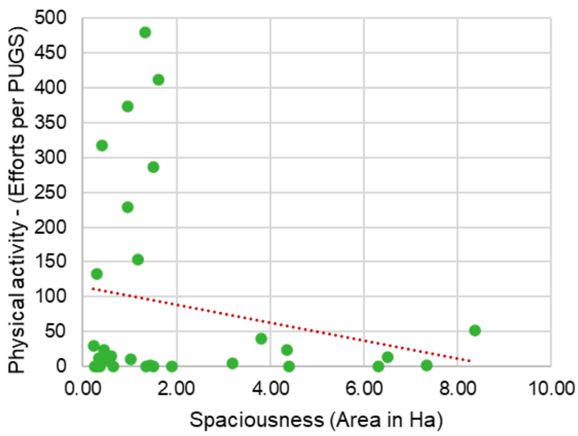


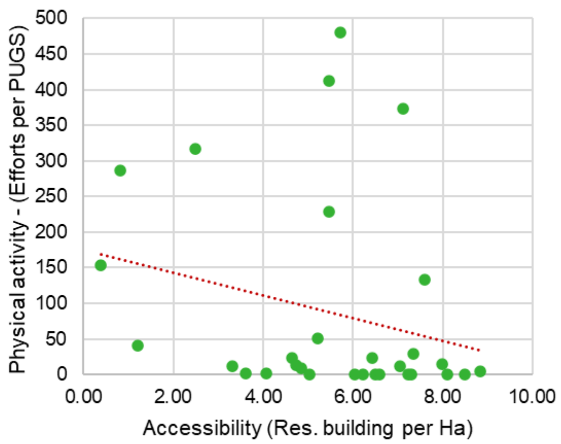












Appendix 4: Correlation coefficients for Quality Characteristics and Physical activity

Correlations (Person's Correlation)		Spaciousness	Quiteness	Greenness	Accessibility	Physical Activity
Spaciousness	Pearson Correlation	1	-.304	.521**	-.165	-.211
	Sig. (2-tailed)		.102	.003	.382	.264
Quiteness	Pearson Correlation	-.304	1	-.310	-.154	.287
	Sig. (2-tailed)	.102		.096	.417	.124
Greenness	Pearson Correlation	.521**	-.310	1	.123	-.263
	Sig. (2-tailed)	.003	.096		.518	.161
Accessibility	Pearson Correlation	-.165	-.154	.123	1	-.248
	Sig. (2-tailed)	.382	.417	.518		.186
Physical Activity	Pearson Correlation	-.211	.287	-.263	-.248	1
	Sig. (2-tailed)	.264	.124	.161	.186	
**. Correlation is significant at the 0.01 level (2-tailed).						

	Correlations (Spearman's rho)	Spaciousness	Quiteness	Greenness	Accessibility	Physical Activity
Spaciousness	Correlation Coefficient	1.000	-.272	.446*	-.304	-.024
	Sig. (2-tailed)	.	.146	.013	.103	.900
Quiteness	Correlation Coefficient	-.272	1.000	-.176	.015	.228
	Sig. (2-tailed)	.146	.	.351	.938	.226
Greenness	Correlation Coefficient	.446*	-.176	1.000	-.011	-.201
	Sig. (2-tailed)	.013	.351	.	.954	.286

Accessibility	Correlation Coefficient	-.304	.015	-.011	1.000	-.355
	Sig. (2-tailed)	.103	.938	.954	.	.054
Physical Activity	Correlation Coefficient	-.024	.228	-.201	-.355	1.000
	Sig. (2-tailed)	.900	.226	.286	.054	.

Appendix 5: Collinearity diagnostics for independent variables (Quality Characteristics)

Coefficients			
		Collinearity Statistics	
Model		Tolerance	VIF
1	Spaciousness	.643	1.556
	Quietness	.848	1.180
	Greenness	.670	1.492
	Accessibility	.883	1.132
a. Dependent Variable: Physical Activity			

Appendix 6: Interpretations from statistical outputs of the physical activity estimation model

Statistical output	Description	Interpretation
Significance of explanatory variables denoted as Sig	confidence interval of 95%, p-values < 0.05 = variable statistically significant and vice versa if p-value >0.05	Indicates the importance of quality characteristics for predicting physical activity
Odds ratio (OR)	Value >1 = as the explanatory variable increases, so do the odds that a response variable will occur	Indicates the degree of influence of quality characteristics on the probability of physical activity
Confidence interval (C.I.) for odds ratio	upper and lower bounds >1 = relation observed between explanatory and response variables is true. The upper limit is >1, and the lower limit is <1 = a possibility that the relationship is not true.	Indicates if it can be said with 95% confidence that the observed relation between quality characteristics and physical activity is true or not
-2 Log-Likelihood (-2LL)	The lower the value, the better is model fit	A model with the lowest -2LL value is supposed to be predicting physical activity better than other models
Nagelkerke R-square	A value near 1 = high goodness-of-fit and vice-versa	The models with high r-squared values are well- predicting the physical activity
Hosmer and Lemeshow test (H-L Test), Chi-square and p-value	H_0 = observed physical activity values are significantly different from the predicted values. So, it is desired that the chi-square value is non-significant (p-value >0.05)	If the physical activity estimation models have a non-significant chi-square, they can predict the probability of physical activity in a public urban green space
Classification table	"1" not correctly classified = likelihood underestimated "0" not correctly classified = likelihood overestimated	Indicates if the quality characteristics underestimate or overestimate the probability of physical activity in a public urban green space
Area Under Curve (AUC) of Receiver Operator Characteristics (ROC)	values range from 0 to 1; nearer the value to 1 = better model; values near 0.5 the model is predicting almost randomly	If the values are high, the quality characteristics are almost realistically predicting the probability of physical activity in a location and vice versa

Appendix 7: Quality characteristics of all public urban green spaces measured from online spatial data

ʼUGS_ID	Name	Type	Spaciousness (Area in Ha)	Quiteness (Road length per Ha)	Greenness (Mean NDVI)	Accessibility (No. of residential buildings per Ha)
0	Dr.Sophie Redmond Straat	Street Trees	4.36	0.29	0.15	4.65
1	Torricellistraat	Street Trees	0.96	0.25	0.31	5.46
2	Copernicus Straat	Street Trees	6.50	0.25	0.34	4.73
3	Onafhankelijkheidsplein	Green square	1.51	0.51	0.29	0.82
4	Palmentuin	Public park	3.82	0.46	0.47	1.20
5	BVSS Sport complex	Public park	1.61	0.29	0.29	5.46
6	Albertlaan	Street Trees	1.02	0.36	0.56	7.05
7	Waterkant	Public park	1.18	0.25	0.04	0.39
8	Cultuurtuin	Public park	8.36	0.23	0.65	5.22
9	Fernandesplein	Public park	0.55	0.29	0.35	4.84
10	Nassylaan	Street Trees	1.45	0.14	0.20	3.61
11	Nickeriestraat	Street Trees	1.33	0.33	0.28	5.73
12	Wolfertweg	Forest fragment	7.34	0.07	0.62	4.06
13	Bakamoejoweg/Sohawanweg	Forest fragment	1.91	0.12	0.56	6.22
14	Priscillastraat	Forest fragment	3.20	0.17	0.60	8.83
15	Kinderdorpstraat	Street Trees	4.41	0.22	0.27	8.10
16	Mottonshooplaan	Street Trees	1.34	0.29	0.30	6.50
17	Kristalstraat	Street Trees	0.29	0.27	0.18	6.05
18	Leonardo Da Vincistraat	Street Trees	0.30	0.28	0.23	7.60
19	Nachtegaalstraat	Street Trees	0.40	0.26	0.35	2.48
20	Powisi Street	Street Trees	0.33	0.45	0.24	3.32
21	Watrakanoestraat	Street Trees	1.50	0.39	0.30	7.23
22	Brokopondolaan	Street Trees	0.23	0.34	0.20	7.35
23	Remoncourtstraat/Vigilantiawe	Street Trees	0.26	0.29	0.20	8.50
24	Lalla Rookhweg/ Hermitage m	Street Trees	0.44	0.32	0.29	6.43
25	Kawemhakanstraat	Street Trees	0.37	0.31	0.33	7.31
26	Boekoestraat	Street Trees	0.65	0.27	0.40	6.60
27	Gladiolen St 1	Green square	0.96	0.49	0.14	7.12
28	Gladiolen St 2	Green square	0.60	0.37	0.39	7.99
29	Axwijk Sportcentrium	Public park	6.30	0.37	0.43	5.03

Appendix 8: Quality characteristics of public urban green spaces measured from survey/field data

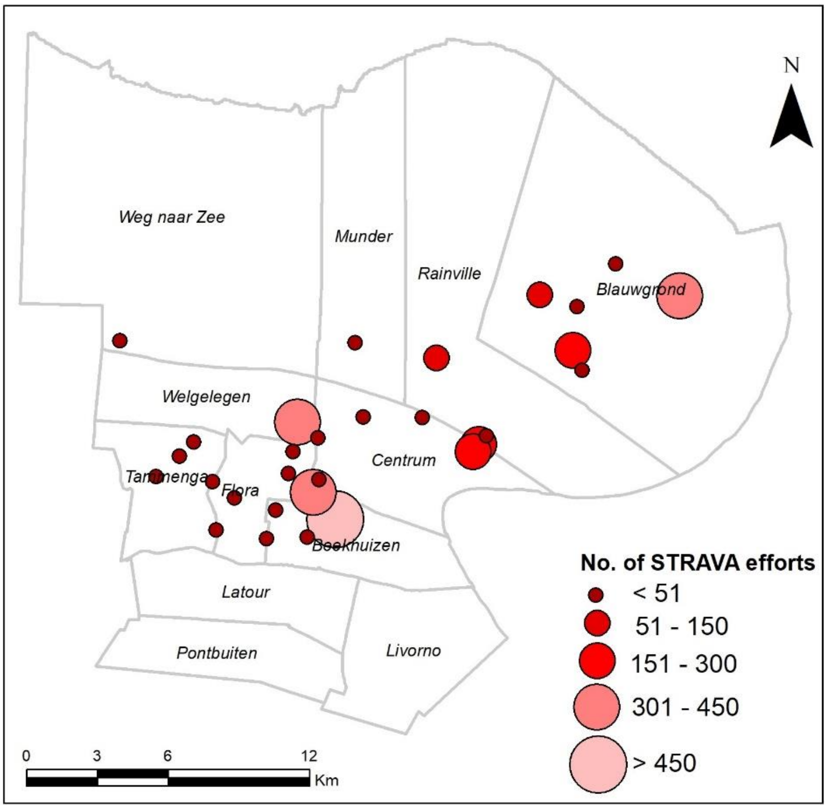
EPI COLLECT QUESTION RESPONSE	Anything that makes you feel less safe (Q23)		Bulky waste (Q20)			People doing physical activity			
	Yes	No	Yes, mainly recently left waste	No	I do not know	None	Small number (1-5)	Reasonable number (6-15)	Many (more than 15)
Cultuurtuin	3	6	6	2	0	0	0	3	5
Fernandesplein	0	11	4	5	2	3	4	2	2
Nassylaan	0	8	5	3	0	4	4	0	0
Wolfertweg	0	10	5	4	2	10	1	0	0
Kinderdorpstraa	0	7	1	2	4	5	2	0	0

Appendix 9: Physical activity in Public Urban Green Spaces

STRAVA efforts recorded during 01-Feb-2022 and 01-May-2022 on most popular segment of each Public urban green space

FID	Name	Efforts
13	Bakamoejoweg/Sohawanweg	0
15	Kinderdorpstraat	0
16	Mottonshooplaan	0
17	Kristalstraat	0
21	Watrakanoestraat	0
23	Remoncourtstraat/Vigilantiaweg	0
25	Kawemhakanstraat	0
26	Boekoestraat	0
29	Axwijk Sportcentrium	0
10	Nassylaan	1
12	Wolfertweg	2
14	Priscillastraat	5
9	Fernandesplein	9
6	Albertlaan	11
20	Powisi Street	12
2	Copernicus Straat	13
28	Gladiolen St 2	15
0	Dr.Sophie Redmond Straat	23
24	Lalla Rookhweg/ Hermitage mall	23
22	Brokopondolaan	29
4	Palmentuin	40
8	Cultuurtuin	51
18	Leonardo Da Vincistraat	133
7	Waterkant	153
1	Torricellistraat	229
3	Onafhankelijkheidsplein	287
19	Nachtegaalstraat	317
27	Gladiolen St 1	373
5	BVSS Sport complex	412
11	Nickeriestraat	480

Appendix 10: Spatial distribution of physical activity based on STRAVA data



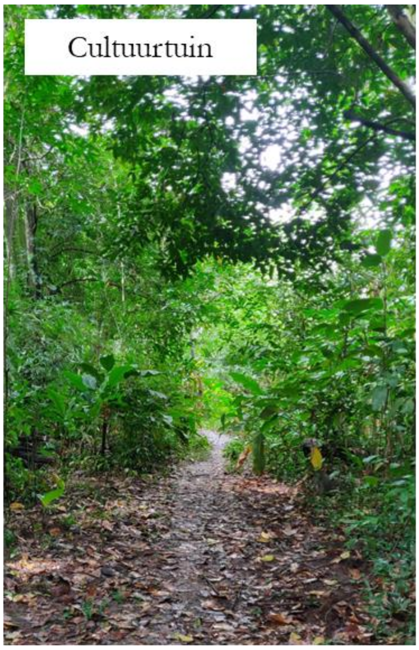
Appendix 11: Sensitivity analysis of Physical Activity estimation model

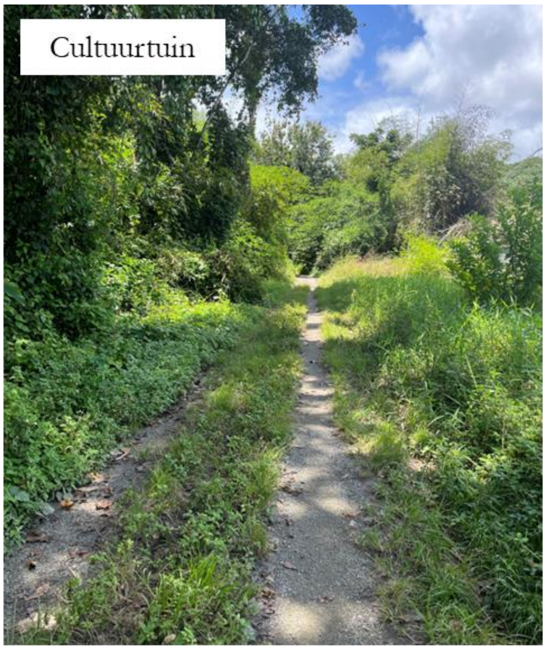
Statistical results for a model where Physical Activity is recoded as efforts < 25 = 0 and efforts > 25 = 1

Model (Step)	*Variables*	*Sig.*	*Exp (B)*	*95% C.I. for Exp (B)*		*Model Summary*			*H-L Test*	
				Lower	*Upper*	*- 2LL*	*Cox & Snell R Square*	*Nagelkerke R Square*	*Chi-square*	*Sig.*
1	Spaciousness	0.833	0.953	0.611	1.488	32.821	.198	.270	9.234	0.323
	Quietness	0.270	223.690	0.015	3362409.93					
	Greenness	0.771	0.341	0.000	478.398					
	Accessibility	0.093	0.680	0.433	1.066					
2	Spaciousness	0.680	0.913	0.591	1.409	34.148	.161	.221	12.004	0.151
	Greenness	0.641	0.188	0.000	210.053					
	Accessibility	0.061	0.669	0.440	1.018					
3	Spaciousness	0.433	0.863	0.589	1.247	34.317	.155	.212	9.155	0.329
	Accessibility	0.048	0.659	0.436	0.996					
4	Accessibility	0.055	0.680	0.459	1.008	35.035	.136	.186	16.953	0.031

	Observed	**Predicted**		**Percentage Correct**	**Overall percentage**	**Likelihood under/overestimated**	**AUC of the ROC**
Step		**0**	**1**				
1	**0**	18	1	94.7	76.7	Likelihood Underestimated	0.701
	1	6	5	45.5			
2	**0**	19	0	100	63.3	Likelihood Underestimated	0.629
	1	11	0	0			
3	**0**	17	2	89.5	70.0	Likelihood Underestimated	0.629
	1	7	4	36.4			
4	**0**	17	2	89.5	70.0	Likelihood Underestimated	0.629
	1	7	4	36.4			
0= not popular for running/walking and 1= popular for running/walking							

Appendix 12 : Public Urban Green Spaces in Paramaribo






Nassylaan


Palmentuin
Afval


Waterkant


Onafhankelijkheidsplein