Leveraging Spatial Analysis Techniques for Developing a Climate Resilient and Localized Urban Greening Plan for Pasig City

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Abstract

A recent study has been conducted to evaluate the current state of green spaces in Pasig City, Philippines, and to propose a Climate Resilient and Localized Urban Greening Plan (CRLUGP) to address urban greening that is essential for creating sustainable cities, especially in the face of climate change and urban population growth. The study utilized Geographic Information Systems (GIS), Remote Sensing (RS), and Machine Learning (ML) to map green spaces, analyze climate risks, and identify necessary corrective measures. The findings revealed that Pasig City currently only has 70.18 hectares of green space, which is significantly below the World Health Organization's recommended minimum of nine (9) square meters of green space per capita. Projections indicate that by 2032, the city will need 925.72 hectares of green space to meet the needs of its growing population. Additionally, the study identified a connection between low canopy cover and increased urban heat island effects, with the top 10 barangays showing a canopy cover of only 27.64%, well below the recommended 40%. Moreover, areas with limited green spaces were found to be at a higher risk of flooding, highlighting the importance of more vegetation for managing stormwater and mitigating climate-related risks. The study recommends a strategic approach to urban greening, leveraging spatial analysis for continuous monitoring and evaluation. By integrating spatial technologies and data-driven decision-making, Pasig City aims to establish a more sustainable and resilient urban environment for its residents.

1. Introduction

Urban greening has become increasingly important in the face of climate change, especially in densely populated cities like Pasig City. To further mitigate the effects of climate change, the Department of Environment and Natural Resources (DENR) has signed an agreement with the Local Government Unit (LGU) of Pasig City to create a Climate Resilient and Localized Urban Greening Plan (CRLUGP) (Aguilar, 2022). Consultants from various disciplines, including geomatics engineering, urban planning, forestry, and landscaping, collaborated and used spatial technologies to develop the CRLUGP for Pasig City.

Several crucial factors were found to affect the suitability of urban green areas, including existing land use, proximity to settlements, roads and water bodies, population density, land ownership, topography, and scenic attractiveness. (Gelan, 2021). Data collection of these factors was prioritized during several Key Informants Interviews (KII) and Focus Group Discussions (FGDs) with concerned agencies. Aside from gathering spatial data, KIIs and FGDs were also formulated to get answers on how urban greenspaces (UGS) have made immense contributions to the social, economic, and environmental spectrums of sustainable development (Hyder & Haque, 2022) in Pasig City. Digitization of private parks was also done using knowledge provided by experts from the city, as most studies focus on public green spaces, while private green spaces are less commonly mapped. (Neyns & Canters, 2021)

The CRLUGP also uses the model developed and calibrated by Argamosa in 2020 for the Philippines, which uses the CatBoost regression model and Sentinel 2 images to assess the canopy coverage (Argamosa, 2020) in each barangay in Pasig City. This information was then used to evaluate the cooling effect of urban green spaces in each barangay, assess the vulnerability of plant species to flooding, and project future urban green space needs of the city based on existing area and population.

Urban planners undertook a thorough analysis of these maps to align with the existing policies of the LGU Pasig. Furthermore, landscape architects and foresters utilized the maps to provide detailed and tailored recommendations on the selection of plant species and appropriate planting methods that are best suited to the unique characteristics of the specific area of interest, considering soil type, topography, climate, and existing vegetation in order to ensure that landscaping and reforestation are approached most effectively and sustainably.

The combination of Geographic Information Systems (GIS), Remote Sensing (RS), and Machine Learning (ML) technology has given local governments powerful resources to develop and implement robust green initiatives. This method seeks to establish a sustainable urban environment that enhances the local ecosystem and the overall well-being of the city's residents by mapping out current green spaces, assessing climate risks, and pinpointing areas for enhancement. With the help of spatial technology, Pasig City can adopt a data-driven strategy to enhance its green infrastructure, reduce its vulnerability to climate impacts, and promote a healthier urban landscape.

1.1 Significance of the Study

The CRLUGP for Pasig City is a strategy aimed at establishing and maintaining sufficient climate-resilient greenspaces. The plan aims to promote ecologically balanced and sustainable urban living by incorporating green infrastructure into the city's landscape.

The CRLUGP outlines specific measures that Pasig City will take to mitigate the impact of climate change and ensure its preparedness for any future environmental challenges. The plan

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includes provisions for establishing parks, gardens, and other green spaces that can withstand extreme weather conditions and provide various ecological services. By increasing the number of green spaces within the city, the plan aims to provide residents with access to natural spaces that can improve physical and mental health, reduce stress levels, and enhance overall well-being.

The use of geospatial technology in creating the CRLUGP improves the reproducibility and replicability of the process compared to manual data plotting and encoding. Per DENR, the goal is to create a CRLUGP for Metro Manila. Starting with Malabon and Pasig as the first two (2) cities for analysis is crucial as it will serve as the standard for all other cities.

The CRLUGP is a forward-thinking plan that recognizes the importance of sustainable urban development. By integrating green infrastructure into the city's landscape, Pasig City is reducing its carbon footprint, decreasing energy consumption, and promoting long-term environmental sustainability.

1.2 Scope and Data Sources

According to a study conducted by Taylor and Hochuli in 2017, researchers have different interpretations of the term “green space.” To address this issue, they recommended that researchers should create a definition of greenspace that incorporates both qualitative and quantitative elements that are specific to their research context. (Taylor & Hochuli, 2017)

In this study, LGU Pasig defined greenspace as communal areas that are clean, green, and child-friendly. They also emphasized the importance of efficient land use, walkable streets with ample tree cover, public parks, the use of renewable energy, the availability of breathing spaces, the integration of green materials, and the optimization of riverside areas. (City ENRO, 2022). As such, it is necessary to note that even paved and idle areas within areas that function as communal places, such as parks, are also accounted for in terms of land area in this study.

The consultants conducting the study primarily used secondary data from LGU Pasig to map out the locations of public greenspaces. However, greenspaces on privately owned lands were mapped using Google Earth, and vegetation cover data was derived from Sentinel 2. Additional data required to analyze the climate resilience of urban greenspace (UGS) came from various government agencies and were tabulated in Table 1. The consultants also examined the current Ecological Profile, Comprehensive Land Use Plan (CLUP), Comprehensive Development Plan (CDP) 2022-2027, and Local Climate Change Action Plan (LCCAP) 2016-2026 to gain a thorough understanding of Pasig City.

Data	Data Source
Government-owned greenspaces Land Use Map Ecological Profile LCCAP, CDP, CLUP	LGU Pasig
Land Cover	DENR NAMRIA
Flood Hazard Map	PAGASA
Temperature and Rainfall	Hikersbay
Population	Philippine Statistic Agency
Privately owned greenspaces	Digitized in Google Earth
Canopy Cover	Generated from Sentinel 2
LiDAR Data	DOST Phil-LiDAR 2 Project 3: FRExLS
Elevation Map	FABDEM

Table 1. Sources of Spatial Data

Additional analyses were performed by geomatics engineers using Sentinel 2A to produce a land surface temperature map and canopy cover map, which was modeled from the precise canopy cover data of the Phil-LiDAR Forest Resource Extraction from LiDAR Surveys (FRExLS) Project of the Department of Science and Technology (DOST). On the other hand, the elevation map for Pasig City was obtained using FABDEM.

1.3 Study Area

Pasig City is a highly urbanized city situated in the eastern part of Metro Manila, approximately 12 kilometers away. The city covers an area of approximately 3500 hectares and shares borders with Quezon City and Marikina to the north, Mandaluyong to the west, Rizal province to the east, and Makati, Taguig, and Pateros to the south. Three major waterways, namely, the Marikina River, Pasig River, and Manggahan Floodway, pass through Pasig City. Additionally, the city has 17 creeks that flow into Laguna de Bay and Manila Bay.

Pasig is located at the southern tip of Pasig River and has an approximate coordinate of 14°32' to 14°37' North and 121°03’ to 121°06’ East. The city is divided into 30 barangays and serves as the gateway to Metro Manila in the east. It has maintained its position as the country's top business and financial center. (DTI, 2020)

Pasig City's elevation ranges from 0 to 50 meters, with 53% of its land area being less than 5 meters above mean sea level, as presented in Figure 1. Despite this, its terrain is relatively flat due to its location along the Marikina Valley zone. Pasig City is geologically part of the Central Luzon Basin, which consists primarily of alluvium deposits and loam soil.

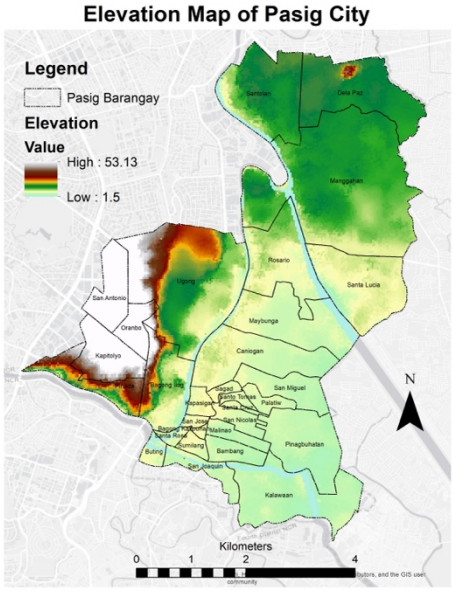

Figure 1. Elevation Map of Pasig City

2. Methodology

The DENR has hired consultants with expertise in urban and environmental planning, geomatics, forestry, and landscaping to create a CRLUGP for Pasig City. This strategy is designed to aid the Enhanced National Greening Program of DENR. The program aims to combat the impacts of climate change and the increasing high heat index in the nation by restoring all the

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remaining unproductive, denuded, and degraded forestlands in the upland community from 2016 to 2028 (DENR-FMB, 2015). Additionally, it aims to create green urban spaces in a highly urbanized area.

In order to collect the necessary data, the city's ecological profile, CLUP, CDP, and LCCAP were reviewed, and KIIs and FGDs were conducted with LGU Pasig, DENR, and other concerned stakeholders. This process aided in gathering existing spatial data, gaining knowledge on current greening plans, programs, and policies, and obtaining insights and perceptions of UGS from the citizens.

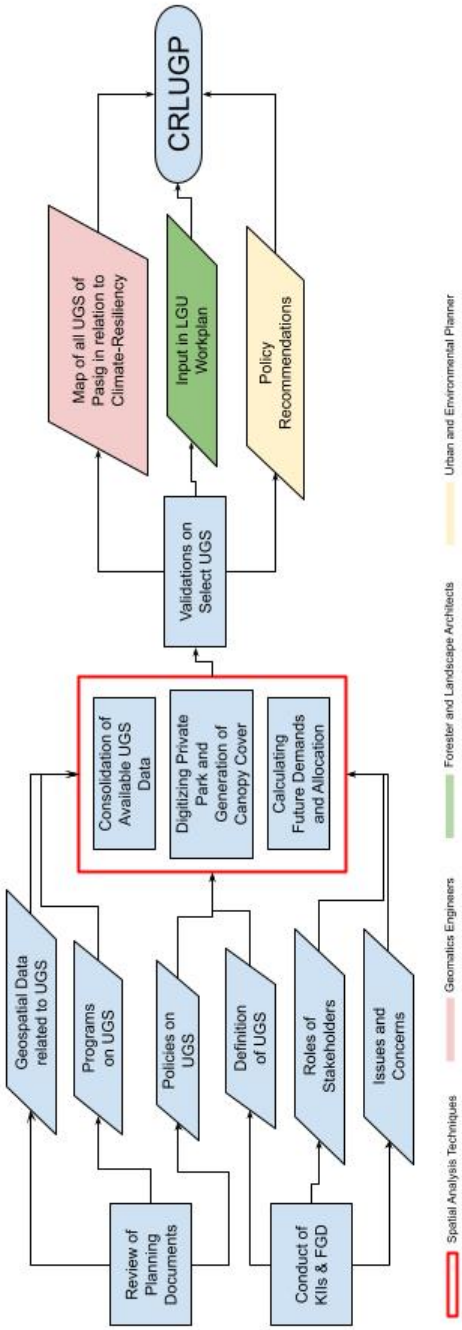

Figure 2. Flowchart of the Process for Crafting the CRLUGP

The utilization of GIS technology facilitated the development of the plan to consolidate spatial data, and an ML algorithm was employed to generate a tree cover map. Additional data on the location of green spaces was also analyzed alongside other factors, such as temperature and flooding, to determine inputs for climate resiliency. Urban planners, foresters, and landscape architects utilized these maps to provide further recommendations on policies, species selection guides, and workplan development. The flowchart of the process is presented in Figure 2.

2.1 Review of Ecological Profile, LCCAP, CDP, and CLUP

Various details on the city's physical, social, economic, environmental, and infrastructure were found in LGU's planning documents. However, for this study, the consultants trimmed down only factors that can affect the analysis of urban greening and climate resiliency.

Reviewing the Ecological Profile of Pasig shows that it is classified as Type III under the Modified Coronas Classification, which means that it has no very pronounced maximum rain period, and the dry season typically only lasts for 1-3 months. The city has an average monthly temperature of 29°C, with the average high temperature ranging from 26-34°C and the average low ranging from 23-26°C. (Hikersbay, 2022)

It is also found that Pasig City is particularly vulnerable to flooding due to various factors such as heavy rainfall, high water levels in the nearby lake, and excessive flows from both the Pasig and Marikina rivers. As a result, as much as 75% of the total land area, which is primarily low-lying areas, is often inundated.

Based on the existing land use plan of Pasig City, 7.69% of the land is allocated for greenbelts, memorial parks, parks and recreation areas, idle land, tourism, and water protection areas. Other potential sites for urban greening are the road networks, which are composed of 26 km of national roads. The 241 schools were also recorded for school gardens, which are also considered UGS. (City Government of Pasig, 2016)

As of May 01, 2020, Pasig City has a total population of 803,159, and the average population growth rate in the city is 1.30% in 2020 (PSA, 2020), suggesting that the projected total population of Pasig City in 2032 will reach 1,048,311, representing an increase of 30.52% from the population in 2020. The city's population density in 2020 was 227 persons per hectare. (City Government of Pasig, 2016)

It is also well noted that per the records of the Pasig Urban Settlement Office (PUSO), 3.55% of the total households are Informal Settler Household (ISH). Most of these ISHs are located in the major waterways, creeks, and waterways of Pasig City. (PUSO, 2022) Though this is not mapped in this study, further recommendations are integrated into the CRLUGP plan as linear parks, which are situated primarily on waterways, will be affected by these ISHs.

Using this information, a map of Pasig City barangays with attributes on area, temperature, land use, population, flood hazard, rainfall, elevation, roads, waterways, and number of schools was prepared to be integrated with KIIs and FGDs findings into further analysis.

2.2 Key Informant Interviews and Focus Group Discussions

The KIIs were conducted with the personnel of the concerned offices of LGU Pasig, namely the City Environment and Natural Office (City ENRO), City Planning Development Office (CPDO), City Parks and Playgrounds Office (CPPO) under the

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City Engineering’s Office (CEO). It aimed to understand each office’s role in Pasig City's greening efforts beyond tree planting and school gardens. Discussions focused on their scope, responsibilities, partnerships, existing green spaces, processes, challenges, and plans.

It has been discovered that LGU Pasig lacks formal guidelines for managing and maintaining UGS. CPPO is working on rehabilitating parks to ensure that the greenspaces are well-maintained (CPPO, 2022) while the City ENRO prunes trees and maintains them (City ENRO, 2022). However, this request is dependent on requests from the barangay LGU to whom existing greenspaces have been handed over.

On the other hand, the FGD was attended by a larger group of stakeholders, including some representatives from the DENR – National Capital Region (NCR).

The discussion centered around defining urban greening and green spaces in the context of Pasig, with participants emphasizing sustainability, aesthetics, and efficient land use. The city's existing vision for urban greening was reviewed, with suggestions to refine it further to encompass participatory governance, ecological balance, and a high quality of life.

Participants identified current green spaces and potential areas for development, particularly along riverbanks and underutilized spaces. They highlighted existing greening initiatives like vegetable gardens, vertical gardens, and the *"Oplan Kaayusan"* program while emphasizing the need for increased private sector participation. Challenges such as limited road space and resistance to reducing motor vehicle space were discussed, along with recommendations for utilizing legal easements and converting vacant spaces into green spaces. (CPDO, 2022)

The discussion further explored the impact of climate change on Pasig City and the role of green spaces in mitigating those effects. Participants recognized the importance of green spaces in managing rainwater, improving air quality, reducing urban heat island effects, and preventing flooding. Existing laws and policies like the Green Building Ordinance were mentioned, with a request for a comprehensive list of relevant regulations. (CPDO, 2022)

Lastly, participants proposed various spatial indicators to measure the success of urban greening initiatives, including the number of tree-lined streets, ambient temperature monitoring, coverage of shaded areas, improved air quality, and reduced flooding.

2.3 Greenspace Profile using GIS

Pasig City has a range of green spaces that include parks, recreational areas, street corridors, center islands, school vegetable gardens, urban gardens, and cemeteries. The increasing urbanization and population in the city have led to a need for more parks and recreation areas.

There are a total of 53 parks in Pasig City, with different sizes ranging from small pocket parks to larger linear parks. These parks are located in different areas, such as residential neighborhoods, waterways, institutional buildings, schools, and commercial areas. Notably, the Rainforest Adventure Experience (RAVE) park is one of the most popular parks in the city, covering an area of four (4) hectares. All 30 barangays in Pasig City have parks and green open spaces. As of 2020, the total area covered by parks, pocket parks, linear parks, and green open spaces in Pasig City is 40.9 hectares.

Pasig City also has other types of UGS, such as green corridors, linear green patches, green site edges, and green landscapes. These greenspaces cover an area of 15.63 hectares as of 2020.

Vegetation such as grass, shrubs, and trees only cover 67.77 hectares of Pasig City's total area. Major developers own a significant portion of these areas for future mixed-use development.

According to the consolidated inventory of greenspaces from LGU and additional data from digitized privately owned greenspaces, the total greenspace for Pasig City is 70.18 hectares. Figure 3 below presents all the consolidated greenspace in Pasig City. All of these data inputs are merged, forming the existing UGS of Pasig City.

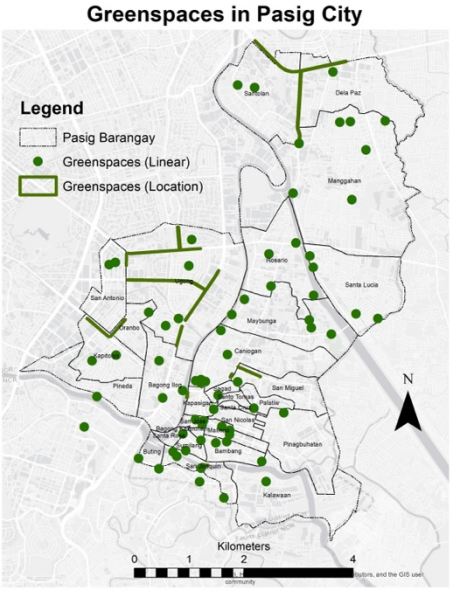

Figure 3. Existing Green Space in Pasig City

In 2020, Argamosa conducted a study on developing a tree cover model to reduce emissions from deforestation and forest degradation (REDD+) in the Philippines. The study utilized Light Detection and Ranging (LiDAR) and various multispectral data to estimate reference tree cover using Sentinel-2, Landsat 8, and MODIS. The stacked CatBoost regression model performed well, showing a linear relationship between the reference and predicted tree cover. The model trained using Sentinel-2 provided the highest accuracy (Argamosa, 2020).

This model was also used to create Pasig's Tree Cover Map. When using Sentinel 2 images, the Normalized Difference Vegetation Index (NDVI) was utilized as one of the variables to estimate canopy cover distribution and assess vegetation health. NDVI is calculated based on the variance between near-infrared and red light. Additionally, a machine learning algorithm called CatBoost, which employs decision trees for classification and regression, was used to learn and generalize from remotely sensed variables (ESRI, 2023); hence, the canopy cover in Pasig City was obtained.

The model enabled the researcher to predict the density of tree cover across an entire area based on satellite imagery. It is trained

to comprehend the relationship between the precise LiDAR data and the more general satellite data, thereby facilitating accurate predictions of tree cover over a larger area using the Sentinel 2 imagery. When applied to Pasig, it provides a comprehensive analysis of the spatial distribution of canopy cover across the entire city. The calculated canopy cover is used to determine the average tree cover per barangay in Pasig.

Barangay	Average Tree Cover (%)	Average Land Surface Temperature (°C)
Bambang	25.45	35.06
Palatiw	27.62	35.01
Santo Tomas	28.48	34.29
Pinagbuhatan	26.23	34.84
Santa Cruz	26.88	38.82
San Nicolas	28.11	34.75
Kapitolyo	27.83	34.73
Malinao	28.52	34.70
Sagad	28.59	34.63
Oranbo	32.26	34.55

Table 2. Top 10 Barangay and their tree cover and land surface temperature

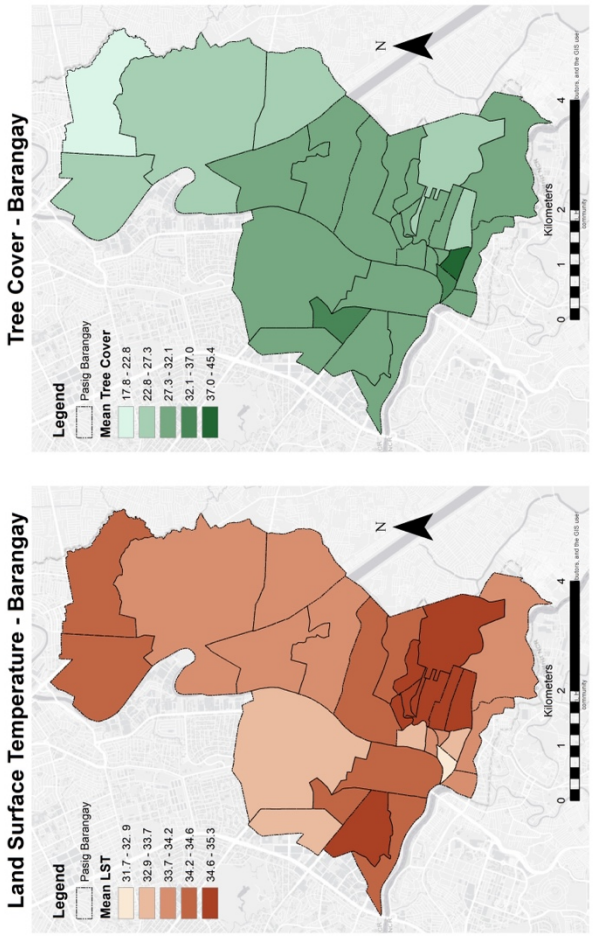

Figure 4. Average Tree Cover and Average Land Surface Temperature per Barangay, City of Pasig

The noticeable effect of climate change in Pasig City is an increase in temperature, which then affects the survival of the plants they are nurturing in their urban greening programs. The recorded hottest temperature in the city is 35.07 degrees Celsius.

The barangays with the highest Land Surface Temperature (LST) are Bambang, Palatiw, Santo Tomas, and Pinagbuhatan. The four (4) barangays also belong to the barangays with the least percentage of tree canopy cover. Barangay Dela Paz has the lowest rate (21.99%) of tree canopy cover. The top 10 barangays with the highest average land surface temperature and average tree cover are shown in Table 2, and Figure 4 depicts the average tree cover and average land surface temperature for each barangay of Pasig.

A more reliable visualization showing the average tree cover and average land surface temperature per 1 kilometer by 1 kilometer is shown in Figure 5.

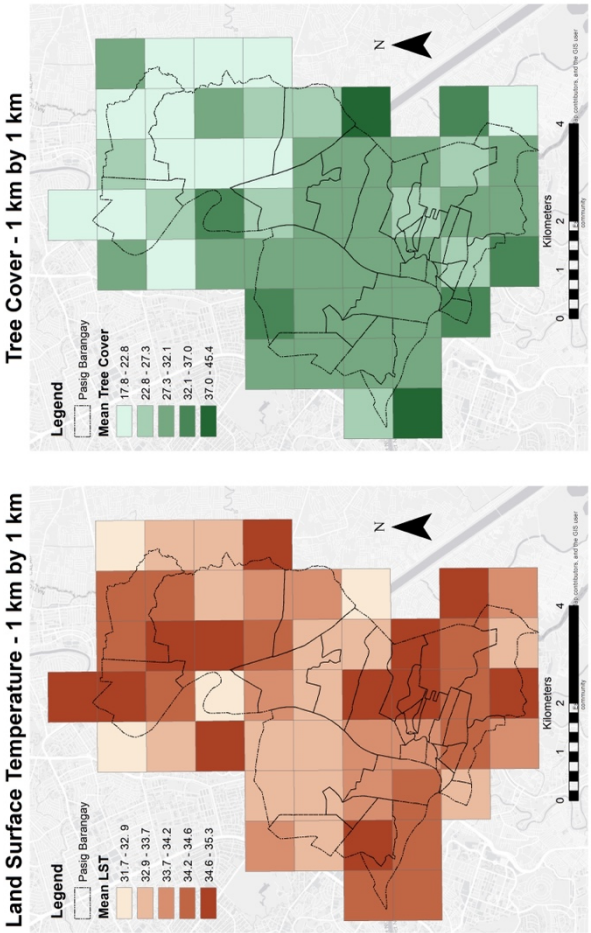

Figure 5. Average Tree Cover and Average Land Surface Temperature per 1 km by 1 km, City of Pasig

This study considers canopy cover greater than 40% green space. In order to effectively combat the urban heat island effect on a typical city block, a minimum of 40% canopy coverage is necessary to maximize the cooling impact of trees. (Ziter et.al., 2019) Based on the maps produced, it can be seen that there is an inverse relationship between the tree cover and temperature, with more tree cover giving a lower temperature.

The impact of climate change was also observed through the occurrence of flooding. In the city, flooding has worsened over time. This is due to various factors, including an abnormal rise in sea level that causes water to overflow from rivers and creeks and the accumulation of rainwater on drainage systems due to blockages or insufficient capacity.

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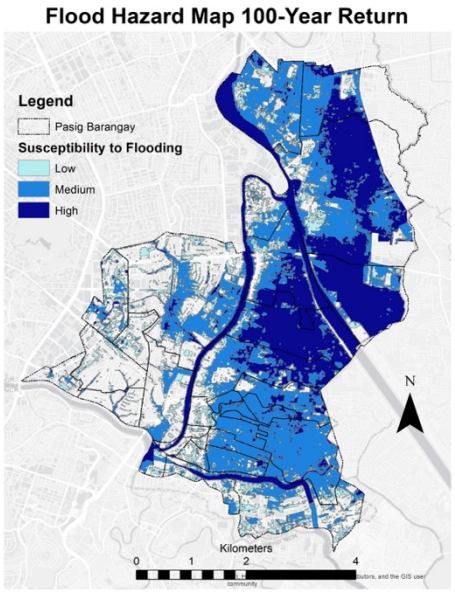

Figure 6. 100-year rain return Flood Hazard Map, City of Pasig (PAGASA, 2022)

The data in Figure 6 depicts the flood hazard that could occur in a 100-year rain return and has been obtained from the Nationwide Operational Assessment of Hazards (NOAH) under the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Based on this data, eleven (11) residential areas, namely Barangay Bagong Katipunan, Dela Paz, Malinao, Oranbo, Palatiw, Sagad, San Antonio, San Roque, Santa Cruz, and Ugong, have been identified as completely urbanized without any natural water bodies or vegetation cover. As seen in Figure 6, the land surface temperature is the same; barangays with no tree cover are those with higher susceptibility to flooding.

Figure 7. Validating Greenspaces in Pasig

For the validation process, consultants and representatives from LGU Pasig conducted site visits to specific urban greenspaces to evaluate their current condition. The first objective was to assess the potential impact of canopies on the heat and flooding issues experienced by the residents. Expert input from foresters and landscape architects was also sought to ensure that the appropriate tree species, capable of providing shade and mitigating flooding, are planted in the identified areas. Figure 7 showcases some of the validated areas visited during the assessment.

3. Results and Discussion

The use of GIS technology facilitated the integration of secondary and digitized data on urban green spaces, making it easier to visualize problem areas and identify priority locations. The resulting maps allowed consultants to effectively communicate to management and stakeholders the correlation between tree cover and the elevated temperatures associated with urban heat islands, as well as the heightened risk of flooding. As a result, they were able to devise strategies for enhancing existing green spaces.

3.1 Assessment of Existing Greenspaces

LGU Pasig has recognized the need for improved connectivity in their linear parks, as indicated by the maps they have created. They have identified narrow sidewalks and obstacles as barriers to the development of these parks. The proposed solution involves identifying the locations of overpasses and flyovers and integrating them into a network of green pathways. Shaded pathways, sidewalks, and street corridors can enhance walkability, which in turn can help reduce the reliance on transportation. (McKay, 2018)

They also plan to work with homeowners' associations to oversee the maintenance of open spaces in private properties and subdivisions.

Furthermore, there are legal easements that are currently not being utilized for greenery and are instead being occupied by homeless individuals and vagrants. Addressing this issue is a top priority in their action plan.

In areas highly susceptible to flooding, foresters recommend planting species that can mitigate flooding, such as Bottle Brush Tree, Red Cascade, or Callistemon. (Palec, 2022) Water-logged resistant species will be planted in gardens to help mitigate flooding (McKay, 2018).

In areas with the least amount of tree cover, it is recommended to plant trees with large canopy cover, such as Dita and Botong Tree (Palec, 2022). Additionally, strategically positioned trees can help cool the area and reduce energy consumption in buildings. Rooftop and vertical gardens can also contribute to cooling a built-up area. (McKay, 2018)

A portfolio of suggested species was also provided to LGU Pasig for ideal plants and trees for different environments, including Aunasin for understories, Araucaria or Norfolk Island Pine for parks, Neem Tree for commercial areas, and Ylang-Ylang for streetscaping/linear parks (Palec, 2022).

3.2 Allocation and Determination of Demand for Greenspaces Using GIS

Urban planners analyzed projections of future trends, and it shows that the trend of land use change from 2012-2021 shows that the city is moving towards more commercial and industrial development, with a decline in non-built-up areas from 2016-2021. This trend may exacerbate the existing flooding issues in the city.

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Additionally, meeting the land and space requirements in the future will be a challenge due to the increasing population. Using the computation of the Food and Agriculture Organization (FAO) standard area for urban uses, between 644.35-1,390.43 hectares of buildable land area will be required for Pasig City by the year 2031. However, the available land supply as of 2022 is only 40.39 hectares. Therefore, the city needs to implement various land supply management strategies, such as mixed-use development, in-filling of vacant lots, renewal and redevelopment of blighted areas, and increasing urban density in strategic locations. By doing so, the available land supply can be expanded to answer the needs of the growing population.

The data on public green spaces, digitized urban green spaces of private lands, and canopy cover from NDVI were collected and consolidated. This inventory shows Pasig City has 70.18 hectares of existing green space. Barangay Ugong has the most green spaces, while Barangay Kalawaan has the fewest. The amount of green space per barangay was also computed using spatial statistics.

The World Health Organization (WHO) recommends that a minimum of nine (9) square meters of green space should be available per individual. The ideal urban green space (UGS) value is 50 square meters per capita. (Russo & Cirella, 2018). Population data from the Philippine Statistics Agency (PSA) were used to project a 10-year period from 2022 to 2032 to calculate future allocation. The green space was computed by multiplying the minimum standard of 9 square meters per individual by the 2032 population of each barangay.

Name of barangay	Population 2020*	Population 2032* (Projected)	2032 Greenspace required*** (sq.m) 9.5 sqm per capita	2032 Greenspace required*** (hectares)	Existing greenspace (hectares)	Balance (hectares)
District 1						
1. Bagong Ilog	20,344	33,314	316,483.00	31.65	1.32	(30.33)
2. Bagong Katipunan	879	387	3,676.50	0.37	0.15	(0.22)
3. Bambang	20,801	21,179	201,200.50	20.12	1.30	(18.82)
4. Buting	10,348	8,695	82,602.50	8.26	2.17	(6.09)
5. Caniogan	28,086	29,432	279,604.00	27.96	1.52	(26.44)
6. Kalawaan	32,145	38,670	367,365.00	36.74	0.03	(36.71)
7. Kapasigan	4,774	3,323	31,568.50	3.16	3.21	0.05
8. Kapitolyo	9,203	3,987	37,876.50	3.79	1.40	(2.39)
9. Malinao	4,817	2,831	26,894.50	2.69	1.10	(1.59)
10. Oranbo	3,267	1,647	15,646.50	1.56	1.51	(0.05)
11. Palatiw	27,499	79,818	758,271.00	75.83	1.44	(74.39)
12. Pineda	19,499	23,345	221,777.50	22.18	1.61	(20.57)
13. Sagad	6,036	4,087	38,826.50	3.88	0.64	(3.24)
14. San Antonio	11,727	2,870	27,265.00	2.73	2.79	0.06
15. San Joaquin	13,823	15,511	147,354.50	14.74	1.09	(13.65)
16. San Jose	1,814	3,506	33,307.00	3.33	2.50	(0.83)
17. San Nicolas	2,602	4,454	42,313.00	4.23	4.03	(0.20)
18. Sta. Cruz	5,610	5,732	54,454.00	5.45	0.60	(4.85)
19. Sta. Rosa	1,015	990	9,405.00	0.94	1.10	0.16
20. Sto. Tomas	12,904	30,034	285,323.00	28.53	0.83	(27.70)
21. Sumilang	4,334	2,568	24,396.00	2.44	0.88	(1.56)
22. Ugong	28,737	54,087	513,826.50	51.38	10.16	(41.22)
District 2						
23. Dela Paz	19,804	18,944	179,968.00	18.00	1.35	(16.65)
24. Manggahan	88,078	74,905	711,597.50	71.16	4.44	(66.72)
25. Maybunga	45,555	77,055	732,022.50	73.20	7.10	(66.10)
26. Pinagbuhatan	163,598	197,278	1,874,141.00	187.41	3.06	(184.35)
27. Rosario	73,979	116,861	1,110,179.50	111.02	3.46	(107.56)
28. San Miguel	40,199	79,189	752,295.50	75.23	1.24	(73.99)
29. Sta. Lucia	43,749	41,799	397,090.50	39.71	4.45	(35.26)
30. Santolan	57,933	71,815	682,242.50	68.22	3.70	(30.33)
TOTAL	**803,159**	**1,048,313**	**9,958,973.50**	**995.90**	**70.18**	**(925.72)**

Table 3: Allocation and Demand for Greenspaces

Table 3 shows a concise overview of the status of green space in Pasig City. After analyzing the data, it becomes evident that the city must cultivate 925.72 hectares of green space by 2032 to meet the mandatory standards. Among the barangays, Kapasigan, San Antonio, and Sta. Rosa has already met the green space requirements and does not require any further development. However, Barangay Pinagbuhatan has a significant shortfall in green space and will need maximum development by 2032.

This demand for additional greenspaces will continue to grow as the population increases. To achieve the required area by 2032, the city must create 92.57 hectares of new greenspaces annually.

Using the maps provided, City ENRO was able to look for undeveloped areas that have the potential for greening. Aside from tree planting activities, City ENRO would continue to establish vertical wall gardens in public schools. Also, suppose the existing 241 schools in Pasig City will strictly adhere to the Department of Education (DepEd) Memorandum No. 223 series of 2016, which requires a 200 square meter area for a vegetable garden in each public elementary and secondary school as part of the Gulayan sa Paaralan Program (DepEd, 2016). In that case, Pasig can gain about 5 hectares of UGS from this initiative.

CPPO will continue the construction of linear parks along creeks and rivers traversing Pasig City. Aside from linear parks, the office is also creating greenspaces on the corridors of bridges and establishing vertical wall gardens in established and existing parks. Also, per Presidential Decree (PD) 957 or the Subdivision and Condominiums Buyers Decree, by strictly implementing at least the 26 kilometers of national road of Pasig, the provision of 1.3 m planting strips to roads with 15-meter width (OP, 1976) then, the LGU can achieve an additional 7 hectares of UGS.

The DENR-NCR, in partnership with the Manila Bay Rehabilitation Program, is also continuously looking for potential areas in Pasig City for greening. They also establish linear parks and pocket parks under the rehabilitation program.

4. Conclusion and Recommendations

The CRLUGP for Pasig City is a crucial step towards developing a sustainable and climate-resilient urban environment. The collaborative effort between LGU Pasig and DENR to develop the CRLUGP is a testament to the growing commitment to sustainable urban development in the face of climate change.

The plan was created through extensive data gathering, KIIs, FGDs, and analysis using different spatial technology. By leveraging spatial technologies and the insights from various stakeholders, meticulous mapping and analysis of existing green spaces, coupled with the identification of potential areas for expansion, lays a strong foundation for data-driven decision-making in urban greening efforts. GIS and RS significantly enhanced the efficiency of drafting the plan by providing extensive information from remotely sensed data, enabling more precise mapping than manual overlays, covering difficult-to-access areas, and also allowing integration with various data types, facilitating a more comprehensive analysis, better decision-making, and cutting down expenses.

The CRLUGP provides a comprehensive framework for increasing greenspaces, improving urban biodiversity, and mitigating the impacts of climate change. It addresses key environmental challenges such as the urban heat island effect, flooding, and the decline in non-built-up areas. By mapping and analyzing greenspace distribution, urban heat variations, and flood-prone areas, the plan offers a data-driven strategy for addressing environmental concerns while fostering community well-being.

4.1 Conclusion

The study conducted GIS, RS, and ML analyses to gain insights into the current state of greenspaces in Pasig City and to identify the issues posed by climate change and rapid urbanization.

Using GIS, the researchers created a comprehensive spatial inventory of existing greenspaces, which included public parks, private green areas, and land cover. This data-driven approach allowed for accurate mapping of green infrastructure across the city, providing a baseline for further urban greening efforts.

The RS techniques used Sentinel 2 satellite imagery to offer a detailed view of canopy cover through the NDVI. Integrating RS with GIS data enabled the identification of regions with lower canopy cover, which corresponded to higher urban heat island effects and increased flood risks.

ML played a pivotal role in analyzing the relationship between climate risks and greenspace distribution. The study used the CatBoost algorithm to model tree canopy cover across Pasig City, demonstrating that ML can effectively predict canopy cover based on remotely sensed data. This facilitated the examination of climate-related impacts, such as rising land surface temperatures, showing a clear correlation between low tree cover and higher temperatures. The analysis also highlighted the increased flood risks in areas with limited greenspaces, further emphasizing the need for sustainable urban greening.

The spatial analysis indicated that Pasig City's existing greenspace, totaling 70.18 hectares, is significantly below the recommended standards. To meet the World Health Organization's minimum requirement of 9 square meters of green space for each individual by 2032, Pasig City needs to create an additional 925.72 hectares of green space. This necessitates developing 92.57 hectares of new greenspaces annually.

In conclusion, the spatial analysis results underscore the pressing need for Pasig City to expand its greenspaces strategically.

4.2 Recommendations for Updating the Urban Greening Plan

The CRLUGP should be promptly translated from a plan into action. The identified potential green spaces should be prioritized for development based on their potential impact on climate resilience, ecological balance, and community well-being.

It is also recommended to invest in capacity building, especially in training for GIS, running the ML model, and using sustainable urban planning principles. This will enable the personnel involved in greening initiatives to plan and monitor their projects independently. Mapping the air quality and relating it to UGS can help improve the CRLUGP as well.

Moving forward, during monitoring and evaluation, LGU Pasig should maintain a database of the initial data of the CRLUGP. This will allow the LGU to track its improvement and success more efficiently. It is recommended that the following spatial initiatives be included in the updating and enhancement of the Urban Greening Plan.

1) Mapping of the implementation of Presidential Decree (PD) 1216, which mandates 30% open space for every residential subdivision (OP, 1977)
2) Integrating the urban forest, geotagging all trees, and creating a database with species type, health condition, pole size, and age attributes.
3) Mapping primary to tertiary roads and utilizing GIS to ensure compliance with required planting strip sizes per road type per PD 957.
4) Mapping areas practicing urban food forestry, sustainable vegetable gardens, and integrating gardening rooftops and balconies into urban gardening areas.
5) Mapping riverbank easements and reclaiming them as linear parks phase by phase from ISH.
6) Mapping schools and implementing the *Gulayan sa Paaralan* Program.
7) Mapping commercial and industrial infrastructure and ensuring compliance with the Green Building Code of the Philippines, which is a referral code of the National Building Code of the Philippines (DPWH, 2021)

As urbanization continues to expand, the local government needs help in implementing urban greening initiatives. However, with thorough planning, the use of geospatial techniques, careful selection of suitable plant species, and strict enforcement, Metro Manila can look forward to the development of an ecological, visually appealing, and sustainable environment.

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