

Urban Landscape Change Effects on Flood Resilience in the Ecological Structure of University Belt, Manila, Philippines

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Abstract. Through biotope mapping and assessment, this study evaluated the ecological structure of the University Belt watershed in highly urbanized Manila, vulnerable to flooding due to proximity to the Pasig River and Manila Bay. An Ecological Plan was proposed to enhance the ecological value and flood resilience of Existing Ecological Structures in the site. Seven (7) biotopes were identified. Coastal Green Space and Lowland Green Space, located near the coast, comprised 8.95% of total land area (2450 ha). Urban, Industrial, Residential, Institutional, and Informal Settlements, dominant built-up areas, comprised 91.05% of total land area. Coastal Green Space garnered D2, A6, R4, and H3 biotope assessment ratings, while Lowland Green Space scored D1, A7, R4, and H2, underscoring their high ecological value. Intramuros Green Space, Rizal Park, and Malacañang Green Space were identified as three (3) Ecological Cores having high ecological value. Several strategies were proposed to improve the site's ecological value and flood resilience. Preservation and expansion of the Ecological Cores were recommended to mitigate stormwater runoff. Interventions such as vegetated river embankments were suggested for Corridors to limit encroachment of impervious surfaces near waterways. Along the Ecological Edge, protecting green spaces was advised to mitigate coastal development impacts

1 Introduction

1.1 The University Belt in Manila, Philippines

The City of Manila, Philippines has been becoming increasingly urbanized since the Spanish colonial period in the 16th to 19th century, wherein Intramuros served as the walled capital for the Hispanic occupation. Several Higher Education Institutions (HEIs) within and outside Intramuros were first established during this period, such as the University of Santo Tomas (UST). During the American occupation in the early- to mid-20th century, American architect Daniel H. Burnham prepared a masterplan for the City of Manila that included an educational hub, among other features. However, this masterplan was not fully realized, and post-World War II urban development was characterized by uncontrolled urban sprawl. Nevertheless, more HEIs were established in Manila, and many of these were built in close proximity within a district that came to be known as the University Belt [1].

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The term “University Belt”, first coined in 1975 by Paul P. Zwaenepoel, has been used both formally and informally to refer to this conglomeration of HEIs [1]. The University Belt includes road networks that extend from España Boulevard to Taft Avenue and encompasses the districts of Sampaloc, Quiapo, San Miguel, Ermita, Intramuros, and Malate [1]. Although some green spaces such as the UST campus grounds, the Intramuros Golf Course, and Rizal Park are present, much of the University Belt area consists of built-up concrete structures and asphalt-paved surfaces [1].

1.2 Flooding in the University Belt

The University Belt district intersects with the Pasig River, a major waterway that feeds into Manila Bay, to which the district is also nearby. These factors along with the lack of permeable surfaces render the University Belt area and its HEIs highly vulnerable to flooding. Typhoon Ondoy (international name Hurricane Ketsana) produced floods that reached neck height due to impermeable surfaces [2]. UST’s overnight provisions of food and shelter for 1,500 stranded students in 2012 and the implementation of “no-walk zones” by the Manila local government unit (LGU) in 2015 [3, 4] were some of the adaptations that Manila had for flooding in the area. Consequently, suspension of classes from primary to tertiary levels due to heavy rain and flooding is common [5].

Government-led efforts such as road and drainage infrastructure projects have been done to address these flooding issues [6], but such initiatives focused on gray infrastructure that did not reduce surface impermeability. On the other hand, blue-green infrastructure (BGI) projects have been shown to mitigate urban flooding by increasing permeable surfaces and allowing stormwater runoff to be detained and percolate underground. A prime example of BGI is Bishan Ang Mo Kio Park in Singapore, wherein a former concrete drainage channel was re-naturalized into a vegetated space with 40% increased conveyance capacity for stormwater runoff [7].

1.3 Biotope mapping

Developing a flood-resilient BGI network entails identifying existing green spaces and hydrological networks in a given region through biotope mapping, a process of identifying habitats and landscape units, and studying the present physical and biological conditions of these ecological structures to evaluate the significance of open spaces and, specifically for this study in the context of flood management [8-9].

The ecological structures of several urban and peri-urban landscapes have been mapped and identified through biotope mapping, allowing insightful analyses of their ecological value. Local Philippine biotope mapping studies include a planning study on *Susong Dalaga*, a karst landscape in Quirino, Philippines. The study used a biotope-focused planning approach that informed the ecological management of the karst landscape, including surrounding *barangays* (smallest Philippine administrative unit) [10]. Another study done in San Mariano, Isabela, Philippines employed a biotope mapping process to allow comprehensive assessment and understanding of the different biotopes in the regional landscape, thereby informing strategies for forest conservation and management. The study also prepared conceptual cross-section diagrams to visually represent the profiles of each identified biotope [11].

International studies that employed biotope mapping includes one conducted in Antalya, Turkey. The study combined the selective biotope mapping approach with a biotope sensitivity analysis method to assess the sensitivity of its urban biotopes to disturbances, based on two criteria: rarity and re-establishment ability of each biotope. Many of the biotopes in the study site were found to be sensitive to highly sensitive to human disturbance, a result of inadequate urban management and lack of an ecological approach to its urban planning [12]. A Mexico City study supplemented their biotope mapping approach with statistical modelling to investigate biotope

mapping accuracy at two (2) scales of biotope classes: broader-level class defined by canopy cover, and finer-level class describing urban forest characteristics. The study found that broader-level biotope mapping yielded better prediction results compared to finer-level biotope mapping and recommended augmenting its accuracy by incorporating more field and spatial data [13].

1.4 Research goals

Biotope mapping allows for a unique spatial approach in assessing landscapes of different scales to inform ecological management and policy development from a landscape ecological perspective. However, application of biotope mapping is limited in the international context and more so in the local Philippine context. While many of the existing biotope mapping studies were conducted in urban sites, none have been done in the context of flood management. The hydrological dynamics of urban areas can be characterized by prevalence of impervious surfaces and of flash floods driven by the urban heat island effect [14], all of which can be addressed through urban green space.

Factors that contribute to the ecological value of a green space include area coverage, complexity of vegetative structure, ecological community development time, and rarity of said communities [15]. Improvement in these factors such as through development of BGI can result in greater delivery of ecosystem services such as flood mitigation.

This study evaluated the existing ecological structure of the University Belt area through Biotope Mapping and proposed an Ecological Plan through several management strategies that enhance the ecological value and flood resilience of the district. Specifically, the study aimed (1) to identify the existing biotopes and ecological structures of the University Belt district in Manila, Philippines; (2) to determine the ecological value of each biotope and ecological structure, and (3) to develop an Ecological Plan addressing the flood management issues in the University Belt district. The study hypothesizes that an ecological management approach focused on improving urban green space coverage and connectivity can enhance the resilience of the University Belt district and its HEIs to urban flooding.

2 Methods

2.1 Delineation of site boundaries

The extents of the University Belt dictated the minimum extents of the site boundaries. From this, the watershed was delineated by identifying high elevation points in the topography, represented as red dots in Figure 1, then connected to the pour-point of the Pasig River. Through this process, watershed with a total area of 2,450 hectares was delineated.

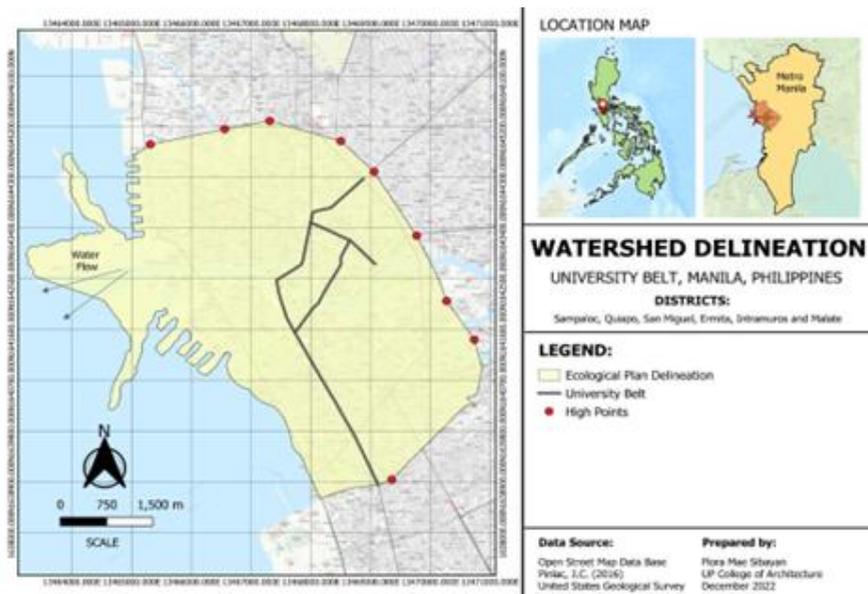


Fig. 1. Watershed Delineation of the University Belt Study Site.

2.2 Biotope mapping approach

To map the ecological structure of the University Belt site, the selective biotope mapping approach was used, which involves characterizing urban green spaces worthy or potentially worthy of protection, as well as a less intensive data acquisition process [8].

Biotope maps allow identifying and categorizing different spatial environments and communities to facilitate analysis of and planning for a flood-resilient Ecological Structure of a region. Biotope maps can be generated from three (3) land classification maps: soil map, landform map, and land cover map. These maps are used to indicate hydro-geological features, plant diversity from soil characteristics, urbanization conditions, and remaining green spaces [9]. Data and classification for the soil map was based on the Open Land Map Soil Texture Class (USDA System), accessed through Google Earth Engine. Data for the landform map was acquired from the OpenStreetMap Database. Land cover map data was acquired from the CGLS-LC100 Collection 3 layer of the Copernicus Global Land Cover database, accessed via OpenStreetMap as well.

The hydrological network within the study site, which includes existing rivers, streams, and esteros, was also delineated in the biotope map to inform the ecological connectivity of high-value biotopes in the site.

Table 1. Biotope Assessment Criteria (adapted from referenced study) [15].

Criterion	Description	Rating
Period of Development (D)	Duration the community will take to establish itself elsewhere.	D0 = 1-2 years
		D1 = 2-5 years
		D2 = 5 - 10 years
		D3 = 10 - 20 years
		A0 = 0.1 ha
		A1 = 0.1 -< 1 ha
		A2 = 1-<5 ha

Area (A)	The larger the area the greater the probability of a species-diverse community.	A3 = 5-<10 ha
		A4 = 10-<25 ha
		A5 = 25-<50 ha
		A6 = 50-<100 ha
		A7 = 100-<200 ha
		A8 = 200+ ha
Rarity (R)	Occurrence of the said biotope or habitat patch.	R0 = many similar biotopes occurring in the built-up area, the nearest equivalent being < 500m away
		R1 = several similar biotopes, the nearest equivalent being 500-1000 m away
		R2 = several similar biotopes, the nearest being 1-2 km away
		R3 = nearest equivalent biotope > 2 km away, or only 5-10 corresponding biotopes in the whole built-up area
		R4 = only 1-4 equivalent biotopes
		R5 = no equivalent biotopes in the built-up area but existing in remaining urban areas or within adjoining communities up to 5 km from the city boundary
		R6 = no equivalent biotope in the whole urban area and local surroundings but > 5 in the total administrative area
		R7 = no more than 5 equivalent biotopes in the whole metropolitan county area
Habitat (H)	Quantity of vegetation structure found.	H0 = almost exclusively grass or trampled ground
		H1 = almost exclusively a uniform vegetation structure other than grass or trampled ground
		H2 = two different vegetation structures
		H3, H4 etc. correspondingly increasing number of vegetation structures by one each time

2.3 Biotope assessment

The ecological value of each biotope identified from the biotope map was assessed through four (4) criteria: Period of Development, Area, Rarity, and Habitat [15]. Period of Development (D) refers to the time required for the ecological community of a biotope to develop and establish itself elsewhere. Communities requiring longer development time such as mangrove forests are considered to have greater value over those needing less time to develop, such as open fields. Area (A) indicates the total spatial coverage of the biotope. Larger biotopes imply greater capacity to host a species-diverse community, hence are valued higher than smaller biotopes. Rarity (R) denotes the uniqueness of a biotope in an area. A biotope is said to be high value if there are less similar biotopes within a given distance, i.e. if the biotope is more isolated from similar biotopes. Lastly, Habitat (H) refers to vegetative structure diversity and complexity. Simple vegetative structures such as lawn areas are considered to have low ecological value,

while those with more complex structures such as multi-layered forests have greater ecological value [15]. Table 1 lists in detail the values, descriptions, and scoring for each given criterion. In addition, the biotopes were classified as either Natural or Built-up biotopes.

2.4 Ecological planning

Each individual biotope was assessed and classified under a major biotope category, allowing for the Existing Ecological Structures of the site to be determined. Clustered biotopes with the highest value were determined to be Ecological Cores, whereas high value but isolated biotopes were considered Ecological Patches. High value biotopes located near the shoreline were identified as Ecological Edges. Existing hydrological networks including streams, esteros, and rivers were considered Ecological Corridors.

Once Existing Ecological Structures were identified, an ecological plan was developed by recommending six (6) general management strategies to improve the ecological value of the Existing Ecological Structure and flood resilience of the study site: Preservation, Conservation, Conversion, Creation, Improvement, and Redevelopment (Table 2). Preservation involves the strictest restriction of human access and development in the most highly valued Ecological Structures to retain its ecological integrity. Similarly, Conservation seeks to retain ecological integrity but permits limited human access and development. Conversion entails drastic changes to the function of select Ecological structures to improve their otherwise lower ecological value. Creation involves the development of new high-value biotopes in areas with no ecological value, such as parking lots with impermeable pavement. Improvement entails enhancing biotopes with already high ecological value and may involve expansion of existing green development projects. Lastly, Redevelopment entails minor adjustments to an Ecological Structure to enhance its ecological value but still retain its original functions.

Table 2. General Management Strategies (adapted from reference study) [9].

Management Strategy	Description	Approximate Range of Biotope Assessment Scores
<i>Preservation</i>	Strictest restriction of human access and development. Applied to the most high-valued biotopes	Very High D score, low to high A score, High R score, and very high H score.
<i>Conservation</i>	Limited permission for human access and development. Applied to high-valued biotopes that directly experience limited anthropogenic impacts	Medium to High D score, low to high A score, High R score, and High H score
<i>Conversion</i>	Drastic changes to the function of select biotopes to improve their otherwise lower ecological value.	Very low D score, medium to high A score, very low R score, and very low H score
<i>Creation</i>	Development of new high-value biotopes in areas with no ecological value such as parking lots with impermeable pavement.	Very low D score, medium to high A score, very low R score, and very low H score
<i>Improvement</i>	Enhance biotopes with already high ecological value. May involve expansion of existing green development projects.	Low to medium D score, medium to high A score, low to medium R score, and low to medium H score
<i>Redevelopment</i>	Minor adjustments to biotopes to enhance ecological value but still retain their original functions.	Low to medium D score, medium to high A score, low to medium R score, and low to medium H score

2.5 Scope and limitations

This study was developed to demonstrate the potential of purely remote-sensing approaches in mapping and ecological assessment hence field validation was outside the scope of the study. The limitations of this approach have been acknowledged, since previous biotope mapping studies highlighted the value of ground-truthing through field data [12-13]. Nonetheless, this study still presents valuable insights into the flood management of the University Belt district through a spatial approach. Future research that builds upon this study is implored to supplement their biotope mapping approach with field data.

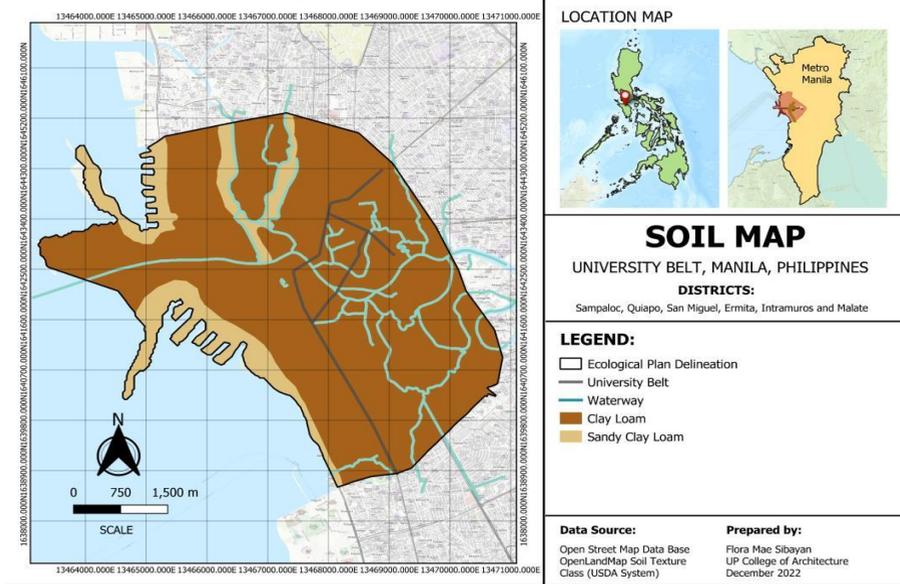


Fig. 2. Soil Map of the University Belt Study Site.

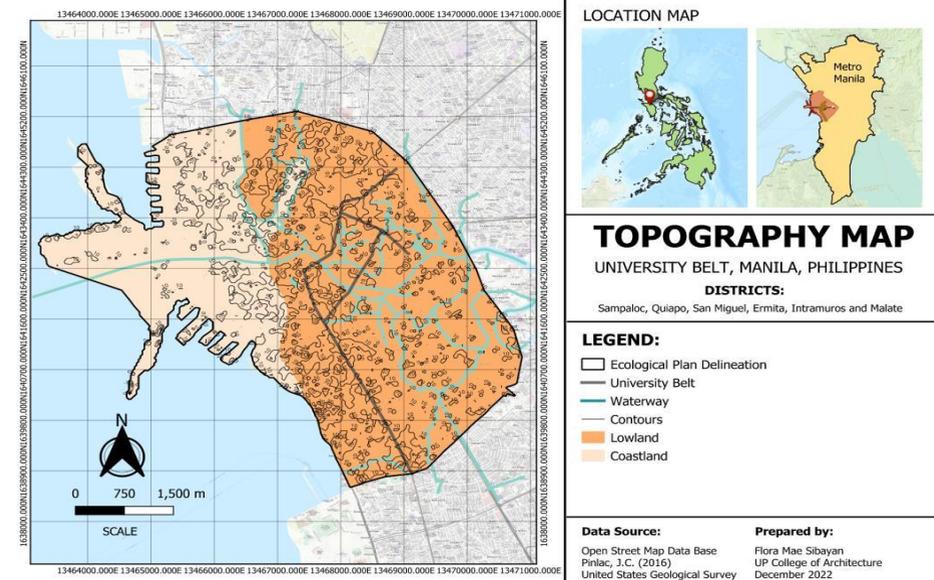


Fig. 3. Landform Map of the University Belt Study Site.

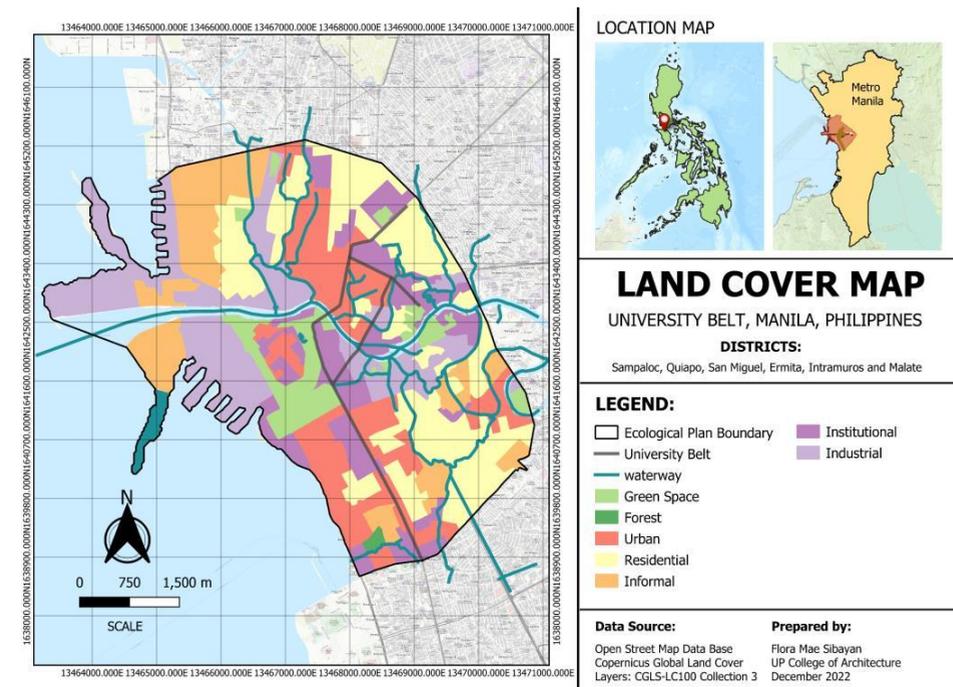


Fig. 4. Land Cover Map of the University Belt Study Site.

3 Results and discussion

3.1 Biotope mapping

Soil mapping showed that much of the study site, especially the entire lowland and many coastal areas consisted of clay loam soil. Sandy clay loam comprised the soil of areas located along or near the coast and areas surrounding major and minor waterways and networks in the study site (Figure 2). Landform mapping showed that much of the study site is flat and under 20 meters above sea level. Hence, landforms in the study site were identified as Lowland and Coastland (Figure 3). Built-up urban and residential areas dominate the land cover of the study site. The high level or degree of development found on site is also reflected by the accumulation of various institutions and industries (Figure 4). Table 3 presents the Biotope Matrix enumerating the soil, land cover, and landform characteristics of each biotope.

Table 3. Biotope Matrix enumerates the soil, land cover, and landform characteristics of each biotope.

Unit	Soil	AREA (hectares)	Land Cover	Landform	Biotope
1	CL	75.07	Green Space	Coastal	Coastal Green Space
2	SCL	25.08	Urban	Coastal	Coastal Urban Area
3	CL	73.26	Residential	Coastal	Coastal Residential Area
4	CL	224.99	Informal	Coastal	Coastal Informal Settlement
5	CL	60.61	Institution	Coastal	Coastal Institution
6	CL	342.22	Industrial	Coastal	Coastal Industry
7	CL	144.14	Green Space	Lowland	Lowland Green Space

8	CL	370.73	Urban	Lowland	Lowland Urban Area
9	CL	519.42	Residential	Lowland	Lowland Residential
10	CL	100.95	Informal	Lowland	Lowland Informal Settlement
11	CL	354.61	Institution	Lowland	Lowland Institution
12	SCL	158.92	Industry	Lowland	Lowland Industry
	Total Area:	2450.00			

SCL= sandy clay loam; CL = clay loam.

Figure 5 shows the biotopes identified from the land classification maps. Two (2) natural biotopes and ten (10) built-up biotopes were identified. Natural biotopes include coastal green spaces and lowland green spaces, both dominated by managed vegetated landscapes, comprised 75.07 ha (3.06%) and 144.14 ha (5.88%) of the total site area (2,450.00 ha), respectively. In total, green spaces comprised only 219.21 ha (8.95%) of the total site area. Notable examples of lowland green space biotopes include the turfgrass-dominated Intramuros Golf Course, as well as public parks and civic spaces such as Rizal Park and Malacañang Park. Built-up biotopes comprised 91.05% (2230.79 ha) of the total site area. Urban (395.82 ha, 16.16%), Industrial (501.14 ha, 20.45%), Residential (592.68 ha, 24.19%), Institutional (415.22 ha, 16.95%), and Informal Settlements (325.94 ha, 13.30%) were prevalent across both the coastland and lowland areas. Table 4 enumerates the assessment for each biotope.

Biotopes with the highest ratings for Period of Development (D), Rarity (R), and Habitat (H) are Coastal Green Space (D2, R4, H3) and Lowland Green Space (D1, R4, H7). Coastal Green Space had one of the lower Area (A) ratings of A6, tying with Coastal Residential Area and Coastal Institution. Only Coastal Urban Area had a lower rating at A5. Lowland Green Space had a higher A rating at A7. Overall, these ratings suggest that Coastal Green Space and Lowland Green Space have the highest ecological value among all other biotopes, hence would comprise the Existing Ecological Cores of the site

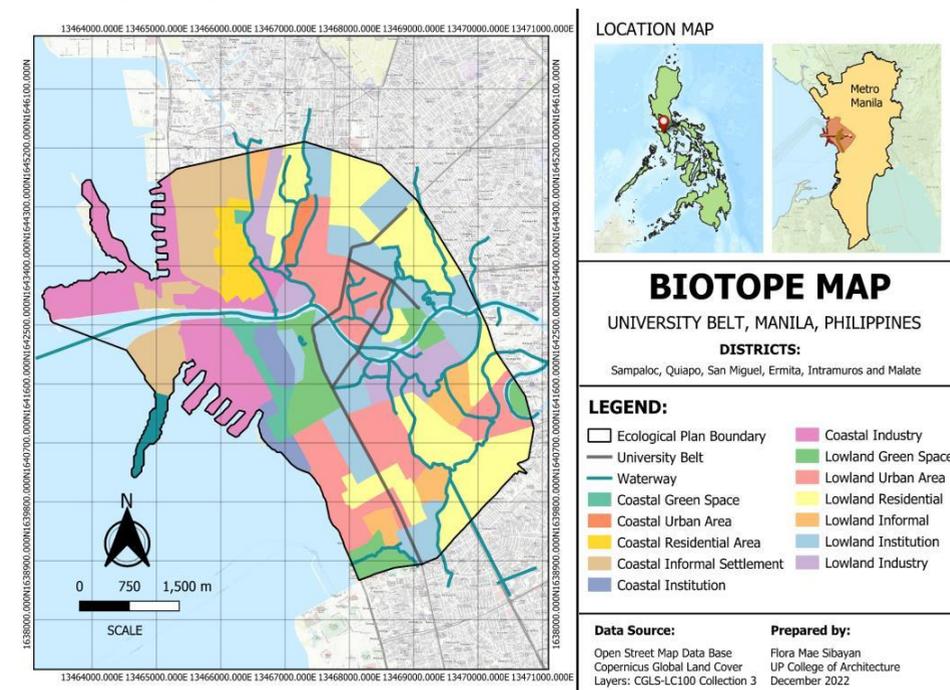


Fig. 5. Biotope Map of the University Belt Study Site.

Table 4. Biotope Assessment Matrix enumerating the ratings for each biotope.

Unit	Biotope	D	A	R	H
1	Coastal Green Space	D2	A6	R4	H3
2	Coastal Urban Area	D0	A5	R0	H0
3	Coastal Residential Area	D0	A6	R0	H0
4	Coastal Informal Settlement	D0	A8	R0	H0
5	Coastal Institution	D0	A6	R0	H0
6	Coastal Industry	D0	A8	R0	H0
7	Lowland Green Space	D1	A7	R4	H2
8	Lowland Urban Area	D0	A8	R0	H0
9	Lowland Residential	D0	A8	R0	H0
10	Lowland Informal Settlement	D0	A7	R0	H0
11	Lowland Institution	D0	A8	R0	H0
12	Lowland Industry	D0	A7	R0	H0

D = Period of Development rating, A = Area rating, R = Rarity rating, and H = Habitat rating.

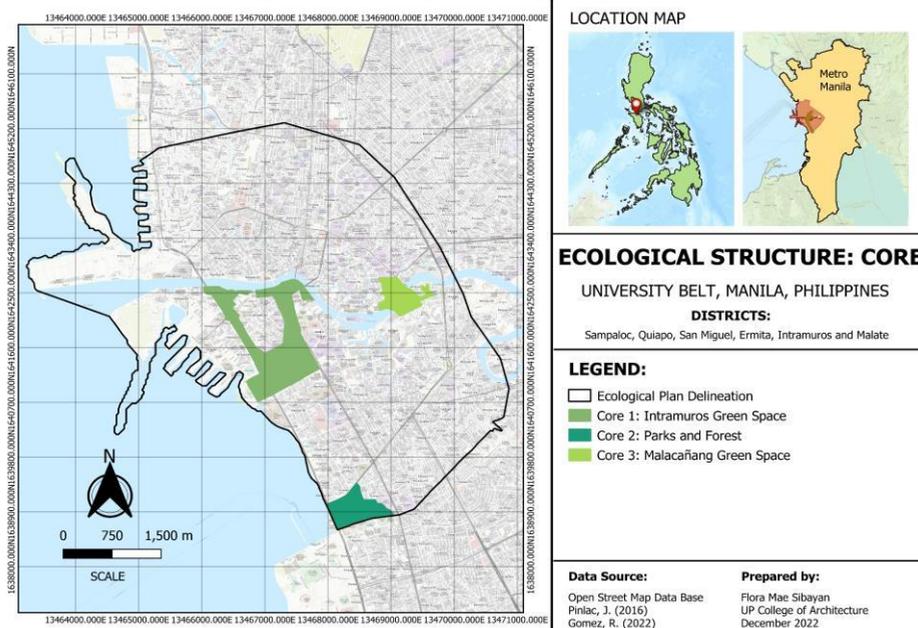


Fig. 6. Existing Ecological Cores in the University Belt Study Site.

3.2 Existing ecological structures

3.2.1 Existing cores

Larger or clustered biotopes with the highest ecological value were determined to be the Ecological Cores that provide significant urban ecosystem services, especially flood mitigation (Figure 6). Three (3) Cores were identified in the study site: (1) The Intramuros Green Space, comprising the largest cluster of green spaces in the site at 116.6 ha, (2) Parks and Forest which are comprised of the Rizal Park and surrounding greenery (35.22 ha), and (3) The Malacañang Green Space (22.78 ha) in which the Malacañang Palace, the seat of the Philippine national

government, is located. Table 5 summarizes the area coverage of each core as well as the biotopes that comprise each one.

Table 5. Existing Ecological Cores in the University Belt study site.

Unit	Name of Core	Biotopes within Core	Area of Each Biotope (hectares)	Area of Core (hectares)
Core 1	Intramuros Green Space	Coastal Green Space	45.67	116.60
		Lowland Green Space	70.93	
Core 2	Parks and Forest	Lowland Green Space	35.22	35.22
Core 3	Malacañang Green Space	Lowland Green Space	22.78	22.78
			Total Core Area:	174.60
			Percentage (%) of Total Site Area:	7.13%

3.2.2 Existing patc

Isolated biotopes with high ecological value were considered as Ecological Patches, which feature green spaces distinct from the surrounding gray infrastructure (Figure 7). These patches are either underdeveloped lots with spontaneous vegetation or are part of private or institutional lots. Though only a few isolated Patches were identified in the study site, they nonetheless contribute to mitigating urban flooding by virtue of green space permeability and stormwater runoff detention.

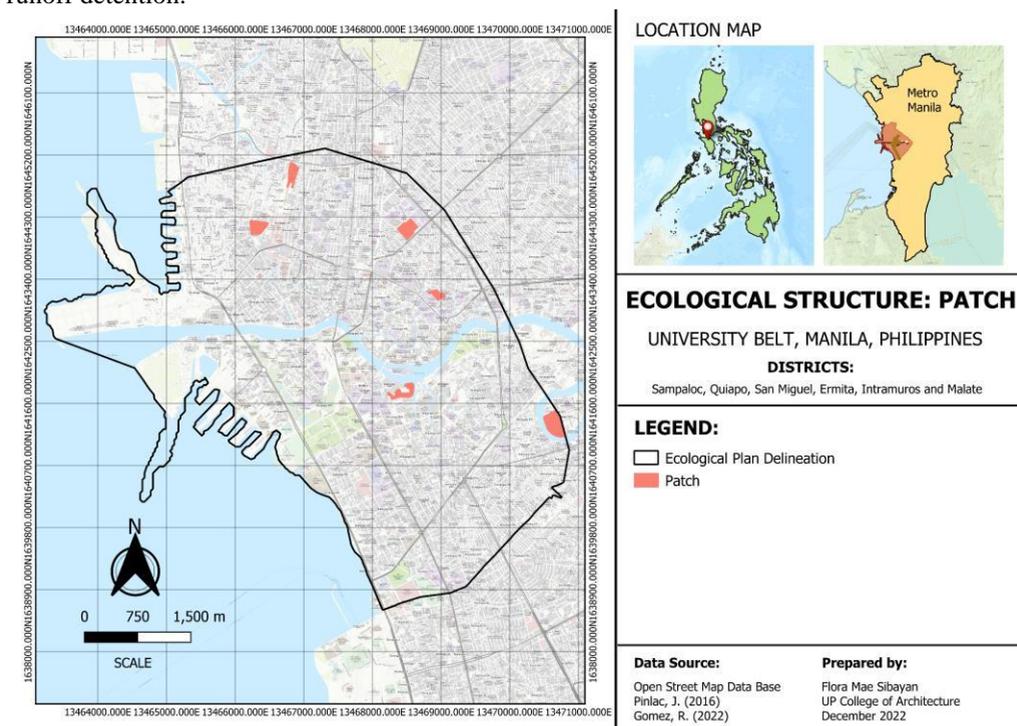


Fig. 7. Existing Ecological Patches in the University Belt Study Site.

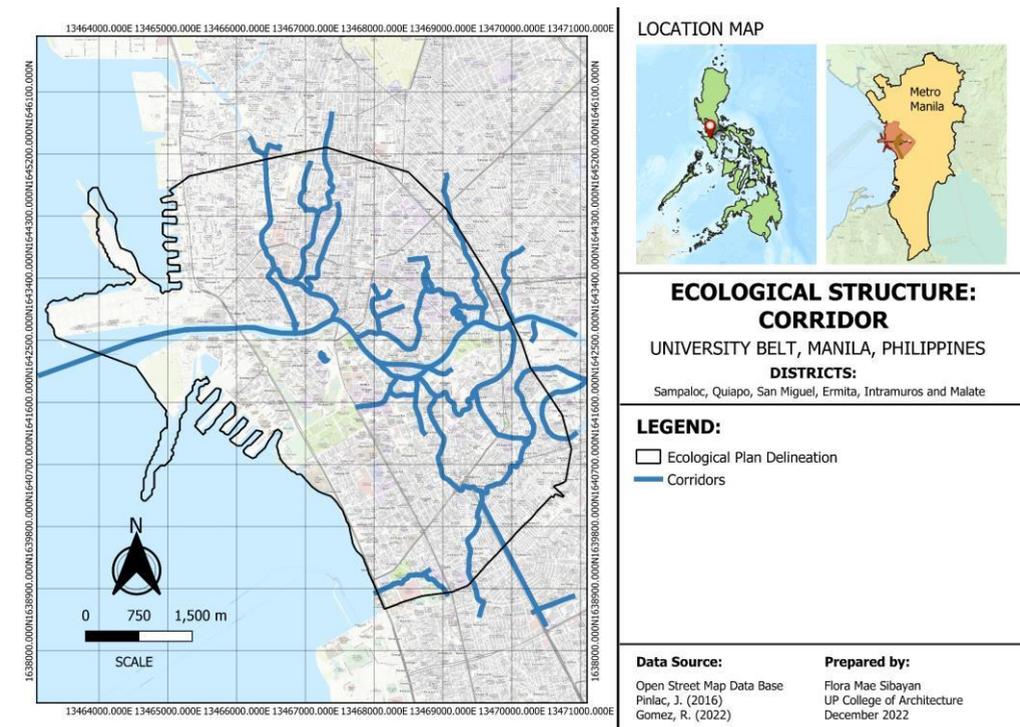


Fig. 8. Existing Ecological Corridors in the University Belt Study Site.

3.2.3 Existing corridors

The existing water network of the study site, which includes streams, esteros, and the Pasig River, comprise the Ecological Corridors, shown in Figure 8. The Corridors traverse throughout the study site and facilitate ecological connectivity between upland, lowland, and coastal environments. Corridors may allow movement of populations between habitats in urban and peri-urban regions. The significant spatial coverage of the Corridor network means many areas within the study site are exposed to varying levels of flooding.

3.2.4 Existing edge

Through biotope mapping and assessment, several Existing Ecological Structures were identified and mapped in Figure 8. Composed mostly of port-related structures, areas along or near the coastline of Manila Bay were determined to be the Ecological Edge of the study site. The Edge serves as the ecological interface between terrestrial and marine environments and processes, notably storm surges and coastal inundation. The Existing Edge of this site is notable for being mostly comprised of built-up areas, hence may be less effective in coastal protection. Figure 8 maps out the Ecological Edge of the study site. Figure 10 shows all Existing Ecological Structures of the site on one map.

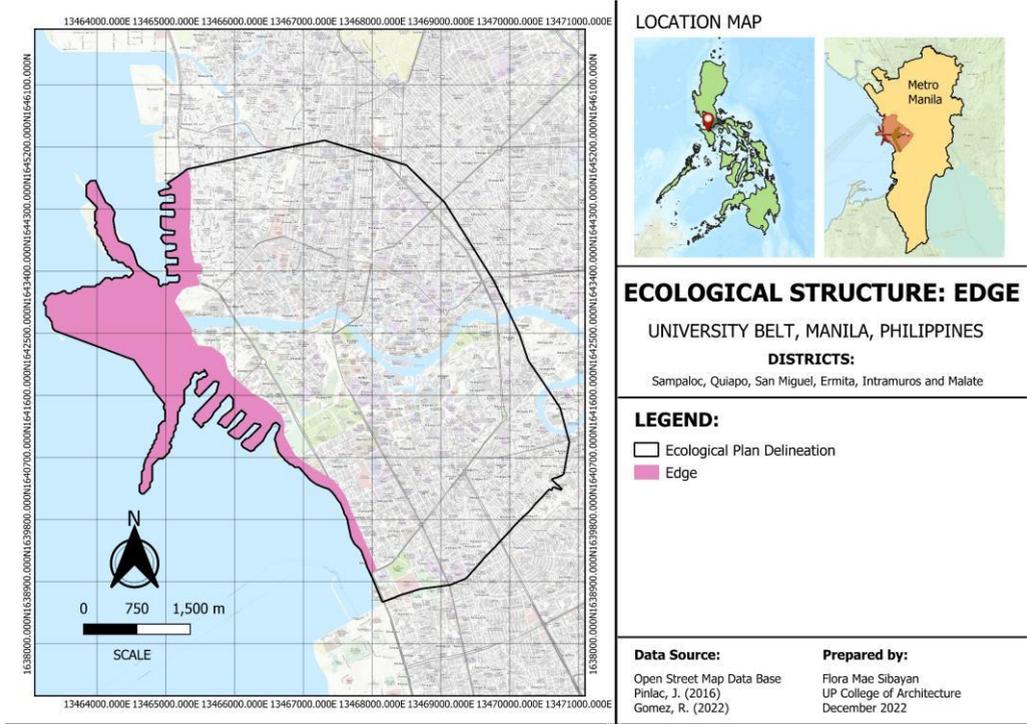


Fig. 9. Existing Ecological Edges in the University Belt Study Site.

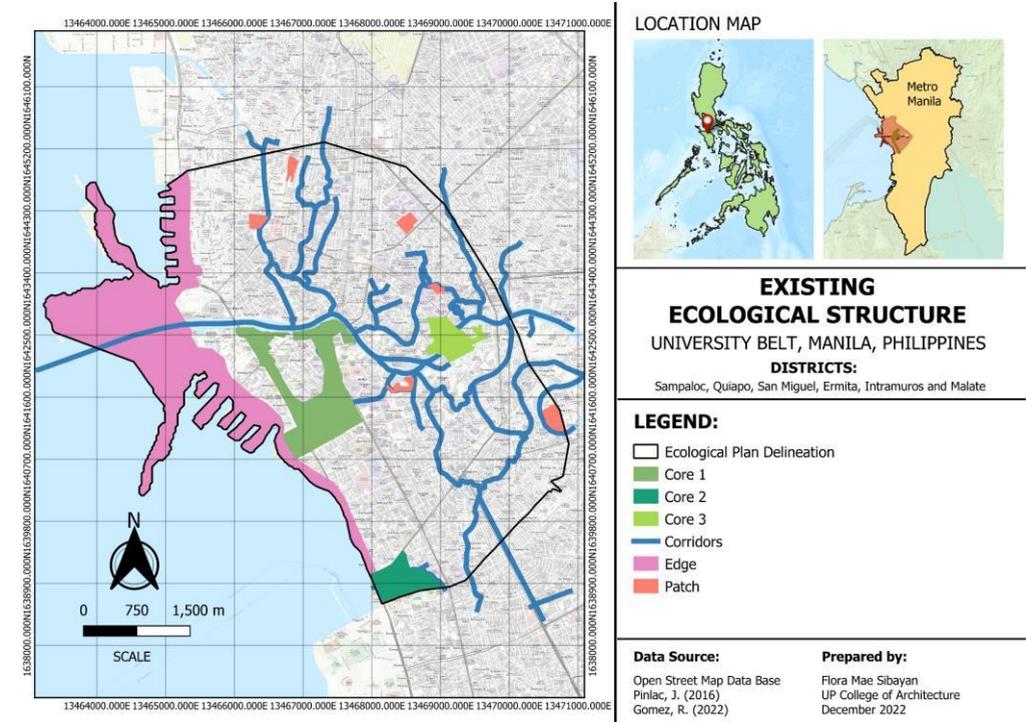


Fig. 10. Existing Ecological Structures in the University Belt Study Site.

3.3 Management strategies

Table 6 enumerates and explains the specific management strategies recommended for each Ecological Structure to enhance the ecological value and flood resilience of the University Belt area. Figure 11 shows the Ecological Plan featuring the different management strategies for each Proposed Ecological Structure.

Table 6. Proposed specific management strategies for each Ecological Structure.

Management Strategy	Description
<i>Core Preservation</i>	Limit direct public access in Intramuros Green Space to allow preservation of vegetated golf hazards as patches of woodlands.
<i>Core Conservation</i>	Retention of Rizal Park and Malacañang Park as publicly accessible green civic spaces.
	Compromise between human use and maintaining the natural environment.
<i>Core Conversion</i>	Convert built-up spaces around the cores into green spaces that act as buffer zones for the cores
<i>Core Creation</i>	Convert open built-up areas such as parking lots into public pocket parks.
	Introduce trees and vegetation along streetscapes.
<i>Corridor Preservation</i>	Retention of remaining greenery found along Pasig River, streams, esteros, and other tributaries.
<i>Corridor Conservation</i>	Retain existing government-funded green riverbank development projects.
<i>Corridor Conversion</i>	Bottom-up development of vegetated linear parks that improve flood resilience of local communities along these streams and esteros.
<i>Corridor Creation</i>	Convert built-up areas near waterways into public green spaces to mitigate inundation.
<i>Corridor Improvement</i>	Expand and develop government-funded green riverbank development projects
<i>Corridor</i>	Bottom-up development of vegetated linear parks that improve flood resilience of local communities along these streams and esteros.
<i>Redevelopment</i>	Expand and develop government-funded green riverbank development projects
<i>Edge Preservation</i>	Strictly control further coastal development, including construction of more built-up structures.
	Retention of remaining mangroves, beach vegetation, and other flora along the coastal area
<i>Edge</i>	Permit controlled and limited development for green spaces further inland.
<i>Conservation</i>	Provide the economic needs of local communities without fully compromising their ecosystem services, especially coastal inundation.
<i>Edge Creation</i>	Convert impermeable open areas such as parking lots into public pocket parks
	Introduction of streetscape planting incorporating native trees and shrubs
	Retrofit vertical gardens and green roofs on existing buildings.

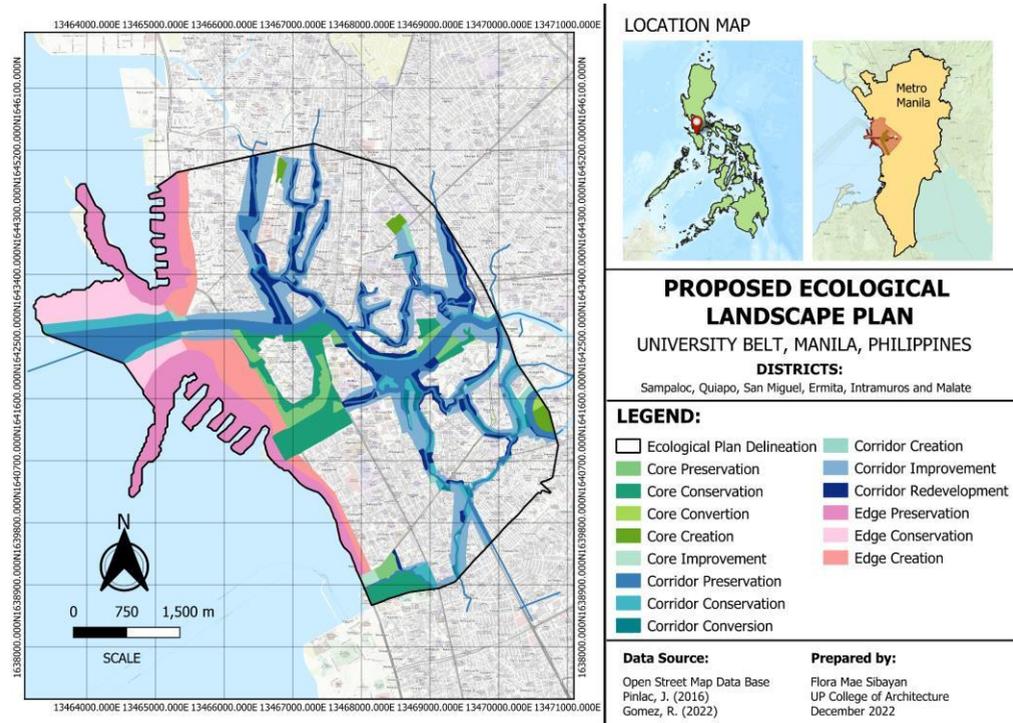


Fig. 11. Proposed Ecological Plan for the University Belt Study Site.

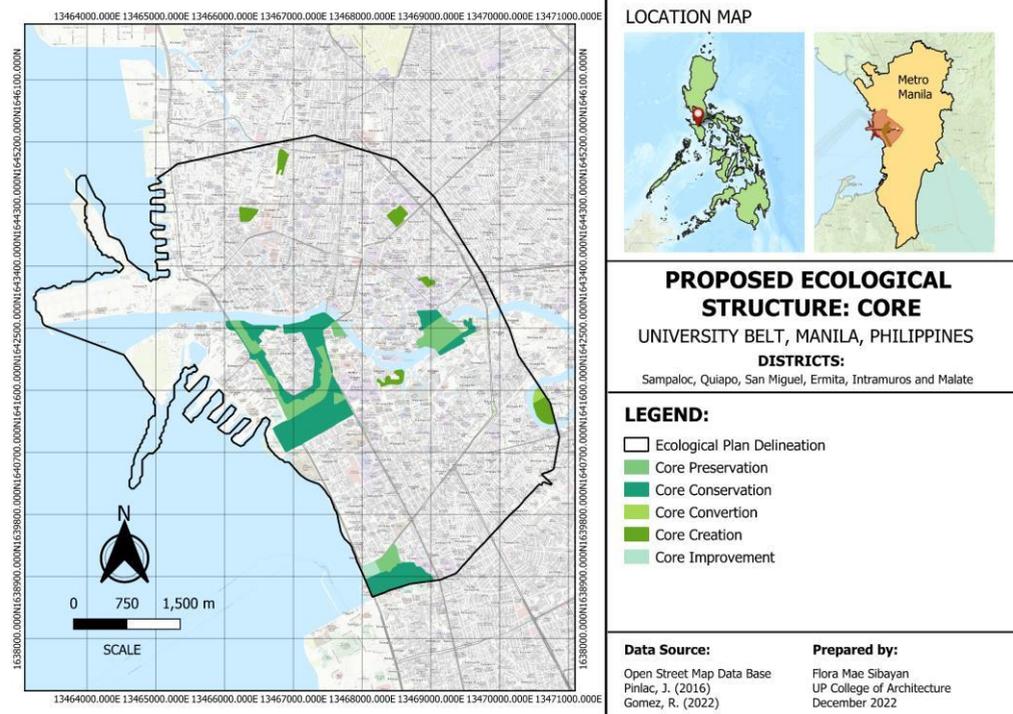


Fig. 12. Proposed Cores for the University Belt Study Site.

3.3.1 Proposed cores

With high ecological value, the existing Ecological Cores are proposed to be preserved and conserved (Figure 12). The expansive Intramuros Green Space, the Malacañang Park, and Rizal Park serve as vital “sponges” that mitigates urban flood through percolation and detention of excess stormwater runoff. High public patronage of Rizal Park and Malacañang Park disallows complete prohibition of human activities; hence these civic spaces are to be conserved as publicly accessible green spaces. The Intramuros Green Space is a golf course, hence direct public access is limited which allows for the preservation of vegetated golf hazards as patches of woodlands. The three (3) major Cores can be expanded by converting open built-up areas into public pocket parks and introducing trees and vegetation along streetscapes, wherever possible.

3.3.2 Proposed corridors

To enhance the interconnectivity of the Cores, Edge, Patches, and other green spaces, several management strategies were proposed for the Ecological Corridors (Figure 13). Government-funded river development projects such as the Pasig River Esplanade serve as starting points for subsequent Corridor improvements, hence must be preserved and expanded upon through further riverbank green developments. Similarly, several esteros and streams course through many local communities, which presents opportunities for bottom-up development of vegetated linear parks that improve community flood resilience along these streams and esteros. Built-up areas near waterways can be converted into public green spaces to mitigate inundation.

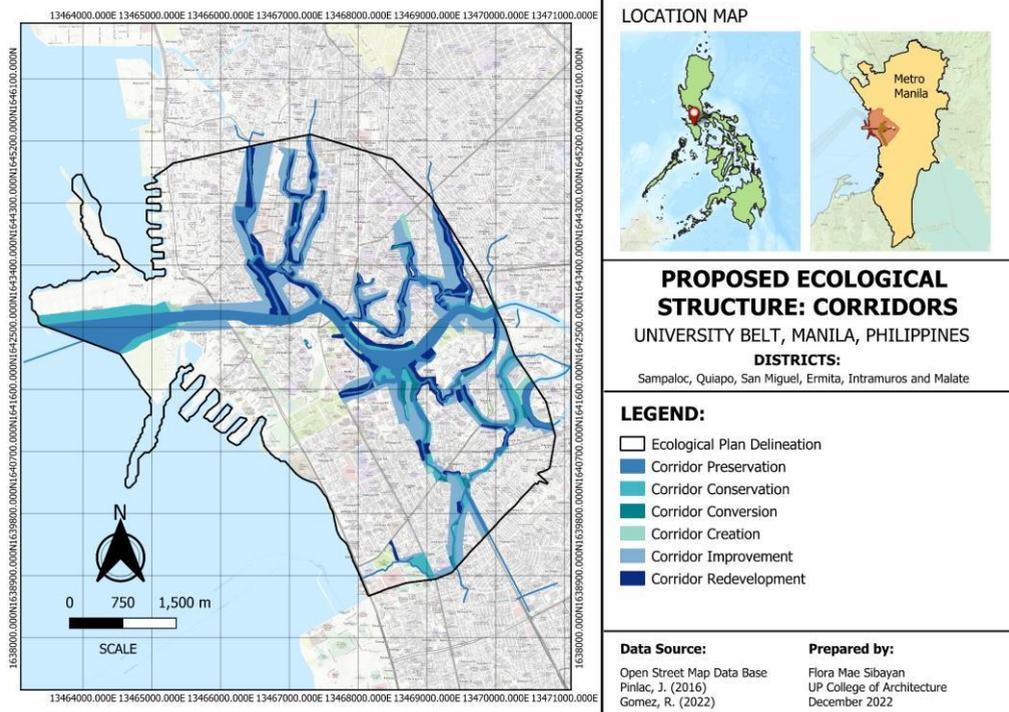


Fig. 13. Proposed Corridors for the University Belt Study Site.

3.3.3 Proposed edge

Management strategies for the Proposed Edge involved preservation and conservation of remaining coastal green spaces and creation of new green spaces (Figure 14). Preservation of coastal green spaces entails strict control of coastal development and retention of all vegetation in the remaining coastal green spaces, including mangroves and beach species. Green spaces further inland are to be conserved, wherein controlled and limited development will be permitted for these green spaces to provide the economic needs of local communities without fully compromising their ecosystem services, especially coastal inundation. To enhance the capacity of the Edge to mitigate inundation and storm surges, the creation of more coastal and lowland green spaces is recommended. Coastal green space creation may entail the conversion of impermeable open areas such as parking lots into public pocket parks, introduction of streetscape planting, and retrofitting of vertical gardens and green roofs on existing buildings.

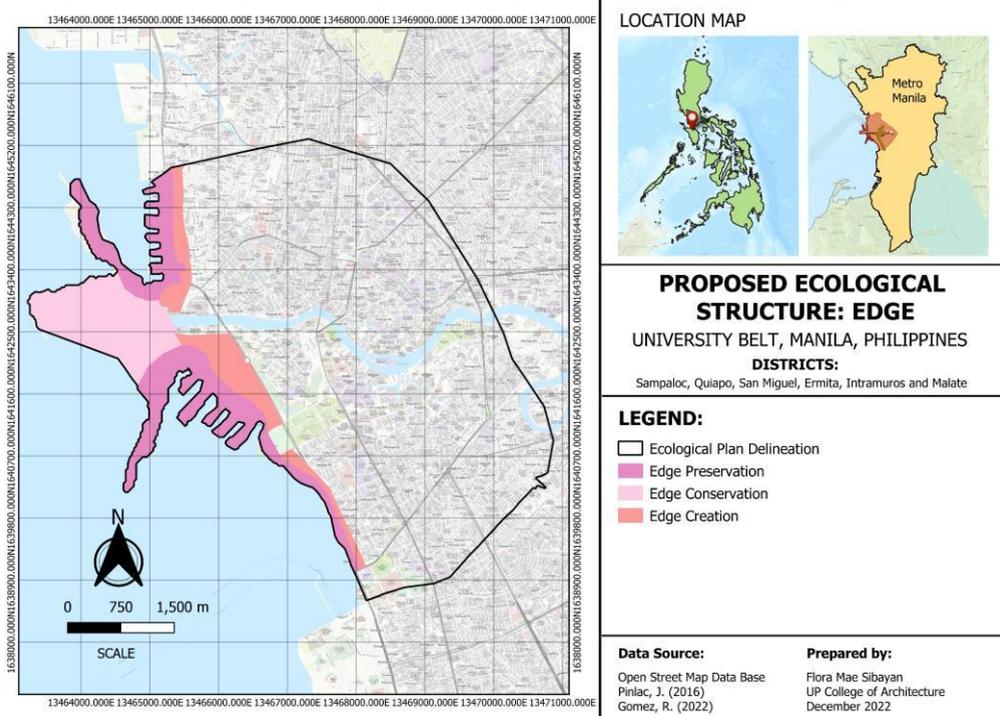


Fig. 14. Proposed Edges for the University Belt Study Site.

4 Conclusion & recommendations

As cities become increasingly built-up with impermeable surfaces, institutions such as the University Belt in Manila, Philippines become increasingly vulnerable to the impacts of flooding. Through biotope mapping, the ecological structure of such flood-prone urban areas can be identified, which can lead to development of a blue-green infrastructure network to mitigate urban flooding.

A total of two (2) natural biotopes and ten (10) built-up biotopes were identified in the University Belt watershed. Natural biotopes comprised only 219.21 ha (8.95%) while built-up biotopes comprised 2230.79 ha (91.05%) of the total site area (2450.00 ha). Through biotope assessment, natural biotopes were assessed to have the highest ecological value and were identified as major Ecological Structures. The Malacañang Park, Rizal Park, and Intramuros Green Space comprised the Existing Ecological Cores representing the majority of all green spaces in the region and providing much of the urban stormwater runoff mitigation in the site. The Existing Ecological Edge was composed of all built-up and green spaces along the coast of

Manila Bay. Pasig River and its tributary streams and esteros represented the Existing Ecological Corridors of the watershed.

From this, an Ecological Plan was proposed to enhance the ecological value and flood resilience of the University Belt watershed through various management strategies. These strategies included preserving and conserving existing coastal and lowland green spaces, conversion of paved streets and areas into new green spaces, and redevelopment of vegetated riparian landscapes.

This study explored the potential of the University Belt watershed to become a flood-resilient institutional landscape that integrates BGI with the collective infrastructure of HEIs. Further research on this topic that incorporates the specific needs of stakeholders and the local community is recommended. Alignment and coordination of such research with current and future LGU infrastructure projects will lead to the mainstreaming of BGI in the Philippines to enhance its resilience towards flooding, among other disasters.

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