



## IDENTIFICATION AND PRIORITISATION OF URBAN ECOLOGICAL CORRIDORS IN PORLAMAR–PAMPATAR USING THE ECOCONNECT-URB INDEX

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### KEYWORDS

*Urban Ecological Corridors  
Ecological Connectivity  
Territorial Fragmentation  
Urban Resilience  
EcoConnect-URB Index  
Ecological Connectivity*

### ABSTRACT

*The objective of this study is to identify and characterise ecological fragments and their potential connections within the urban space of Porlamar-Pampatar, Venezuela, using the EcoConnect-URB Index. This index integrates territorial, ecological, and social variables to identify ecological corridors that contribute to addressing ecological fragmentation, urban pressure, and climate vulnerability. Porlamar-Pampatar is an urban conurbation with a lack of effective planning, which negatively affects coastal vegetation and ecosystems and results in the loss of local ecological integrity. The methodology for identifying, assessing, and prioritising ecological corridors comprised four phases: an integrated ecological-territorial diagnosis, ecological connectivity modelling, participatory socio-ecological analysis, and the calculation of the EcoConnect-URB Index. The results identified four corridors with distinct levels of environmental, functional, and social performance, each with the potential to create a cohesive network of green spaces. The index constitutes a replicable technical tool for mid-scale cities seeking to become more sustainable, resilient, and inclusive.*

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## 1. Introduction

Urban ecological corridors originated in the field of landscape ecology as a response to the fragmentation of natural habitats caused by human activity. They constitute a strategy for connecting isolated ecological spaces, facilitating species movement, genetic exchange, and the restoration of ecosystem dynamics (Cervigón, 1980; Gómez, 2020; Hernández & López 2021; Jiménez-Zabala, 2018; Santos & Muñoz, 2023)

In the urban context, corridors function as multifunctional green infrastructure, providing not only ecological benefits but also social, landscape, and climatic services. They integrate elements of sustainable urban planning, climate resilience, and the right to a green city.

Gómez (2020), Martínez & Hernández (2022) & Santos & Muñoz (2023) argue that ecological corridors promote species mobility and the provision of ecosystem services, while reconnecting fragmented green spaces. López (2021) demonstrates that the design and implementation of urban corridors in Loja, Ecuador, can be effective for ecological restoration and the mitigation of environmental degradation.

Various approaches have been applied to the analysis and planning of urban ecological corridors, including ecological connectivity models such as least-cost path analysis and circuit theory, the use of Geographic Information Systems (GIS) to map green fragments and potential connections, participatory cartography, and citizen perception methodologies.

Several studies have examined the territorial ecology of Margarita Island, in the state of Nueva Esparta, Venezuela, from landscape, marine-coastal and vegetation cover perspectives. However, these studies do not adopt a comprehensive approach integrating territorial, ecological, social, and resilience dimensions. The literature shows that vegetation patterns and land use reveal a highly fragmented landscape and sustained urban encroachment (Sanz D'Angelo et al., 2011). Forested areas have decreased, while agricultural and artificial soils have increased (Camargo, 2024), and an active process of territorial ecological transformation is occurring in the marine-coastal environment (Gómez, 2016).

From a climate change perspective, fragmentation of urban green spaces, high building density, and unplanned urbanisation contribute to the intensification of warm microclimates, increasing vulnerability in dense urban environments (Debbage & Shepherd, 2015; Molina, 2007; Peng et al., 2022). Riparian ecosystems are particularly important for ecological restoration, water quality improvement, and urban biodiversity conservation (Apan et al., 2002; Maekawa and Nakagoshi, 1997). Interconnected green infrastructure can enhance climate resilience and support sustainable water resource management (Gill et al., 2007; Hernández & López (2019); Jiménez 2018; Vásquez, 2016).

The literature consistently indicates that integrating nature into urban planning reduces fragmentation, improves ecological functionality, enhances quality of life, and strengthens territorial resilience. However, there is evidence that technical methods are often applied from a sectoral perspective, with limited integration of territorial analysis and citizen participation. There is a need for an integrative methodology to guide decision-making that incorporates ecological, social, and climate resilience dimensions.

In this context, the EcoConnect-URB methodology seeks to contribute to the state of knowledge through a replicable, multiscale approach that integrates territorial, ecological, and social variables. Its application in a Latin American coastal city such as Porlamar-Pampatar, with a particular focus on the coastal strip, aims to identify opportunities for ecological restoration, reconnection, and nature-based sustainable urban planning.

The problem addressed arises from the growth of the Porlamar-Pampatar conurbation, the main urban centre on Margarita Island, which has generated ecological fragmentation, particularly in the densest areas, tourist zones, and along the coastal strip. The conurbation possesses significant natural resources, including the coastal zone, the lagoons of El Morro, mangrove relicts, and low hills with xerophytic vegetation; however, these elements do not form a functional ecological network.

Unregulated urban development, informal occupation of green areas, impacts of tourism, and the absence of an ecological perspective in territorial planning have resulted in the progressive loss of habitats, fragmentation of natural areas, and reduced equitable access to green spaces for residents. Moreover, there is no territorial strategy for green infrastructure or resilience that would enable adaptation to environmental phenomena such as sea-level rise, urban heat islands, or flooding.

In Porlamar-Pampatar, identifying natural spaces and their spatial integration is crucial for promoting environmental tourism and enhancing urban resilience. To achieve this, a methodology is required that allows for the diagnosis, assessment, and planning of urban ecological corridors from a comprehensive perspective, incorporating ecological, social, and functional dimensions. A thorough understanding of ecological corridors will support the strategic and sustainable management of the urban territory.

## **2. Objective**

This study aims to identify ecological corridors in the Porlamar-Pampatar conurbation through the application of the EcoConnect-URB Index, Geographic Information Systems (GIS), and evaluation criteria encompassing ecological, territorial, and social variables, in order to address the challenges of ecological fragmentation, urban pressure, and climate vulnerability.

The identification and characterisation of ecological corridors from a comprehensive perspective provides a foundation for decision-making aimed at strengthening the connectivity of natural ecosystem fragments within and surrounding the city. Such corridors facilitate species movement and migration, prevent the genetic isolation of animal and plant populations, and reduce habitat fragmentation.

Moreover, the integration of multifunctional green axes into the urban fabric contributes to improved air quality and temperature regulation, provides shade and humidity, mitigates the urban heat island effect, and enhances the urban landscape and residents' contact with nature. When combined with sustainable mobility infrastructure, these corridors also reduce air pollution, improve mental health, alleviate stress, and provide accessible spaces for recreation and environmental equity.

## **3. Theoretical Basis**

### ***3.1. Green Infrastructure and Ecological Connectivity***

Green infrastructure constitutes an interconnected and planned system that generates nature-based solutions, provides multiple benefits, and enhances ecological resilience. It comprises networks of natural and semi-natural elements that deliver ecosystem services, with the primary objective of improving ecological resilience, human health, social well-being, and overall quality of life through nature-based interventions.

Ecological connectivity facilitates the flow of organisms, energy, and ecological processes. Connectivity is understood in terms of structural and functional dimensions. In urban environments, connectivity is frequently disrupted by built barriers such as roads, buildings, and impervious surfaces. Ecological corridors restore connectivity through vegetated links, linear parks, median strips, naturalised streams, and urban green axes.

### ***3.2. Urban Ecological Corridors***

The urban ecological corridor is a form of green infrastructure that enables the spatial integration of green public spaces, natural ecosystems, and urban facilities, forming dynamic areas accessible to the population. Its design is informed by the potential of the territory and generates naturalised spaces within the city (Antequera, 2019; Molina, 2014).

Ecological corridors function as structuring axes in land use planning, ensuring equitable access to nature for all sectors, particularly marginalised neighbourhoods, and providing spaces conducive to environmental education and the regeneration of the social fabric.

Riverbanks and coastal areas can be transformed into urban corridors aimed at preserving, restoring, or protecting green areas and ecosystems, while promoting biodiversity, outdoor recreation, water quality, and the well-being of surrounding communities.

In addition to supporting biodiversity conservation, corridors fulfil landscape, recreational, climatic, and human well-being functions. They are considered a key component of green infrastructure for the development of resilient, healthy, and inclusive cities, ensuring spatial continuity and connectivity (Molina, 2014; Peng et al., 2022). Furthermore, they help to minimise socio-economic problems, environmental threats, and impacts on ecosystems (Gill et al., 2007; Girling et al., 2000; Molina, 2007; Peng, et al.2022).

Planning corridors in such areas requires careful consideration of marine ecosystems alongside urban and social dynamics, integrating land use planning, risk management, and community participation.

#### 4. Methodology

This study was conducted using the EcoConnect-URB methodology, which enables a comprehensive analysis of ecological fragments by integrating ecological, territorial, social, and resilience dimensions to support the planning of green infrastructure, ecological restoration, or the establishment of new corridors. The composite index incorporates weighted sub-indices of structural and functional connectivity, friction to movement, and resilience (Table 1).

**Table 1.** Dimensions considered by the EcoConnect-URB Methodology

Dimension	Approach
Ecological	Types of vegetation cover, biodiversity, connectable habitats.
Territorial	Integration with the urban fabric, accessibility, physical continuity.
Social	Use, perception, appropriation and benefits for the population.
Resilience	Ability to mitigate the effects of climate change and other risks.

Source: Own elaboration, 2026.

The EcoConnect-URB methodology comprises five phases that facilitate the development of an integrated ecological-territorial diagnosis, ecological connectivity modelling, participatory socio-ecological analysis, and index analysis for the identification of ecological corridors.

##### 4.1. Phase 1: Integrated Ecological-Territorial Diagnosis

This phase aims to characterise the ecological environment and to identify and characterise ecological fragments within the urban space. It involves delimiting the study area, producing base maps, and mapping public and private green areas, streets, motorways, walls and other physical barriers, buildings, land use, water bodies, biodiversity, and natural relics. Data sources include satellite imagery (Sentinel-2, Landsat), municipal databases, and multi-layer GIS analysis.

##### 4.2. Phase 2: Modelling of Ecological Connectivity

The objective of this phase is to analyse structural and functional ecological connectivity. Structural connectivity is based on the spatial pattern of vegetation cover and the urban network, while functional connectivity assesses whether organisms can actually move or interact between habitat patches, taking into account built barriers, land use, urban friction, and species behaviour. The analysis considers four dimensions: ecological, territorial, social, and resilience, each defined by specific variables and indicators that enable the quantification of ecological connectivity (Table 2).

**Table 2.** Dimensions, variables, and indicators for the analysis of ecological connectivity

<b>Dimension</b>	<b>Component</b>	<b>Variable</b>	<b>Indicator</b>	<b>Calculation method</b>	<b>Scale</b>
<b>Ecological</b>	<b>Structural connectivity</b>	<b>Fragmen-tation</b>	E1. Patch density	No. of green patches/km <sup>2</sup>	Normalised between 0 and 1
		<b>Proximit-y between patches</b>	E2. Average effective patch size	Average connected area / Total green area	0 (very small) to 1 (large and continuous)
		<b>Spatial distrib-ution</b>	E3. Proximity index	Average distance between relevant patches	Normalised inverse
		<b>Linear continui-ty</b>	E4. Linear connectivity	Length of vegetated roads / total road length	0 to 1
		<b>Presence of multiple nodes</b>	E5. Equitable distribution	Assessment by urban quadrants (e.g. 500x500 m grids) with minimum green coverage	%
<b>Territoria-l</b>	<b>Connecti-vity</b>		F1. Functional connectivity between key nodes	Number of strategic nodes actually connected / Total number of possible nodes	Direct proportion
			F2. Continuity of existing corridors	Length of continuous functional corridors / Optimal theoretical length	Direct proportion
			F3. Permeability of the urban matrix	Percentage of urban territory with low or medium friction ( $\leq 0.5$ )	Proportion
	<b>Function-al connectivity</b>	<b>Quality</b>	F4. Ecological quality of corridors	Average ecological quality score (	native vegetation, width, coverage, shade)
		<b>Friction</b>	F5. Average landscape friction	Average ecological friction values in the urban area.	Average
			F6. Presence of high friction areas	Proportion of the city with severe friction	%
			F7. Continuity of low friction zones	Existence of continuous routes with low resistance	Routes
			F9. Absolute ecological barriers	Infrastructure that completely interrupts the flow	avenues, walls, industrial areas
			F10. Ecological permeable surface	Percentage of the city with low or moderate friction.	%
		<b>Resilienc-e</b>	<b>Resilience</b>	<b>Diversity</b>	<b>R1.</b> Ecological diversity rate (IDVU)
<b>Redunda-ncy</b>	<b>R2.</b> Functional redundancy rate			Percentage of replicable patches	Patches with redundant

			(similar function) in the area of analysis	function / Total patches	
Social	Perception	<b>Connectivity</b>	R3. Backup connectivity level	Existence of alternative routes between nodes	0: None, 0.5: Partial, 1: Total
		<b>Regeneration potential</b>	R4. Regeneration potential rate	Degradation index	Ecologically viable degraded areas / Total degraded areas
		<b>Ecological buffering</b>	R5. Ecological buffering rate	Percentage of territory with shade, retention, and cooling functions.	Area with buffering function / Total urban area
		<b>Use of green areas</b>	S1. Perception, safety, appropriation	Surveys Interviews	

Source: Own elaboration, 2026.

By assigning friction values that consider factors affecting ecological connectivity, areas of low, medium, and high ecological friction were identified. Tools such as the Normalised Difference Vegetation Index (NDVI) and land cover typology (wooded, herbaceous, impervious, among others) were used for this purpose. Connectivity algorithms based on a movement resistance model were developed, and key ecological nodes and functional links were evaluated.

### 4.3 Phase 3: Participatory Socio-Ecological Analysis

This phase aims to integrate citizen perception and social use of the territory into the assessment of ecological fragments. Perception surveys were conducted among residents and government managers, addressing accessibility, ecological quality, safety, and land use. The results were used to map valued, unsafe, or potential green areas, incorporating local knowledge into corridor planning.

### 4.4 Phase 4: Calculation and Analysis of the EcoConnect-URB Index

The objective of this phase is to generate a composite EcoConnect-URB Index that integrates ecological, territorial, social, and resilience dimensions, thereby identifying critical areas and opportunities for the development of ecological corridors. The Index calculation applies adjustable weightings, using the following formula:

$$IECU = (0.3 \times CE) + (0.3 \times CF) + (0.2 \times FR) + (0.2 \times R)$$

Where:

- CE = Structural Connectivity
- CF = Functional Connectivity
- FR = Friction (inverse; lower friction corresponds to a better score)
- R = Resilience

Each indicator is assessed on a scale from 0 (worst condition) to 1 (best condition) (Tables 1-7).

**Table 3.** Interpretation scale for Structural Connectivity

CE Range	Category	Interpretation
0.00 – 0.20	Very low	Extremely fragmented city, scattered and isolated patches.
0.21 – 0.40	Low	Partial connectivity, no functional green structure.
0.41 – 0.60	Med	Basic patchwork network with limited connections.
0.61 – 0.80	High	Interconnected green network, presence of corridors.
0.81 – 1.00	Very high	Consolidated and continuous urban ecological system.

Note: Result: value between 0 (very low structural connectivity) and 1 (high structural connectivity)  
 $CE = (E1 + E2 + E3 + E4 + E5) / 5$   
 Source: Own elaboration, 2026.

**Table 4.** Functional Connectivity interpretation scale

FC range	Category	Interpretation
0.00 – 0.20	Very low	Almost no ecological functionality. Interrupted flow.
0.21 – 0.40	Low	Very limited and fragmented ecological connectivity.
0.41 – 0.60	Medium	Partial functional flow, dependent on a few corridors.
0.61 – 0.80	High	Functional ecological network, multiple routes available.
0.81 – 1.00	Very high	High ecological exchange capacity throughout the landscape.

Note: Result: value between 0 (very low functional connectivity) and 1 (high functional connectivity)  
 Formula:  $CF = (F1 + F2 + F3 + F4 + F5) / 5$   
 Source: Own elaboration, 2026.

**Table 5.** Interpretation scale for the level of movement friction

SF range	Category	Interpretation
<b>0.00 – 0.20</b>	Very high friction	Ecological flow almost blocked; hostile landscape
<b>0.21 – 0.40</b>	High friction	High resistance to movement; severe fragmentation
<b>0.41 – 0.60</b>	Medium	Obstacles present, but with intermittent functional routes
<b>0.61 – 0.80</b>	Low friction	Mostly viable flow with some critical points
<b>0.81 – 1.00</b>	Very low friction	High ecological permeability; fluid urban landscape

Note: Result: value between 0 (very high friction) and 1 (very permeable landscape).  
 Formula:  $FR = (FR1 + FR2 + FR3 + FR4 + FR5) / 5$   
 Source: Own elaboration, 2026.

**Table 6.** Resilience (R) interpretation scale

SR range	Category	Interpretation
0.00 – 0.20	Very low	Highly vulnerable urban ecosystem
0.21 – 0.40	Low	Low adaptability and regeneration
0.41 – 0.60	Medium	Limited capacity but with potential
0.61 – 0.80	High	Functional, resilient ecological network
0.81 – 1.00	Very high	Highly robust and flexible urban system

Note: Final result: a value between 0 (zero resilience) and 1 (ideal urban ecological resilience).  
 $R = (R1 + R2 + R3 + R4 + R5) / 5$   
 Source: Own elaboration, 2026.

**Table 7.** Interpretation scale for the EcoConnect-URB Composite Index (IECU)

IECU value	Classification	Description
0.8 – 1.0	Very High	Robust and functional ecological connectivity
0.6 – 0.79	High	Good connectivity, with areas for improvement
0.4 – 0.59	Average	Evident fragmentation, partial connectivity
0.2 – 0.39	Low	High fragmentation, poorly functional
0 – 0.19	Very low	Disconnected urban ecosystems

Source. Ratings between 0 and 1

#### 4.5. Phase 5: Design Proposals and Adaptive Management

The objective of this phase is to propose potential ecological corridors and specific interventions to enhance and consolidate ecological connectivity, based on the analysis of each corridor's characteristics. Each corridor is assessed by identifying its limitations and potential in terms of connectivity, accessibility, and social use, using a Specific EcoConnect-URB Index with ratings ranging from 0 (lowest performance) to 1 (highest performance).

### 5. Results

#### 5.1 Territorial Ecological Diagnosis

The study area is the Porlamar-Pampatar conurbation, located on Margarita Island in northeastern Venezuela, specifically in the southern part of the municipalities of Mariño and Maneiro. This urbanised zone lies within a coastal landscape characterised by mangroves, estuaries, beaches, arid plains, and dry hills, and is highly exposed to climate threats, coastal pressures, and the progressive loss of urban green areas and wetlands (Figure 1). Porlamar is the largest urban centre on the island, forming part of a semi-arid Caribbean environment with developed eastern coastal cities and substantial natural ecosystems in proximity.

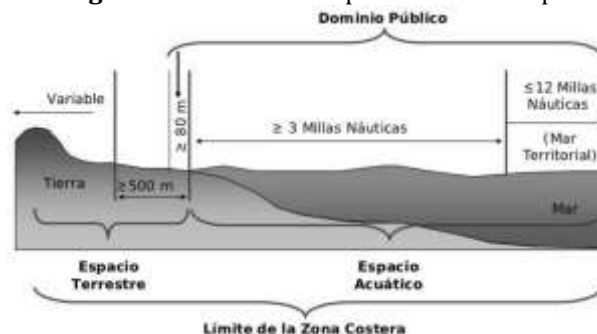
**Figure 1.** Porlamar-Pampatar conurbation



Source: Google, s.f.

The coastal strip is defined by an area of land approximately 500 metres wide and the adjacent aquatic space, with its natural resources, ecosystems and the socio-economic dynamics that develop there (Coastal Zones Law, Articles 2 and 4) (Figure 2).

**Figure 2.** Porlamar-Pampatar Coastal Strip



Source: Coastal Zones Act, Articles 2 and 4

From a geological perspective, the study area forms part of the Caribbean mountain system. The eastern sector of Margarita Island is characterised by highly complex geomorphology, with diverse landscape types shaped by systems of hills and ridges arranged in three alignments of low

mountains and coalescing valleys. These formations generate a glacia relief that gradually transitions into coastal and marine units, ultimately shaping the island's coastal landscape.

As a result of these geomorphological conditions, the area presents a wide variety of soils, including deposits of fine silty sand with low gravel content; poorly graded clayey sands; poorly graded sands with few fines; inorganic clays of high and low-to-medium plasticity with low gravel content; and inorganic silts with very fine sand and slight plasticity.

The average annual precipitation is 202 mm, while average annual evapotranspiration reaches 1,994 mm, resulting in a negative moisture coefficient throughout the year and an estimated annual water deficit of 1,595 mm (INAMEH, 2021). Another significant ecological factor is wind action and its influence on the coastal system, particularly between February and June, when wind speeds can reach up to 63 km/h (INAMEH, 2022).

Hydrologically, the area is structured around the El Valle River micro-basin. Its main channel extends approximately 10.5 km and is bordered by green spaces along several sections. The basin has an average concentration time of 63.98 minutes (1 hour and 4 minutes) for the longitudinal section.

Under the environmental conditions described, several protected areas have been designated by the Ministry of the Environment and the National Institute of Cultural Heritage, including:

- Coastal Strip Protected Area
- Las Salinas Protected Area
- Gasparico Lagoon Protected Area
- Open-Air Protected Area at Punta Ballena
- Protected Area above 50 metres above sea level
- El Morro Protected Area

The ecological fragments within the study area contain vegetation cover characteristic of dry scrubland, coastal shrub communities, remnants of gallery vegetation, and mangrove ecosystems. The most tolerant and resilient vegetation unit, and the only one capable of widespread establishment under current environmental conditions, is the very low and sparse scrub community dominated by *Castela erecta*. This species exhibits limited above-ground biomass and accounts for approximately 80% of the individuals recorded within this vegetation type (González, 2007).

In the mangrove ecosystems of Pampatar and the associated lagoon systems, red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and button mangrove (*Conocarpus erectus*) are present. The coastal plains support species such as divi-divi (*Libidibia coriaria*), abrojo (*Tribulus cistoides*), afilito (*Sporobolus virginicus*), foxtail grass (*Cenchrus* spp.), brusca (*Croton* spp.), common cardón (*Stenocereus griseus*), yaunero cardón (*Cereus repandus*), and fishbone cactus (*Acanthocereus tetragonus*) (es.wikipedia.org).

The fauna of the area includes a wide range of migratory and resident bird species, including flamingos (*Phoenicopterus ruber*), herons (*Ardeidae*), the togogo (*Icterus nigrogularis*), the Margarita subspecies of the yellow warbler (*Setophaga petechia*), the Margarita parrot (*Amazona barbadensis*), diving ducks (*Aythya* spp.), gannets (*Sulidae*), gulls (*Laridae*), skimmers (*Rynchops* spp.), pelicans (*Pelecanus* spp.), and blue, reddish, and royal herons (*Ardea* spp.). Native reptiles, including the Margarita iguana (*Iguana insularis*), are also present, as well as pollinators such as native bees and butterflies (ibid.).

Marine fauna in the surrounding Caribbean Sea includes species such as croaker (*Micropogonias* spp.), snapper (*Lutjanus* spp.), sardine (*Sardinella* spp.), grouper (*Epinephelus* spp.), dogfish (*Squalus* spp.), Spanish mackerel (*Scomberomorus* spp.), mullet (*Mugil* spp.), lebranche mullet (*Mugil liza*), and sea bass (*Dicentrarchus* spp.). Molluscs of ecological and economic importance include oysters (*Crassostrea* spp.), chipichipi (*Donax* spp.), guacuco (*Tivela mactroides*), mussels (*Mytilidae*), and pepitona (*Arca zebra*). It is particularly important to note that several species of sea turtles use the island's beaches as nesting sites for egg laying, highlighting the ecological significance of the coastal system (ibid.).

### 5.2. Modelling of Structural Urban Ecological Connectivity

Structural ecological connectivity in the Porlamar-Pampatar conurbation depends on the spatial configuration of vegetation cover and the urban fabric. The analysis yields a very low weighted index value of 0.11, indicating a landscape characterised by fragmented ecosystems, limited spatial continuity, and the absence of a functional green structure (Table 8).

**Table 8.** Evaluation of the Ecological Structural Connectivity (CE) Sub-index

Indicator	Value	Observation
E1. Patch density	0.25	Low patch density (very scattered)
E2. Average effective patch size	0.40	Small (less than 1 ha) and fragmented sizes. Most patches are isolated without direct corridors.
E3. Proximity index	0.30	High distance between significant patches. Urban patches are between 300 and 1000 m from main natural features such as lagoons, hills, and coastline.
E4. Linear connectivity	0.45	Some tree-lined avenues connected
E5. Equitable distribution	0.35	Poorly distributed green areas (spatial inequality)

Source: Own elaboration, 2026.

$$CE = (0.25 + 0.40 + 0.30 + 0.45 + 0.35) / 5 = 0.35 \cdot 0.3 = 0.11$$

Green areas exhibit a high degree of fragmentation, with a fragmentation index of 0.25, and individual patches rarely exceeding one hectare in size. These areas are embedded within an impermeable urban fabric and lack a planned green infrastructure system capable of linking ecological nodes and connectors. Green patches are separated by average distances ranging from 300 to 1,000 m, which significantly limits ecological flows for species such as birds and insects, as well as processes related to seed dispersal.

Structural barriers, including wide avenues with high-speed traffic and large-scale developments with low vegetation permeability, further intensify vegetation fragmentation and disrupt spatial continuity.

### 5.3. Modelling Functional Urban Ecological Connectivity

In contrast to structural connectivity, which examines the physical spatial pattern of the landscape, functional connectivity assesses the potential for species movement and interaction between habitat patches. This analysis incorporates factors such as physical barriers, land use, urban friction, accessibility, and wind dynamics along the coastal strip (Tables 9 and 10).

**Table 9.** Evaluation of the Functional Ecological Connectivity (FEC) Sub-index

Indicator	Value	Observation
F1. Functional connectivity between key nodes	0.40	Only some strategic nodes are connected
F2. Continuity of existing corridors	0.45	Corridors present but not continuous
F3. Permeability of the urban matrix	0.35	Urban matrix with low ecological permeability
F4. Ecological quality of corridors	0.50	Partial and ornamental vegetation in corridors

Source: Own elaboration, 2026.

$$CF = (0.40 + 0.45 + 0.35 + 0.50) / 5 = 0.43 \cdot 0.3 = 0.13$$

In the Porlamar-Pampatar conurbation, functional ecological connectivity is very low, with a weighted index value of 0.13. This reflects the disconnection of ecosystems into small parks that

function as isolated patches, together with a high density of impermeable buildings that generates extreme fragmentation of green areas. This situation is further exacerbated by the absence of ecological planning and the presence of significant urban friction.

Along the coastline, built structures create additional friction for species movement and disrupt wind flows. At present, approximately 20 corridors associated with road and pedestrian access routes, oriented perpendicular to the coastline, allow for the partial circulation of marine and hill winds.

Despite these constraints, there is potential for ecological restoration along major tree-lined roads, pedestrian boulevards, lagoons integrated into the urban fabric, beach areas with palm vegetation, dry hills adjacent to the city, and school and institutional green spaces.

**Table 10.** Interpretation of ecological functionality according to urban factors

Element	Current functionality	Location
Small isolated parks	Low functional connectivity They act as "green islands"	Historic centre, Gómez and Guevara Boulevards, Rómulo Gallegos Promenade (Guaraguao Promenade), La Puntilla Lighthouse, El Morro, Pampatar Lighthouse
Tree-lined streets (some main avenues)	Can serve as connectors if they are continuous Require improvement	Bolívar Avenue, Santiago Mariño Avenue and Aldonza Manrique Avenue
Coastal areas	Limited. There is no spatial integration as it is interrupted by buildings that act as barriers to the movement of birds and winds.  Potential if beach access corridors are restored and construction is regulated	Pampatar Bay and Porlamar coastline
Continuous bodies of water	Protected bodies of water, integrated into the urban fabric with potential for ecological corridors	Las Salinas and El Morro
Hills	Potential connectivity, if linked to the urban network. Key area.	Vegetation north of Porlamar and Pampatar
Vacant lots and roadside verges	Opportunities for temporary corridors Must be restored and protected	Porlamar and Pampatar

Source: Own elaboration, 2026.

#### **5.4. Movement Friction Model**

Movement friction for species in Porlamar-Pampatar is very high, with a weighted index of 0.10, indicating high resistance to movement and severe fragmentation (Table 11).

**Table 11.** Movement friction assessment (functional connectivity)

Indicator	Value	Observation
FR1. Landscape friction	0.35	High average landscape friction
FR2. Presence of high friction areas	0.3	70% of urban territory registers high friction
FR3. Continuity of low friction areas	0.40	Few continuous routes with low friction
FR4. Absolute ecological barriers	0.50	Some critical barriers such as floodplains and enclosed areas
FR5. Ecological permeable surface	0.38	Only 38% of the territory has friction $\leq$ 5

Source: Own elaboration, 2026.

$$\text{Subindex FR} = (0.35 + 0.30 + 0.40 + 0.50 + 0.38) / 5 = (0.38 \cdot 0.2) = 0.10$$

Areas with different levels of friction are identified (Table 12):

- Areas with low ecological friction: these are located along stream edges, interconnected green areas, and open school playgrounds. They constitute connected and accessible spaces with low ecological resistance to movement, facilitating both species mobility and the flow of natural processes.
- Areas with medium ecological friction: these present moderate obstacles to ecological movement, due to factors such as transition areas between urban areas and semi-natural spaces. These areas include the lagoons of El Morro, Las Salinas de Pampatar, zones with higher building density but containing open spaces or scattered vegetation, and areas of urban or suburban expansion where there is potential to promote ecological connectivity.
- Areas with high ecological friction: these are areas where there are barriers with very low ecological permeability, making it difficult for species to cross them and interrupting natural connectivity. They are identified in urban areas where there are buildings and gated tourist developments. High friction limits ecological movement for small birds, pollinators, reptiles and seed dispersers.

**Table 12.** Interpretation of friction levels considering factors that affect connectivity

Element	Location
Wide tree-lined avenues	High ecological fragmentation on Bolívar Avenue, Santiago de Mariño Avenue, and Aldonza Manrique Avenue, which limits movement but has potential for restoration
Residential streets	Urban developments in Porlamar and Pampatar limit movement
Urban parks or green areas	Parks and green areas such as the Castillo de San Carlos Borromeo in Pampatar and its surroundings and the historic centre of Porlamar, although urbanised, have cultural value and scattered green spots that can act as ecological islands if connected. River corridors, undeveloped interstitial spaces, natural access to the beaches of Pampatar.
Beaches on the coastline (flat slope)	Pampatar Bay . Flat area but with man-made barriers and residential and tourist activities that limit the movement of species. Noise and inappropriate lighting impact fish stocks and other species
Semi-natural peri-urban vegetation	Porlamar and Pampatar hills in contact with limited integration into the urban fabric
Hills and mountains	Porlamar and Pampatar hills with little connection to the urban fabric
Protected areas with limited access	Pampatar and El Morro salt flats, protected areas with moderate access
Continuous bodies of water	El Morro, beaches on the coastline and Las Salinas with mangrove vegetation

Source: Own elaboration, 2026. The analysis of friction to movement is inverse to structural and functional connectivity indices.

### 5.5. Ecological Resilience

Porlamar-Pampatar register the weighted resilience index is very low (0.19) due to an urban ecological network with limited capacity to resist and adapt, although there are clear opportunities for restoration (Table 13).

**Table 13.** Ecological Resilience Sub-indices

Indicator	Value	Estimated source
<b>R1.</b> Ecological diversity rate (IDVU)	0.3	Low diversity of cover
<b>R2.</b> Functional redundancy rate	0.5	Presence of some similar patches
<b>R3.</b> Backup connectivity level	0.5	Partial connectivity between nodes
<b>R4.</b> Potential regeneration rate	0.65	Good restoration potential
<b>R5.</b> Ecological damping rate	0.20	Small area with climate buffering

Source: Own elaboration, 2026.

$$SR = (0.30 + 0.50 + 0.50 + 0.65 + 0.20) / 5 = 0.43 * 0.2 = 0.9$$

There is no significant representation of native species or multiple vegetation strata; consequently, ecological diversity is low and dominated by a limited range of vegetation types, primarily ornamental species and urban grass. As a result, the capacity of the urban ecosystem to respond to disturbances, such as heatwaves or the loss of wildlife habitat, is limited. This condition reflects high vulnerability to pests, low functional complexity, and reduced biological resilience.

Tree-lined avenues and public squares with similar vegetation patches can fulfil functions such as shade provision and water infiltration, thereby increasing functional redundancy (0.50). However, access to this type of green space is unevenly distributed across the urban fabric.

Partial ecological connections exist between strategic nodes, including the lagoons of El Morro, the coastline, and adjacent mangrove systems, generating a form of backup connectivity (0.50). Nevertheless, these connections do not constitute a continuous ecological network and remain insufficiently protected from ongoing urban pressures.

The potential for ecological regeneration is high (0.65), particularly in coastal areas, along the banks of the El Valle River, and in peri-urban hills. These areas retain spatial and building characteristics that would allow their functional integration into a broader ecological network.

By contrast, the proportion of the territory providing thermal regulation, water retention, or protection against extreme events is very low (0.20). This is due to sparse vegetation cover in critical zones such as urban centres, major road corridors, and coastal fronts exposed to intense solar radiation. Consequently, the area experiences high exposure to urban heat islands, low climate resilience, and increased urban risk.

To enhance resilience, it is necessary to activate ecological corridors within fragmented spaces and to strengthen strategic nodes, particularly the lagoons and surrounding hills. These areas offer favourable conditions for the restoration and creation of new functional green spaces that support climate change adaptation.

Prioritising the design and implementation of functional and redundant ecological corridors would increase plant diversity through the incorporation of native and low-maintenance species. In addition, this approach would facilitate the identification of degraded urban areas with high regeneration potential and mitigate zones vulnerable to heat stress and urban runoff. Achieving these objectives requires the promotion of public policies and active community participation to ensure the long-term maintenance and protection of ecological infrastructure.

### 5.6. Participatory Socio-Ecological Analysis

The Porlamar-Pampatar conurbation is characterised by poorly articulated and weakly interconnected public spaces and green areas, with proximity indices ranging between 300 and 500 metres. Within this spatial configuration, relationships and connections of different types and scales converge. Interviews with local residents identified several of these spaces as key sites for

social interaction and recreation, including Plaza Bolívar, Paseo Guaraguao, and abandoned or underused school and sports green areas.

The population perceives a range of problems related to green infrastructure, including the presence of vulnerable areas without access to green spaces in the Genovés and Achípano sectors, limited spatial integration between public spaces and green areas, insufficient connectivity and accessibility to the coastline, and the progressive loss of visual access to seascapes. At the same time, residents express a growing interest in environmental revaluation, ecological restoration, and the promotion of sustainable tourism as mechanisms for improving urban quality and resilience.

### 5.7. EcoConnect-URB Index

Based on the analysis of the ecological territorial diagnosis, structural and functional connectivity, and resilience, the EcoConnect-URB Index was obtained for Porlamar – Pampatar, which is at a medium level (0.43), indicating that there is evident ecological fragmentation with partial connectivity.

$$IECU = 0.35 + 0.43 + 0.38 + 0.43 = 0.43$$

Critical areas and opportunities for delimiting ecological corridors were identified (Table 14).

**Table 14.** Critical areas and opportunities for prioritising ecological corridors

Area	Critical area	Connection opportunity
East-west connection: from Pampatar (coastal area) to peri-urban areas of Porlamar.	Very high fragmentation	Green road corridors
Linear corridors: Bolívar Avenue and 4 de Mayo Avenue in Porlamar and Aldonza Manrique Avenue	Partially wooded	Strengthen linearity through revegetation and ecological passages.
Buffer zones and passageways in public institutions (schools, squares)	Avenue margins with internal vegetation	Create functional nodes and secondary corridors
Porlamar-Pampatar coastline	High urban-tourist pressure	Develop a continuous coastal ecological corridor between Playa Bella Vista, El Morro and Pampatar Bay. Coastal recovery
North of Pampatar	Close to vegetated areas (El Morro)	Possible ecological node
West of Porlamar	Greater connectivity with undeveloped hills	Buffer node

Source: Own elaboration, 2026.

Porlamar–Pampatar has a green structure with functional flow that depends on four corridors: Porlamar, Pampatar Bay–Mangroves, El Morro Lagoons–Bolívar Avenue, and Educational Zone – Sierra. They are highly resistant to movement due to severe fragmentation, and their resilience has limited capacity but potential for restoration (Figures 3 and 4).

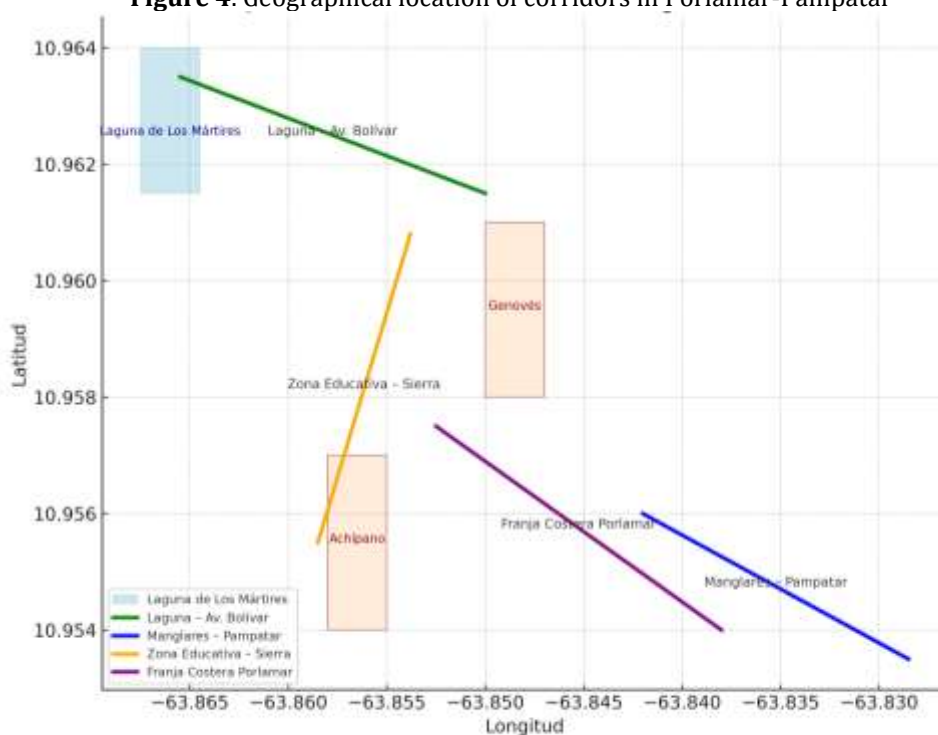
**Identification and Prioritisation of Urban Ecological Corridors in Porlamar–Pampatar Using the EcoConnect-URB Index**

**Figure 3. Location of Corridors in Porlamar – Pampatar**



Source: Image of Porlamar – Pampatar from Google (2025)

**Figure 4. Geographical location of corridors in Porlamar-Pampatar**



Source: Porlamar-Pampatar. UTM coordinates. Google 2025.

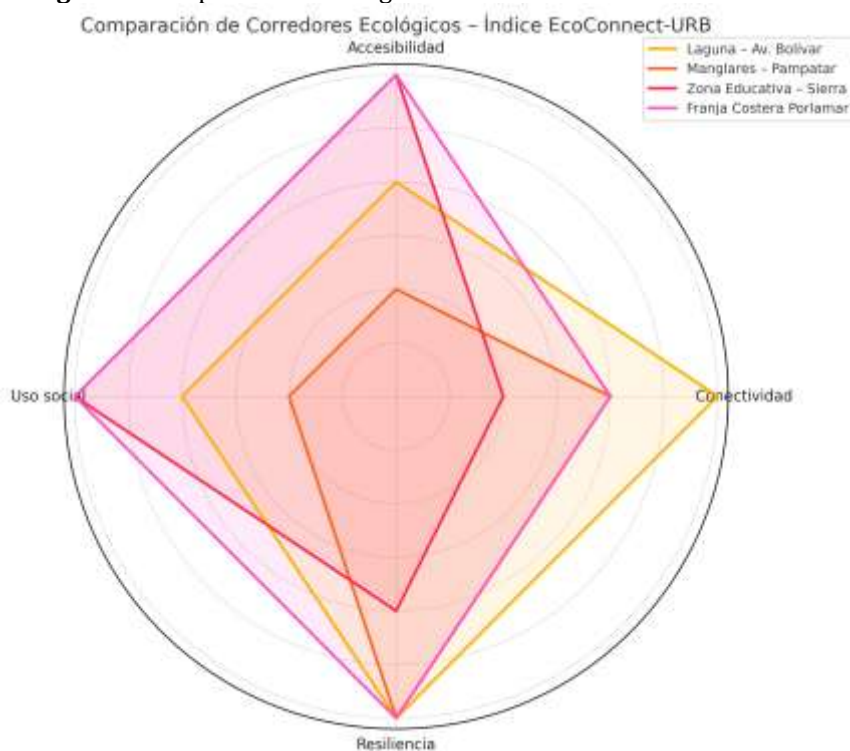
Porlamar-Pampatar's priority is to consolidate the Lagunas El Morro–Av. Bolívar (0.76) corridor due to its high functional potential, while activating the Educational Zone–Sierra (0.61) social corridor and protecting key natural areas such as the Porlamar coastline (0.53) and Bahía de Pampatar–mangroves (0.63) (Table 15 and Figure 5).

**Table 15.** Characteristics of the corridors in Porlamar-Pampatar

Corridor	Connectivity		Accessibility		Social use		EcoConnect-URB Specific (0-1)	
	Calif.	Val.	Calif.	Val.	Calif.	Val.	Calif.	Valo
Coastal Strip Porlamar	Average	0.40	Average	0.40	High	0.80	High	0.53
Pampatar Bay-Mangroves	High	0.6	Medium	0.5	High	0.80	Low	0.63
El Morro Lagoons-Bolívar Avenue	High	0.7	High	0.8	High	0.80	Medium	0.76
Educational Zone-Sierra	Low	0.25	High	0.80	High	0.80	Medium	0.61

Source: Own elaboration, 2026.

**Figure 5.** Comparison of ecological corridors – EcoConnect-URB Index



Source: Field data and satellite images (2024)

### 5.8. Porlamar Coastal Strip Corridor

This corridor constitutes a Priority Urban Coastal Ecological Corridor, with the capacity to function as the Porlamar-Pampatar Coastal Green Axis. It is characterised by existing natural ecosystem connectivity, encompassing beaches, dune systems, brackish wetlands, and scattered mangrove formations. As such, it represents a strategic coastal green corridor for climate change adaptation.

The coastal strip has the potential to operate as a natural protective barrier against coastal flooding and marine erosion. Its revegetation with native, salt-tolerant species would significantly enhance its protective and regulatory functions. These ecosystems provide habitats for coastal birds, reptiles, crustaceans, and halophytic flora adapted to saline conditions. With appropriate ecological restoration and spatial planning interventions, the corridor could be connected to the

Pampatar mangroves and remnant vegetation in the western sectors, thereby strengthening coastal biological connectivity and increasing species resilience.

The corridor presents a strong potential for integration within the dense urban fabric, despite the presence of underused or degraded spaces. These areas benefit from both pedestrian and vehicular accessibility, enabling the linkage of ecological zones with public and recreational spaces. In this way, the corridor can function as an interface between the city and the sea, contributing to improved coastal climate resilience and urban environmental quality.

Given Porlamar's strong coastal and tourism-oriented vocation, this green axis could promote urban ecotourism, generate spaces for environmental education and family-oriented recreation, and serve as a catalyst for coastal urban regeneration. Its feasibility is supported by the longitudinal configuration of the coastline, which allows for the phased development of a continuous linear corridor extending several kilometres. Initial interventions could prioritise strategic areas such as the Santiago Mariño Avenue promenade, the edges of residential areas with restricted access, and zones near the mouths of streams or drainage canals.

### ***5.9. Pampatar Bay-Mangroves Corridor***

The Pampatar Bay – Mangroves corridor is an ecological corridor of strategic value. Although currently disconnected, it exhibits medium connectivity and high resilience, as it links key coastal ecosystems such as mangroves, which are vital for climate change mitigation and adaptation.

Accessibility and social use are low due to inadequate pedestrian infrastructure and safety conditions, and the corridor remains largely isolated from the main urban fabric. The development of coastal ecological routes, elevated walkways, environmental interpretation centres, and community-based conservation policies is therefore proposed.

### ***5.10. El Morro Lagoons Corridor–Av. Bolívar***

The El Morro Lagoon–Av. Bolívar corridor (0.56) exhibits high connectivity with the dense urban areas of Porlamar through Av. Bolívar and other wide avenues that have significant potential for greening. It demonstrates high resilience, with capacity for water regulation and the provision of urban shade.

Accessibility and social use are currently supported by pedestrian infrastructure; however, improvements are required to ensure continuity and encourage stronger community appropriation.

Immediate strategic intervention is therefore proposed, including the rehabilitation of linear parks such as La Caracola, the planting of trees along major avenues, and the incorporation of green urban furniture.

### ***5.11. Educational Zone–Sierra Corridor***

The Corridor Educational Zone–Sierra (0.55) functions primarily as a corridor of social activation, although it presents ecological limitations. It is characterised by high accessibility and social use due to its proximity to schools and universities, with strong appropriation by students and local residents.

Ecological connectivity is low as a result of significant fragmentation and the absence of continuous natural links. Resilience is moderate, given the prevalence of impervious surfaces that limit climate mitigation capacity.

To support its consolidation, the implementation of educational green infrastructure is proposed, including school gardens and micro-scale urban corridors connecting schools and public squares, thereby strengthening ecological connectivity and environmental awareness.

## **6. Discussion**

There is clear evidence of ecological gaps; however, it is possible to prioritise interventions through the EcoConnect-URB methodology, which integrates territorial, ecological, and social

variables. This index enables a more comprehensive approach than perspectives that equate the mere presence of green areas with sustainability, without accounting for their functional performance or social context.

The analyses indicate a sustained decline in ecological connectivity in Porlamar–Pampatar, where unplanned urban growth has led to significant fragmentation of the vegetation landscape, in line with the findings of Sanz D'Angelo et al. (2011). Furthermore, there is evidence of an ongoing process of territorial ecological transformation, supporting the conclusions reported by Camargo (2024).

These findings highlight the need to design strategic green infrastructure, restore natural connectors, and strengthen integrated territorial planning policies that contribute to improvements in vegetation cover, water quality, biodiversity, and climate resilience, as noted by Apan et al. (2002), Vásquez (2016), and Maekawa and Nakagoshi (1997).

To ensure functionality, safety, accessibility, and spatial continuity for public use, it is necessary to expand green areas while actively planning for the maintenance of ecological connectivity. Such measures enhance the effectiveness of ecological infrastructure within the urban system.

Several areas of ecological opportunity exist between Porlamar and Pampatar that can be leveraged to establish ecological corridors. These corridors would facilitate linkages between existing green areas, creating a functional ecological network connecting urban and tourist environments.

One proposed strategy involves the restoration of native vegetation and the creation of green connectors, establishing ecological nodes in areas of intermediate or low urban friction, such as parks and green spaces. In contrast, high-friction areas, particularly to the east of Pampatar, require targeted restoration strategies, the identification of strategic nodes, and the implementation of artificial ecological connectors to improve integration with the urban fabric.

Finally, public awareness of the importance of protecting ecological connectivity can be strengthened through the integration of citizen participation into the analytical and planning processes. The development of educational programmes therefore plays a key role in mitigating impacts on green spaces and enhancing their long-term functionality.

## 7. Conclusions

The high degree of fragmentation and uneven distribution of green areas results in low structural connectivity (0.35). Vegetation patches are small and widely spaced, and tree-lined avenues or continuous linear corridors are scarce.

Functional connectivity is also limited (0.40), as the connections between the lagoons, the Pampatar mangroves, the coastline, and the peri-urban hills are partial and highly vulnerable. Ecological movement and corridor efficiency are constrained by a dense urban grid characterised by extensive soil sealing.

Ecological resilience is moderate (0.43), reflecting a certain capacity for recovery due to the presence of restoration opportunities and potential corridor development. However, low plant diversity and spatial fragmentation reduce the system's capacity for climate change mitigation and its ability to adapt to disturbances such as heat waves and flooding.

Urban friction to ecological movement is high (0.39), particularly in the most densely built and tourist-oriented areas, where interruptions to the flow of fauna, seed dispersal, and shading further intensify ecological fragmentation.

Despite these limitations, several strategic opportunities for improvement were identified, including the establishment of a continuous coastal corridor from Pampatar to Porlamar with native vegetation; the creation of a functional green axis connecting the Laguna de Los Mártires to Avenida Bolívar; the linkage of educational areas with the Sierra through strengthened vertical corridors; the restoration of mangrove ecosystems; and the recovery of vacant lots as urban micro-parks.

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