INGENIO
2025, VOL 9(1), JULIO - DICIEMBRE, PP. 026-042

REVISTA INGENIO

Urban Morphology and Structure as Sustainability Indicators in Crucita la Bella, Manabí, Ecuador

Morfología y estructura urbana como indicadores de sostenibilidad en Crucita la Bella, Manabí, Ecuador

Jhonny Leonardo Álvarez Ochoa | UTE University, Faculty of Architecture and Urbanism, UTE University
Carlos Patricio Zambrano Solórzano | UTE University, Master in Urbanism with a mention in Sustainable Urban Planning

Recibido: 18/9/2025
Recibido tras revisión: 13/10/2025
Aceptado: 31/10/2025
Publicado: 28/1/2026

KEY WORDS
Urban Morphology, Urban Structure, Sustainability, Cartography, Urban Indicators, Strategies, Resilience.

ABSTRACT
This article provides a detailed analysis of the morphology and urban structure of the parish of Crucita la Bella, located in the province of Manabí, Ecuador. It reveals profound urban weaknesses linked to the spontaneous growth of the parish, the disorder of land use, the lack of planning, the scarcity of green areas and the lack of public infrastructure. Despite these weaknesses, strengths have been identified that allow the formulation of concrete proposals for improvement. Through the development of thematic maps and multivariate analysis, sustainable intervention strategies are established based on road reorganization, strategic pedestrianization, the creation of green circuits and the integration of resilient solutions to climate change. These proposals focus on improving sustainability indicators such as population density, land use, accessibility, road connectivity, proportion of green spaces, energy efficiency, quality of public space and sustainable mobility. In this context, a comprehensive intervention is foreseen that will include the zoning of urban intervention polygons as general strategies, applying key urban indicators to evaluate the current state of sustainability in the locality. Thus, the article seeks to provide a useful technical and conceptual basis for decision-making in land-use planning and coastal urban resilience policies, promoting a more orderly and sustainable development in the region. This comprehensive approach will improve the quality of life of the inhabitants and strengthen the culture.

PALABRAS CLAVE
Morfología Urbana, Estructura Urbana, Sostenibilidad, Cartografía, Indicadores Urbanos, Estrategias, Resiliencia.

RESUMEN
El presente artículo realiza un análisis detallado de la morfología y estructura urbana de la cabecera parroquial de Crucita la Bella, ubicada en la provincia de Manabí, Ecuador. Se identifican profundas debilidades urbanas vinculadas al crecimiento espontáneo de la parroquia, el desorden en el uso del suelo, la falta de planificación, la escasez de áreas verdes y las carencias de infraestructura pública. A pesar de estas debilidades, se han identificado fortalezas que permiten formular propuestas concretas de mejora. A través de la elaboración de mapas temáticos y análisis multivariados, se establecen estrategias sostenibles de intervención basadas en la reorganización vial, la peatonalización estratégica, la creación de circuitos verdes y la integración de soluciones resilientes frente al cambio climático. Estas propuestas se centran en mejorar indicadores de sostenibilidad, como la densidad poblacional, el uso del suelo, la accesibilidad, la conectividad vial, la proporción de espacios verdes, la eficiencia energética, la calidad del espacio público y la movilidad sostenible. En este contexto, se prevé una intervención integral que incluirá la zonificación de polígonos de intervención urbana como estrategias generales, aplicando indicadores urbanos clave para evaluar el estado actual de sostenibilidad en la localidad. Es así como el artículo busca aportar una base técnica y conceptual útil para la toma de decisiones en políticas de ordenamiento territorial y resiliencia urbana costera, promoviendo un desarrollo más ordenado y sostenible en la región. Este enfoque integral permitirá mejorar la calidad de vida de los habitantes y fortalecer la cultura.

1. INTRODUCTION

In Ecuador, contemporary urban challenges, particularly visible in peripheral parishes such as Calderón in Quito, reveal a lack of adequate planning and excessive growth of informal settlements. These circumstances have fostered residential segregation and fragmentation of the urban fabric, resulting in isolated communities and accentuating existing social inequalities [1]. This phenomenon is part of a broader context of rapid urbanization in Latin America, where the expansion of cities has led to growing social and territorial polarization, negatively impacting the quality of life of residents and restricting their access to basic services [2].

https://doi.org/10.29166/ingenio.v9i1.8778

pISSN 2588-0829
eISSN 2697-3243
fing.revista.ingenio@uce.edu.ec

In April 2016, the province of Manabí, Ecuador suffered an earthquake that severely damaged infrastructure and public spaces [3], among them is the city of Portoviejo, in the Crucita parish, especially its waterfront, which has faced negative impacts due to its vulnerability to flooding, affecting its tourist and commercial activity and hindering urban revitalization. In addition, the current exercise of urban planning and local management has failed to promote sustainable development focused on the most important local aspects, thus limiting the quality of life of its inhabitants.

Over the past 20 years, the parish of Crucita has experienced remarkable urban and demographic growth, which has been a key factor in the transformation of its urban fabric. This growth, however, has been marked by disorderly development and inefficient land use, largely due to the lack of adequate urban planning. This deficiency has triggered a significant deterioration in the urban, spatial, and environmental conditions of the area. As a result of these problems, the parish faces serious socioeconomic challenges that affect the quality of life of its inhabitants. The lack of adequate infrastructure, basic services, and public spaces has contributed to aggravating the situation, creating an environment that limits opportunities for development and well-being for the community.

Currently, the parish of Crucita faces a series of challenges that encompass social, economic, and environmental aspects. These factors have led to a notable deterioration of its urban spaces, resulting in a loss of vitality in the community. Given this situation, it is essential to implement urban strategies that contribute to the creation of a sustainable urban model. This model should be geared toward revitalizing, improving, and humanizing the urban ecosystem, allowing life to flow harmoniously through these spaces. In other words, the goal is to establish an urban support system that is endowed with energy and dynamism, thus promoting the comprehensive development of life in all its dimensions and complexities [4].

The disorderly use of land and lack of planning in activities along the seafront have had a significant impact on the coastal morphology of Crucita. This alteration has negatively affected the image of the area, resulting in a notable decrease in commercial and tourist activity, which, in turn, has repercussions on the local economy and the quality of life of its inhabitants.

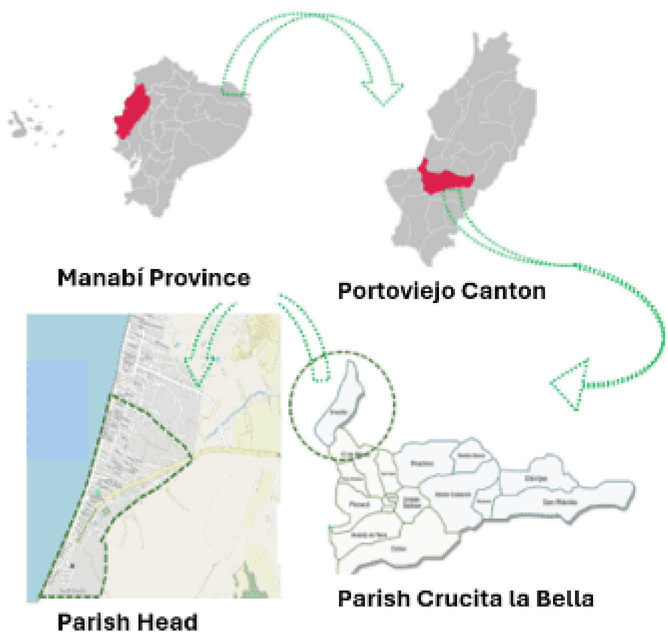
In addition, limited accessibility to the promenade prevents both residents and visitors from fully enjoying this space. The scarcity of green areas also represents a problem, as it reduces opportunities for recreation and leisure, directly affecting the health and well-being of the community. To further complicate the situation, the lack of cartographic information hinders an adequate diagnosis of current conditions, as well as the identification of critical areas that require urgent attention.

The implementation of a sustainable urban model, based on adequate land use planning and geospatial analysis, will improve the resilience of the parish of Crucita to the effects of climate change, revitalizing its tourism and commercial activity and, consequently, increasing the quality of life of its inhabitants. Given this situation, it is essential to propose strategies for a sustainable urban model in the parish of Crucita. This will be achieved through geospatial analysis and the application of Geographic Information Systems (GIS), focusing on urban morphology and structure, as well as social issues that affect the vitality of the locality. The implementation of these urban strategies will seek to improve the quality of life of the inhabitants and promote a dynamic, inclusive, safe and resilient sector.

Crucita, located in the province of Manabí Fig. 2, is only 30 minutes from the cities of Portoviejo and Manta [5], This locality covers an area of 6,228.08 hectares and is located at coordinates 0°52'15.80"S and 80°32'13.52" W. It has a characteristic climate, with a dry summer and a warm and rainy winter season. According to data from the PDOT [5] is bordered to the north by the resorts of San Jacinto and San Clemente of Charapotó parish, to the south by Jaramijó canton, to the east by Charapotó, El Pueblito and Cañitas of Sucre canton, as well as Higuerón of Rocafuerte canton, and to the west by the Pacific Ocean. For the analysis of the work, the study area was delimited, corresponding to the parish headwaters.

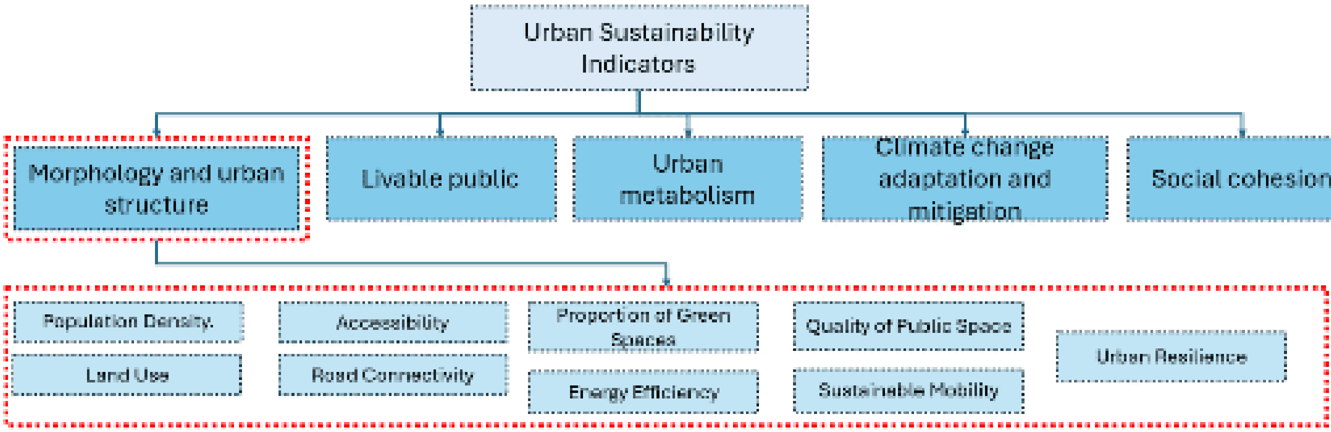
Fig. 1.

Location "Cabecera parroquial de Crucita la Bella".



Therefore, the present study asks: to what extent do urban morphology and urban structure condition sustainability performance in Crucita la Bella? Accordingly, the article aims to: (i) select and normalize a set of territorial indicators aligned with international frameworks [6], [7]; (ii) determine variable weights through a transparent and reproducible procedure; (iii) identify intra-urban typolo-

Fig. 2.
Urban Sustainabilitv Indicators.



Source: [10].

gies through Principal Component Analysis (PCA) and hierarchical clustering; and (iv) derive spatially oriented intervention lines that link the empirical findings with feasible policy and design actions.

Urban sustainability indicators provide an operational bridge between diagnostic evidence and strategic decision-making. Beyond describing the status quo, they capture trends and trade-offs across environmental, social and functional dimensions, enabling comparability over time and space [6], [7], [8], [9]. In coastal and post-disaster contexts, indicator systems are particularly relevant because they reveal spatial inequalities in access, exposure and adaptive capacity, and make visible the territorial conditions that either constrain or enable resilience-oriented planning [6], [7], [9].

Within this indicator family, urban morphology and urban structure are key determinants of sustainability outcomes. Density, land-use mix, street connectivity and block configuration influence accessibility, energy demand, public space quality and the viability of active and public transport [11], [12], [13]. Morphology describes the physical organization and form of the built fabric, while structure relates these forms to functional, social and economic dynamics. Together, they shape the spatial logic through which opportunities, risks and amenities are distributed across the city [11], [12], [13]. Recent studies in Ecuadorian intermediate cities have confirmed the relationship between morphological typologies and habitability levels [13].

In coastal settlements, the interaction between urban form and environmental exposure positions resilience as a central dimension of sustainability. The provision of green areas, microclimatic regulation, and the robustness of circulation networks condition both everyday livability and emergency performance. For this reason, the set of indicators fulfills a dual role: (a) it guides short-term improvements—for example, by generating shade in public spaces, ensuring permeability, and providing safe crossings, among others—and (b) it informs medium-term strategies, such as promoting urban consolidation while guaranteeing access to basic services, as well as planning public-space systems that are properly distributed and accessible, in alignment with international guidelines and references[7], [9], [14], [15].

Given the multiscalar and interdependent nature of these dimensions, multivariate techniques are suited to reduce redundancy, reveal latent patterns and delineate urban typologies. Principal Component Analysis (PCA) synthesizes co-varying indicators into a small set of components, while hierarchical clustering (Ward's method) groups areas with similar profiles, supporting targeted, place-based interventions [13], [16]even though 70% of the world's population lives in urban areas. The Sustainable Development for Energy, Water, and Environment Systems (SDEWES. This analytical pathway connects the indicator framework to an index and to an actionable territorial narrative.

2. METHODS

This research is based on a positivist quantitative methodological approach, which allows the analysis of urban sustainability from measurable, replicable and objective indicators. The design adopted is non-experimental, since the variables will not be directly manipulated, but observed in their real territorial context. Within this framework, a combination of two types of scope is proposed: descriptive, aimed at characterizing the current conditions of the territory, and explanatory, focused on establishing relationships between urban variables and their influence on sustainability.

2.1. DATA COLLECTION

The data collection stage is based on a socio-spatial analysis technique, understood as an approach that allows understanding the spatial organization of social, environmental and functional phenomena through their cartographic representation. To this end, Geographic Information Systems (GIS) tools will be used to process and represent georeferenced information at different territorial scales.

Primary and secondary data will be integrated into thematic layers, associated to key variables of analysis. These layers will include, among others: administrative boundaries, land use, population density per hectare, road networks and connectivity hierarchies, green spaces (with their classification by type and function), equipment distribution, public transport routes and urban heat generation points. The data source will include municipal cadastres, databases of the National Institute of Statistics and Census (INEC), satellite images (Landsat, Sentinel), OpenStreetMap, and official base cartography.

2.2. PREPARATION OF SPATIAL MAPS

Once the layers have been consolidated, the thematic maps will be produced using software tools such as QGIS 3.28 or ArcGIS Pro, applying geoprocessing functions, spatial overlay, network analysis and distance calculations. Density, accessibility and road connectivity maps will be produced using methods such as Kernel Density Estimation (KDE) for population distribution, cost distance for accessibility, and centrality analysis (closeness and betweenness) to evaluate road hierarchies.

Likewise, an analysis of green coverage will be carried out using the NDVI (Normalized Difference Vegetation Index), which will allow estimating the degree of urban vegetation through the interpretation of multispectral images. The results of these maps will serve as input for the development of the composite indicator of urban sustainability, the central axis of the analysis.

2.3. CONSTRUCTION OF THE URBAN SUSTAINABILITY INDICATOR

The urban sustainability indicator will be developed under a compositional and hierarchical approach, structured around the urban morphology and structure dimension. This indicator will integrate ten main variables, selected for their relevance in international sustainable urban assessment models [7], [16]:

- Population density (inhab/ha)
- Mixed land use (%)
- Accessibility to basic services (average distance to key nodes)
- Road connectivity (nodes and connections per hectare, connectivity index)
- Proportion of green spaces (% of urban area)
- Energy efficiency (consumption intensity per m²)
- Quality of public space (assessed by presence of furnishings, lighting and maintenance)
- Sustainable mobility (infrastructure for non-motorized transport)
- Urban resilience (capacity to respond to natural and anthropogenic hazards)

Table 1 summarizes the ten indicators selected for constructing the Urban Sustainability Index (USI), detailing their description, units of measurement, data sources, and expected relationship with sustainability performance.

These variables will be normalized using standardization techniques (z-score or min-max), and weighted according to their relative incidence in the theoretical framework and empirical evidence [13], [17]even though 70% of the world's population lives in urban areas. The Sustainable Development for Energy, Water, and Environment Systems (SDEWES. These indicators are aligned with international frameworks but require local calibration to Latin American realities, as demonstrated by the CEDEUS approach in Chile [14] especially since the generation of specific urban indicators for the Agenda 2030. Urban sustainability is a broad concept involving many dimensions, therefore the generation of a short, but comprehensive list of indicators is a significant challenge. In this paper, we present a set of 29 indicators designed to characterise urban sustainability in Chile, which we also expect to be relevant to other cities, particularly in the Global South where issues of poverty and inequality are prevalent. We first outline the process of selecting the indicators through expert consultation. Then we present selected indicators, and the variables used to measure them. Subsequently the set is applied to six Chilean cities that are diverse in terms of population, socio-economic conditions and geography. We show that some indicators highlight negative nationwide trends that are common to the cities, while other indicators reveal notable differences that can be traced back to their local contexts. The CEDEUS indicators provide a complement to the UN's Sustainable Development Goals (SDGs. The integration of these variables into a single index will make it possible to compare intra-urban areas and to evaluate the sustainability of the territory in an aggregated manner.

To determine the relative weight of each variable within the Urban Sustainability Index (USI), a statistical weighting procedure was applied to ensure transparency and reproducibility. Principal Component Analysis (PCA) was first conducted on the normalized dataset to identify latent dimensions of co-variation among indicators. The weights (w_i) were derived from the absolute factor loadings of each variable across the retained components, proportionally adjusted by the variance explained by each component, and normalized so that $\Sigma w_i = 1$. This data-driven approach minimizes subjectivity compared to expert scoring methods.

TABLE I.

Summary of indicators, data sources, and measurement units

Code	Indicator	Description	Unit / Scale	Source	Expected effect (+/–)
V1	Population density	Number of inhabitants per hectare	hab/ha	INEC (2020)	+
V2	Land-use diversity	Degree of functional mix measured through Shannon Index	dimensionless	Field survey, GAD Mejía (2024)	+
V3	Street connectivity	Density of intersections per square kilometer	intersections/ km^2	QGIS analysis (2024)	+
V4	Green-space ratio	Proportion of public green areas per inhabitant	m^2/hab	QGIS, field verification	+
V5	Accessibility to services	Mean network distance to primary facilities (education, health, commerce)	meters	ArcGIS Pro, OSM data	–
V6	Building coverage index	Percentage of built-up surface over total parcel area	%	Cadastral layer, GAD Mejía (2024)	–
V7	Road condition index	Share of paved vs. unpaved roads	%	Field survey	+
V8	NDVI vegetation index	Normalized Difference Vegetation Index (mean value per block)	dimensionless	Sentinel-2 imagery (ESA, 2024)	+
V9	Public-space provision	Ratio of open spaces suitable for public use	m^2/hab	QGIS + fieldwork	+
V10	Proximity to coastline risk	Distance to high-risk coastal exposure areas	meters	MAAE, GAD Mejía (2023)	–

The final index was computed through a linear aggregation model:

$$USI = \sum_{i=1}^{n} w_i \cdot V_i^{norm}$$

where V_i^{norm} represents the standardized value of variable i, and w_i its corresponding weight.

Subsequently, hierarchical cluster analysis (Ward's method, Euclidean distance) was performed using the component scores obtained from the PCA to classify urban sectors with similar sustainability performance. This sequence—PCA followed by clustering—ensures dimensional reduction while preserving the internal structure of the data. The resulting groups form the empirical basis for identifying urban typologies and for spatializing sustainability outcomes across Crucita's territory.

Prior to applying the PCA, correlation tests were performed to verify the absence of redundancy among variables. Sampling adequacy and sphericity were confirmed through the Kaiser–Meyer–Olkin (KMO) statistic and Bartlett's test of sphericity, ensuring the suitability of the dataset for multivariate analysis. This step guaranteed that the structure of the indicators was statistically consistent and robust for dimensional reduction.

Finally, the calculated USI values and the resulting urban typologies were spatialized in QGIS to visualize intra-parish disparities and identify critical or resilient sectors. Choropleth and cluster maps were generated to facilitate interpretation and to support the formulation of targeted spatial strategies within Crucita's urban fabric.

2.4. DATA ANALYSIS TECHNIQUES

Once the database has been constructed, multivariate analysis techniques will be applied, aimed at identifying behavioral patterns and grouping urban areas with similar characteristics. The main techniques used will be:

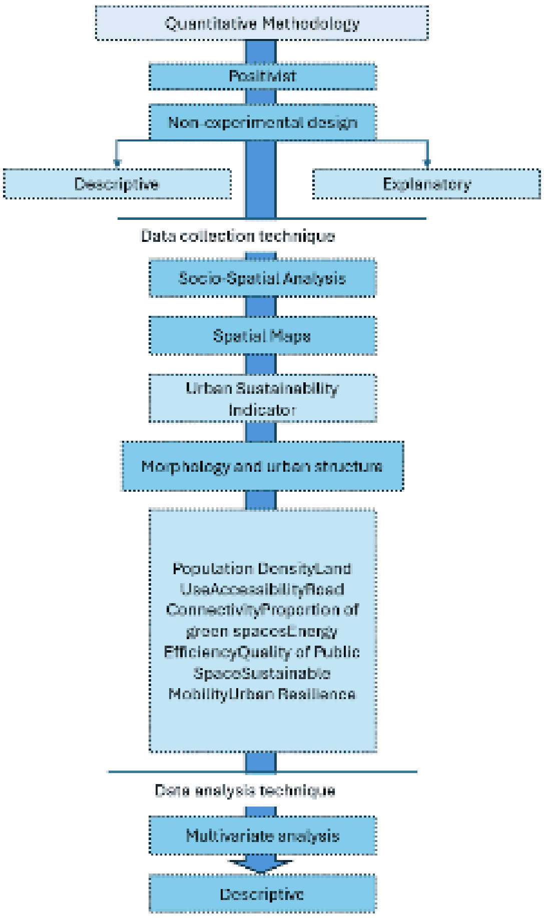
- Principal Component Analysis (PCA): will reduce the dimension of the database, identifying structural axes (components) that explain most of the variance between variables. This will make it easier to visualize the relationships between dimensions and eliminate redundancies.
- Hierarchical Cluster Analysis (Ward's Method): applied to the components extracted by the PCA, it will allow generating urban typologies according to their sustainability performance, grouping similar areas to facilitate their comparison.
- Descriptive Analysis: measures of central tendency, dispersion, box plots and heat maps will be used to visualize the distribution and behavior of each variable, as well as the differences between the clusters generated.

These tools will be applied using IBM SPSS Statistics, RStudio and Excel Power Pivot programs, guaranteeing statistical rigor and ease of representation.

In conclusion, the proposed methodology seeks to provide a rigorous territorial evaluation that, from the spatial and quantitative dimension, allows for an accurate diagnosis of the current conditions of the urban system. In addition, it will make it possible to simulate different transformation scenarios based on the relationship between urban form and sustainability. This approach will facilitate decision-making aimed at planning more equitable, resilient and environmentally sustainable cities, with technical, empirical and territorially contextualized support.

Fig. 3.

Methodology to be used.



3. ANALYSIS AND RESULTS

MULTIVARIATE RESULTS: PRINCIPAL COMPONENT AND CLUSTER ANALYSIS

The multivariate analysis began with a Principal Component Analysis (PCA) applied to the ten standardized sustainability indicators. The KMO test (0.78) and Bartlett's test of sphericity ($p < 0.001$) confirmed the statistical adequacy of the dataset. Three principal components with eigenvalues greater than 1 were retained, explaining 71.4% of the total variance. Component 1 (Density–Connectivity Pattern) concentrated variables associated with population density, road connectivity, and accessibility. Component 2 (Green and Environmental Quality) grouped indicators such as the green-space ratio, NDVI, and distance from coastal exposure. Component 3 (Public Space and Urban Form) integrated land-use diversity, building coverage, and public-space quality. These components summarize the main structural relationships underlying sustainability performance across Crucita's urban fabric.

Based on the PCA scores, a hierarchical cluster analysis (Ward's method, Euclidean distance) was carried out to classify urban sectors according to their sustainability performance. Three clusters were identified, representing distinct morpho-structural typologies: Cluster 1—compact and connected areas with intermediate sustainability values; Cluster 2—peripheral zones with low density and higher environmental quality; and Cluster 3—central consolidated sectors with high density but low environmental indicators. The spatial distribution of these clusters highlights a marked contrast between the coastal front, where environmental exposure is higher, and inland sectors, where accessibility and green-space ratios improve.

Table 2 presents the variance explained by each component and their interpretation.

The following sections detail the spatial behavior of each indicator, providing a descriptive analysis that complements the multivariate findings and supports the formulation of urban strategies.

The study of urban morphology and structure allows us to understand how the territory is organized and spatially configured, and how these forms directly impact the sustainability, quality of life and resilience of communities. To evaluate these aspects in the Crucita parish, an analysis framework has been structured based on key indicators that allow the identification of occupation patterns, access to services, mobility, energy efficiency and adaptation to climate change, among others. These indicators, based on recent methodological proposals such as those of doinGlobal [10], have been adapted to the local context in order to provide a comprehensive view of the urban reality of Crucita.

This set of indicators includes: population density, land use, accessibility, road connectivity, availability of green spaces, energy efficiency, quality of public space, sustainable mobility and urban resilience. Each of these aspects is addressed through socio-spatial analysis supported by thematic mapping, statistical sources and territorial observation, which allows for the precise identification of the weaknesses and potential of the urban system. This approach not only facilitates the technical evaluation of urban sustainability, but also guides planning towards strategies that integrate the principles of territorial equity, sustainable development and spatial justice.

TABLE II.

PCA results: variance explained and interpretation.

Component	Eigenvalue	% Variance	Cumulative %	Interpretation
1	3.45	34.5	34.5	Density–Connectivity Pattern
2	2.15	21.5	56.0	Green and Environmental Quality
3	1.55	15.4	71.4	Public Space and Urban Form

The following is an individualized analysis of each indicator, complemented with empirical evidence, census data and cartographic results, in order to establish a clear diagnosis of the current state of the Crucita parish and generate a technical basis for the formulation of intervention proposals.

3.1. URBAN MORPHOLOGY AND STRUCTURE INDICATORS.

This framework of indicators contains the following items Population Density, Land Use, Accessibility, Road Connectivity, Green Spaces, Energy Efficiency, Quality of Public Space, Sustainable Mobility and Urban Resilience [10], the first indicator to be used to evaluate the indicators in each of the cartographies is the shape of the parish, which will provide a better understanding of the shape of the parish, as well as to evaluate the indicators in each of the cartographies.

3.1.1. Population Density

In 2001, Crucita parish had a population of 11068 inhabitants, which corresponded to 5.89% of the total population of the canton of Portoviejo. In 2010 this population changed to 14050, in terms of proportion with respect to the canton's population, Crucita remains the second most populated rural parish in the canton, as mentioned in the [18]. The population growth rate is the highest in the canton in terms of rural parishes with a growth rate of 2.64% between 2001-2010. It presents a spontaneous and unplanned growth. According to the population pyramid of the rural parish of Crucita, the largest range of the population is young, between 5 and 29 years old, with a total average of 48% as shown in Fig. 4.

TABLE III

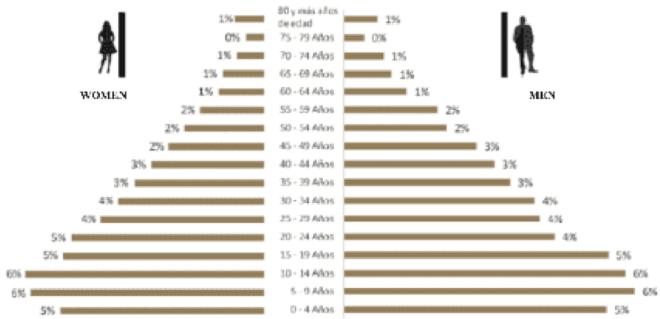
Population growth of the rural parishes of Portoviejo.

PARISH	POPULATION 2001	POPULATION 2010	GROWTH RATE
Calderón	12.511	14.164	1,38 %
Alhajuela	3.285	3.754	1,48 %
Crucita	11.068	14.050	2,65 %
Pueblo Nuevo	2.804	3.169	1,36 %
Río Chico	10.227	11.757	1,55 %
San Plácido	8.039	7.687	-0,50%
Chirijos	2.736	2.362	-1,63 %

Source: [18]

Fig. 4.

Population pyramid.



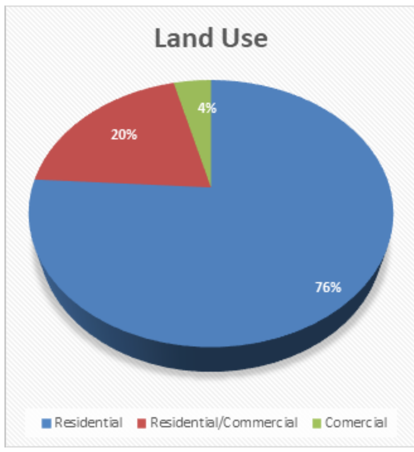
Source: [18]

3.1.2. Land Use

Land use is essential in territorial planning, and in Crucita la Bella, 76% of the land is allocated to residential use, which can limit functional diversity and generate a monotonous urban dynamic. Only 20% is used for commercial activities, concentrated on the coast, which benefits tourism, but lacks a mixed approach to revitalize the area. In addition, only 4% of the land is used for educational institutions and other services, demonstrating the need for diversification. To promote sustainable urban development, it is crucial to integrate mixed uses that include housing, commerce and green areas, as well as to increase the supply of educational and recreational facilities. These strategies would improve the quality of life and social cohesion in the community.

Graph 1.

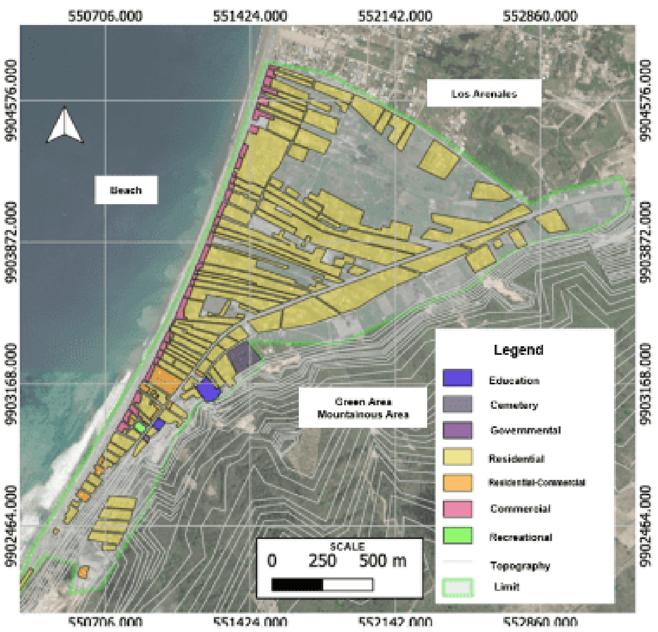
Land Use.



Source: [18]

Map 1.

Land use in the parish seat of Crucita.



3.1.3. Accessibility and Road Connectivity

Accessibility and connectivity are fundamental in urban planning, directly affecting the quality of life of citizens and the sustainability of cities. In Crucita, proximity to essential services such as health, education, and commerce is a significant challenge. The scarcity of these services forces residents to travel long distances, which can negatively impact their well-being, especially in emergencies. Furthermore, the reliance on main roads to access these services highlights the lack of adequate infrastructure in other areas.

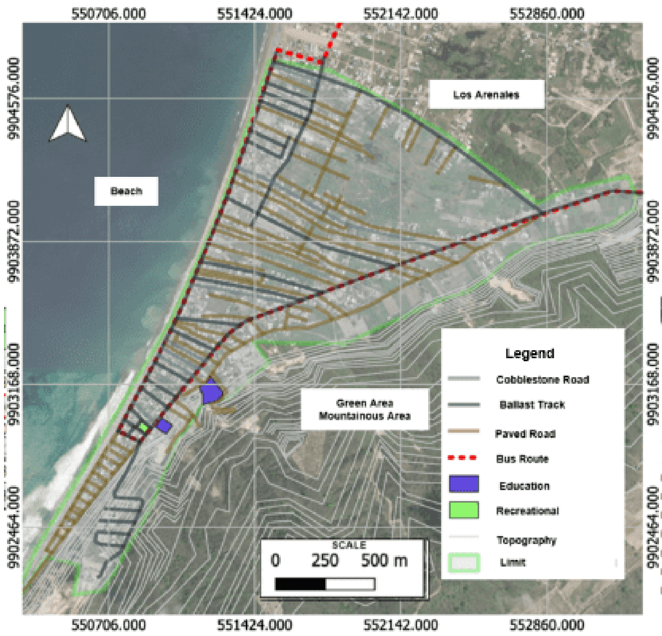
The road infrastructure in Crucita faces numerous problems that limit internal connectivity. Many streets are unpaved or in poor condition, making transit difficult for both vehicles and pedestrians, creating unsafe conditions. The gravel roads can become impassable during rainy seasons, worsening the situation and restricting the mobility of residents. This lack of maintenance and planning perpetuates a cycle of exclusion for those who depend on these routes.

Despite these challenges, access to public spaces such as the boardwalk and the park is relatively good, which is crucial for the social and physical well-being of the residents. However, access to the beach is obstructed by a large breakwater that limits direct connection to the sea, also impacting the region's tourism potential.

In conclusion, the situation regarding accessibility and connectivity in Crucita highlights the urgent need for more comprehensive and sustainable urban planning. To improve the quality of life for citizens, it is vital to address deficiencies in infrastructure, diversify services, and ensure adequate access to public spaces and natural resources. This will not only foster more cohesive and sustainable development but also strengthen the community's resilience to future challenges, promoting a more inclusive and equitable urban environment [15].

Map 2:

Accessibility of the parish head of Crucita.



3.1.4. Green Spaces

The World Health Organization (WHO) establishes that the index of urban green areas should be equal to or greater than 9 m^2 per inhabitant [19]. In the case of the parish of Crucita, according to the INEC of 2010, the population is 14,050 inhabitants and the total area is 6,228.08 hectares. This results in an urban green index of 2.26 m^2 per inhabitant [5]. This data reveals a significant deficit of green spaces that contribute to the comfort and environmental quality of the urban surroundings. Therefore, the use of vacant lots for green areas, along with reforestation using native species, becomes a priority. Such interventions have been promoted, for example, in national urban projects as mentioned by Cevallos, Álvarez & Almeida [20] in the article "University-Community Linkage for Sustainable Development: A Case Study in Miranda Mirador Sur".

The map of green and recreational areas in the parish head of Crucita reveals a concerning situation regarding the availability of spaces for recreation and connection with nature. Currently, there is only one recreational area, which is a park, in addition to a mountainous zone that, although it contributes vegetation, does not compensate for the scarcity of accessible green areas for the community. This limitation in green infrastructure not only affects the aesthetics of the urban landscape but also has direct implications on the quality of life of the inhabitants. The lack of adequate green areas limits opportunities for recreational and leisure activities, which are essential for the physical and mental well-being of citizens.

Green spaces are crucial for fostering social cohesion, as they provide places where people can gather, interact, and participate in community activities. The scarcity of these spaces can also contribute to an increase in public health issues, such as stress and obesity, by limiting options for outdoor exercise and connection with nature.

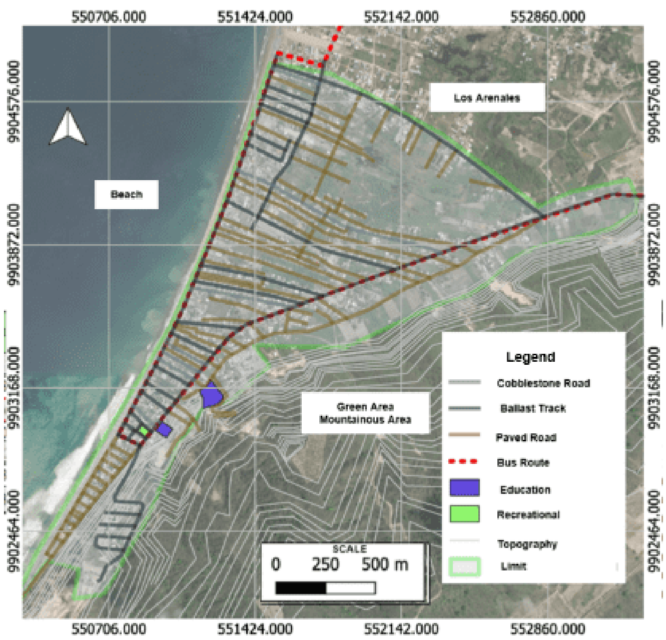
Furthermore, the large percentage of vacant land in the area represents a missed opportunity for the development of green spaces that could transform the urban landscape. Repurposing these lands to create parks, community gardens, or recreational areas would not only beautify the area but also improve residents' quality of life by providing them with access to natural spaces.

The incorporation of native species and reforestation in Crucita are essential to mitigate the effects of heat and improve air quality. Native species are adapted to the local climate and require fewer resources to maintain, making them a sustainable option for creating green spaces. Planting trees and creating shaded areas not only contributes to the aesthetics of the urban landscape but also helps regulate temperature, providing much-needed relief during the hottest months.

In summary, the current situation of green and recreational areas in Crucita underscores the urgent need to implement strategies that promote the creation and maintenance of these spaces. Reforestation, the incorporation of native species, and the reuse of vacant lots are essential steps to improve the urban landscape and the quality of life for residents. By investing in green areas, Crucita will not only benefit from a healthier and more aesthetically pleasing environment but will also move towards more sustainable and resilient development, fostering a more united community that is aware of its surroundings.

Map 3:

Green spaces in the parish seat of Crucita.



3.1.5. Energy Efficiency

Energy efficiency in the parish head of Crucita is prominent, highlighting a growing commitment to sustainability and reducing environmental impact. Currently, most residents have access to efficient energy solutions, resulting in relatively low energy consumption. This is made possible by the implementation of strategies and technologies aimed at the rational use of energy.

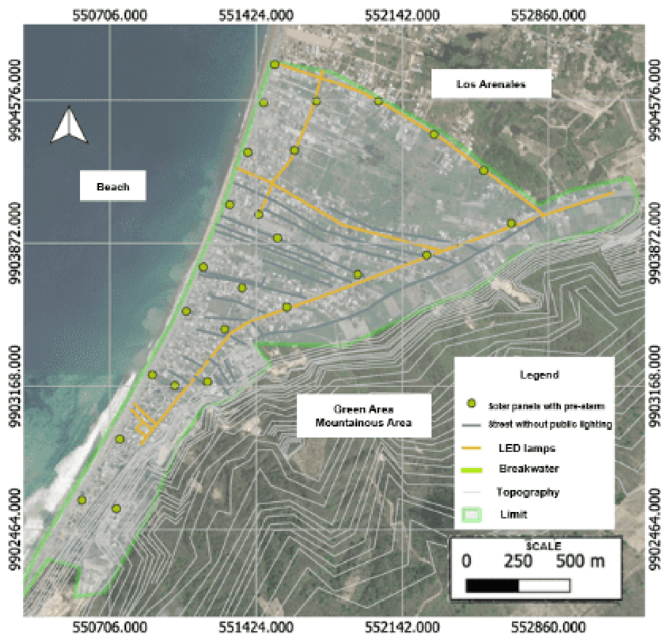
The use of renewable energies, especially solar energy, has become widespread, reducing dependence on non-renewable sources and contributing to lower energy costs. Meanwhile, the modernization of public lighting infrastructure to LED has been a key step in improving efficiency, decreasing energy consumption and greenhouse gas emissions.

For the parish seat of Crucita, it is essential to adopt sustainable construction practices that not only improve the energy efficiency of homes but also enhance their comfort and functionality. These measures, along with growing environmental awareness in the community, will make Crucita a model of energy efficiency in the region.

However, challenges remain, such as the need to increase awareness about energy savings and promote a broader shift toward responsible consumption practices. Despite this, the current scenario presents a unique opportunity to consolidate a sustainable and resilient urban development model that maximizes renewable energy and strengthens the quality of life of its residents.

Map 4:

Energy Efficiency of the parish seat of Crucita.



3.1.6. Quality of public space

Public space in the parish head of Crucita faces several issues that affect the quality of life for its residents and the experience of visitors. This space is not limited to a park or recreational area; it includes the boardwalk, streets, and sidewalks, forming the circulation system of the area. A critical aspect is the condition of the roads, which are mostly unpaved and dusty, hindering mobility and causing inconveniences both in dry seasons and during rains. The lack of proper paving compromises road and pedestrian safety, obstructing sustainable urban development.

The boardwalk, one of Crucita's main attractions, shows evident deterioration, affected by tidal waves and the wear of time, which limits its use and appeal as a tourist space. Additionally, the breakwater has given way over the years, making beach access difficult. Although residents have improvised steps, the lack of proper infrastructure remains a functional and aesthetic challenge.

Another issue is the scarcity of urban furniture. The lack of benches and adequate resting areas has led the community to use logs as makeshift solutions, which are unappealing and do not provide comfort or accessibility. The existing furniture is in poor condition, which diminishes the quality of the urban environment and affects the user experience.

The lack of vegetation is a critical factor. The absence of trees and plants limits the creation of shaded areas, reducing thermal comfort and environmental sustainability in the beach and its surroundings. Vegetation is essential for improving user well-being and preserving ecological balance, and its scarcity affects biodiversity and urban climate. It is urgent to address these issues to improve the quality of public space in Crucita. An integrated intervention that includes the improvement of road infrastructure, the rehabilitation of the boardwalk, the creation of adequate urban furniture, and the incorporation of vegetation is essential to transform the parish into a more accessible and sustainable place. These actions would not only enhance the quality of life for residents but also boost the tourist appeal of Crucita, favoring its economic and social development.

3.1.7. Sustainable mobility

Sustainable mobility has become an essential aspect for improving the quality of life in the parish head of Crucita. This concept advocates for a transportation model that is accessible, efficient, economical, and environmentally friendly, aiming to create a healthier and more dynamic urban environment. In an area like Crucita, characterized by its growing population and influx of tourists, promoting sustainable mobility not only enhances the quality of life for residents but also strengthens economic development and social cohesion.

Currently, the road infrastructure in Crucita faces challenges that affect the mobility of its inhabitants. Many of its streets are unpaved and dusty, which complicates not only vehicle circulation but also the transit of pedestrians and cyclists, especially during the rainy season. The lack of adequate sidewalks and limited road

Map 5:
Quality of Public Space in the parish seat of Crucita.

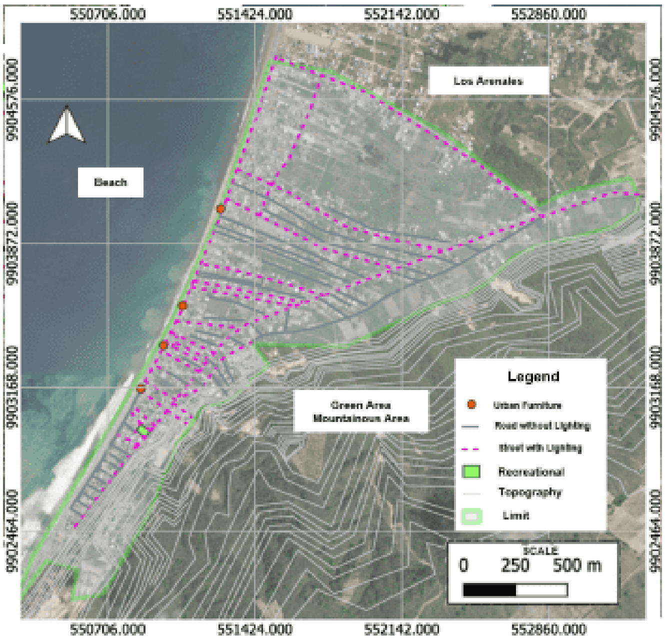


Fig. 5.
Photographic evidence of the public space.

signage complicate pedestrian safety, encouraging the use of private vehicles and contributing to traffic congestion. Moreover, public transportation is limited and does not efficiently meet the community's needs, increasing dependence on personal cars and, consequently, traffic and pollution problems.

However, there are numerous opportunities to promote more sustainable transportation alternatives in Crucita. One of the first actions would be the construction of adequate and safe sidewalks for pedestrians, which would not only facilitate their movement but also be inclusive and accessible for people with reduced mobility. Additionally, the creation of exclusive bike lanes would encourage the use of bicycles as a means of transportation, which would not only reduce traffic congestion but also improve public health by promoting physical activity.

Another fundamental measure is the improvement of public transportation, which must be efficient, accessible, and affordable for the residents of Crucita. This could involve implementing a broader and more modern public transport network, with low environmental impact vehicles, such as electric or hybrid buses, that contribute to reducing pollution and noise in the area. Furthermore, restructuring routes and schedules would allow for more efficient coverage, facilitating citizens' access to various points in the parish without the need to rely on private cars.

The integration of green spaces along mobility routes is crucial for improving the aesthetics and functionality of urban infrastructure. Incorporating gardens, trees, and green areas not only beautifies the environment but also provides shade and improves air quality, especially in high-traffic areas. Trees act as thermal regulators, creating a more comfortable environment for pedestrians and cyclists.

The use of geographic information systems helps strengthen these strategies by allowing the design of optimal and accessible routes for different modes of transportation. This tool has proven to be effective in similar scenarios, such as in the parish of Calderón, where it was key in identifying connection opportunities between neighborhoods through more efficient transport networks [21].

Promoting active mobility, such as walking and cycling, and raising awareness of its environmental, economic, and health benefits can lead Crucita towards a more accessible and sustainable urban environment. Additionally, reducing dependence on private cars would help decrease emissions of harmful gases, which is essential for mitigating the effects of climate change and improving the urban resilience of the parish.

In conclusion, the implementation of sustainable mobility strategies in Crucita would not only facilitate more efficient and safe movement for residents but also contribute to creating a more cohesive community, aware of its environmental impact and willing to adopt practices that favor its well-being. Improving road infrastructure, strengthening public transport, and creating green spaces are key elements that, when integrated coherently, will transform Crucita into a model of urban sustainability and responsible mobility (See annex map 6).

3.1.8. Urban Resilience

Urban resilience refers to a community's ability to anticipate, prepare for, respond to, and recover effectively from adverse events such as natural disasters, economic crises, or social transformations [22]socioeconomic, and political uncertainty and risk has captured the attention of academics and decision makers across disciplines, sectors, and scales. Resilience has become an important goal for cities, particularly in the face of climate change. Urban areas house the majority of the world's population, and, in addition to functioning as nodes of resource consumption and as sites for innovation, have become laboratories for resilience, both in theory and in practice. This paper reviews the scholarly literature on urban resilience and concludes that the term has not been well defined. Existing definitions are inconsistent and underdeveloped with respect to incorporation of crucial concepts found in both resilience theory and urban theory. Based on this literature review, and aided by bibliometric analysis, the paper identifies six conceptual tensions fundamental to urban resilience: (1. In the parish head of Crucita, this concept is of crucial relevance, given that the locality faces significant challenges such as infrastructure deterioration, climate change, and tsunami alerts.

Crucita has implemented early warning systems designed to notify the population in cases of natural disasters like earthquakes or tsunamis. These alarms are tested frequently, every two days, to ensure their effectiveness. However, there is a considerable challenge: the dispersion and unequal accessibility to designated meeting points. Not all residents have immediate access to these designated shelters, which can put vulnerable sectors of the population at risk. Therefore, it is crucial to increase the number of elevated refuge points and design more accessible evacuation routes, ensuring that all sectors of the community can reach them quickly and safely.

The breakwater in Crucita plays a key role in safety, serving as a physical barrier against wave action and natural phenomena. However, this approach could be complemented by the creation of a coastal green barrier, using native vegetation that would not only act as a buffer against wave impact but also help protect biodiversity and prevent coastal erosion. This integrated approach strengthens both environmental protection and resilience against climate change.

The incorporation of efficient technologies in homes, such as the installation of solar energy systems and the adoption of sustainable building practices, is essential for optimizing resource use in the community. These measures not only reduce dependence on the electrical grid during emergencies but also improve the quality of life for residents by lowering energy costs and ensuring the operational continuity of homes after a natural disaster. It is important that buildings are designed with coastal climate resilience in mind, using appropriate materials that reduce long-term vulnerability.

Improving the road infrastructure in Crucita is another fundamental pillar for strengthening its resilience. Having well-connected and well-maintained evacuation routes ensures that the population can efficiently move to safety points in emergency situations. This includes not only the expansion of existing roads but also the creation of alternative paths that allow for agile evacuation, even under adverse conditions.

Fostering a culture of sustainability and preparedness within the community is essential. This involves educating residents about the importance of sustainable practices, such as reducing energy consumption and using renewable sources, as well as training them in evacuation protocols and disaster response. Additionally, community initiatives should be strengthened to promote collaboration among residents for the protection and maintenance of shared spaces.

Crucita has the potential to become a model of sustainable urban resilience, where the community, environment, and infrastructure align to successfully face the challenges of the present and future. Implementing these strategies will not only ensure the safety and well-being of its inhabitants but also consolidate Crucita as a prepared and sustainable parish in the face of any adversity (See annex map 7).

In summary, the combination of PCA and cluster analysis allowed the identification of three coherent urban typologies that integrate morphological, environmental, and structural dimensions. These typologies constitute the empirical foundation for the intervention strategies proposed in the next section.

3.2. PROPOSAL

The parish seat of Crucita has been selected due to its significant loss of vitality, resulting from abandonment and a decrease in tourism and commercial activity, currently making it one of the weakest urban areas. Therefore, the recovery of public space is projected through the reorganization of the road layout and the pedestrianization of strategic sections. Additionally, green circuits will be promoted to connect the boardwalk with key points in the parish center, aiming to energize and revitalize the area.

In this context, a comprehensive intervention is anticipated, which will include the zoning of urban intervention polygons as general strategies. This intervention will focus on improving sustainability indicators within the morphology and urban structure, covering aspects such as population density, land use, accessibility, road connectivity, the proportion of green spaces, energy efficiency, the quality of public space, and sustainable mobility.

It is proposed to regulate population density to avoid disorderly growth, optimize land use through a plan that considers residential, commercial, and recreational areas, and improve access to services through public transport routes and pedestrian pathways. Furthermore, the aim is to strengthen the road network, increase the number of green spaces to enhance quality of life, promote energy efficiency in buildings, and boost urban resilience. These actions will be strategically integrated to ensure sustainable and balanced development in the parish.

The implementation of the proposed strategies is conceived in three progressive stages to ensure feasibility and monitoring. Short-term actions (0–6 months) prioritize low-cost, high-impact interventions such as shade generation, sidewalk recovery, and public-space maintenance. Medium-term actions (6–18 months) include the construction of green corridors, pedestrian circuits, and the rehabilitation of the waterfront promenade. Long-term actions (18–36 months) aim to consolidate the sustainability network through the integration of complementary facilities, tree planting programs, and continuous community participation mechanisms.

3.2.1. Zoning of intervention polygons

The territory of the parish head of Crucita is characterized by its longitudinal extension, which allows for a diversity of land uses ranging from residential areas to commercial, recreational, and service zones. This geographical configuration poses a significant challenge in terms of urban planning and management, as the distribution and utilization of natural resources must be managed efficiently to ensure harmonious and sustainable development (See annex map 8).

In order to organize this territory coherently, the implementation of a zoning of action polygons is projected. This zoning aims to strategically cover the entire territory of Crucita, ensuring that urban growth occurs in an orderly and controlled manner, respecting the characteristics of the place and the needs of the community. The subdivision into action polygons will allow for detailed planning, adapted to the particularities of each zone, facilitating the implementation of adequate infrastructures and services, such as road networks, access to basic services, public facilities, and green areas.

Furthermore, the zoning of action polygons aims to promote organized population settlements, favoring the development of neighborhoods and sectors that grow efficiently and sustainably over time. This type of planning not only responds to the need for growth but also facilitates access to services and resources for residents, optimizing their distribution based on population density and future projections. The idea is that as the population of Crucita grows, settlements will densify in a controlled manner, integrating new urban developments without compromising quality of life or environmental balance.

In summary, the zoning of action polygons in Crucita is not only a technical tool for organizing space but also a strategy for sustainable development that seeks to balance urban growth with respect for the natural environment and the quality of life of its inhabitants. The gradual and organized densification of the territory will ensure urban development that adapts to the needs of the community, promoting a more accessible, functional, and resilient environment for future generations.

3.3. RESILIENT PROPOSAL

The parish head of Crucita needs a comprehensive strategy to address the challenges of climate change and improve the resilience of its community (See annex map 9). Below are several key initiatives:

- Curved Breakwater: The construction of a curved breakwater on the coast will help protect the parish from erosion and flooding. This structure will not only reduce the impact of waves but also facilitate sediment accumulation, contributing to the stability of the coastline.
- Green Barriers: Implementing green barriers, such as hedges of native vegetation, will help decrease the forces of currents during floods. These barriers will act as a natural buffer, reducing water velocity and protecting inhabited areas.
- Creation of Meeting Points: The proposal includes the creation of two additional strategic meeting points to cover a larger population in case of emergencies. These spaces will be designed to be accessible and safe, facilitating the evacuation and sheltering of residents.
- Camps at Meeting Points: The meeting points will be equipped with temporary camps to accommodate the majority of the population during emergencies. These camps will be stocked with basic supplies, medical care, and psychological support.
- Strategic Parks with Shelters: The creation of strategic parks that include shelters designed for post-disaster use will be planned. These shelters will provide a safe place for residents and will be equipped with resources to facilitate recovery.
- Use of Solar Panels: Solar panels will be integrated into the shelters and meeting points, ensuring energy supply during emergencies. This renewable energy source will not only support the operation of the shelters but also promote environmental sustainability.
- This comprehensive proposal seeks to strengthen the resilience of the parish head of Crucita, ensuring that the community is better prepared to face future disasters and emergencies.

The implementation of these actions requires coordinated participation among multiple actors. The Municipal Autonomous Government of Mejía (GAD Mejía) will lead infrastructure execution and maintenance, while the Universidad UTE will provide academic and technical support through student–community collaboration programs. Community organizations will play a key role in local stewardship, awareness campaigns, and environmental monitoring. Financial resources are expected from a combination of municipal budgets, private sponsorships, and academic extension projects.

3.4. PROPOSED LOCATION OF EQUIPMENT

The aim is to establish facilities to reactivate the economy and tourism in the parish head of Crucita. This initiative focuses on creating recreational spaces that will include vegetation, recreational areas, and leisure zones. These spaces will be complemented by commercial plazas, promoting trade in areas that currently lack such activities and improving accessibility for residents and visitors (See annex map 10).

Additionally, municipal parking lots will be implemented to prevent tourist vehicles from parking on the boardwalk, which would create traffic and congestion. By offering adequate parking points, it will be easier for both the local population and tourists to enjoy the boardwalk in a more comfortable and safe manner.

A key proposal is the creation of a bike path that will be surrounded by tree vegetation, making the cycling experience more pleasant and attractive. This bike path will connect all the parks, promoting an active and healthy lifestyle while enhancing the recreational experience for visitors.

With these actions, the aim is not only to revitalize the local economy but also to transform Crucita into a more accessible and sustainable tourist destination, where the community and visitors can enjoy an enriched natural and recreational environment.

The expected outcomes of the proposal will be evaluated through measurable indicators aligned with the Urban Sustainability Index (USI) dimensions. Key monitoring metrics include: (i) increase in public green-space provision from 2.3 m^2/hab to 9 m^2/hab; (ii) 25 % improvement in road connectivity index; (iii) reduction in average pedestrian travel time to essential services by 20 %; and (iv) annual increase of 15 % in community participation in environmental activities. These indicators provide a quantitative framework to monitor the medium-term impacts of the proposed interventions.

4. CONCLUSIONS

The study confirmed that urban morphology and structure significantly condition the sustainability performance of Crucita la Bella. Compactness, connectivity, and functional diversity emerged as determining variables influencing environmental quality, accessibility, and resilience.

The evaluation of urban sustainability in the parish head of Crucita la Bella has allowed for the construction of a comprehensive diagnosis of the current state of the territory, revealing both strengths and structural weaknesses that condition its development. Through a methodological approach based on the analysis of indicators related to urban morphology and structure, it has been possible to clearly identify the critical variables that limit the consolidation of a sustainable urban model, as well as those that present a high potential for being integrated into intervention strategies. This chapter elaborates in detail on the main conclusions reached throughout the study, highlighting their relevance in technical, social, and territorial terms, of which will be presented in the following points:

4.1. STRUCTURAL DEFICIT AND TERRITORIAL OPPORTUNITIES

The results of the analysis reveal a significant deficit in several key indicators, including: accessibility to services, road connectivity, coverage of green spaces, quality of public space, and land use management. This deficit is reflected in a fragmented territorial organization, precarious physical infrastructure, and a low supply of basic urban services, especially in peripheral sectors and high-density areas. However, clear opportunities were also identified to reverse this situation: the existence of underutilized vacant lots, coastal landscape heritage, the presence of facilities with potential for reactivation, and a local community with growing environmental awareness and participation in neighborhood improvement processes.

These opportunities, if articulated through planned interventions, could become catalysts for urban revitalization processes and improvements in quality of life. These findings provided the empirical foundation for the spatial strategies proposed in the subsequent chapter, ensuring that each intervention directly responds to the identified structural gaps.

4.2. STRENGTHENING URBAN RESILIENCE

Urban resilience has been one of the indicators with the greatest potential in Crucita, especially due to the existence of early warning systems and the progressive adaptation to coastal risks such as tsunamis. However, there is a clear need to strengthen this resilience through more comprehensive and adaptive infrastructures. The implementation of elevated shelters with guaranteed access from all sectors, passive energy systems (such as solar panels on community buildings), and a network of clearly identified and accessible evacuation routes is proposed.

Furthermore, the use of coastal green barriers through native vegetation would not only help mitigate the effects of waves and erosion but also contribute to the ecological balance and landscape value of the coastline. These strategies should be accompanied by community training campaigns in risk management, consolidating a resilience approach centered on people and the territory.

Beyond physical infrastructure, strengthening resilience also requires institutional coordination and continuous community participation. Establishing local committees for risk prevention and integrating these processes into municipal planning instruments will ensure the long-term sustainability of the proposed measures.

4.3. CONSOLIDATION OF SUSTAINABLE MOBILITY

Another of the identified strategic pillars is sustainable mobility. The current state of the roads, mostly unpaved and poorly maintained, seriously limits connectivity, accessibility, and road safety. The scarcity of efficient public transport, pedestrian sidewalks, and bike lanes reinforces dependence on private vehicles, exacerbating problems of pollution, congestion, and territorial inequality.

To reverse this scenario, the development of an active mobility network based on bike paths and safe pedestrian routes connected to community points of interest and essential facilities is proposed. This network should be complemented by a public transportation system with greater coverage, frequency, and accessibility, ideally based on low-impact electric vehicles. The implementation of these measures will contribute to a healthier, more equitable city that is resilient to climate change. In addition to improving physical connectivity, promoting sustainable mobility reduces carbon emissions and contributes to social inclusion, allowing equitable access to opportunities and public services.

4.4. EXPANSION AND INTEGRATION OF GREEN SPACES

The current coverage of green spaces in Crucita is well below the standards recommended by the WHO, directly affecting environmental quality, public health, and social cohesion. The lack of parks, shaded areas, urban vegetation, and recreational spaces represents a critical deficiency that particularly impacts vulnerable populations such as children, the elderly, and women.

The diagnosis proposes strategies to expand these spaces through the recovery of vacant lots, the creation of linear parks and pocket plazas, and the integration of native species to ensure environmentally sustainable management. These spaces should be designed with criteria of inclusion, universal accessibility, and multifunctionality, so that they respond to the diverse needs of the population and serve as nodes for social interaction, environmental education, and climate resilience.

Expanding the green infrastructure network not only enhances ecological balance and urban comfort but also increases the city's capacity to absorb environmental shocks and provide everyday benefits in terms of thermal regulation and well-being.

4.5. DIVERSIFICATION AND MIXING OF LAND USES

Land use in Crucita shows a clear predominance of residential areas, with very little presence of commercial, cultural, or institutional activities. This mono-functionality has led to monotonous urban dynamics, dependence on other parishes for basic services, and low utilization of urban space. The proposal developed here suggests a functional diversification through the gradual incorporation of mixed uses: housing, commerce, services, recreation, and compatible productive spaces.

This type of planning allows for the consolidation of compact, polycentric, and efficient communities, where distances between home, work, and leisure are shorter, promoting greater urban vitality. The mixing of uses also stimulates the local economy and reduces unnecessary travel, contributing to a more sustainable city with a better quality of life.

This approach directly aligns with the PCA results, which demonstrated that mixed-use and connected areas exhibited the highest composite sustainability scores, confirming the effectiveness of integrated urban morphologies.

4.6. METHODOLOGICAL CONTRIBUTION AND REPLICABILITY

Finally, this study not only provides a technical-territorial proposal for Crucita but also constitutes a relevant methodological contribution. The combination of spatial analysis using GIS, composite indicators of urban sustainability, and multivariate analysis techniques allows for the development of precise territorial diagnoses based on empirical data and adaptable to other contexts.

Moreover, the linkage of this diagnosis with concrete territorial intervention proposals, along with community involvement as a transversal axis of the analysis, demonstrates that it is possible to build more participatory, rigorous, and sustainable planning models. This experience can be replicated in other coastal locations in Ecuador or Latin America that face similar issues of unplanned growth, climate vulnerability, and social fragmentation.

The articulation between quantitative evidence and spatial design represents a replicable model for diagnosing and improving sustainability in other small and medium-sized coastal settlements. This approach fosters evidence-based decision-making and strengthens academic–institutional collaboration as a key mechanism for sustainable territorial governance.

Ultimately, sustainability in small coastal cities depends not only on physical transformations but also on governance, participation, and the capacity to integrate social and spatial dimensions. The case of Crucita la Bella illustrates how an integrative, data-supported, and participatory approach can guide the transition toward more resilient and inclusive urban systems.

REFERENCES

[1] J. L. Álvarez Ochoa, "Barreras invisibles del territorio: segregación residencial socioespacial multitemporal de la parroquia Calderón," *Eídos*, vol. 13, no. 18, pp. 97–107, 2021.

[2] UN-Habitat, "World Cities Report 2016: Urbanization and Development - Emerging Futures," Nairobi, Kenya. [Online]. Available: https://unhabitat.org/world-cities-report-2016

[3] IGEPN, "Informe Sísmico Especial N. 18 - 2016 - Instituto Geofísico - EPN," May 2016. [Online]. Available: http://www.igepn.edu.ec/servicios/noticias/1324-informe-sismico-especial-n-18-2016

[4] J. Casariego Ramírez, *La construcción del Espacio Turístico*. San Bartolomé de Tirajana, Canarias: Exploraciones EX2, 2002.

[5] GADM del cantón Portoviejo, "Actualización del Plan de Desarrollo y Ordenamiento Territorial del cantón Portoviejo," Portoviejo, Manabí, Mar. 2016.

[6] M. E. Pesántez-Yépez and N. E. Cabrera-Jara, "Produciendo periferias: morfología y habitabilidad en las conurbaciones de Cuenca, Ecuador," *Urbano*, vol. 27, no. 49, pp. 78–93, May 2024, doi: https://doi.org/10.22320/07183607.2024.27.49.06.

[7] UN-Habitat, "World Cities Report 2020: The Value of Sustainable Urbanization," Nairobi, Kenya, 2020. [Online]. Available: https://unhabitat.org/world-cities-report-2020-the-value-of-sustainable-urbanization

[8] V. S. Torres López, "Construcción de un sistema de indicadores de sostenibilidad urbana: estudio de caso Santo Domingo de los Colorados.," M.S. Thesis, FLACSO, Quito, Ecuador, 2015. [Online]. Available: http://hdl.handle.net/10469/7187

[9] V. Klotchkov, "Estructura urbana y ambiente," *Revista de Ciencias Ambientales*, vol. 27, no. 1, pp. 3–10, Jan. 2004, doi: https://doi.org/10.15359/rca.27-1.1.

[10] doinGlobal, "Indicadores de sostenibilidad urbana: claves para el equilibrio ecosistémico," Make the world a better place. [Online]. Available: https://doinglobal.com/qu-son-los-indicadores-de-sostenibilidad-urbana/

[11] OECD, "Green Growth Indicators 2017," OECD Publishing, Paris, Jun. 2017. [Online]. Available: https://doi.org/10.1787/9789264268586-en

[12] W. A. Aponte Rodríguez, "Morfología urbana de Madrid, Cundinamarca," *Perspectiva Geográfica*, vol. 16, pp. 211–232, 2011, doi: https://doi.org/10.19053/01233769.1756.

[13] A. Altamirano-Avila and M. Martínez, "Urban sustainability assessment of five Latin American cities by using SDEWES index," *Journal of Cleaner Production*, vol. 287, p. 125495, Mar. 2021, doi: https://doi.org/10.1016/j.jclepro.2020.125495.

[14] S. Steiniger *et al.*, "Localising urban sustainability indicators: The CEDEUS indicator set, and lessons from an expert-driven process," *Cities*, vol. 101, p. 102683, Jun. 2020, doi: https://doi.org/10.1016/j.cities.2020.102683.

[15] D. Banister, "The sustainable mobility paradigm," *Transport Policy*, vol. 15, no. 2, pp. 73–80, Mar. 2008, doi: https://doi.org/10.1016/j.tranpol.2007.10.005.

[16] R. Eales, O. White, R. Saudaskis, C. Heeckt, and I. Pereira Martins, "Urban sustainability in Europe: a stakeholder-led process," European Environment Agency, Copenhagen, DK, Monograph, Oct. 2021. [Online]. Available: https://www.eea.europa.eu/publications/urban-sustainability-in-europe-a

[17] J. F. Hair Jr., W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate data analysis*, Eighth. Andover, Hampshire: Cengage Learning (EMEA), 2019.

[18] GAD parroquial de Crucita, "Plan de Desarrollo y Ordenamiento Territorial Parroquia Crucita 2015," 2015.

[19] World Health Organization, "Urban green spaces: a brief for action," WHO. Regional Office for Europe, Copenhagen, DK, Oct. 2017. Accessed: Nov. 04, 2025. [Online]. Available: https://www.who.int/europe/publications/i/item/9789289052498?utm_source=chatgpt.com

[20] F. S. Cevallos Gangotena, J. L. Álvarez Ochoa, and F. J. Almeida Navarrete, "Vinculación Universidad Y Comunidad: Guía de Intervención Para El Desarrollo Sostenible En Proyectos Urbano-Arquitectónicos. Caso de Estudio: Miranda Mirador Sur, Quito," *Eídos*, vol. 18, no. 25, pp. 25–45, Jan. 2025, doi: https://doi.org/10.29019/eidos.v18i25.1467.

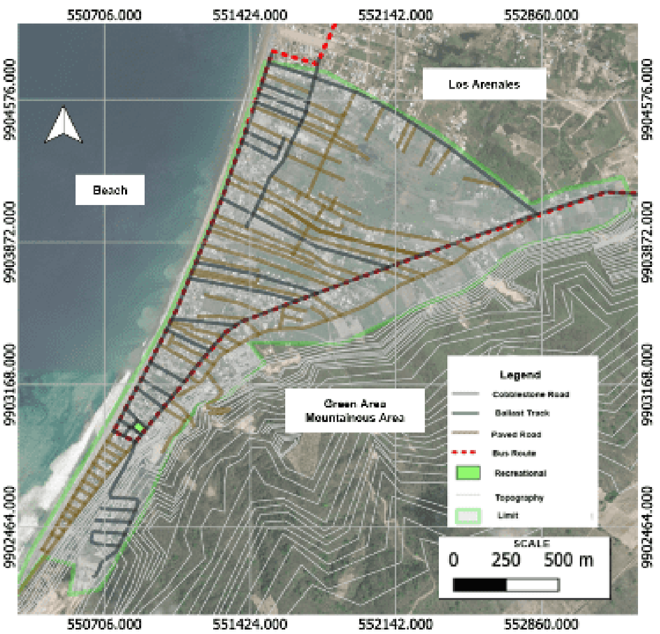
[21] P. Granja Alencastro and J. Álvarez Ochoa, "Un Calderón accesible; rutas de transporte urbano para la Parroquia de Calderón a través de SIG's," *Eídos*, no. 11, Jun. 2018, doi: https://doi.org/10.29019/eidos.v0i11.419.

[22] S. Meerow, J. P. Newell, and M. Stults, "Defining urban resilience: A review," *Landscape and Urban Planning*, vol. 147, pp. 38–49, Mar. 2016, doi: https://doi.org/10.1016/j.landurbplan.2015.11.011.

ANNEXES

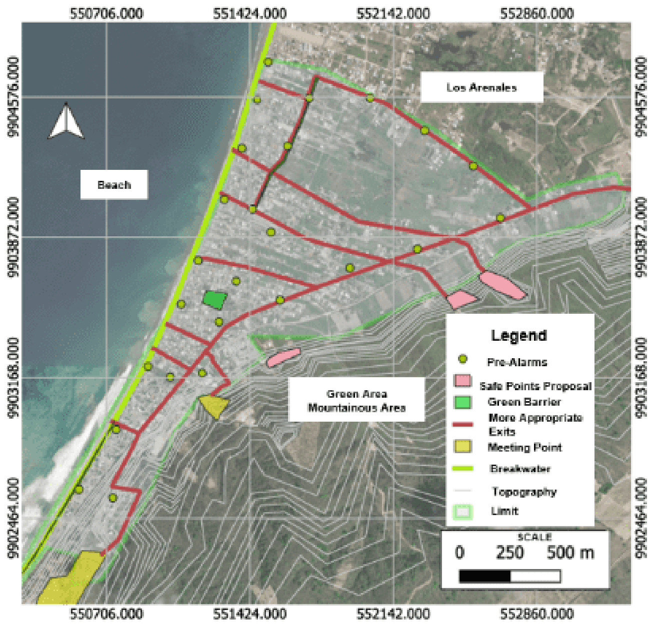
Map 6:

Sustainable Mobility in the parish seat of Crucita.



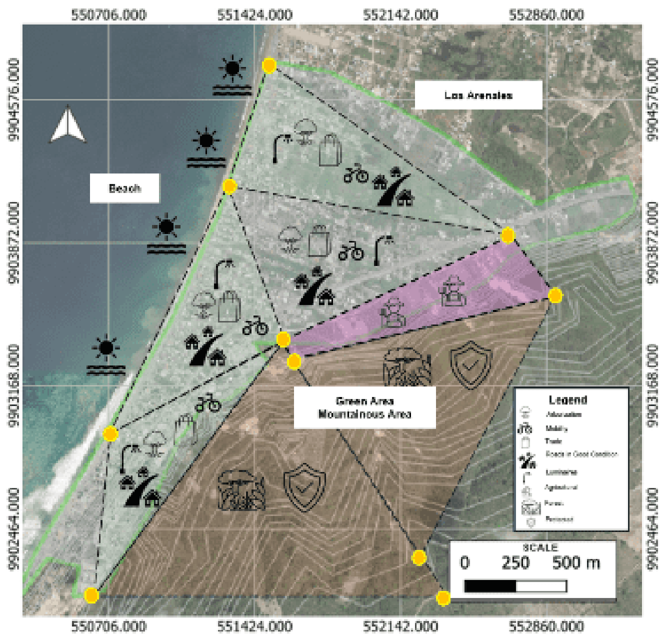
Map 7:

Urban Resilience of the parish seat of Crucita.



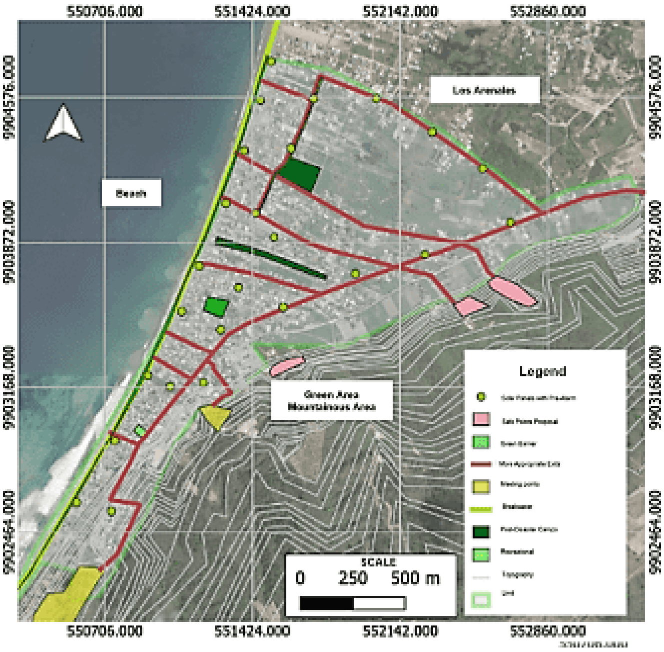
Map 8:

Proposed zoning of polygons in the parish seat of Crucita.



Map 9:

Resilient Proposal for the parish seat of Crucita.



Map 10:

Proposed Location of Facilities for the Parish Headquarters of Crucita.