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Ecological Public Corridor as a Sustainable Urban Strategy for Comfort, Riverfront Recovery, and Public Space Management in Iquitos, Peru, 2025

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Abstract

In Amazonian cities, river landscapes may function as key spaces of environmental, social, and cultural convergence, particularly in areas with significant human activity. This research proposes the design of an ecological corridor as a multifunctional public space that strengthens the relationship between the city of Iquitos (Loreto, Peru) and its river environment, promoting user comfort, sustainability, and the revaluation of water resources. The methodology is based on analyses of local flora and fauna, climatic conditions, and the application of passive architectural strategies, supported by digital tools such as AutoCAD 2024, Google maps 2025, OpenStreetMap, Photoshop 2024, SketchUp 2024, and Snazzy Map. The proposal integrates renewable energy through the installation of 55 photovoltaic-powered lampposts mainly distributed along the road and pedestrian infrastructure of the corridor, responsible water management via rainwater harvesting systems, and the use of local eco-friendly materials, including capirona wood for structural elements, bolaina wood for furniture and finishes, and bamboo for shading structures. Additionally, 81.61% of the total area is allocated to green spaces with native flora, complemented by an Amazonian plant nursery. Although similar integrative riverfront regeneration projects have been implemented in several international cities, their application in Amazonian urban contexts remains limited, highlighting the relevance of this proposal. In conclusion, the project aligns with the Sustainable Development Goals and contributes to contemporary discussions on public space planning in tropical contexts, proposing an ecological regeneration model adaptable to other Amazonian cities.

Keywords: ecological corridor; water resource; sustainable development; public spaces; urban resilience; environmental recovery; eco-friendly materials; solar energy

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1. Introduction

Globally, green infrastructure has become a key strategy in contemporary urban planning, contributing to climate change adaptation, improved human well-being, and enhanced urban resilience. Recent studies have shown that urban green infrastructure provides ecosystem services that mitigate the effects of warming, improve water management, and support the environmental sustainability of cities [1]. Furthermore, ecological

connectivity promoted by green corridors facilitates the movement and exchange of species between urban habitats, while improving air quality and ventilation, integrating environmental and social functions within urban systems [2]. These corridors consist of strips of vegetation, such as trees, shrubs, or landscaped areas, that connect natural or urban spaces, enabling species movement and ecological restoration. Green corridors are key elements of urban ecological infrastructure that fulfill essential environmental, social, and climate functions [3]. This feature helps reduce the formation of urban heat islands, lower temperatures in cities, and improve stormwater management, contributing to flood risk mitigation. Furthermore, these infrastructures contribute to the conservation and strengthening of urban biodiversity by facilitating ecological connectivity between green areas and fragmented habitats [4].

The recreational and leisure value of urban spaces has gained increasing importance in contemporary planning. In this context, architecture, spatial planning, and social geography share a common theoretical framework used to interpret how space satisfies human needs. Researchers such as Ruppert, Schaffer, Maier, and Paesler employ this approach as a normative matrix to guide the balanced provision and optimal distribution of usable space within the urban cultural landscape [5]. In several cities around the world, ecological corridors integrating bodies of water have been implemented, contributing to environmental restoration and the revaluation of water resources. These projects offer valuable lessons applicable to diverse urban contexts, highlighting the importance of integrating vegetation and water systems as structural components of the landscape and urban planning. As shown in Figure 1, the analyzed cases demonstrate how ecological connectivity and water management can be effectively integrated into established urban environments [6].

A representative example is the Madrid Río project in Spain (Figure 1A), where the transformation of more than 6 km of road infrastructure into an extensive green corridor allowed for the recovery of the Manzanares River's environment, incorporating pedestrian zones, cycle paths, and ample riparian vegetation, thus restoring the river to a central role within the city's ecological and social structure. Similarly, in Mexico City, the Cuernavaca Railway Linear Park, approximately 4 km long, reuses a former railway line as an urban green corridor, integrating sustainable drainage solutions and rainwater harvesting systems that contribute to water management and the reduction in surface runoff. In the Asian context, the Geylang Park Connector in Singapore is part of a metropolitan network of green corridors spanning over 300 km, connecting parks, nature reserves, and bodies of water via pedestrian and cycling paths, thus promoting both sustainable mobility and adaptation to extreme hydrological events. Similarly, in Europe, the Santa Comba Bridge in Galicia [7] integrates connecting infrastructure with local riverine environment restoration projects, while the Planten un Blomen park in Hamburg [8], covering nearly 45 hectares, stands out for integrating water gardens, recreational spaces, and water management systems within a consolidated urban fabric, demonstrating how green corridors can function as nature-based solutions in complex urban contexts.



Figure 1. Examples of green corridors around the world. (**A**) Proyecto Madrid Río, image source: Google Maps © Google, 2025 [6]; (**B**) Cuernavaca Linear Railway Park, image source: Google Maps © Google, 2025 [7]; (**C**) Geylang Park Connector, image source: Google Maps © Google, 2025 [8]; (**D**) Santa Comba Bridge, image source: Google Maps © Google, 2025 [9]; and (**E**) Planten un Blomen Park, image source: Google Maps © Google, 2025 [10]. Created by the authors using Adobe Photoshop 2024.

In the Latin American context, urban rivers play a strategic role in shaping cities and in providing fundamental ecosystem services for urban sustainability. Latin America is one of the most urbanized regions in the world, with approximately 81% of its population residing in urban areas, many of which historically developed around rivers and other water bodies [11]. These fluvial systems contribute to water regulation, ecological connectivity, the provision of public spaces, and urban resilience, including flood risk reduction [12].

Achieving an adequate integration of these river systems into urban planning capable of generating multiple environmental, social, and functional benefits requires the convergence of multiple factors and the adoption of multifunctional and inter-thematic approaches, in which different spatial scales, disciplinary perspectives, and urban objectives interact synergistically [13]. From this perspective, urban rivers and riparian corridors should not be understood solely as environmental infrastructures, but as complex urban systems that simultaneously integrate ecological functions, social uses, landscape values, and risk management strategies. Such multifunctional planning frameworks are particularly relevant in Latin American cities, where accelerated urbanization, informal settlement patterns, and climate-related hazards intensify pressures on riverbanks and floodplains [14,15].

Urban river environments contribute to urban sustainability by functioning as green–blue infrastructures that support ecological regulation and human well-being. When these systems are integrated into urban development and land-use planning, they can mitigate environmental risks, moderate local climatic conditions, and promote social interaction and public health through accessible and restorative open spaces [16]. In this regard, nature-based strategies such as public corridors oriented toward the ecological restoration of riverbanks have demonstrated high potential to enhance urban resilience and environmental quality in riverine cities, particularly in tropical and Amazonian contexts [17].

Urban regeneration projects along riverbanks in Latin America, such as Parques del Río Medellín and the Malecón de Villahermosa, demonstrate the capacity of nature-oriented public corridors to simultaneously improve environmental, social, and urban conditions in riverine cities. In Medellín, the Parques del Río intervention transformed a section of the Medellín River historically dominated by road infrastructure into a continuous green corridor, incorporating more than 70 ha of public space and green areas. This intervention increased the amount of accessible green space in the central area of the city and improved pedestrian connectivity between both riverbanks [18], as shown in Figure 2A.

In the case of Villahermosa, a city characterized by high hydrological vulnerability, the Malecón de Villahermosa project was developed as an integrated strategy for the recovery of the Grijalva River edge through the implementation of a public corridor approximately 2.5 km in length. This corridor integrates green areas, pedestrian spaces, bicycle lanes, and cultural facilities adapted to a tropical and flood-prone context [19], as illustrated in Figure 2B. According to official data, more than 60% of Villahermosa's urban territory is exposed to some degree of flood risk; therefore, the riverfront intervention incorporated criteria of urban resilience and riverbank management, strengthening the city–river relationship and expanding public access to riparian public spaces [20]. Taken together, both cases demonstrate that nature-based public corridors can help reduce urban fragmentation, improve environmental comfort, and revalorize riverbanks as key socio-ecological infrastructures within the urban system as shown in Figure 2.



Figure 2. (**A**) Great Malecon of the Magdalena River, image source: Google Maps © Google, 2025 [21]; and (**B**) Villa Hermosa Malecon, image source: Google Maps © Google, 2025 [22].

Peru has a wide variety of water resources, with the Amazon Basin standing out as one of the regions with the highest freshwater availability on the planet, playing a strategic role in global hydrological regulation. Within this basin, more than 1000 rivers of different lengths and flow regimes have been identified, of which 107 constitute the most representative hydrographic basins of the country, supporting ecological processes, economic activities, and human settlements [23]. Among them, the Amazon River, the longest river

in Peru and one of the most important fluvial systems worldwide, crosses extensive areas of the Amazonian territory and transports enormous volumes of water, sediments, and nutrients that sustain agriculture, fisheries, biodiversity, and the cultural identity of riverine populations. In the context of territorial planning and the integration of natural systems with urban areas, green infrastructure is defined as an interconnected system of natural areas and open spaces that preserves ecosystem functions and values while providing social benefits such as water management, biodiversity, and human well-being. Urban green infrastructure integrates natural elements—such as parks, green roofs, ecological corridors, and sustainable drainage systems—to create more resilient, healthy, and resource-efficient environments [24]. At the national scale, Peru has promoted several ecological and conservation corridor initiatives, particularly within the Amazon region, aimed at strengthening landscape connectivity and preserving ecosystem services. The most extensive of these is the Purús–Manu Conservation Corridor, which integrates the Alto Purús National Park and the Purús Communal Reserve across the departments of Madre de Dios, Ucayali, and Cusco. Covering approximately 10 million hectares of continuous forest, this corridor represents the largest protected Amazonian area in Peru and one of the regions with the highest biological diversity worldwide, ensuring the conservation of large mammals, endemic species, and intact hydrological systems [25]. Similarly, the Marañón–Alto Mayo Bird Corridor, located mainly in the departments of San Martín and Amazonas, focuses on connecting fragmented montane and cloud forest ecosystems, safeguarding critical water sources, and supporting biodiversity conservation while promoting sustainable local development [26,27]. In addition, the Vilcabamba–Amboró Conservation Corridor integrates sixteen protected natural areas, encompassing cloud forests, montane forests, tropical rainforests, the Tumbes Dry Forest, and the Abra Patricia Cloud Forest, extending from southern Peru to Bolivia and prioritizing large-scale ecological connectivity and long-term ecosystem service conservation [27]. Although these initiatives operate primarily at a regional and territorial scale, they provide a valuable conceptual and methodological reference for the development of urban-scale green corridors, particularly in Amazonian cities, where water-based ecological infrastructure could play a decisive role in mitigating environmental risks and improving socio-environmental integration.

In Iquitos, it is largely the inhabitants who live along the riverbank who contribute to its environmental deterioration, as, in this sector, there is a constant accumulation of solid waste from riverside homes, untreated sewage discharges and waste generated by nearby commercial activities [28]. A 2022 sampling of the Itaya River revealed the following physicochemical conditions: pH 5.75 (slightly acidic), meaning it is outside the optimal range for drinking water/domestic use; turbidity 35.43 NTU (very high), indicating that the water is laden with particles and is unsafe; color 30.8 NTU, indicating the presence of organic matter; dissolved oxygen 2.10–1.30 mg/L, indicating very low levels for maintaining healthy ecosystems; heavy metals within maximum permissible limits; and thermotolerant coliforms 24.70–22.70 MPN/100 mL, indicators of fecal contamination [29]. All these contaminants are carried by the river's current, and its waters continue to be used by the same population for domestic activities and even for consumption, generating a cycle of contamination that directly affects the health and well-being of the inhabitants. Studies conducted by the Institute of Amazonian Research of Peru (IIAP) between 1985 and 1988 identified that the Itaya River already showed significant pollution from human waste and petroleum products at its mouth at that time [30]. The measures taken so far have been preventative, educational, or last-minute solutions, as occurred in 2010, when an oil spill into the Itaya River was controlled in an emergency by the Port Authority with the support of the company involved (Electro Oriente), using containment barriers and dispersant material to reduce the spread of the pollutants [31].There is also the GETRAMI

group that manages and proposes plans to deal with this problem. However, at present, the problem of pollution remains unsolved, especially as long as the settlements continue to exist on the riverbank. For this reason, we pose the following question: How can a nature-oriented public corridor solve the socio-ecological problems on the banks of the Itaya River in the city of Iquitos [32]?

Thus, when analyzing how the strategies used in the green corridors generate a healthy relationship between urban life and river, we thought of a way to integrate this proposal in a more rural and jungle context such as Iquitos, similar to a conservation corridor but focused on the riverbank and the ecological restoration of the Itaya River.

2. Materials and Methods

2.1. Methodological Framework

The methodological structure of this research is organized into four analytical phases that integrate qualitative analysis with quantitative and spatial validation. In the first phase, a conceptual framework is developed to establish the relevance of green corridors and water systems at global, regional, and national scales, emphasizing their role in urban sustainability and environmental resilience, supported by scientific literature and institutional publications. The second phase consists of a site analysis of the city of Iquitos and the Itaya River, incorporating geospatial data, climatic information, urban vulnerability indicators, and the characterization of local flora and fauna using datasets from INEI, OpenStreetMap, and Google Earth Pro. In the third phase, design strategies are formulated to revalue the hydraulic system through the proposal of a multifunctional green corridor, integrating recreational, cultural, and social spaces while prioritizing water-based sustainability and visual connectivity with the river. Finally, the fourth phase involves a comparative evaluation of the proposed corridor against international and Latin American green corridor experiences, allowing the assessment of potential environmental and social impacts and validating the proposal within a broader sustainable urban framework, as illustrated in Figure 3.

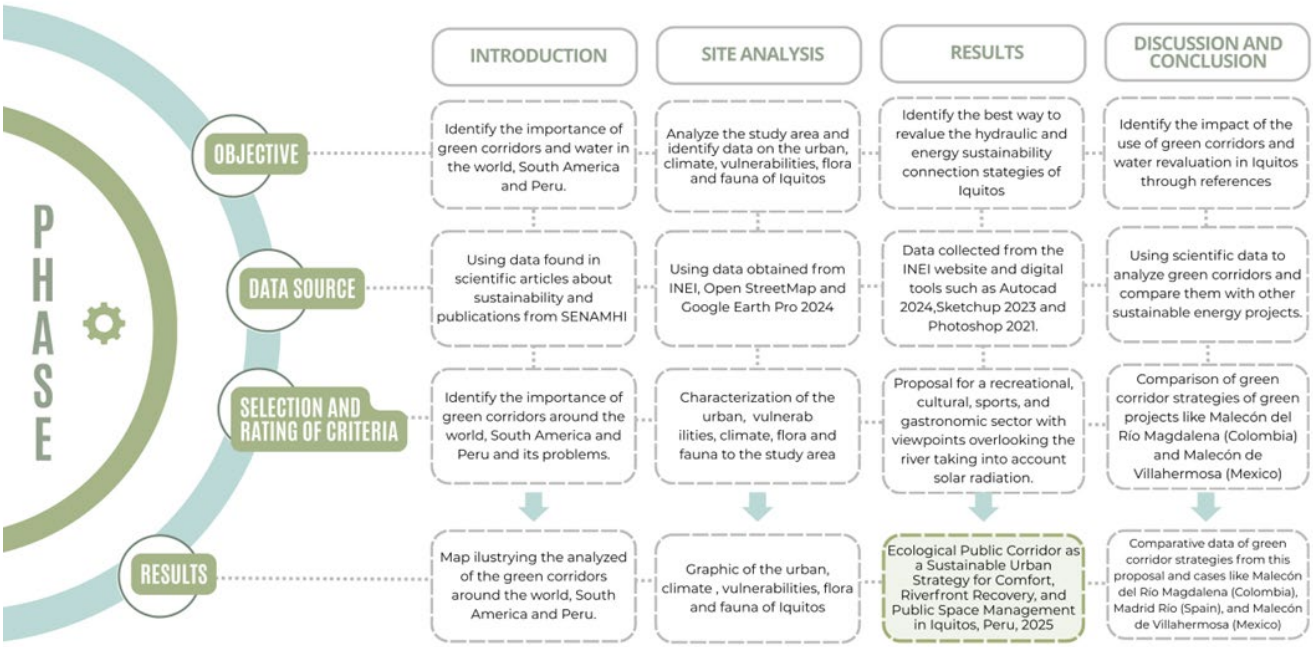


Figure 3. Phases of the methodology. Created by the authors using Adobe Photoshop 2024.

2.2. Methodological Process

2.2.1. Literature Review

The introduction presented a general overview of the importance of ecological corridors and water resource management, highlighting their contribution to the protection of natural ecosystems, ecological connectivity, and improved environmental quality. Successful international experiences were also reviewed, along with regional studies that demonstrate the problems faced by the Nanay and Itaya rivers, such as industrial pollution, illegal mining, and the drastic reduction in aquatic fauna. These precedents support the relevance of this research, entitled "Ecological Corridor as a Sustainability Strategy for User Comfort and the Revaluation of Water Resources in Iquitos", aimed at proposing strategies that combine ecological restoration, conservation, and sustainable water use.

2.2.2. Site Analysis

During the second phase, a detailed analysis of the intervention site was carried out, focusing on urban characterization and identification of vulnerabilities, as well as climate analysis, fauna and flora, with the specific territorial conditions of Iquitos. This phase followed a spatial and environmental analysis methodology based on urban-territorial diagnosis and GIS-supported cartographic interpretation. This study was key to guiding design strategies adapted to the Amazonian context. For this purpose, 2D and 3D analysis tools were employed and updated data from INEI and the Ministry of the Environment were collected, which allowed for identifying the climatological, demographic, urban, and road characteristics of the study area. The site analysis process is described below. In this study, an analysis was conducted to identify the intervention area located in Iquitos, Peru, with support from data provided by the National Institute of Statistics and Informatics. Relevant information was collected to develop an urban-territorial analysis of the city. The urban data acquisition process is described below:

- Road System Analysis: The road system of Iquitos was studied using Google Earth Pro 2025, identifying primary, secondary, and local avenues.
- Vulnerability Analysis: Maps collected from SIGRID revealed that the study area, located near the Iquitos Boulevard, is susceptible to seasonal flooding risks.
- Climate Analysis: Annual data on temperature, humidity, precipitation, and wind speed were obtained from official sources (SENAMHI, Ministry of the Environment).
- Collection of hydrometeorological data from SENAMHI's Iquitos meteorological station, covering a five-year period (2020–2025). The data obtained included temperature (°C), wind (m/s and °), relative humidity (%), and monthly and annual precipitation (mm).
- Using a solar chart as a meteorological data viewer for Iquitos and being able to propose climate strategies.
- Obtaining the Stereographic Solar Chart of Iquitos with Sun-Path from Andrew Marsh's website.
- An analysis of the results obtained and their influence on the future proposal.

Finally, a flora and fauna analysis were carried out, which consisted of identifying local biodiversity and its distribution in the territory, with the aim of preserving its habitat and avoiding negative impacts derived from the project.

2.2.3. Results and Design Criteria

Based on the synthesis of urban, environmental, and climatic analyses, the information was systematized to derive spatial, environmental, and functional criteria that guided the definition of the intervention area and the formulation of the ecological corridor proposal.

This analytical process allowed the establishment of design guidelines related to green space continuity, connectivity between the city and the riverfront, environmental restoration strategies, and sustainable infrastructure integration.

Finally, technical drawings were developed in AutoCAD 2024 and three-dimensional models in SketchUp Pro 2023, complemented with architectural visualizations using V-Ray 2022, D5 Render 2.1 and Adobe Photoshop 2024, which allowed the evaluation of the relationship between the proposal, the topography and the built urban environment, verifying the adequate integration of the ecological corridor with the riverfront of the Itaya River

The estimation of the electrical energy generation from photovoltaic systems was conducted using the following equation:

$$E = P(\text{kW}) \times R(\text{kWh/m}^2\text{/day}) \times \eta p \times \text{days} \quad (1)$$

where E is the energy produced during the analysis period (kWh), P corresponds to the nominal power of the photovoltaic panel (kW), R represents the average daily solar radiation (kWh/m^2/day), ηp is the efficiency of the photovoltaic system and "days" indicates the number of days of operation considered. This expression allows the total energy production of the system to be calculated based on its technical parameters and local solar conditions [33].

To account for losses associated with real operating conditions, such as temperature variations, dust accumulation, module degradation and seasonal changes in irradiance, a safety margin of 20% was applied. The adjusted energy was calculated using the following ratio:

$$E_a djusted = E_a lculated \times (1 + \text{M}) \quad (2)$$

where $E_a djusted$ is the corrected annual energy (kWh/year), $E_a lculated$ corresponds to the estimated annual energy without losses and M represents the adopted safety margin (20%). This adjustment allows a more realistic estimate of the energy performance of the photovoltaic system under real operating conditions [34].

2.2.4. Procedure for Discussion and Conclusions

In the fourth stage, a comparison will be made between the proposed green corridor in Iquitos and two previously mentioned corridors, whose strategies will be adapted according to the location of our project. These references are the Gran Malecón of the Magdalena River in Colombia and the Malecón of Villahermosa in Mexico, as both present a context and problems like those in Iquitos: the lack of urban connection with nature and the need for cultural recognition and local connection.

3. Site Analysis

3.1. Study Area

The city of Iquitos is located in the Amazon rainforest, in the province of Maynas, within the department of Loreto as can be seen in Figure 4A. The region covers approximately 358.15 km^2 and has a population of 163,163 people [35]. The department of Loreto is situated in the northeastern part of the country and borders Ecuador, Colombia, and Brazil, forming part of the Amazon Basin and constituting the largest department in Peru in terms of territorial extension, shown in Figure 4B. The province of Maynas constitutes the main administrative division of Loreto and contains Iquitos as its capital and principal urban center, shown in Figure 4C. At the urban scale, the spatial structure of Iquitos reflects its close relationship with the surrounding river system, shown in Figure 4D. Lacking

direct overland connectivity to the national road network, its urban structure and economic dynamics depend mainly on river and air transport [36].

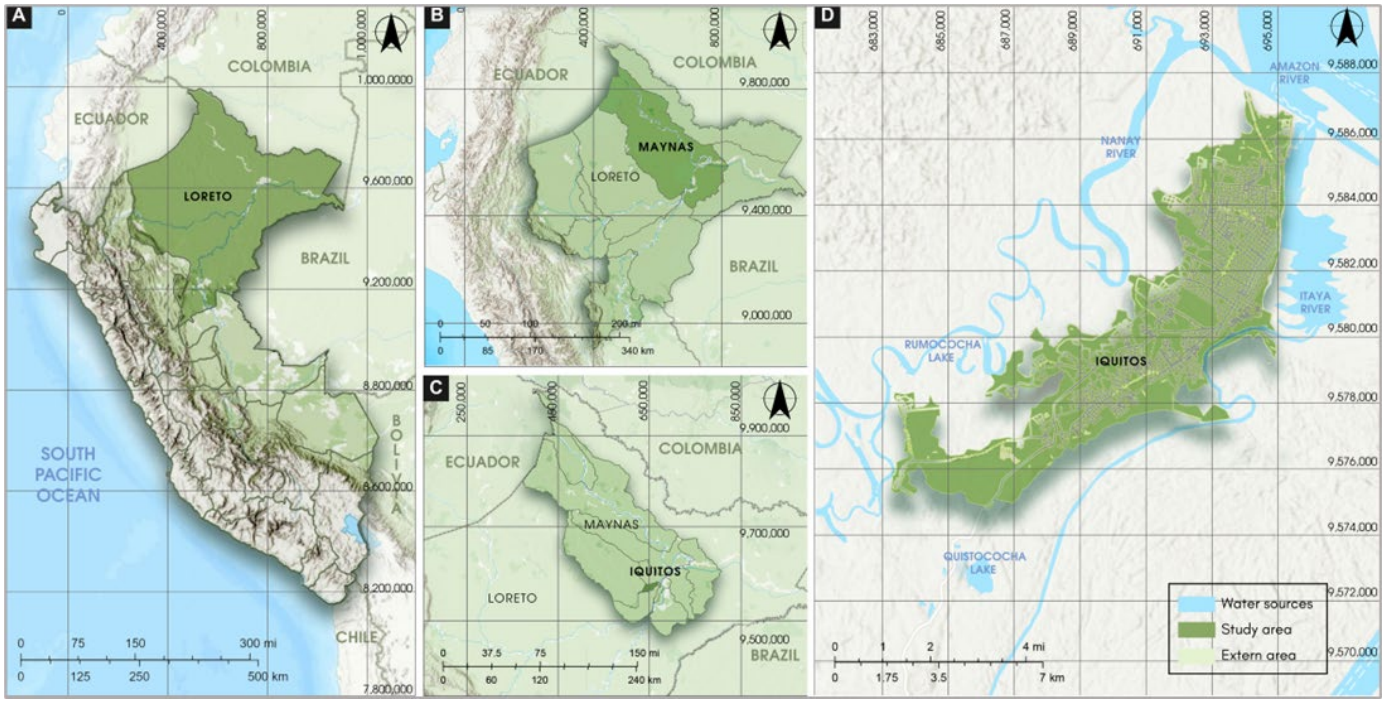


Figure 4. (**A**) Map of Peru; (**B**) map of the department of Loreto; (**C**) map of the province of Maynas; and (**D**) map of the urban area of the district of Iquitos. Figure created by the authors using Adobe Photoshop 2024 and ArcGISonline https://www.arcgis.com.

The historical development of Iquitos is strongly associated with the rubber boom that took place between the late nineteenth and early twentieth centuries. During this period, the city experienced rapid urban expansion and socio-economic transformation driven by the extraction and commercialization of rubber. This process played a decisive role in establishing Iquitos as a key economic, cultural, and social center within the Peruvian Amazon, shaping its urban structure and regional importance [37]. Over time, and after the collapse of the rubber economy, Iquitos managed to reinvent itself thanks to its strategic role in the region. Today, it is recognized as the largest city in the Peruvian Amazon and an important hub for activities related to commerce, education, and ecotourism.

3.2. Urban and Territorial Analysis

3.2.1. Road Analysis

The city of Iquitos presents a particular road network influenced by its geographical location and its limitations in land connectivity; as shown in Figure 5. Unlike other cities in the country, Iquitos is not connected to the national highway system by continuous land routes, which makes its main access either by river or by air [38]. Within the city, the road network consists of main avenues, secondary roads, and local streets that structure the urban fabric. Key axes include Mariscal Cáceres Avenue, Quiñones Avenue, and La Marina Avenue, which form the backbone of urban mobility and connect key sectors such as the airport, the historic center, and port areas. These avenues serve functions similar to trunk roads in other cities, allowing the movement of people, goods, and services across the urban core [39]. The main road that crosses the area near the Iquitos Boulevard is the Malecón Tarapacá, an urban street that runs along the Itaya River and links vital locations in the city's historic core with residential and commercial districts. This road plays a crucial role in the central activities of the city, facilitating pedestrian and vehicular movement

in a zone with significant tourism and commerce. Being in direct contact with the Itaya River makes it an important point where the problem of river pollution and riverbank degradation can be addressed, becoming a potential strategic space for comprehensive urban intervention.



Figure 5. Road system of the urban area of Iquitos. Figure created by the authors using Google Maps 2025 and Adobe Photoshop 2024.

3.2.2. Vulnerability Analysis

The city of Iquitos occupies an urban area of approximately 4000 hectares, developed on the Amazonian plain and shaped by the confluence of the Amazon, Itaya, and Nanay rivers. According to flood risk mapping, approximately 60–65% of the urban area is located in zones of high and very high vulnerability, corresponding to low terraces and riverbank complexes exposed to seasonal flooding during the rainy season (March–May) [40].

The areas adjacent to the Itaya and Amazon rivers concentrate the highest levels of risk, identified in Figure 6, with shades of red and orange, where recurrent flooding affects urban infrastructure, mobility, and sanitation. The studied sector is located in the central-southern part of the city, within an area classified primarily as medium risk, near areas of low vulnerability. This location gives it a moderate environmental vulnerability, determined by its proximity to flood zones and by the hydrological dynamics of the Itaya River, a situation also recognized by the Provincial Municipality of Maynas in its territorial diagnoses [41].

3.3. Climate Analysis

Iquitos has a hot–humid equatorial climate, characterized by high temperatures, high relative humidity, and abundant rainfall throughout the year [42]. These conditions directly influence thermal comfort, the habitability of public spaces, and the environmental

performance of urban interventions, making climate analysis crucial for the design of the proposed ecological corridor.

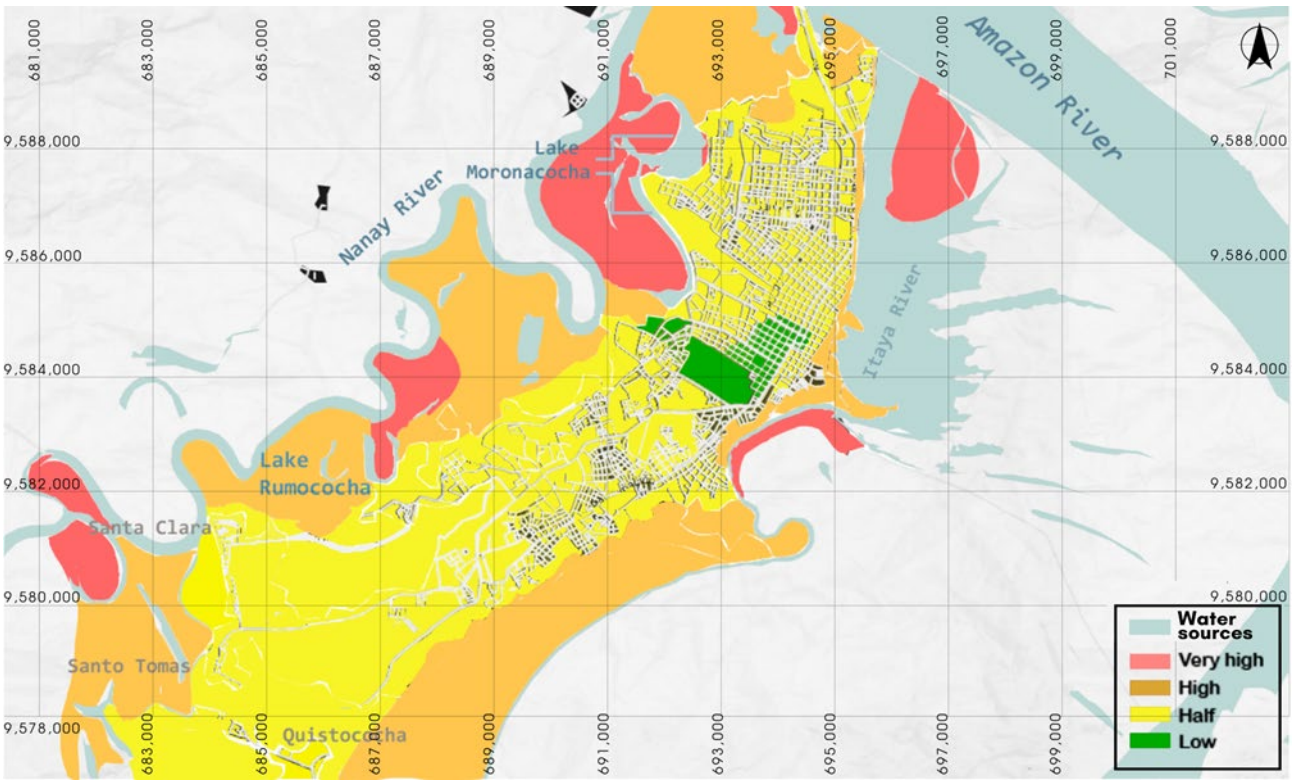


Figure 6. Vulnerability and soil analysis in Iquitos. Figure created by the authors using Google Maps 2025 and Adobe Photoshop 2024.

The analysis was developed using an urban–bioclimatic approach, aimed at translating local climatic conditions into passive design criteria, rather than performing detailed predictive simulations. For this purpose, official climate data from the National Meteorology and Hydrology Service of Peru (SENAMHI) and the Ministry of the Environment, corresponding to a recent period (2020–2025) [43], were used. The variables analyzed include air temperature, relative humidity, precipitation, wind direction and speed, as well as solar radiation and the apparent path of the sun, evaluated using stereographic solar charts. The results show high and relatively constant average temperatures, ranging approximately between 22 °C and 35 °C, with persistent humidity between 80% and 100%, and annual rainfall exceeding 2600 mm, without a clearly defined dry season [42,43]. These conditions generate frequent scenarios of heat stress, especially in open spaces with high exposure to solar radiation. These variables are represented in Figure 7.

From the perspective of thermal comfort in hot–humid climates, the bioclimatic literature highlights the importance of shading, natural ventilation, the reduction in impermeable surfaces, and the intensive use of vegetation as key strategies for mitigating urban heat. In this context, vegetation plays a fundamental role by reducing incident radiation, lowering surface temperature, and improving microclimatic quality through evapotranspiration processes [43].

Based on this analysis, the design of the ecological corridor incorporates passive bioclimatic criteria, such as the planting of native trees with broad canopies to generate continuous shade, an open spatial configuration that promotes natural ventilation, the use of permeable soils and lightweight roofs for protection from sun and rain, as well as nature-based solutions for stormwater management. These strategies contribute to

mitigating the urban heat island effect and improving the environmental comfort of the public space, in accordance with the Amazonian climate context.

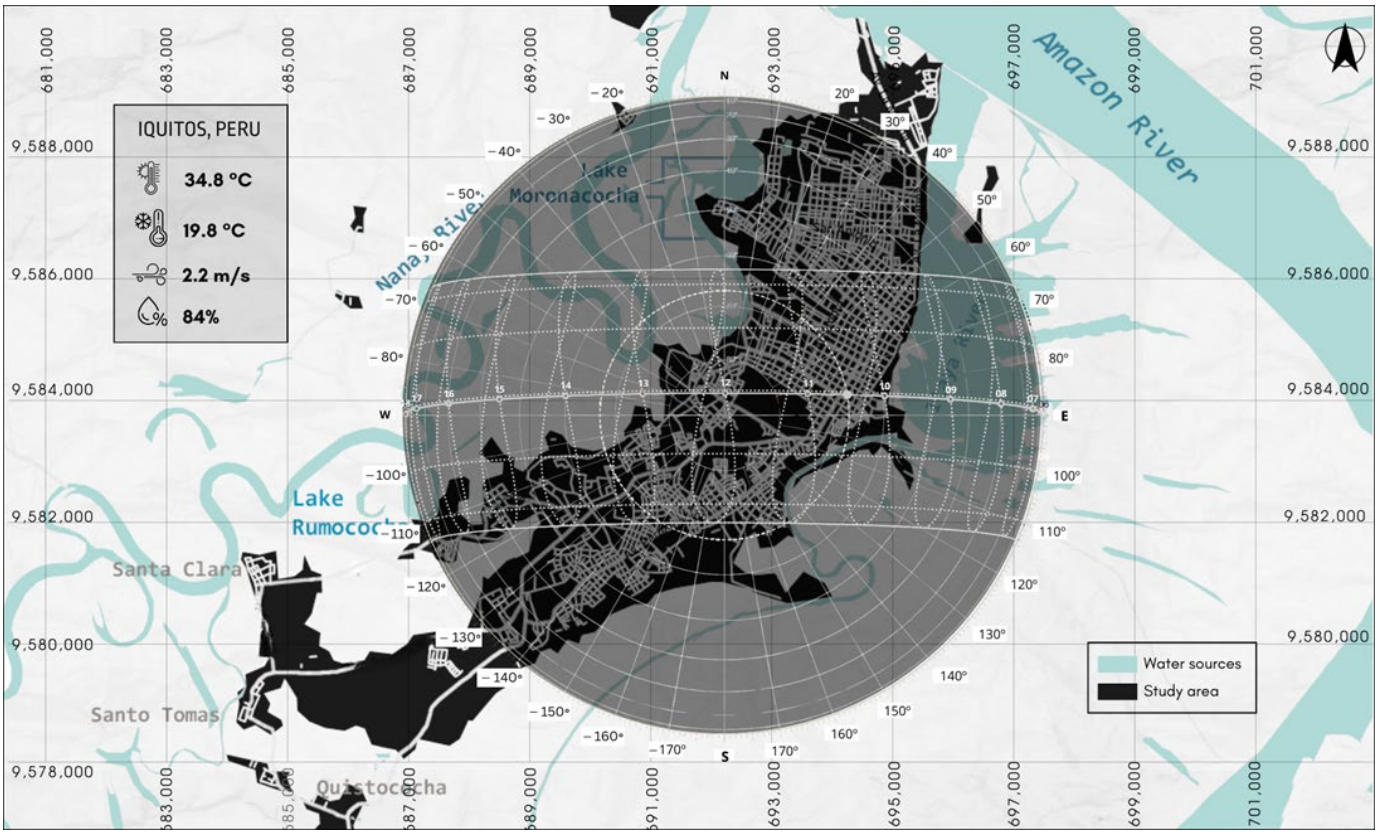


Figure 7. Solar chart graph in Iquitos. Figure created by the authors using Adobe Photoshop 2024.

3.4. Ecological Conditions and Biodiversity of the Intervention Zone

The flora and fauna of the Amazonian region of Iquitos perform essential ecological functions that ensure ecosystem stability and resilience [44,45]. Neotropical forest species contribute to microclimatic regulation, biomass accumulation, and soil stabilization, particularly in nutrient-poor and seasonally flooded environments typical of the Loreto region [46]. Tree communities and palm species act as primary producers and key food sources for birds, mammals, and aquatic fauna, facilitating seed dispersal processes and natural forest regeneration that sustain long-term ecosystem dynamics [45]. The presence of a well-developed understory, including ferns and floodplain vegetation, enhances moisture retention, soil protection, and erosion control, reinforcing the ecological integrity of riparian and lowland forests identified in Figure 8 [46]. In terms of fauna, apex predators and aquatic species play a decisive role in regulating trophic interactions and maintaining biodiversity, while river-dependent species such as fishes and aquatic mammals strengthen the river–forest ecological connection, particularly during seasonal flood pulses [45]. Altogether, these interactions consolidate the Amazonian ecosystem of Iquitos as a highly interdependent socio-ecological system, where biodiversity, hydrological dynamics, and human well-being are closely linked [45,46].

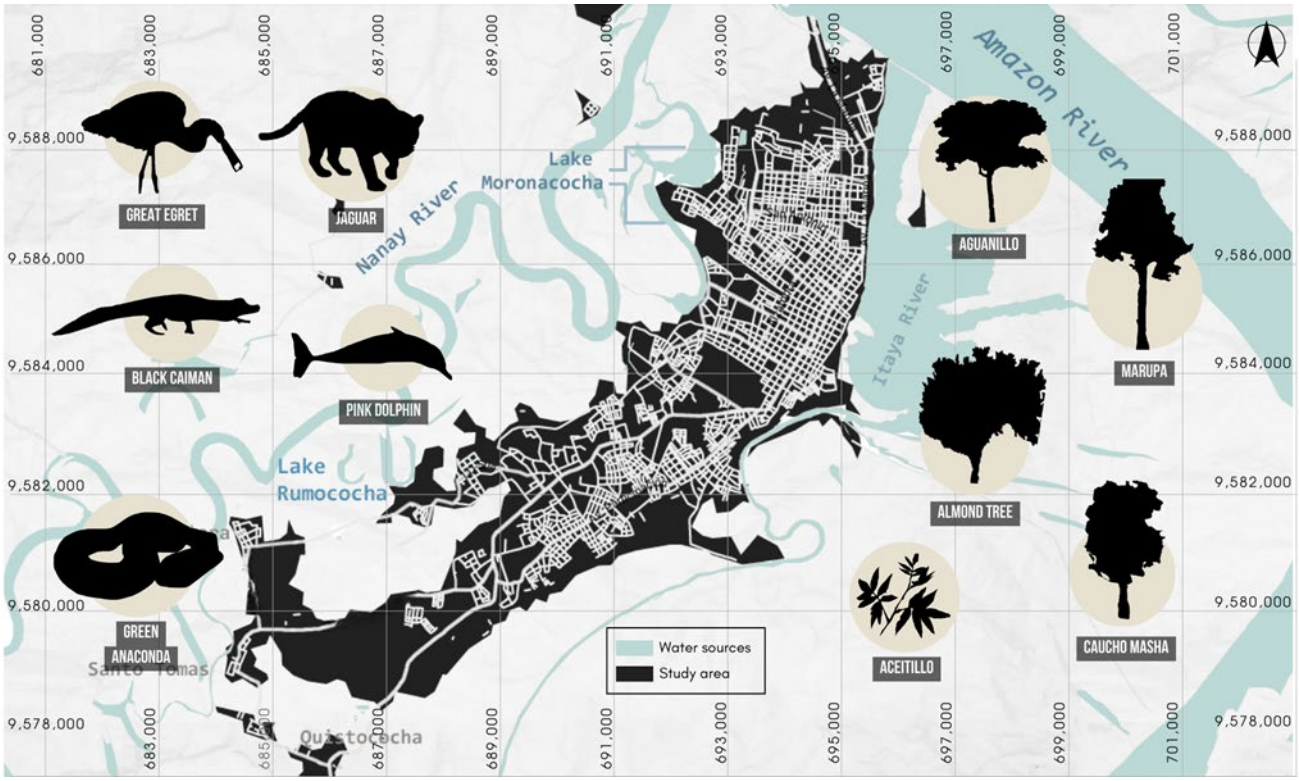


Figure 8. Fauna and flora of Iquitos city. Figure created by the authors using Snazzymaps and Adobe photoshop 2024.

4. Results

4.1. Study Area and Topography

The urban proposal for the ecological corridor is located along Malecón Tarapacá, on the banks of the Itaya River, and aims to achieve the environmental and social regeneration of a strategic sector of the city of Iquitos by capitalizing on both its landscape value and its urban significance, as illustrated in Figure 9A. The study area occupies a privileged location, with direct connectivity to the main road network and functional proximity to the Coronel FAP Francisco Secada Vignetta International Airport, located approximately 20 min away by vehicle. This condition reinforces its role as an area that supports tourism and recreational activities [47].

Access to the intervention area is ensured through several urban roads, among which Avenida Napo stands out as a structuring axis of connectivity. The site has a longitudinal configuration and an approximate surface area of 46,000 m^2, extending from Ricardo Palma Street to Ramón Castilla Square. It integrates relevant urban facilities such as Bulevar Iquitos, the Anaconda Market, and consolidated public spaces, thereby strengthening its potential as a continuous urban corridor capable of articulating the existing urban fabric [48], as shown in Figure 9D,E.

The design of the ecological corridor is grounded in principles consistent with sustainable urban development and aligned with the Sustainable Development Goals (SDGs), particularly those related to sustainable cities and communities, climate action, and the responsible management of natural resources [49].

From an edaphological and topographic perspective, the study area is located on soils characteristic of the Amazonian floodplain, predominantly sandy–clayey in composition, which present limitations associated with natural drainage and moderate fertility. The soil composition is dominated by clay (≈62%) and sand (≈35%), with a low organic matter content (≈3%). These conditions are intensified by high water saturation during rainfall

periods and by the presence of a shallow water table [50,51]. In the central sector of Iquitos, clayey soils with sandy fractions predominate, while in peripheral areas, the proportion of sand and silt increases, generating local variations in infiltration capacity and ground stability [52], as represented in the cross and longitudinal sections shown in Figure 9B,C.

The relationship between the intervention area and its surrounding urban landmarks strengthens the corridor's role as a structuring public space within the central urban system, enhancing pedestrian connectivity and socio-spatial integration between recreational, commercial, and institutional areas, as evidenced in Figure 9D–G.

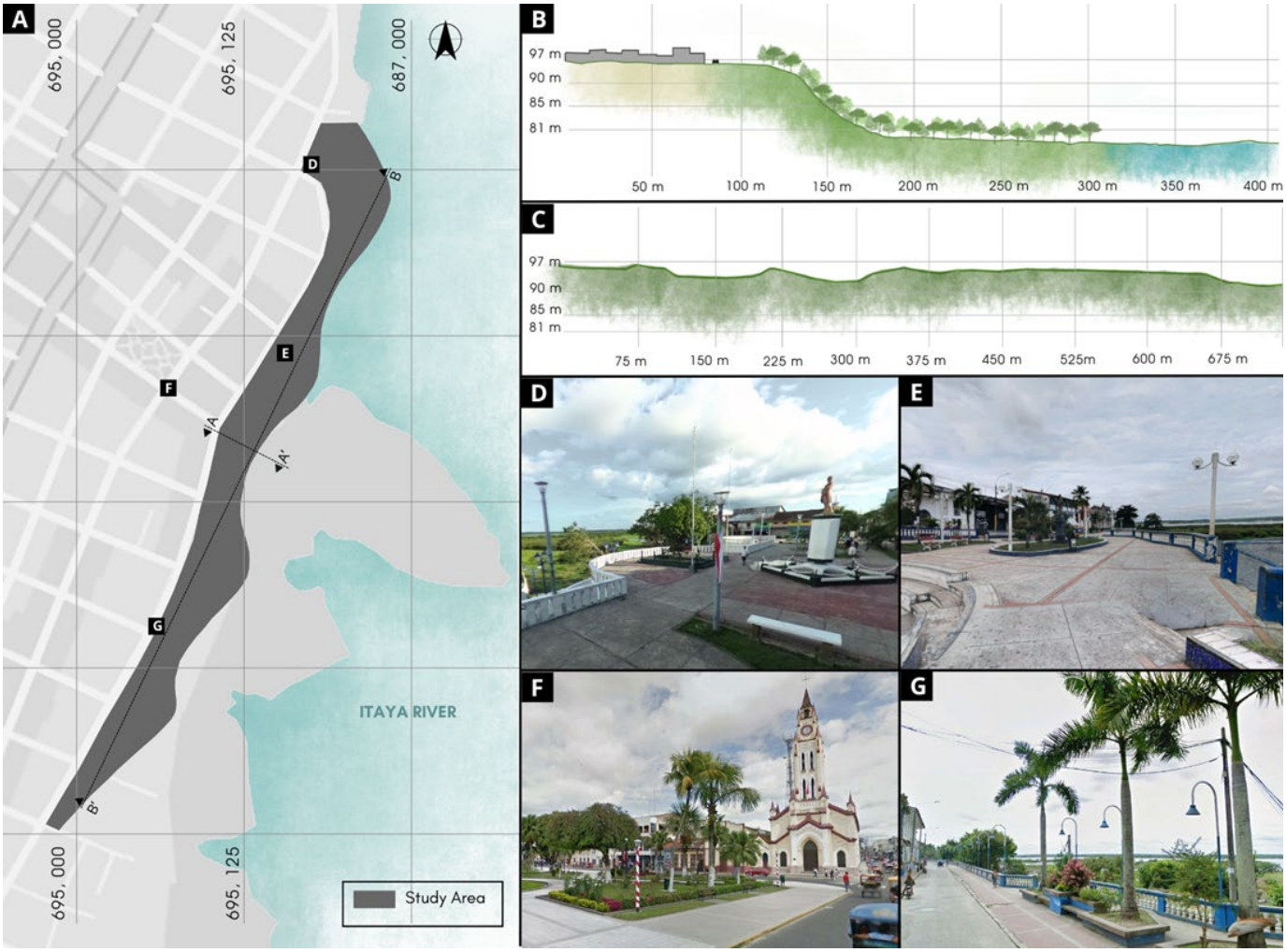


Figure 9. (**A**) Site analysis; (**B**) cross section A–A′ and (**C**) longitudinal section B–B′. Figures created by the authors using Google Maps 2025 and Adobe photoshop 2024; (**D**) Ramón Castilla Square reprinted with permission from Ref. [53]. 2025, Google Street; (**E**) Iquitos Boulevard, reprinted with permission from Ref. [54]. 2025, Google Street; (**F**) Main Square of Iquitos, reprinted with permission from Ref. [55]. 2025, Google Street; and (**G**) Tarapacá Boardwalk, reprinted with permission from Ref. [56]. 2025, Google Street.

4.2. Urban Analysis

The study area has characteristics that allow for its connection by both land and river. Land access is provided by a network of 10 main local roads (Ucayali, San Martín, Ricardo Palma, Brasil, Morona, Sargento Lores, Putumayo, Napo, Nauta, and Pevas), which connect with higher-level thoroughfares such as Avenida Ramírez Hurtado and the Tarapacá Boardwalk, forming strategic urban nodes that reinforce the area's connect-

ivity (Figure 10A) [57]. River access is facilitated by the study area's direct location along approximately 1.2 km of the Itaya River's riverfront.

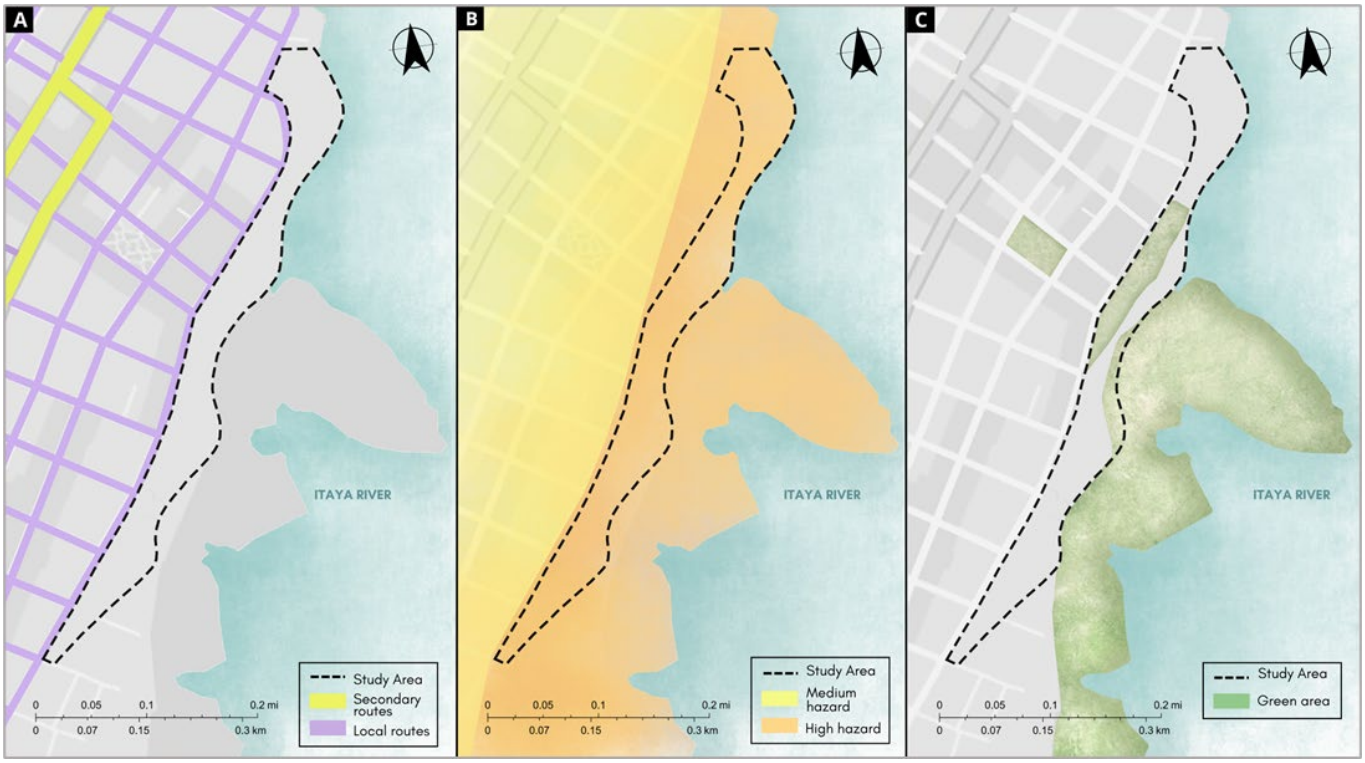


Figure 10. (**A**) Roads of study area; (**B**) vulnerability of study area; and (**C**) green areas of study area. Figures created by the authors using Snazzymaps and Adobe Photoshop 2024.

In terms of environmental risk, approximately 70–75% of the study area is located in a high-risk zone due to exposure to recurrent flooding, riverbank erosion, and seasonal overflows, while the remaining 25–30% corresponds to medium-risk zones (Figure 10B) [58]. These conditions increase urban vulnerability during periods of river flooding.

The distribution of green areas is uneven, concentrated mainly along the riverbank. Approximately 65% of the existing green cover corresponds to natural vegetation associated with the river edge, while within the consolidated urban fabric, accessible green areas represent less than 5% of the total area, with the Main Square of Iquitos standing out as one of the few formal public spaces (Figure 10C) [59]. This deficit reinforces the need for strategies such as the proposed ecological corridor to improve environmental resilience and urban quality.

4.3. Conceptualization

The conceptualization of the project is inspired by the textiles of the Shipibo–Conibo community, an Indigenous group that makes a substantial contribution to the cultural identity of Iquitos through its traditions, language, and artisanal expressions [60]. The geometric and symbolic patterns present in these textiles were reinterpreted as spatial organizing structures, influencing the layout of circulation routes, the hierarchy of movement systems, and the configuration of public spaces [61].

The preservation and enhancement of cultural heritage are essential to sustaining collective memory, promoting cultural diversity, and strengthening territorial identity, particularly in Amazonian cities where the relationship between culture and landscape is inseparable [62]. In this context, the project acknowledges that Iquitos, being surrounded by the Amazon and Itaya rivers, maintains a historical, symbolic, and functional rela-

tionship with water, which shapes its social, economic, and spatial dynamics. Water is therefore conceived as an integrative, dynamic, and articulating element that connects the different sectors of the ecological corridor, mirroring its role in the everyday life of the local population.

The overall form of the project is inspired by the organic morphology of the Amazon River, reflected in the fluidity of the main circulation path and in the patterns that traverse the site. This formal logic promotes a flexible and non-rigid spatial organization, capable of adapting to topographic variations and the inherent dynamics of the river edge, thereby reinforcing a sense of movement, continuity, and exchange identified in Figure 11. Beyond their symbolic value, the Shipibo–Conibo textile patterns were incorporated as a spatial and environmental structuring tool; their geometric logic based on continuous grids, modular repetition, and non-linear connections was reinterpreted to organize circulation routes, green areas, and ecological transition zones within the corridor.

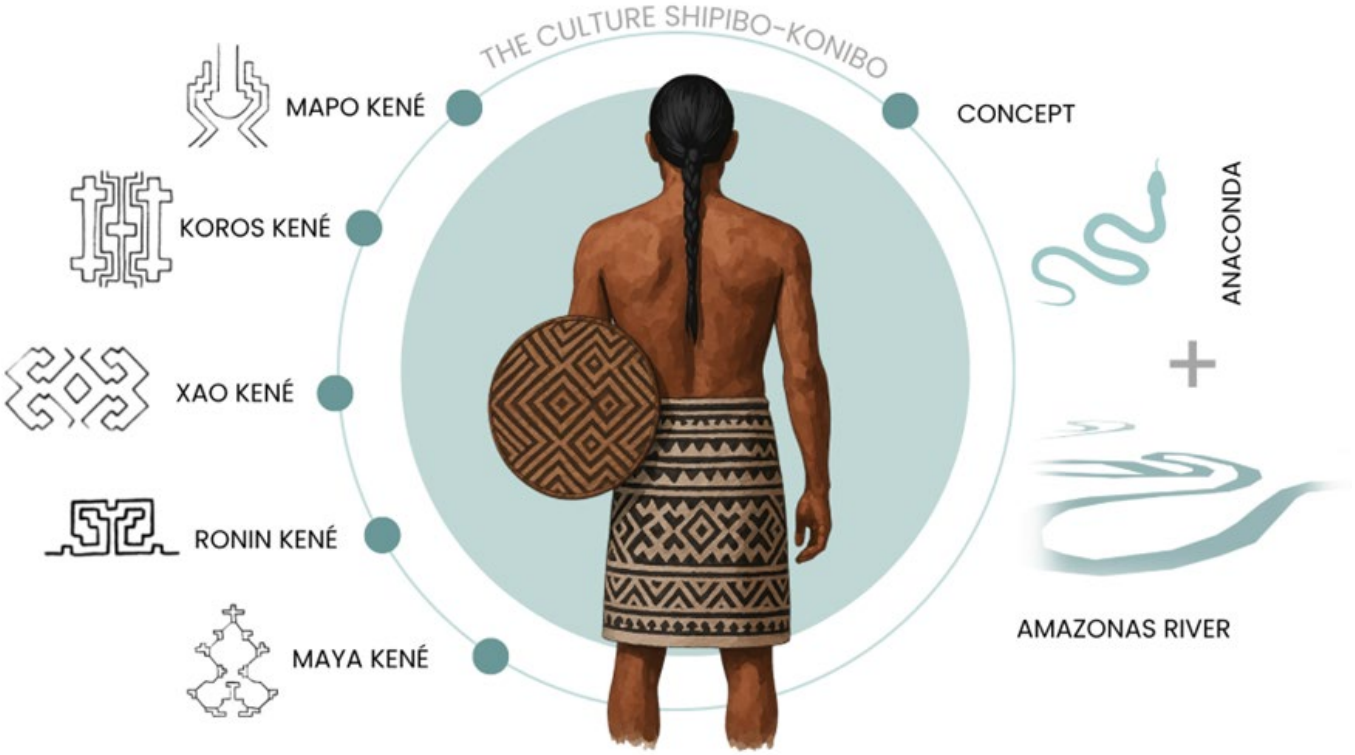


Figure 11. Architectural conceptualization of the project based on Kené patterns from Shipibo–Konibo culture and Amazonian fluvial dynamics. Figure created by the authors using Adobe Photoshop 2024.

4.4. Urban Design Strategies

The ecological corridor project in Iquitos was structured around a set of urban design strategies aimed at ecological integration, cultural identity revaluation, and sustainable mobility (Figure 12). These strategies include the definition of strategic urban and internal nodes that articulate access to the corridor and connect it with the surrounding urban fabric; a pedestrian- and non-motorized-oriented circulation system that prioritizes universal accessibility and environmental continuity; and a functional sectorization integrating sports, cultural, recreational, and gastronomic uses. At the core of the proposal, a continuous green corridor runs parallel to the Itaya River, acting as an ecological axis that enhances landscape connectivity, restores urban ecosystems, and reinforces water as a central element of the Amazonian environment.

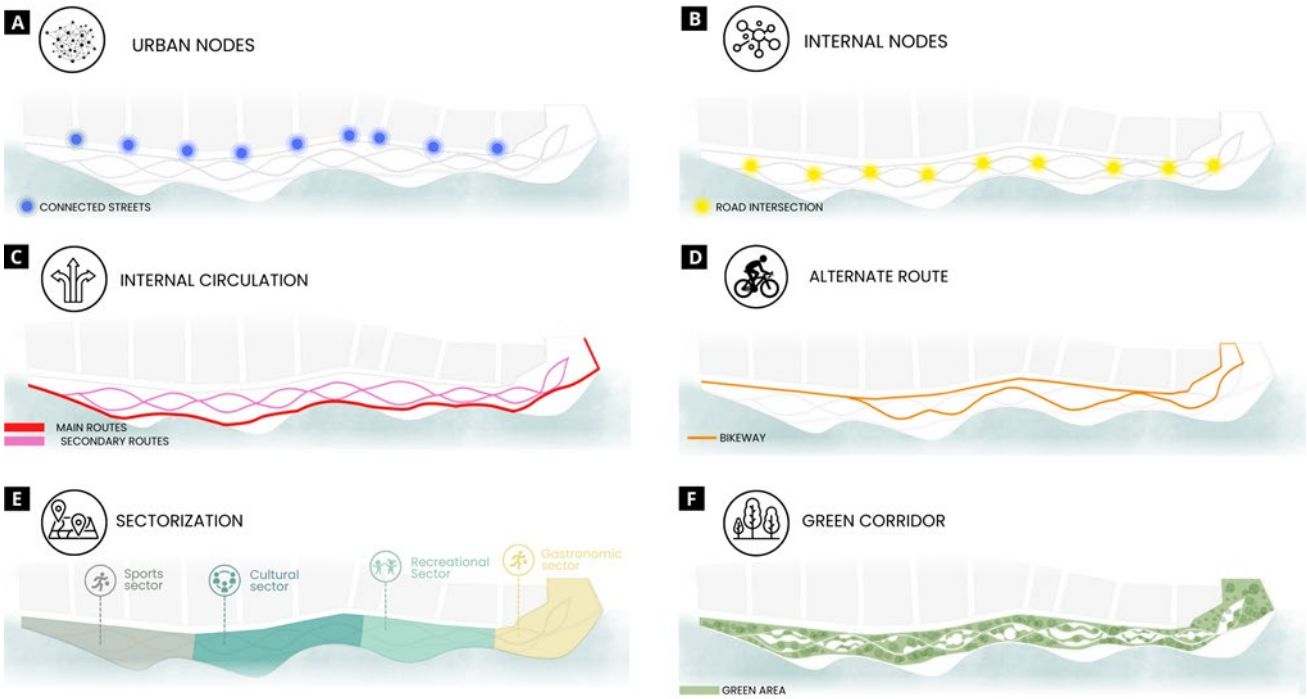


Figure 12. Analysis of the study area. (**A**) Urban nodes; (**B**) internal nodes; (**C**) internal circulation; (**D**) alternate route; (**E**) sectorization; and (**F**) green corridor. Figures created by the authors using Snazzymaps and Adobe Photoshop 2024.

4.5. Master Plan Proposal

The master plan envisions an ecological corridor that serves as an articulating axis between the city and its water ecosystems, contributing to strengthening the relationship between nature and the urban environment The project is organized into four sectors: Cultural zone, aimed at strengthening and promoting the living culture of Iquitos; Recreational zone, designed as a meeting and resting space; Gastronomic zone, focused on promoting local cuisine with spaces offering products to visitors and tourists; Sports zone, encouraging healthy habits in a natural environment. The entire corridor incorporates sustainability criteria, using solar energy, responsible water management, and low-impact environmental materials, seeking to consolidate a living, inclusive, and sustainable space as shown in Figure 13.

4.6. Urban Proposal

Among insects, diurnal butterflies (Lepidoptera: Papilionoidea) act as pollinators of riparian and pioneer plant species, facilitating the reproduction of plants that stabilize the soil and contribute to the regeneration of the riverside forest [63]. In addition, their larval stages (caterpillars) consume foliage and constitute an essential source of food for insectivorous birds, integrating them as a key link in the terrestrial food web [64]. Insectivorous birds, such as *Pitangus sulphuratus* (*bienteveo*), act as consumers of arthropods and other invertebrates lurking from perches or through active captures, helping to reduce populations of herbivorous insects and other small invertebrates that can damage vegetation. [65]. On the other hand, fruit birds, such as *Ramphocelus carbo* (*red tanager*), *Cacicus cela* (*yellow-backed chieftain*) and *Psarocolius angustifrons* (*oriole*), play a key role as seed dispersers, transporting seeds along the banks of the Itaya River and favoring the natural regeneration of the riparian forest, especially in areas disturbed by floods or human activity [66]. Herbaceous species such as *Justicia secunda* and *Dieffenbachia* spp. play a key role in producing flowers and plant structures that attract butterflies, bees, and other pollinating insects, which depend on these plants as a source of nectar, shelter, and breeding

sites [67]. These insects, in turn, constitute a main source of food for insectivorous birds, establishing a direct trophic relationship between the vegetation of the understory and the riparian birdlife [68]. On the other hand, pioneer tree species such as the *Simarouba amara* (*Marupa*) are fast-growing and have the capacity to improve soil conditions through the contribution of organic matter and the regulation of the microclimate and thus facilitate the establishment and development of larger and slow-growing tree species, such as the *Otoba* spp. (*aguanillo*) and the Amazonian almond tree *Dipteryx micrantha* [69,70]. Likewise, the aguanillo and the Amazonian almond tree play an essential role as producers of fruits and seeds, which are consumed by frugivorous birds and riparian mammals; then through the consumption and subsequent movement of these animals, the seeds are dispersed along the banks of the Itaya River identified in Figure 14 [71,72].



Figure 13. Ecological corridor master plan. Figure created by the authors using Adobe Photoshop 2024.

The broker also includes an Amazonian plant nursery to reinforce local identity and sense of belonging, and shade vegetation in lookout points and natural grass in recreational zones for rest and play. In this way, the project dedicates 81.61% of the total area (91,935.89 m^2) to green areas (74,999.32 m^2), reinforcing its ecological focus.

In the ecological corridor, photovoltaic panels are being installed as part of a sustainable electricity generation strategy, aimed at meeting energy demand efficiently and cleanly. Table 1 presents the technical characteristics of the selected model: a solar luminaire, manufactured by Bluesmart and distributed by Panel Solar Perú, has an efficiency of 24%. This data will be used to calculate the monthly and then annual production of solar luminaires that will be used in the corridor.

Table 1. Characteristics of solar luminaires [73].

	Manufacturer	City	Country	Distributor	Dimensions (mm)	Peak Power (W)	Efficiency (%)
100 W 18,000 lm Bluesmart Outdoor	Bluesart	Shenzhen	China	Panel Solar Peru	775 × 665 × 120	100	24

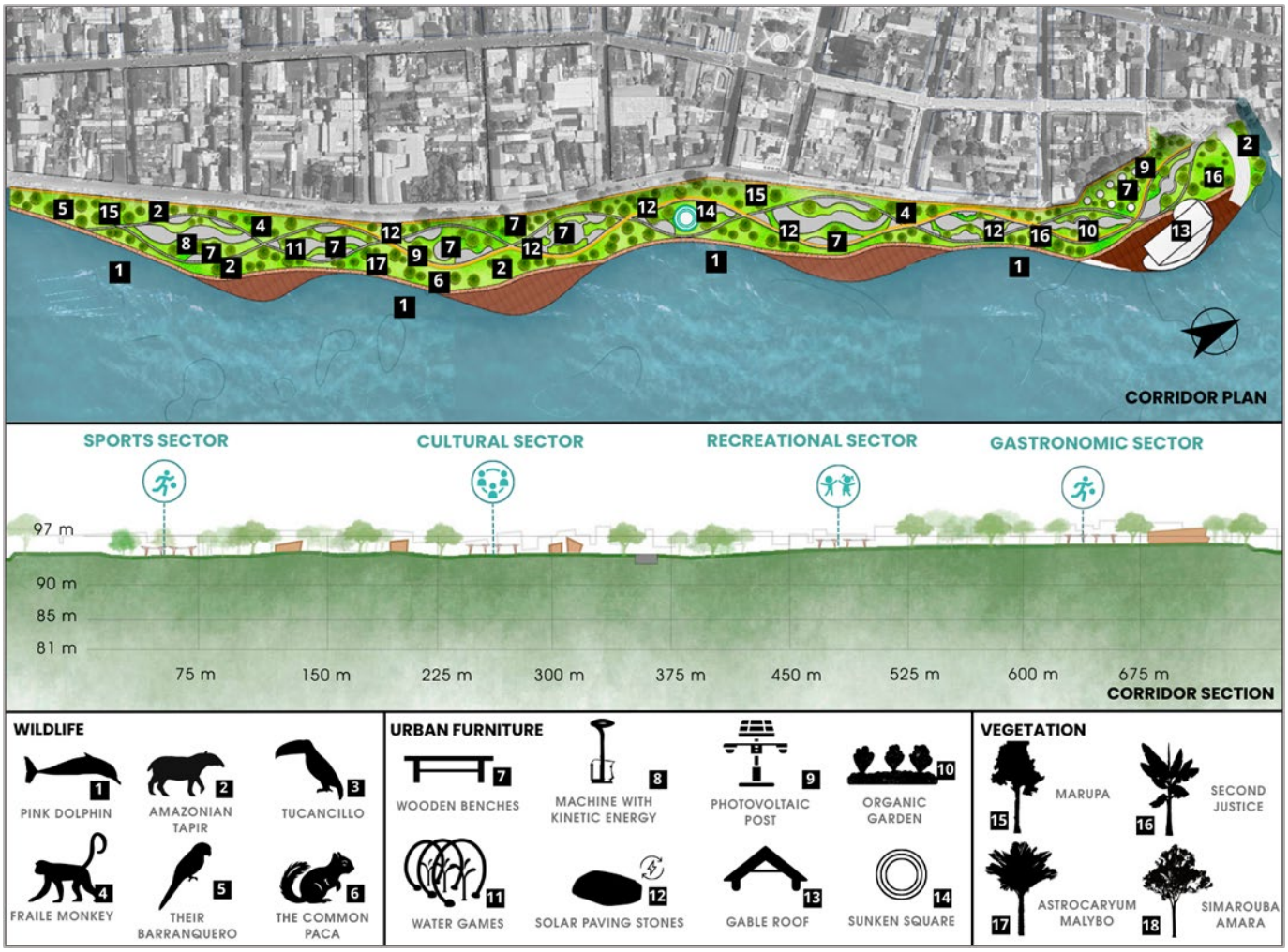


Figure 14. Urban proposal. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

Table 2 shows the estimated energy generated by the solar panels used in the lighting system. This calculation was made considering a unit power of 0.08 kW per panel, an average solar radiation of 5.0 kWh/m^2 per day, and an efficiency of 24%. With this we achieve a monthly production of 192 kWh and an annual production of 4423.7.

Table 2. Production of solar poles for public lighting.

	kW Diary per Panel	Diary Solar Radiation	Efficiency (%)	Numbers of Panels	N° Days per Month	Total Monthly kWh	Total Annual kWh
Solar luminaires	0.08	5.0	24	80	30	192	4423.7

When considering variations in the actual performance of the PV system associated with local environmental conditions, such as dust accumulation, high temperatures, and seasonal variations in the angle of solar incidence, a performance fluctuation of approximately 15% is estimated. As a result, adjusted energy generation reaches a monthly value of close to 220.8 kWh and an approximate annual production of 5087.3 kWh. These values allow us to objectively measure the contribution of the photovoltaic system to the implementation of energy-efficient and environmentally sustainable public lighting solutions.

4.7. Architectural Spaces and Their Strategies

The architectural spaces proposed in the project are structures of construction systems designed to adapt to Iquitos' tropical climate and optimize resources such as water, energy, and vegetation. Each space in the project presents an architectural configuration that combines lightweight infrastructure, local materials, and bioclimatic solutions that guarantee comfort and sustainability appropriate for each use. Thus, each sector integrates morphology, materiality, and spatiality based on climatic, environmental, and cultural conditions.

4.7.1. Recreational Sector

Interactive Play Plaza

This plaza is conceived as an inclusive and active environment that promotes child development from an integrative perspective of culture, nature, and play. It incorporates bamboo and steel structures that support playgrounds built with recycled tires (40% recycled rubber), combined with stone floors and rubber surfaces that cover approximately 30% of the total area to ensure cushioning and safety. Wood and fabrics with Shipibo patterns reinforce Amazonian cultural identity. The Barcelona Play Plan emphasizes that playgrounds should be diverse, creative, inclusive, and accessible [74]. The environment incorporates Bermuda grass and native species such as *Sacharum arundinaceum* and *Roystonea regia*, generating shade and comfortable microclimates, while the urban furniture—integrated by tire-based games, photovoltaic posts, and modular surfaces—aligns with SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production), as seen in Figure 15A.

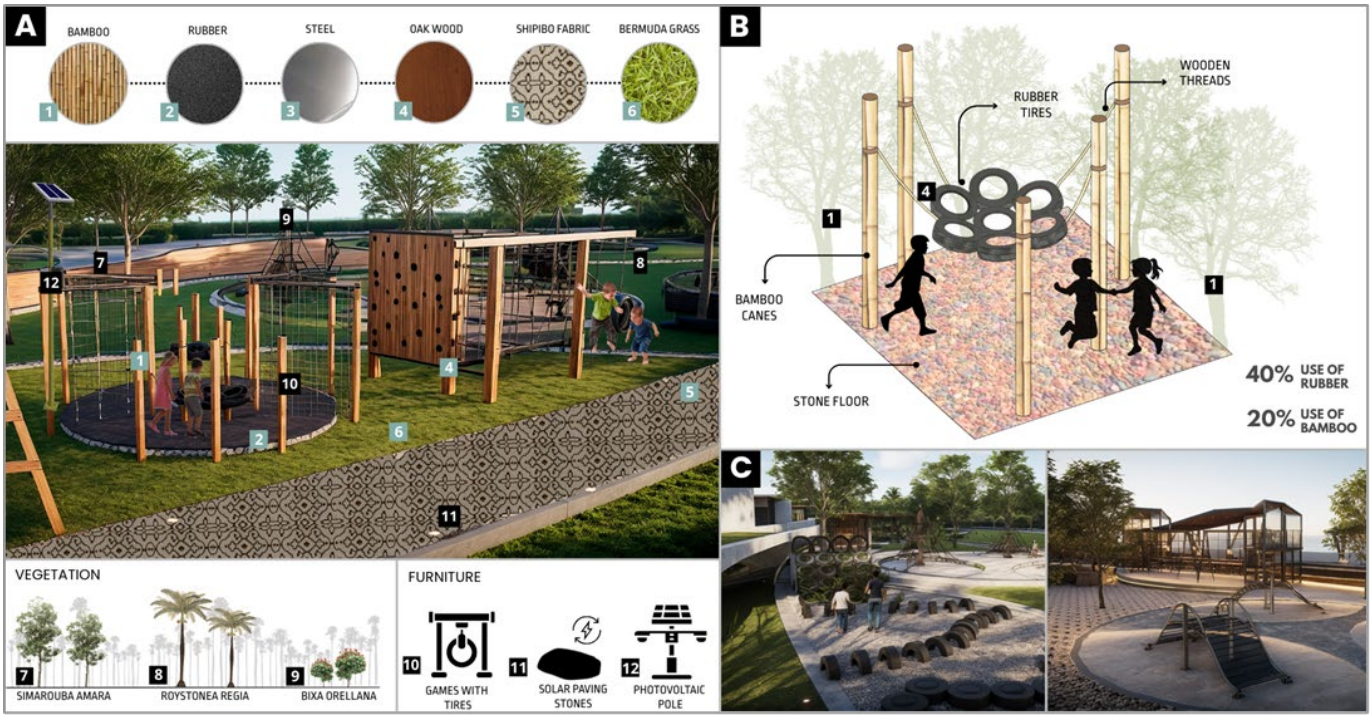


Figure 15. (**A**) Interactive Play Plaza; (**B**) Isometry of the playground; and (**C**) Plaza views. Figure prepared by the authors using Sketchup Pro 2024 and Adobe photoshop 2024.

The constructive scheme in Figure 15B shows the isometry of a bamboo game with ropes, wooden platforms, and rubber areas that ensure safety and comfort. Pedestrian access is resolved through stone paths and grass areas that provide safe and accessible routes shown in Figure 15C. In addition, the space has an autonomous solar lighting system

that reduces conventional energy consumption by 80%, strengthening sustainability and contributing to SDG 7 (Affordable and Clean Energy).

Water Play Area

This recreational space integrates interaction, nature, and sustainability, offering a safe and accessible environment for users of all ages. Its design incorporates channels and paved surfaces with Shipibo textures and laja stone, combined with green areas of grass and native tree species such as *Simarouba amara*, *Mauritia flexuosa*, and *Cedrela odorata*, which provide shade and reduce surface temperature by up to 35%. The play elements include water games made of tempered glass and hardwood, selected for durability and resistance to humidity. The interactive water jets occupy approximately 40% of the total surface, ensuring a dynamic and safe experience for users as shown in Figure 16A. According to the Public Recreational Spaces Manual, the integration of water and vegetation fosters thermal comfort and prolonged visitor stay. Likewise, the World Health Organization recognizes that access to green areas and natural elements improves physical and mental health. The constructive section, represented in Figure 16B, shows the elevation in the wooden and tempered glass structure supporting showers and jets, designed with a water recirculation system that reduces water consumption by 60% compared to conventional facilities, aligned with SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action). Pedestrian access, paved with stone and surrounded by grass, facilitates circulation and connects play areas, show in Figure 16C. The park also features solar-powered lighting, which reduces grid electricity use by 80%, reinforcing its commitment to sustainability and SDG 7.



Figure 16. (**A**) Water play area; (**B**) plaza views; and (**C**) game elevation. Figure prepared by the authors using Sketchup pro 2024 and Adobe Photoshop 2024.

Integrated Recreational Gaming System

In the recreational sector, integrated design strategies are implemented that promote social inclusion, environmental sustainability, and urban comfort: universal accessibility is prioritized through firm and continuous pedestrian paths that connect the playground and the water play area, allowing free movement for people with diverse mobility; shock-

absorbing and safe surfaces such as rubber and stone paving are incorporated, reducing the risk of injuries and facilitating play for all ages; sustainable materials are used—recycled tires (≈40% rubber), bamboo, and local hardwoods—which decrease the environmental footprint and reinforce Amazonian cultural identity through textiles with Shipibo patterns; native vegetation and tree species generate comfortable microclimates and natural shade, improving thermal well-being; water recirculation systems in the water play areas increase water efficiency, reducing consumption compared to conventional installations, while autonomous photovoltaic lighting reduces dependence on grid energy by up to 80%. Finally, the combination of nature, active play, and sensory elements enriches the user experience, fosters community interaction, and contributes to children's physical and cognitive development, aligning with principles of inclusive design and urban sustainability [75].

4.7.2. Cultural Sector

1. Sunken Cultural Plaza

Conceived as a circular public space for gathering and cultural expression, this plaza can be used as an open-air auditorium for cultural activities, artistic performances, talks, or screenings.

Its design features concentric descending stands toward a central area paved with concrete decorated with Shipibo patterns, evoking Amazonian identity, as shown in Figure 17A. As stated in [76], "Cultural spaces must be rooted in the biocultural memory of peoples, integrating nature and ancestral knowledge." The environment is complemented by Bermuda grass and native flora, along with urban furniture that includes benches, photovoltaic posts, and ornamental fountains. The materiality combines polished concrete, stone, bolaina wood, and vegetation, seeking climate resistance and esthetic harmony with the natural surroundings, linked to SDG 12 (Responsible Consumption and Production). Pedestrian access, integrated with stone and wooden paths, allows for comfortable and direct circulation as seen in Figure 17B. The section of the sunken plaza reveals the stepped form of the descending stands in polished concrete that lead to the central space, also covered in concrete. Around the plaza, a garden with ornamental vegetation (*Dieffenbachia* and *Justicia secunda*) is contained by a small bolaina wood wall as seen in Figure 17C. The plaza also incorporates a rainwater harvesting system, linked to SDG 6, used for irrigation and non-potable services, reducing potable water consumption and promoting efficient water management.

2. Rainwater Harvesting System

In the city of Iquitos, located in the Amazon region of Peru, pluviometric conditions are characterized by abundant and well-distributed rainfall throughout the year, with an average annual precipitation of approximately 2600 mm and frequent intense rainfall events associated with tropical convective systems, particularly during the wet season [77,78]. This rainfall regime generates high volumes of surface runoff in impervious urban areas, making rainwater harvesting a technically viable and environmentally appropriate strategy for the sustainable management of water resources in urban public spaces [79].

Within this context, the storage capacity of the rainwater harvesting system is determined based on the runoff generated over the impervious surface of the sunken plaza during a representative rainfall event for the city of Iquitos, using local pluviometric data and widely accepted standard criteria of urban hydrology [79,80]. The runoff volume is estimated using the following basic hydrological expression:

$$V = P \times A \times CV = P \quad (3)$$

where V represents the runoff volume (m^3), P is the effective precipitation (m), A is the catchment area (m^2), and C is the runoff coefficient.

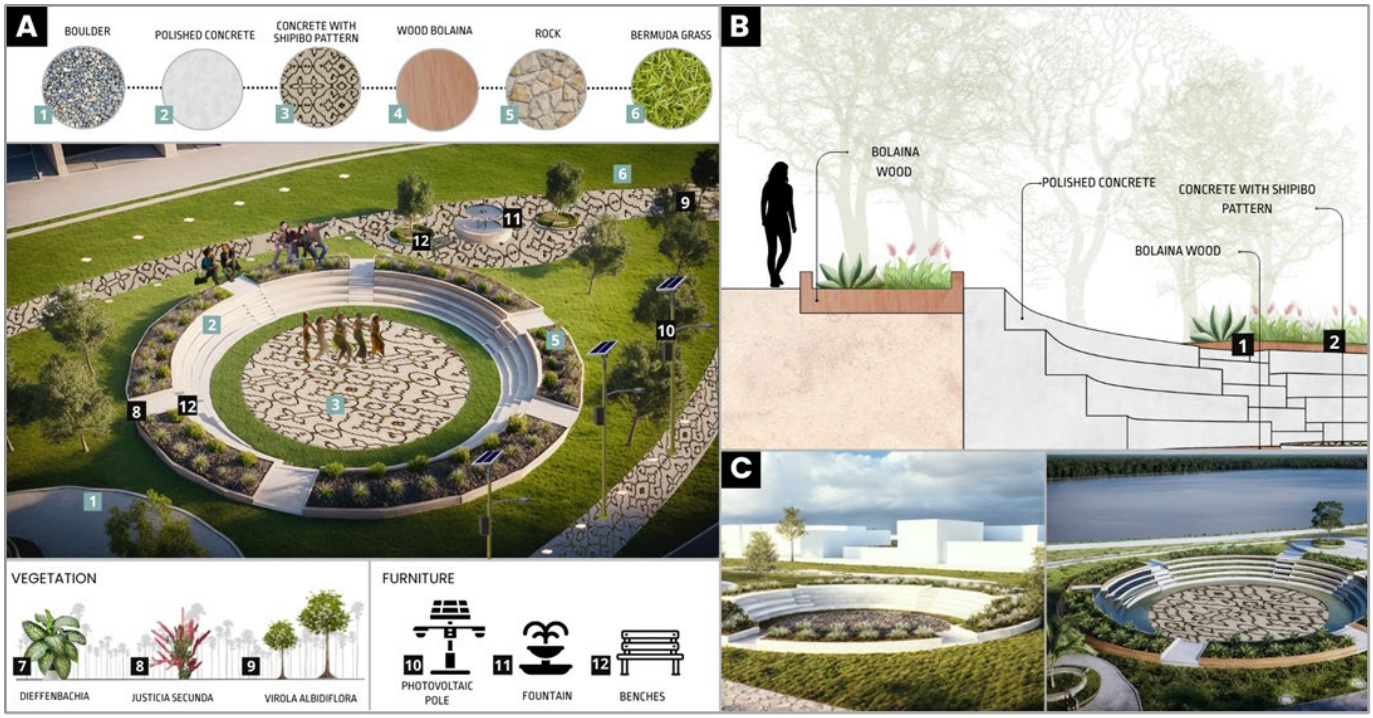


Figure 17. (**A**) Sunken cultural plaza; (**B**) views of the proposal; and (**C**) section of the sunken plaza. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

According to data from the National Meteorology and Hydrology Service of Peru (SENAMHI), the city of Iquitos records monthly precipitation values exceeding 250–300 mm during the wettest months, as well as high-intensity events associated with tropical convective storms [77,78]. For the system design, a representative intense daily rainfall event is adopted, with an effective precipitation of 50 mm (0.05 m) over a 24 h period. This value is considered conservative and recurrent for the city and is commonly used in urban drainage studies for humid tropical climates [78].

The catchment surface corresponds to the sunken plaza, whose effective impervious area is approximately 900 m^2, as obtained from the architectural modeling of the project. Given that this is a paved urban surface, a runoff coefficient (C) of 0.80 is adopted, as recommended for rigid pavements [79,80].

It substitutes the following values:

$$V = 0.05\ m \times 900\ m^2 \times 0.80 \quad (4)$$

$$V = 36.0\ m^3 \quad (5)$$

Considering minor system losses, spatial variability of precipitation, and an operational safety margin, this value can be rounded to a range of 35–40 m^3 to ensure adequate performance under intense rainfall events.

This storage volume allows the retention of excess runoff generated during frequent high-intensity rainfall events and ensures water availability for non-potable uses, such as irrigation of green areas and toilet flushing, during periods of lower precipitation. Previous studies on rainwater harvesting systems in tropical climates confirm that storage volumes within this range are appropriate for medium-scale public infrastructure, as they balance hydraulic efficiency, implementation costs, and maintenance requirements [81,82].

Regarding system operation, rainwater is collected at the lower surface of the sunken plaza through drainage grates (Figure 18A) and subsequently conveyed through underground PVC pipes (Figure 18B), sized to transport flows associated with intense rainfall without generating hydraulic overpressure. The flow then passes through a primary filtration system (Figure 18C) that retains coarse solids and reduces sediment loads. Storage takes place in a waterproofed cistern (Figure 18D), from which the water is pumped mechanically (Figure 18E) to a secondary filtration stage (Figure 18F).

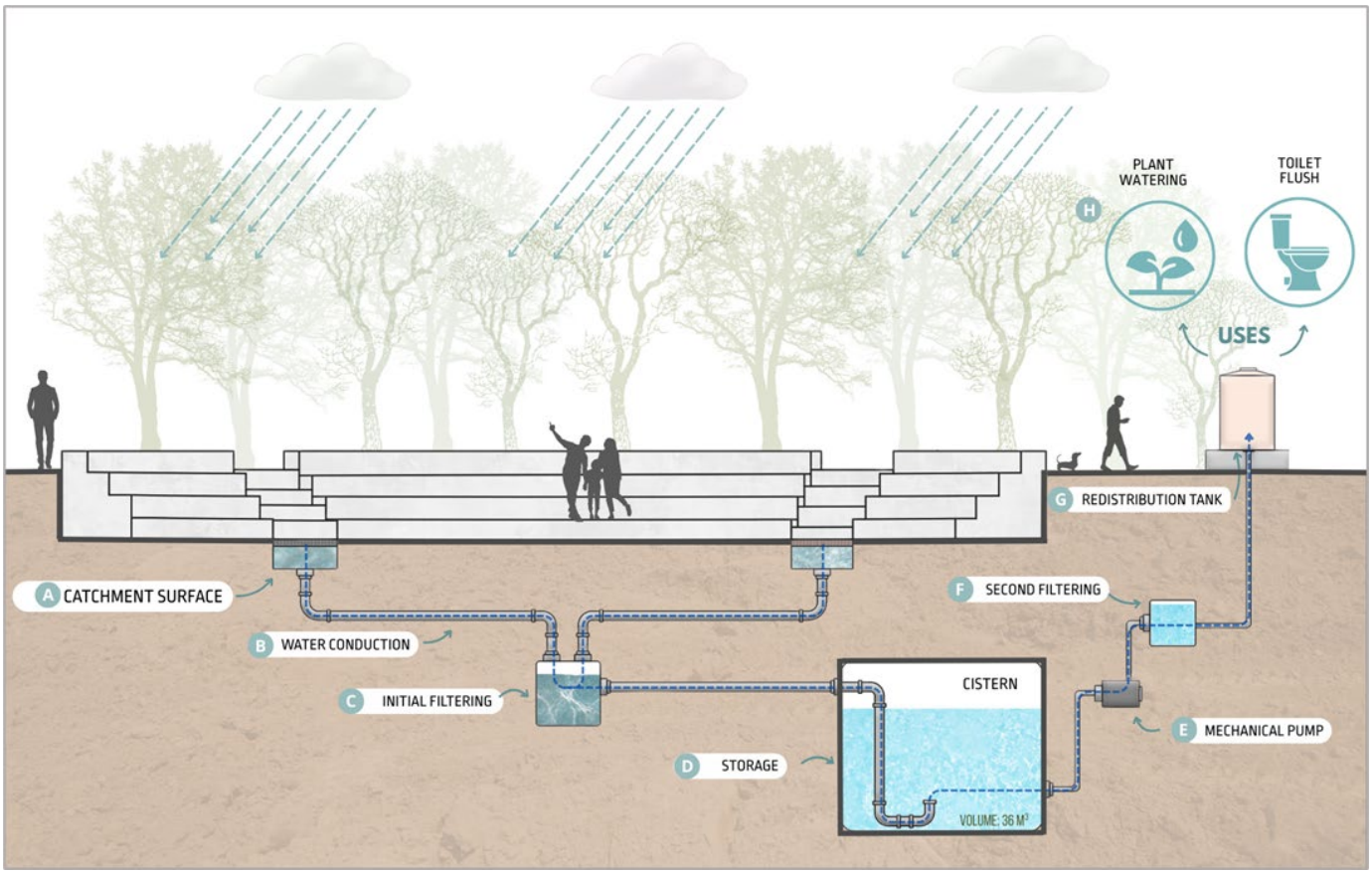


Figure 18. Water harvesting system for the sunken plaza. (**A**) Catchment surface; (**B**) water conduction; (**C**) initial filtering; (**D**) storage; (**E**) mechanical pump; (**F**) second filtering; (**G**) redistribution tank; and (**H**) uses. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

Finally, the treated water is conveyed to a redistribution tank (Figure 18G) and used for irrigation of green areas and for toilet flushing in sports facilities (Figure 18H). This system reduces potable water consumption and simultaneously mitigates the impacts of extreme rainfall events by decreasing direct surface runoff into the urban drainage system.

3. Amazonian Plant Nursery

The Amazonian Plant Nursery was analyzed as a productive ecological infrastructure oriented toward environmental restoration, ecological connectivity, and environmental education. The nursery integrates fruit, horticultural, and ornamental species characteristic of Amazonian agroecological systems, including camu camu (*Myrciaria dubia*), cocona (*Solanum sessiliflorum*), tomato (*Solanum lycopersicum*), cassava (*Manihot esculenta*), ají charapita (*Capsicum frutescens*), loche squash (*Cucurbita moschata*), and Swiss chard (*Beta vulgaris* var. *cicla*), as well as ornamental and flowering species such as dwarf rose (*Rosa* spp.), Amazonian orchids, red ginger (*Alpinia purpurata*), and red shrimp plant (*Justicia brandegeeana*). This plant selection responds to the criteria of climatic adaptability, nutritional value, contribution to urban biodiversity, and educational function, all

of which are widely documented for humid tropical contexts, this distribution can be observed in Figures 19 and 20 [83].

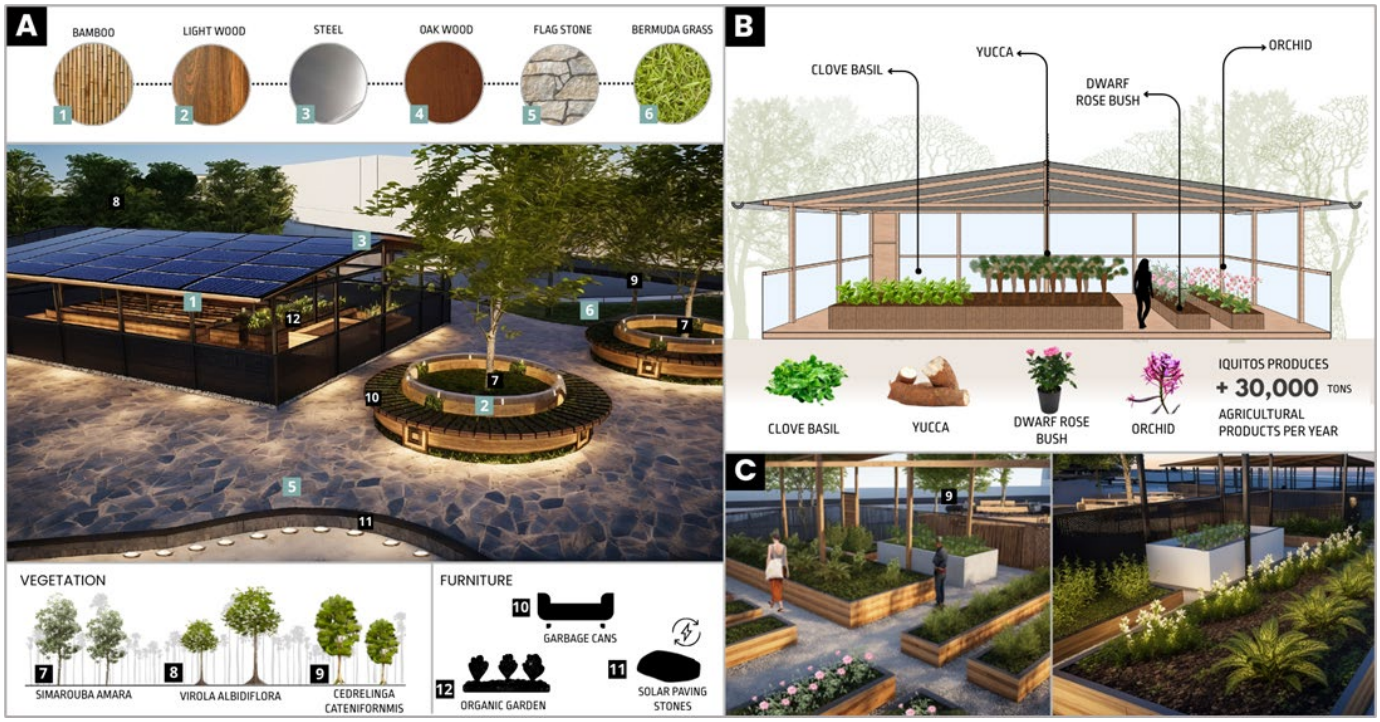


Figure 19. (**A**) Amazonian plant nursery; (**B**) proposal views; and (**C**) interior section of the Amazonian plant nursery. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

From an environmental performance perspective, the analysis of the nursery also considers the efficient management of water and energy resources as integral components of its operation. In terms of water use, biofiltration systems and irrigation using recycled water derived from rainwater harvesting are incorporated, thereby reducing dependence on potable water for vegetation maintenance. The reuse of harvested and treated rainwater for irrigation is a practice supported by the literature on integrated water resources management, circular economy, and urban green infrastructure, particularly in regions with high annual precipitation such as the Amazon [84,85].

Complementarily, an analysis of the nursery's energy demand was conducted in order to evaluate the potential for supply through photovoltaic solar energy. Under the solar radiation conditions available in the city of Iquitos, photovoltaic systems applied to agricultural infrastructure and urban nurseries can fully or partially meet operational electricity demand, contributing to reduced dependence on the conventional power grid and to the mitigation of emissions associated with fossil fuel-based energy consumption [86].

In addition, the nursery's architectural and landscape configuration integrates climate-responsive materials such as bamboo, wood, steel, flagstone, and Bermuda grass, reinforcing its ecological identity, as shown in Figure 19A. Its sectional organization defines the relationship between cultivation areas and circulation paths while incorporating species such as clove basil, yucca, dwarf rose bush, and orchid, as represented in Figure 19B. The use of raised planting beds, organic gardens, and solar paving stones strengthens its environmental performance and educational function, as shown in Figure 19C.

Table 3 presents the technical characteristics of the 370 Wp Amerisolar monocrystalline PERC solar panel used in the lighting system. This data will be used to calculate the demand for energy in the plant nursery.



Figure 20. Floor plan and section of the organic garden. Created by the authors using Sketchup 2024, Autocad 2024 and Adobe Photoshop.

Table 3. Features of the selected solar panel [87].

	Manufacturer	City	Country	Distributor	Dimensions (mm)	Peak Power (W)	Efficiency (%)
Solar Panel 370 Wp Amerisolar Monocristal-ino PERC	Amerisolar	Champs-sur-Marne	France	ALBAM group	1956 × 992 × 40 mm	370	19.07

Furthermore, the maximum electrical demand has been calculated considering the lighting system, as shown in Table 4. In this case, a total of lighting, emergency lights, and normal outlets was evaluated, resulting in a total installed power of 4418 W and a maximum demand of 4191.2 W (4.19 kW).

Table 4. Calculation of maximum electrical demand.

Device	Quantity	Load (W)	Installed Power	Diversity Factor	Max. Demand
Lighting	3	12	36	1	36
	4	20	80	1	80
	48	40	1920	1	1920
	20	60	1200	1	1200
Emergency lights	8	6	48	1	48
Normal outlets	7	162	1134	0.8	907.2
TOTAL			4418		4191.2

On the other hand, Table 5 presents the total electricity demand in the organic garden. A 30-day-per-month operation with 15 h of daily use has been considered to ensure optimal functionality of the facilities. Under these conditions, the total power demand is 4191.2 W (4.1912 kW), resulting in a monthly energy consumption of 1886.04 kWh and an annual energy demand of 22,632.48 kWh.

Table 5. Demand for electricity in the nursery.

Total (W)	Total (kW)	Days per Month	Hours per Day	Monthly Energy (kWh)	Annual Energy (kWh)
4191.2	4.1912	30	15	1886.04	22,632.48

Table 6 presents the solar panel production at the nursery, considering a daily solar radiation of 5.0 kWh/m^2/day and an efficiency of 19.00%. With a 0.37 kW panel, the generation is 1072.8 kWh per month and 12,873.7 kWh per year. These values far exceed the demand established in Table 5, guaranteeing not only the energy supply for the camp areas but also a surplus that can be utilized within the system, reinforcing the project's efficiency and sustainability.

Table 6. Production of solar panels in the nursery.

	Power per Panel (kW)	Daily Solar Radiation	Efficiency (%)	Number of Panels	Days per Month	Monthly Production (kWh)	Annual Monthly Production
Solar panel	0.37	5.0	19	2	30	2109	25,308

The calculation is based on a unit power of 0.08 kW per panel, with an average daily solar radiation of 5.0 kWh/m^2/day and an efficiency of 19%, considering the installation of 55 modules in continuous operation for 30 days per month. Under these conditions, a monthly production of 13,200 Wh and an annual production of 15,840 Wh are estimated. These values allow us to gauge the contribution of the photovoltaic system to the sustainable and efficient energy supply for use of spaces.

Finally, Table 7 presents the comparison between energy demand and energy supply in the nursery. The results indicate that the supplied energy slightly exceeds the energy required, demonstrating the system's efficiency and reliability in meeting the operational energy needs of the facility.

Table 7. Monthly and annual energy supply by source in the nursery.

Source	Monthly Energy Supplied (kWh)	Annual Energy Supplied (kWh)
Electrical grid	1886.04	22,632.48
Solar Panel	2109	25,308

The estimation of photovoltaic generation was developed from a comparative approach between the projected energy demand and the potential production capacity of the system, considering the solar irradiance levels of the local context. This method contemplates the application of an adjustment factor that allows the behavior of the system to be represented more realistically under real operating conditions, incorporating losses derived from factors such as ambient temperature, the accumulation of dust on the modules,

electrical losses in the wiring, inverter inefficiencies and the progressive degradation of the components over time.

In accordance with the recommendations of the International Renewable Energy Agency (IRENA) and the photovoltaic system design guidelines of the National Renewable Energy Laboratory (NREL), a 20% safety margin was applied to the energy balance, in order to ensure the reliability of the system against seasonal variations in irradiance and the gradual reduction in the efficiency of the modules. This adjustment was made after the base energy production had been calculated.

Under this procedure, the estimated annual energy consumption per installation was 47,940.48 kWh/year; after the application of the 20% safety margin, the adjusted value reached 57,528.58 kWh/year.

4.7.3. Sports Sector

In this sector, sports courts are incorporated within the green corridor, optimizing land use by integrating physical activity infrastructure with ecological recreational areas. The proposal includes outdoor exercise machines powered by kinetic energy generated by users themselves, promoting community physical activity and social interaction, especially among youth and older adults. This strengthens social cohesion, fosters energy self-sufficiency, and raises awareness about resource use. In addition, self-sustaining bathrooms are incorporated, using rainwater harvesting systems to minimize potable water consumption. The system consists of roof-integrated gutters that channel rainwater into storage tanks equipped with sediment filtration and basic purification mechanisms, a strategy widely recognized for reducing surface runoff, mitigating flood risk, and enabling the local reuse of water resources for non-potable purposes such as sanitation and cleaning, while also preventing excessive groundwater extraction.This space, located in front of the Itaya River in Iquitos, is designed to promote exercise and physical well-being within the community. It includes free-to-use outdoor exercise machines powered by kinetic energy, as well as urban furniture. Access to green areas is integrated, as it is associated with a significant reduction in stress levels and improved cardiovascular health. The proposal incorporates solar-powered public lighting, aligned with Sustainable Development Goal (SDG) 7—Affordable and Clean Energy—contributing to energy efficiency and reduced carbon emissions (Figure 21A) [88]. The integration of the landscape with sports areas contributes to a healthier and more sustainable experience, strengthening the connection between physical well-being and environmental care. It also emphasizes the valorization of native vegetation, linked to SDG 13 (Climate Action), as local plant species enhance biodiversity, improve microclimatic conditions, provide shade, and reduce environmental impacts in outdoor recreational areas (Figure 21B) [88,89]. Finally, in alignment with SDG 3 (Good Health and Well-Being), this sector encourages active lifestyles, supports cardiovascular and mental health, and improves overall quality of life. The presence of abundant vegetation and panoramic views of the Itaya River creates a restorative landscape that fosters relaxation, stress reduction, and increased motivation for physical activity (Figure 21C) [90].

4.7.4. Gastronomic Sector

This sector includes spaces designed to highlight the gastronomic and cultural richness of Iquitos and to promote local chefs. Recreational and public spaces are also integrated. We incorporated a picnic area, where the community can gather to share breakfast, lunch, or dinner. A gastronomic fair features stalls selling a variety of local dishes, desserts, beverages, and other specialties. In addition, a bio-garden is included, cultivating the ingredients that will be used in the grand viewpoint restaurant “Tambo Yaku”, the landmark of this sector.

The name was chosen as a fusion of the words "Tambo" (meaning inn or lodge) and "Yaku" (meaning water in Quechua). Together, "Tambo Yaku" translates as "Water Lodge."



Figure 21. (**A**) Outdoor machines; (**B**) cutaway of exercise machines; and (**C**) views of the proposal. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

This elevated space facing the Itaya River functions as an emblematic gastronomic point and panoramic viewpoint, enhancing the value of water resources as both a natural landscape and a tourist attraction, as seen in the Figure 22A. It is built on stilts or a raised platform, using materials such as oak wood for finishes, due to its durability and resistance [89], and bamboo for external structures, given its high strength and low environmental impact as represented in Figure 22B [91]. Both are local and sustainable materials. The restaurant will include outdoor terraces, an Amazonian cocktail bar, spaces for live music, and access to a public sunset-viewing area, integrating culture, architecture, and nature as seen in Figure 22C. In terms of strategies and their alignment with the Sustainable Development Goals (SDGs), the project emphasizes the revaluation of local plants (SDG 13). These plants enhance biodiversity, reduce environmental impact, and create a natural and shaded environment, strengthening the link between physical well-being and environmental care. Among the species selected for the picnic area is Marupa (*Simarouba amara*), which can grow up to 35 m high [92], providing natural shade. Its sweet fruit is also used to prepare beverages in the restaurant. The Royal Palm (*Roystonea regia*) adds ornamental value, enhancing the appeal of the gastronomic sector and contributing to climate regulation [93]. In addition, Achiote (*Bixa orellana*), a small shrub, is traditionally used in the production of food, pharmaceutical, and cosmetic dyes [94]. Its fruit is also incorporated in the restaurant and in the local production of natural ingredients. Thus, the landscape and cultural design of the restaurant promote sustainable integration and the responsible use of Amazonian biodiversity.

4.7.5. Yorao Ibobo Viewpoint

"Yorao Ibobo," which in the Shipibo–Konibo language means "Lookout of the Spirit of the River," symbolizes the spiritual and cultural connection between the Itaya River, the Amazonian landscape, and ancestral Indigenous knowledge. Rather than functioning

solely as a viewpoint, these lookouts serve as spaces for contemplation and respect toward water, biodiversity, and the fluvial environment, integrating Indigenous cosmology into the design of the green corridor.

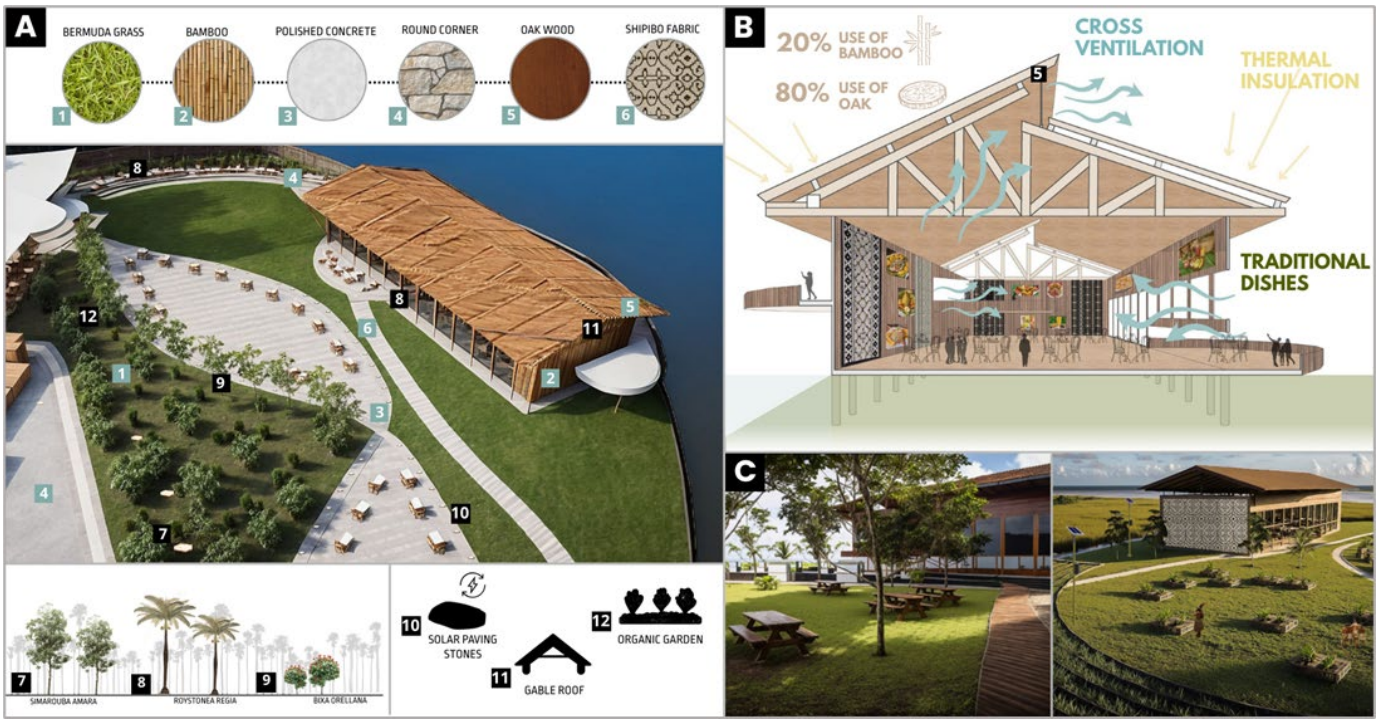


Figure 22. (**A**) Viewpoint restaurant; (**B**) views of the picnic zone; (**C**) restaurant section. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

These elements are replicated along different sections of the corridor to maintain a continuous relationship with the river, providing reflective pauses and panoramic views that reinforce the bond between human experience and the natural environment. The use of wood as the primary construction material aligns with sustainability principles and supports the local economy (SDG 11), while bioclimatic roofs and shading structures enhance thermal comfort and climate adaptation in Iquitos' tropical conditions (SDG 13). In addition, these spaces promote physical and mental well-being (SDG 3) and encourage the appreciation of local flora and fauna, strengthening environmental education and conservation of Amazonian ecosystems (SDG 15).

The wood used for structures is bamboo which can capture up to approximately 40 tons of CO_2 per hectare per year. Also, bamboo is one of the fastest growing plant materials in the world, with harvest cycles between 3 and 5 years, which allows its continuous use without degrading the forest resource or requiring intensive replanting as represented in Figure 23A [91]. From a constructive point of view, bamboo has a high strength-to-weight ratio and flexible structural behavior, which is advantageous in areas exposed to constant humidity and ground movements; these conditions also degrade the material faster but through proper preservative treatments, the shelf life of bamboo can be extended up to 15 or even 20 years [95].

On the other hand, oak, in terms of durability, can maintain its structural integrity for several decades in tropical exteriors if protection treatments are applied and adequate ventilation is guaranteed as seen in Figure 23B [96]. In riparian contexts such as that of the Itaya River, the use of oak wood offers additional advantages by visually and environmentally integrating with the Amazonian landscape as seen in Figure 23C [96] and

when it comes from certified sources of responsible forest management, its use promotes sustainable practices and contributes to the reduction in illegal logging in the Amazon [97].

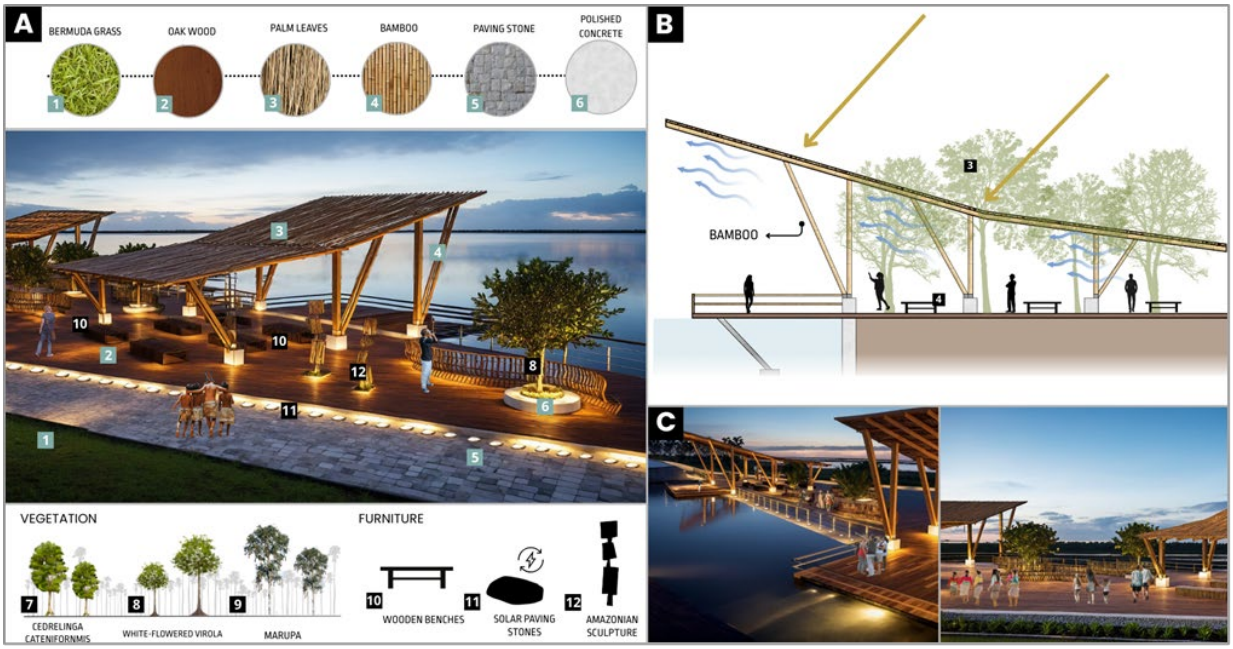


Figure 23. (**A**) Lookout; (**B**) lookout section illustrating natural ventilation (blue arrows) and solar radiation control (yellow arrows); and (**C**) proposal views. Figure prepared by the authors using Sketchup Pro 2024 and Adobe Photoshop 2024.

5. Discussion

The ecological corridor project in Iquitos is part of the contemporary approach of urban river regeneration based on nature-based solutions (NBSs), which have proven to be effective in improving climate resilience, environmental quality and social inclusion in intermediary cities in Latin America [98]. By integrating bioclimatic strategies, green infrastructure, decentralized water management, and symbolic elements of the Amazonian worldview—such as the Shipibo–Konibo patterns and the river as a structuring axis—the proposal seeks to respond to environmental and social problems specific to the Amazonian context, aligning with SDGs 3, 6, 11, 13, and 15 [99].

Comparison with international experiences allows us to identify measurable benefits, but also structural limitations. In the case of the Gran Malecón of the Magdalena River (Barranquilla), the intervention incorporated more than 1200 native trees and 70 ha of recovered public space, which allowed a reduction in surface temperature between 2 and 4 °C in adjacent sectors and a significant increase in the recreational use of the river edge [98,100]. However, subsequent studies show processes of land valuation and real estate pressure, with increases in land value of more than 30% in nearby areas, which generated risks of indirect displacement of vulnerable populations [101]. These results show that environmental regeneration, if not accompanied by housing and urban control policies, can deepen socio-spatial inequalities.

Similarly, the Malecón de Villahermosa (Mexico) is based on a Hydraulic Master Plan aimed at mitigating the risk of flooding, through elevated walkways and adaptive river terraces. Technical studies report a reduction in the risk of waterlogging in events of ordinary flooding, as well as improvements in pedestrian and bicycle accessibility along more than 6 km of river edge [102,103]. However, its implementation depends on high maintenance costs and continuous public management, which limits its replicability in cities with less institutional and budgetary capacity [104].

Based on this background, the ecological corridor proposed for Iquitos adopts a strategy of less hard infrastructure load, prioritizing native vegetation and rainwater management through rainwater harvesting and photovoltaic lighting systems. Studies of urban green corridors in humid tropical climates indicate that increasing riparian vegetation cover can reduce surface runoff by 15 to 30 percent, as well as improve infiltration and water quality [105]. However, the effectiveness of the project in Iquitos faces key limitations, such as the informal occupation of the banks of the Itaya River, the absence of a comprehensive sanitation system and the weakness of inter-institutional governance mechanisms, aspects that have been identified as critical factors in Amazonian river projects [106].

Likewise, the literature warns that projects to revalue the waterfront can induce green gentrification processes, especially when landscape quality is increased without parallel strategies of social inclusion [107]. In this sense, the ecological corridor of Iquitos must be articulated with housing policies, community participation, and local environmental management to avoid the exclusion of historically settled riverside populations.

Finally, the validation of the impact of the corridor cannot be based solely on project criteria, but requires verifiable indicators and monitoring in the medium and long term. The proposed indicators include the following: increase in the percentage of riparian vegetation cover, reduction in surface temperature, improvement in water quality parameters of the Itaya River (BOD, coliforms), increase in the diversity of birds and insects as bioindicators, and increased level of social accessibility to public space [108]. The incorporation of these indicators would allow for an empirical evaluation of the project's contribution to the urban and environmental resilience of Iquitos.

6. Conclusions

The analysis of the ecological corridor proposed for Iquitos, based on the review of international experiences of urban river regeneration and the literature on nature-based solutions, shows that the integration of green infrastructure, water management and public space constitutes a pertinent strategy to revalue the Itaya River as a structuring element of the urban landscape. The incorporation of rainwater harvesting systems, renewable energies and riparian green spaces responds to widely documented approaches to sustainability and climate adaptation in tropical contexts.

However, the comparative review shows that the environmental and social benefits of this type of intervention depend on complementary conditions, such as institutional governance, long-term maintenance, social inclusion of riverine populations, and the implementation of environmental monitoring mechanisms. In this sense, the project is proposed as a contextualized and transferable proposal, whose main contribution lies in articulating ecological restoration, cultural identity and public space in the construction of a vision of sustainable urban development for Iquitos.

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