Original Paper

Land use conflicts.

Urban expansion vs. mangrove conservation in the Portoviejo River estuary, Ecuador

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Received: 18 March 2025 | **Accepted:** 30 May 2025 | **Published:** 8 June 2025

Keywords: mangrove ecosystem; natural reserves; land use; sustainability; urban expansion.

Abstract. *Mangrove ecosystems are considered vulnerable environments with a high risk of disappearing due to anthropogenic activities. Currently, territories prioritize economic development over the conservation of environmental resources, which paradoxically sustain their economy and, therefore, their own existence. This is the case of the Mangrove Community Reserve of the Portoviejo River Estuary, an ecosystem that has been affected*

since 1950 by the expansion of urban boundaries, intensive agricultural practices, and, most notably, aquaculture activities, which have deforested approximately 86% of the original mangrove cover. Consequently, the purpose of this research was to understand how urban expansion, driven by the population growth of the communities within the estuary's biocorridor and their associated economic activities, has generated significant land-use conflicts that hinder conservation efforts for the remaining mangroves in the community reserve. Three methodological phases were applied: (a) characterization of the study area, (b) evaluation of human interactions and environmental pressure, and (c) identification of key patterns driving land-use changes. It was concluded that the urban footprint has increased by 146% since 2006, the population is growing around the mangrove reserve, and their socio-productive activities have fragmented the ecosystem and transformed the natural landscape. It is estimated that 407.55 hectares of mangrove forest have disappeared over the past seven decades due to indiscriminate logging for the construction of shrimp farms and agricultural plots, causing significant environmental alterations in the reserve.

1. Introduction

According to Leberger et al. (2020), urban growth in Latin America is closely tied to ongoing land-use conflicts, as the prioritization of socioeconomic development over natural conservation has led to a significant disruption in ecosystem balance, most notably reflected in the extensive loss of forest cover. The Food and Agriculture Organization of the United Nations (FAO, 2020) estimates that approximately 2.6 million hectares of forest have been lost over the past decade due to deforestation, urban expansion, and the compounded effects of climate change. Moreover, in 2015, wildfires were reported to have affected nearly 98 million hectares, resulting in a 4% reduction of forested areas in tropical regions.

The United Nations (UN, 2023) has highlighted that the rise in greenhouse gas emissions has triggered extreme events such as droughts, floods, and wildfires.

In this context, mangrove forests hold particular significance, as they constitute transitional coastal-marine ecosystems that provide critical protection for shorelines, support biodiversity, and contribute to CO_2 sequestration. According to Kathiresan and Bingham (2001), these forests create ecological niches characterized by distinctive morphological and physiological traits that sustain substantial biological diversity. Meanwhile, Mendoza et al. (2023) emphasize the importance of mangroves in maintaining ecological balance and supporting local economies through extractive and tourism-related activities. Afonso et al. (2022), on the other hand, underscore their role in ensuring food security for surrounding communities, despite the fact that socioeconomic factors often skew public perception regarding their conservation.

The issue is further exacerbated by the proximity of these ecosystems to population centers. Cruz et al. (2024) note that demographic pressure has historically contributed to the reduction of mangrove cover. Recent studies (Maurya et al., 2021; Vancutsem et al., 2021; Deng et al., 2021; Charrua et al., 2020) concur that increasing population density in coastal areas promotes the displacement of native vegetation and the conversion of mangrove habitats into land designated for agricultural and aquacultural production, thereby intensifying the overexploitation of forest and wildlife resources. Additionally, Davis et al. (2020) report that in tropical regions, large-scale land acquisition has led to a 59% loss in forest cover between 2000 and 2018.

In Ecuador, the expansion of urban frontiers has emerged as one of the greatest challenges to environmental management. According to Carvajal and Santillán (2019), the country hosts approximately 161,835 hectares of mangrove forest, with 67% concentrated in the province of Manabí. However, Shiguango (2022) warns of an alarming rate of mangrove cover reduction in this province, reaching as high as 70%. The FAO (2007) documented that, starting from 203,000 hectares in 1980, mangrove coverage had declined by 20.28% by 2015 equivalent to a loss of approximately 41,165 hectares - primarily due to anthropogenic activities in estuarine zones.

The phenomenon of accelerated urbanization is also reflected in population growth. Between 1990 and 2020, Ecuador's population increased by 63% - approximately 8 million people - according to the National Institute of Statistics and Censuses (INEC, 2022). The disparity between urban (119%) and rural (44%) growth rates underscores a territorial transformation that has had adverse effects on natural ecosystems, particularly in coastal areas. One such case is the lower basin of the Portoviejo River, where land-use conflicts have intensified in parallel with demographic expansion.

The mangrove forest at the estuary of the Portoviejo River - a community-managed reserve located at the border of the Sucre and Portoviejo cantons - serves as a clear illustration of these challenges. Covering an area of 53 hectares, this ecosystem supports high biodiversity despite having been subjected to over three decades of pressure from human settlements and productive activities. Unregulated deforestation to establish shrimp farming ponds, the discharge of untreated wastewater, and the accumulation of contaminated sediments have compromised the area's ecological integrity. Furthermore, the significant presence of solid waste and microplastics - carried downstream by the Portoviejo River from upstream settlements - highlights the lack of an integrated management plan to regulate socioeconomic activities and mitigate the progressive conversion of natural areas into agricultural and urban mosaics. This situation is further exacerbated by the economic dependence of vulnerable local populations, who increasingly rely on the overexploitation of mangrove resources for their livelihoods.

2. Research aims and methodology

In light of this complex scenario and the significant environmental pressures involved, the present study aims to understand how the growth of communities within the biocorridor, along with their socioeconomic needs, has altered land-use patterns and generated conflicts that challenge the true cost of territorial development. This research not only seeks to document these transformations but also to propose a sustainable territorial management model that integrates ecological, social, and economic criteria for the conservation of the Portoviejo River Estuary Mangrove Community Reserve. The findings are expected to provide both the scientific community and environmental policymakers with a valuable tool to support the development of more effective management strategies in coastal areas, thereby contributing to the advancement of knowledge in the fields of sustainability and environmental conservation.

The applied research was exploratory and non experimental, employing both qualitative and quantitative approaches. In order to determine how the expansion of urban frontiers and their growing demands have altered land-use patterns and increased environmental pressure on the Portoviejo River Estuary Mangrove Community Reserve, three methodological phases were developed, as described below.

In the first phase, a characterization of the study area was carried out with the aim of understanding, from a multidimensional perspective, the various

components that converge in the territory - social, economic, environmental, and political - and how their interactions influence land-use patterns. This was achieved through a literature review and the application of analytical, synthetic, and descriptive methods. Additionally, ArcGIS Pro was used as a tool for cartographic development and geospatial analysis operations.

The second phase focused on evaluating human interactions and the environmental pressure exerted on the Portoviejo River estuary, with the objective of determining the impact of urban expansion on the integrity of the mangrove ecosystem and its biodiversity. Key analyses were also conducted to identify the main territorial, environmental, and social dynamics directly affecting the ecosystem. These analyses were guided by criteria such as support from the scientific literature, empirical visibility within the study area, and relevance for understanding the observed territorial changes.

Among the main analyses conducted were ecosystem fragmentation, population growth, urban footprint expansion, territorial zoning, and multitemporal analysis of land-use change. This phase employed analytical, synthetic, and descriptive methods, combined with qualitative techniques such as interviews with community leaders, communal presidents, and key stakeholders, as well as field observation and the use of spatial analysis tools through ArcGIS Pro.

Finally, the third phase aimed to identify and characterize the predominant patterns driving land-use change around the mangrove reserve. To this end, a land-use pattern assessment matrix was applied, which enabled a comprehensive understanding of territorial changes, their causes and effects, as well as the severity of the impacts generated on the estuarine ecosystem of the Portoviejo River.

3. Results and Discussion

3.1 Characterization of the study area

The Portoviejo River Estuary Mangrove Community Reserve was established on April 14, 2011, with the objective of protecting its ecosystemic biodiversity. It is geographically located at the mouth of the Portoviejo River and, according to Cedeño (2020), encompasses a total of 53 hectares of mangrove forest that supports a significant biological load. This ecosystem forms part of the Portoviejo River Estuary Biocorridor, which includes dry forests, mangroves, salt flats, agricultural and aquacultural zones, archaeological sites, dunes, and beaches (Portoviejo River Estuary Biocorridor, 2023). The biocorridor is composed of

four communities: San Jacinto, Santa Teresa, and San Roque - located in the Sucre canton - and Las Gilces, which belongs to the Portoviejo canton.

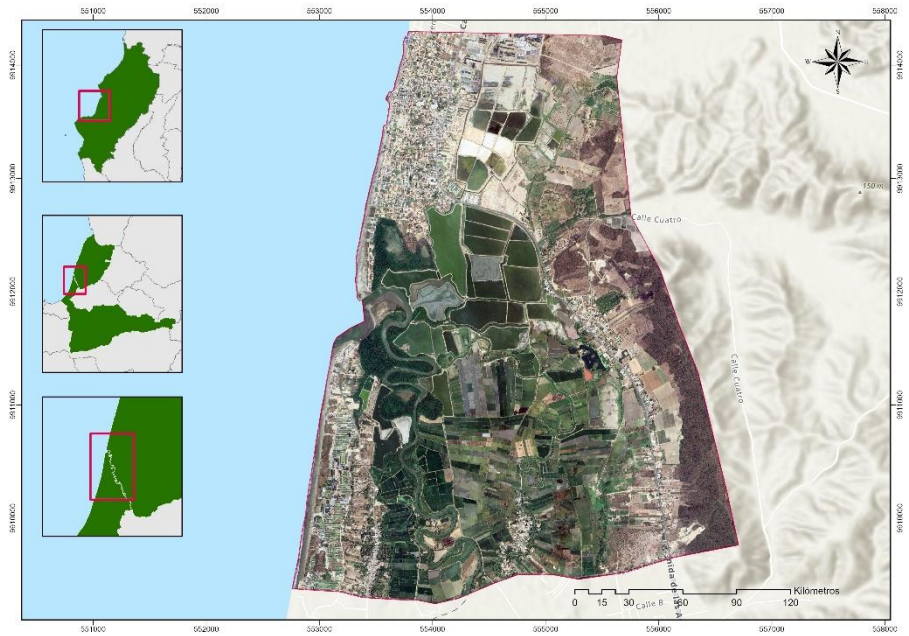

Figure 1. Delimitation of the study area

The estuarine ecosystem's area of influence is characterized by a warm, tropical dry climate, with temperatures ranging from 25°C to 30°C, influenced by the interoceanic Humboldt and El Niño currents. Annual precipitation averages 343.9 mm. Based on geospatial data from MAG (2017), the geological profile indicates that 48% of the area surrounding the reserve consists of alluvial deposits, with smaller proportions made up of marine deposits and the Borbón Formation, which accounts for 7%. This suggests a predominance of materials transported and deposited by water currents, typical of lowland regions and fluvial plains.

Therefore, the soil and substrate dynamics present within the reserve suggest a historical presence of coastal or marine areas, which have created favorable conditions for the sustained growth of mangroves and their associated ecosystems over time.

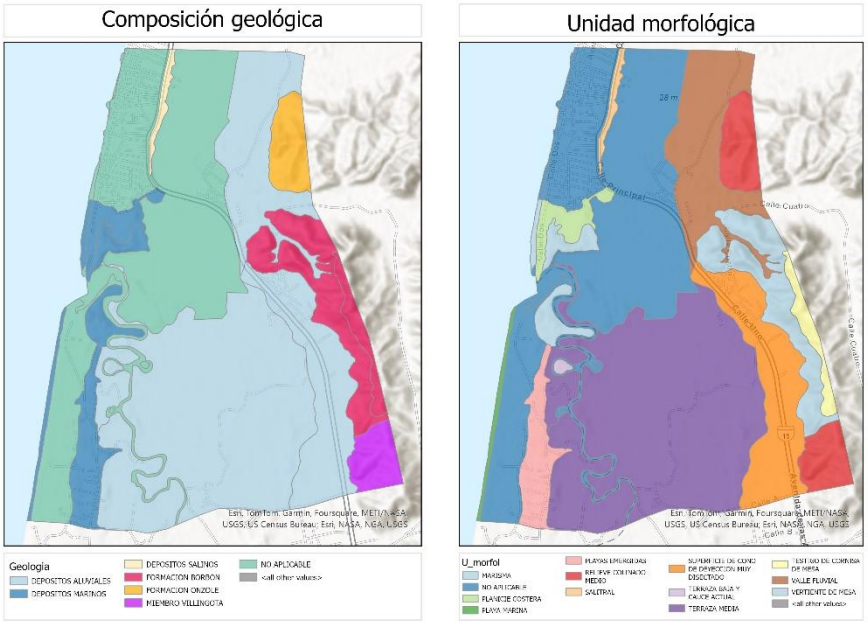

Figure 2. Maps of geological structure and morphological units.

According to Zirufo (2024), the Portoviejo River Watershed is considered one of the most important in the province of Manabí. It forms a valley that has enabled the development of agricultural and livestock activities, thereby driving the economic and social development of the populations settled within it. At its mouth lies the mangrove ecosystem - a buffer zone with significant biological richness that hosts a wide variety of birds, crustaceans, and fish.

According to Vaca and Piguave (2024), the reserve is home to 75 species of phytoplankton, 13 species of higher plants, 4 types of mangroves, 10 types of zooplankton, 2 species of annelids, 18 crustaceans, 27 fish, 27 mollusks, 42 species of birds, 4 reptiles, 3 mammals, and one species of echinoderm. Its great marine-coastal biodiversity of species underscores the ecosystemic complexity and vulnerability of La Boca Mangrove, making conservation efforts an ideal tool for preserving the integrity of the environment; however, population and urban growth that has generated conflicts over land use weaken its safeguarding effectiveness.

From a socioeconomic perspective, INEC (2022) states that the Charapotó parish in Sucre canton has a rural population of 23,361 people, while the Crucita parish in Portoviejo canton has 16,997. The economic base of these parishes revolves around the development of agricultural activities, livestock, salt, trade, fishing and tourism. However, the GAD Municipal Portoviejo (2019) recognizes that the territory faces significant problems with respect to urban land management, the lack of regulation of population settlements, limited access to basic services infrastructure, especially water and sanitation, which, together with the expansion of tourism activities, affect the quality of life and create gaps in socioeconomic inequalities that affect the most vulnerable groups.

On the other hand, from a political perspective, Zirufo (2024) argues that, although in the territorial framework there are agencies responsible for managing local projects, promoting development and guaranteeing equal access to essential services, there is evidence of complex problems that arise due to budgetary and infrastructure limitations. Although Charapotó has a much more effective policy for managing agricultural and livestock projects, they generate significant environmental impacts in which economic factors are placed above the integrity of natural spaces. In the case of Crucita, public policy is much more focused on the regulation of tourism and fishing activities; however, its territorial planning and management processes do not consider the problems of unregulated urban expansion and the unregulated proliferation of salt and aquaculture activities that affect the La Boca Mangrove due to the conflict over land use.

3.2 Evaluation of human interactions and environmental pressures

Population settlements have always been responsible for the mediation of spaces, and the area of influence of the Mangrove Community Reserve of the Portoviejo River Estuary has not been exempt from this process. As the communities that make up the estuary's bio-corridor have promoted territorial development, they have caused significant conflicts over land use in the last 20 years as a result of the growth of urban, agricultural, aquaculture, and saline frontiers. These activities pose a significant threat to the natural balance of the ecosystem (Cuásquer et al., 2022).

The result of the multi-temporal analysis of the urban footprint carried out using satellite images from 2006 and 2024 indicates that in the last 18 years the population settlements have increased by 149%, i.e., from 740 buildings to 1,922 at present.

Table 1. Multi-temporal analysis of urban footprint growth 2006 - 2024

Community	2006	2024	Change	Total urban footprint
San Jacinto	740	1.922	+1.182	2.952
Santa Teresa	218	571	+353	
San Roque	136	284	+148	
Las Gilses	91	174	+83	

Babel et al. (2024) indicate that this considerable population increase generates significant pressure on the reserve due to land use conflicts that arose with the expansion of urban frontiers over the mangrove ecosystem. This process of conversion of the mangrove ecosystem for the development of urban and agricultural infrastructure has considerably altered the reserve's natural cycles and contributed negatively to a process of ecosystem degradation. Consequently, urban pressure and agricultural mosaics have caused habitat fragmentation, alteration of the mangrove's ecological functions such as protection against strong waves and CO2 capture, and a considerable increase in water pollution of the Portoviejo River due to chemical waste discharged into the water body as a result of agricultural and aquaculture activities, which according to Andree et al. (2021) represent a significant threat to the reserve, and frame the urgent need to implement effective measures to promote sustainable land use and minimize the ecosystem duration of the mangrove.

Since 2006, the localities surrounding the mangrove ecosystem have grown considerably. The San Jacinto community presents a population densification in its central area, however, the high demand for beachfront land has caused a trend of vertical growth, i.e., parallel to the coastline. This growth of the urban footprint occurred towards the south of the community, replacing tropical shrub vegetation and a certain percentage of mangrove cover with residential areas

Also, a trend of consolidation of the urban space was identified between the Santa Teresa and San Jacinto communities. And, in the case of the San Roque and Las Gilses communities, they have densified their population centers. Although the consolidation of urban land is an advantage in territorial planning because it allows for better management and provision of basic services to improve the quality of life of citizens (Akram et al., 2024), for areas with high ecosystemic vulnerability such as the Mangrove Community Reserve of the Portoviejo River Estuary, it represents a complex problem. The growth of the urban limits of these communities is characterized by the increasing needs of their own population. This increase in demands has generated behavioral

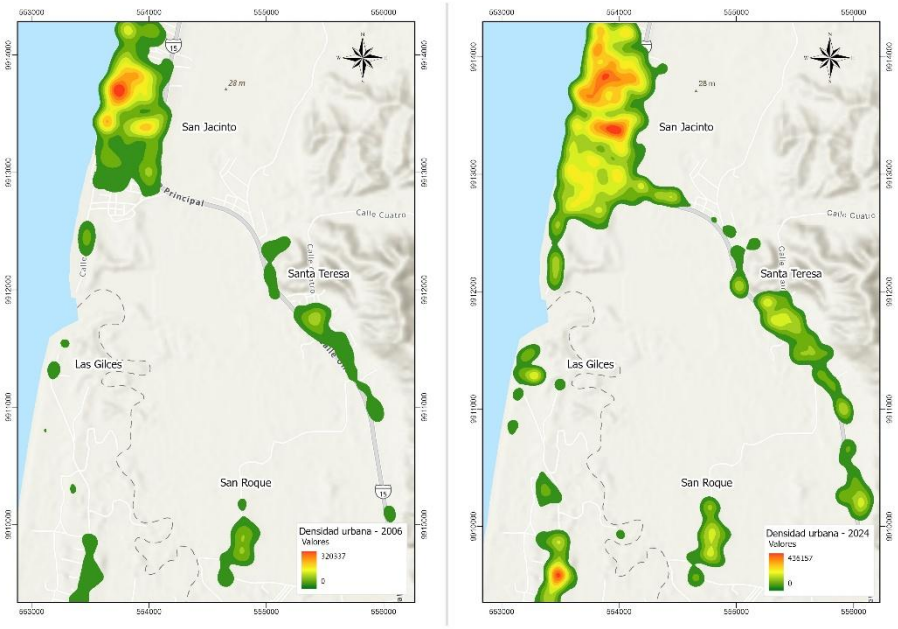

Figure 3. Multi-temporal analysis of urban footprint growth 2006-2024

patterns of constant modification of land use with the purpose of sustaining the local economy and the communities' way of life; however, the environmental implications on the mangrove ecosystem have not been considered. Therefore, urban growth in the communities that make up the Portoviejo River Estuary Biocorridor requires an integrated management approach that considers both economic development and environmental conservation in order to establish a balance between the ecosystemic protection of the mangrove and sustainable land use.

The economy of these communities is based mainly on agricultural activities (35%) and fishing because they are coastal localities (18%). Therefore, it can be concluded that there is a high dependence on resource extraction to sustain the population. Thirteen percent of the population is engaged in aquaculture activities, a rate that has been increasing as a result of the expansion of shrimp ponds. Finally, commerce (12%) and tourism (8%) are considered growth

sectors; however, it is important to note that tourism activities are mainly practiced in the coastal communities of San Jacinto and Las Gilses.

Table 2. Economic activities of the communities

Community	Economic activities	Percentage
San Jacinto	Artisanal salt production	10%
	Aquaculture activities	14%
	Fishing	42%
	Tourism	20%
	Trade	10%
	Other activities	4%
Santa Teresa	Aquaculture activities	18%
	Agriculture	61%
	Trade	8%
	Other activities	13%
San Roque	Agriculture	54%
	Aquaculture activities	12%
	Trade	16%
	Fishing	9%
	Other activities	10%
Las Gilses	Artisanal salt production	22%
	Aquaculture activities	7%
	Agriculture	21%
	Fishing	19%
	Tourism	12%
	Trade	10%
	Other activities	9%

According to Frank et al. (2021), these economic activities are responsible for modifying land use patterns in the reserve's area of influence.

Significant soil modifications and damage to the mangrove ecosystem began in the mid-1920s in San Jacinto and Las Gilses with salt production; the process at that time was entirely artisanal, but they occupied flooded areas with high salt concentration that belonged to the estuarine ecosystem. To improve production, they built canals that allowed seawater to enter the pools, which took about eight months to produce salt. Each pool produced 20 to 25 sacks of salt, including black and grain varieties. By 1996, however, artisanal salt activities were replaced by much more modern methods such as the use of machinery, which increased the rate of modification of the areas.

For these localities, agriculture is considered a historical economic practice; these were practiced around the area of influence of the mangrove ecosystem, which are areas of great productive potential thanks to the influence of the Portoviejo River and the Viejo River that cross the valley of the lower basin of the estuary. These activities have been practiced since 1950 in a permissible manner, however, with population growth and a strong influence of the shrimp boom between the 1980s and 1990s brought with it according to Rodriguez et al. (2016) the massive deforestation of mangrove forest for the construction of shrimp ponds. In order to know the level of affectation of the mangrove ecosystem due to the evolution of anthropic activities settled around the mangrove ecosystem, an approximate recreation of the existing mangrove extension for 1950 was carried out. Based on technical field visits with local stakeholders and the use of reference coordinates, it was possible to estimate a historical coverage of 475.60 ha of mangrove forest. During the last 7 decades, it was determined that 407.55 ha, or 86% of the original mangrove cover, have disappeared due to land use conflicts driven by the development process of the populations surrounding the ecosystem and the impact of their associated socioeconomic activities (Figure 4)

Based on the results of the ortho-mosaic analysis of the study area for 2024, it was identified that the mangrove ecosystem is highly fragmented (Figure 5).

The current mangrove area is approximately 68.06 ha of mangrove, consisting of three main areas with small remnants (Table 3)

There is a significant dispersion of mangrove cover throughout the territory; the areas with the lowest cover correspond to the communities of Santa Teresa and San Roque due to agricultural and aquaculture activities and the extraction of resources from the ecosystem. Approximately 18% of the population of these communities are engaged in river fishing and extraction of species within the mangrove reserve to support their families.

In this sense, the fragmentation of the mangrove ecosystem has significant environmental and socioeconomic implications. On the one hand, the division of the mangrove forest cover into small and isolated remnants has interrupted ecological connectivity causing problems of displacement and reproduction of species that has reduced the biodiversity rate of the reserve and increased environmental risk (Baque and Montilla, 2018).

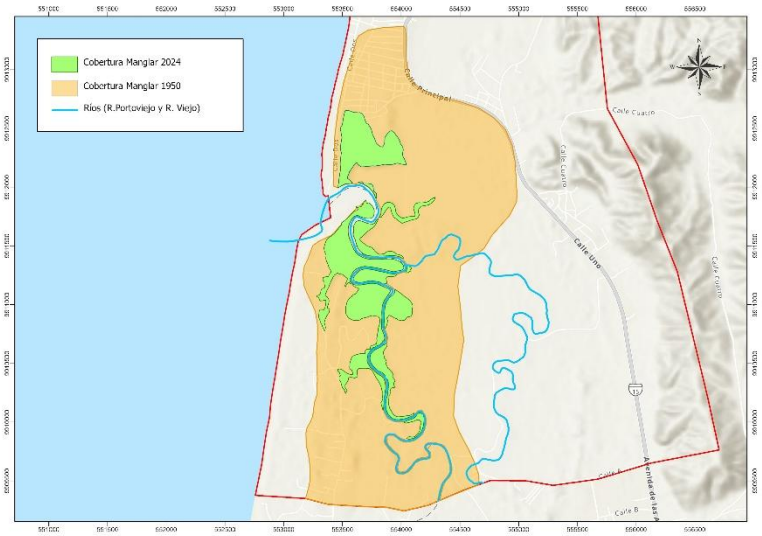

Figure 4. Reduction of mangrove area from 1950 to 2024

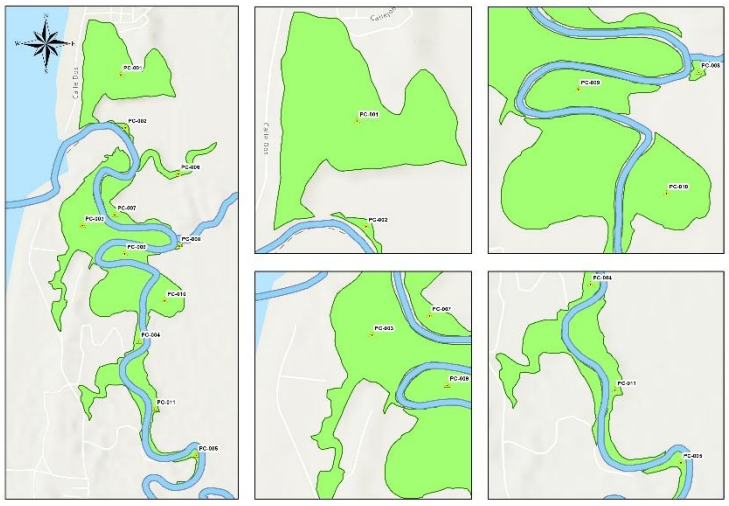

Figure 5. Fragmentation maps of the mangrove ecosystem La Boca

Table 3. Identification of estuarine ecosystem areas and remnants by 2024

Areas	Remaining	Reference coordinates		Surface area (Ha)	Total surface area
		X	Y		
Area 1	A1-R1	553714,24	9912325,29	18,47	18,85
	A1-R2	553741,31	9912007,05	0,38	
Area 2	A2-R1	553484,14	9911418,62	16,60	31,36
	A2-R2	553821,74	9910720,12	13,79	
	A2-R3	554168,88	9910036,43	0,97	
Area 3	A3-R1	554060,93	9911728,71	2,41	17,85
	A3-R2	553677,81	9911483,18	3,68	
	A3-R3	554065,16	9911295,85	0,19	
	A3-R4	553737,08	9911249,28	2,83	
	A3-R5	553977,32	9910965,65	4,49	
	A3-R6	553915,94	9910314,77	4,25	
Result					**68,06**

Likewise, the capacity of the mangrove ecosystem to provide essential ecosystem services such as barrier protection, CO2 capture, and pollutant filtration, among others, has been diminished. However, it is paradoxical how the same anthropogenic activities significantly affect the mangrove ecosystem being this an environmental resource that sustains the economy of local families, therefore, ecosystem fragmentation has generated a considerable reduction of livelihoods and increased economic vulnerability for vulnerable populations of surrounding communities. Consequently, agricultural and aquaculture activities, together with the accelerated growth of the urban frontier, are primarily responsible for mangrove fragmentation (Ahmadia et al., 2023).

Currently, land use in the area of influence of the community mangrove reserve is mostly composed of agricultural areas that represent 43% of the total area. Although agriculture has been one of the most economically important activities for the local communities in the biocorridor, it has generated significant challenges in terms of the conservation of ecosystem resources due to intensive farming methods that do not allow for the environmental sustainability of the environment. Urban areas occupy 15% of the area and have been responsible for the ecosystem pressure on the mangrove reserve due to rapid population growth and irregular settlements around the reserve.

On the other hand, aquaculture and salt production zones represent 12% and 10%, respectively. Although they do not represent a significant proportion, they are considered the historical promoters of mangrove deforestation processes for the construction of shrimp and salt production pools, to the point that mangrove forest cover is currently only 6%. These land-use conflicts around the mangrove

reserve have led to significant transformations of the estuarine ecosystem into urban, agricultural, and shrimp farming areas, affecting the flora and fauna species that depend on it for their survival. The situation of the mangrove ecosystem is alarming because it is enclosed by these activities, which prevents its natural growth or regeneration; in other words, it has no physical space to expand or recover.

3.3 Identification of key patterns driving land-use change

According to the Economic Commission for Latin America and the Caribbean (ECLAC) (2019), land use transformation is considered a multidimensional phenomenon that manifests the social, economic, political and environmental dynamics of a territorial space; therefore, identifying the key patterns that drive these modifications is imperative to understand how the interaction of anthropic activities significantly affect ecosystems and their biodiversity, altering the natural balance. In this sense, the last phase aims to evaluate the activities and determine the level of impact generated in order to contribute in a comprehensive manner to the development of policies and strategies that promote sustainable land use while ensuring the conservation of local resources.

Consequently, it was determined that land use modification patterns around the area of influence of the Portoviejo River Estuary Mangrove Reserve have generated a profound transformation of the natural landscape during the last three decades, driven mainly by the expansion of urban boundaries and their associated economic activities (Table 4).

Since 1952, the mangrove ecosystem has been considerably reduced, 86% of its forest cover has disappeared, that is, about 400 ha due to the effects of the expansion of aquaculture activities (shrimp farming). This activity has led to the fragmentation of the ecosystem and significantly affected the biodiversity index and the essential ecosystem services of the mangrove, generating problems of soil degradation and water pollution of the Portoviejo River. Similarly, agricultural activities increased by 30%, expanding into areas surrounding the Portoviejo River that were previously occupied by mangroves, contributing to deforestation and exacerbating environmental pressure on the reserve. On the other hand, although salt mining activities have been reduced by 20% due to economic and commercial competitiveness with shrimp, they have opted to modernize production methods. However, the use of machinery increases the rate of soil modification through the construction of salt ponds in less time (Caruso and Ríos, 2021).

Table 4. Evaluation matrix of land use patterns with respect to the Mangrove ecosystem

Type of Land Use	Change Observed	Affected Area (ha)	Percentage of Change	Main Cause	Impact Severity (1-5)	Severity Category
Mangrove	Significant reduction	407.55 ha	-86% since 1950	Expansion of shrimp farms, agriculture, and urban frontiers	5	Very High
Agriculture	Expansion over mangrove and natural areas	100 ha	30%	Expansion of the agricultural frontier around communities	4	High
Salt mines	Reduction of traditional activity	50 ha	-20%	Competition with shrimp farms and more modern production methods	3	Moderate
Aquaculture (Shrimp farms)	Massive expansion over mangrove areas	200 ha	+50% since 1980	International demand for shrimp	5	Very High
Tourism	Moderate expansion	80 ha	15%	Growth of tourism infrastructure	3	Moderate
Commercial	Controlled increase	60 ha	10%	Demand for goods and services	2	Low
Urban Zone	Expansion into natural areas and mangrove forests	1182 ha (San Jacinto)	+149% between 2006-2024	Population growth and settlement expansion	4	High

Population growth and the urban footprint of the communities settled around the estuarine ecosystem has also driven land fragmentation and affected local socioeconomic dynamics, which has increased by 149% between 2006 and 2024. Finally, activities such as tourism and commerce are considered moderate patterns of land modification, although they have increased by 15% and are located mainly in areas surrounding the reserve.

4. Conclusions

The results of the multi-temporal analysis of land use and the urban footprint in the area of influence of the Mangrove Community Reserve of the Portoviejo River Estuary are conditioned by social, economic, and political factors. Since 1950, there has been a 86% loss of the original mangrove cover (407.55 ha), mainly attributed to the expansion of agricultural, aquaculture and urban activities.

The disorderly growth of urban boundaries, particularly between 2006 and 2024, has led to a 149% increase in population settlements, i.e., from 740 buildings to 1,922 at present, intensifying land use conflicts and generating direct pressure on the ecosystem. This urban expansion has not been accompanied by effective territorial planning or comprehensive conservation policies, resulting in mangrove fragmentation, loss of biodiversity, and weakening of ecosystem services.

From an economic perspective, the communities of the Biocorridor depend largely on extractive activities such as agriculture (35%), fishing (18%) and aquaculture (13%), which generates a paradoxical relationship of economic sustenance based on the degradation of the very ecosystem that sustains them. In addition, historical impacts such as the expansion of salt ponds and shrimp ponds since 1920 have significantly altered land use patterns.

Geologically, the predominance of alluvial and marine deposits, together with the area's tropical-dry climate, have historically favored mangrove establishment. However, the current fragmented structure of 68.06 ha dispersed in three main nuclei, evidences a severe loss of ecological connectivity, for the processes of reproduction and displacement of species, as well as for functions such as CO_2 capture and coastal protection.

Socially, the high vulnerability of communities such as San Roque and Santa Teresa has encouraged the direct extraction of mangrove resources as a means of subsistence, making it difficult to implement conservation strategies without generating negative impacts on the local economy. In addition, the current institutional frameworks present budgetary and operational limitations that hinder integrated management of the territory. Thus, future research should focus on participatory territorial planning models that integrate simulations of land use change and valuation of ecosystem services.

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Funds

This article is the result of the research project "Land-Use Conflicts: Urban Expansion vs. Mangrove Conservation in the Portoviejo River Estuary", conducted within the framework of the research program "Integrated Management of Agriculture, Agroindustry, and Natural Resources in Planning Zone 4 – Pacific Region for Sustainable Development", under the Environmental Engineering program of the Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López. The project was submitted to the institution's internal research call in 2021.

Competing Interests

The authors declare that they have no conflicts of interest, whether financial or non-financial.

Citation

Zambrano Ureta, L.A., Vera Vera, M.J., Navarrete Schettini, G.A., & Rodríguez Solórzano, A.M. (2025). Land use conflicts. Urban expansion vs. mangrove conservation in the Portoviejo River estuary, Ecuador. *Visions for Sustainability*, 24, 11819, 1-22. http://dx.doi.org/10.13135/2384-8677/11819