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Amphibious Urbanism and Social Inequality: Towards Amphibious Justice in Informal Wetland Settlements

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Abstract

Urban informality in amphibious territories represents a critical yet understudied dimension of contemporary urbanisation in the Global South. This article analyses the interrelations between spatial transformation, social equity, and environmental change in Las Flores, an informal settlement located between the Mallorquín Lagoon and the Magdalena River in Barranquilla, Colombia. Drawing on a mixed-methods approach combining GIS interpretation, participatory mapping, and in-depth interviews, the study examines how processes of informal territorialisation have reshaped both the physical landscape and the social fabric of this amphibious environment. Results indicate that the settlement has expanded progressively over the past two decades, occupying areas of the wetland previously covered by mangroves and natural vegetation. This expansion has been accompanied by environmental degradation, soil infilling, and declining water quality. Residents face persistent infrastructural deficits, limited access to education and healthcare, and increasing social fragmentation between the formal and informal sectors. Yet, the community also exhibits strong organisational capacity, adaptive livelihoods, and a deep sense of place that sustains local identity and resilience. These dynamics exemplify the paradox of amphibious life: coexistence with water as both a resource and a source of vulnerability. Building on these findings, the study develops an urban socio-ecological conceptualisation of Amphibious Justice, a framework for interpreting equity, recognition, and governance in hybrid territories where urbanisation and land–water dynamics intersect. The article proposes a framework of equitable amphibious urbanism that integrates environmental restoration, social inclusion, and participatory governance. The findings suggest that sustainability in such territories cannot be achieved through technocratic restoration or forced resettlement, but through co-produced strategies that recognise local knowledge, tenure security, and ecological stewardship. Ultimately, the case of Las Flores offers insights into how cities in the Global South can pursue just and adaptive coexistence with water amid growing climate and urban pressures.

Keywords: spatial justice; environmental governance; urban sustainability; community participation; ecological restoration; Latin American coastal cities

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Academic Editor: Richard Smardon

Received: 9 July 2026
Revised: 14 August 2026
Accepted: 16 August 2026
Published: 21 August 2026

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1. Introduction

Urban informality constitutes one of the most persistent and complex phenomena shaping contemporary urbanisation, particularly in the Global South. It encompasses a wide range of social, economic, and spatial practices that exist outside the formal frameworks of state regulation, planning, and property rights [1,2]. These practices are not simply manifestations of illegality or the absence of regulation; rather, they reflect the adaptive strategies and creative responses of low-income populations seeking to satisfy their basic needs in contexts of limited institutional capacity and structural inequality [3]. Informality, therefore, represents a dual condition: while it enables survival and the fulfilment of immediate needs, it also contributes to systemic urban inequality, socio-spatial segregation, and environmental degradation [4,5].

According to UN-Habitat [6], urban informality manifests in diverse ways, ranging from informal housing and self-construction to unregulated land tenure, precarious employment, and illegal service provision. Among the most visible and pressing expressions of this phenomenon are informal settlements, defined as unplanned or unregulated urban areas that emerge through unauthorised land occupation or invasion [7,8]. Such settlements are typically characterised by insecure tenure, poor-quality housing materials, lack of access to essential services, absence of public infrastructure, and high exposure to environmental risks [9,10]. As a result, they embody both the consequences of state neglect and the agency of marginalised communities in producing their own spaces of dwelling and livelihood.

Although informality is often associated with developing regions, it remains a global urban condition. In Western Europe, approximately 6% of the urban population lives in precarious or informal housing, while in the United States, New Zealand, and Australia, smaller yet significant proportions inhabit unauthorised dwellings [11]. However, the phenomenon is far more acute in developing countries, where an estimated one billion people reside in informal settlements either within or beyond the boundaries of formal urban areas [12,13]. In the Global South, large proportions of the urban population continue to live in informal settlements, although prevalence varies markedly between regions [11,14,15]. These figures reflect the global scale of a process that challenges the capacity of cities to achieve sustainable and equitable development.

In Latin America, the prevalence of informal settlements is closely linked to the structural dynamics of urban growth, economic inequality, and migration. Rapid population expansion, coupled with insufficient public housing policies and the commodification of land, is connected to extensive areas of informal occupation on the urban peripheries. Such areas often emerge in environmentally sensitive locations (wetlands, floodplains, riverbanks, and coastal zones) where land values are low but exposure to natural hazards is high [16]. Water-related environments may provide livelihood opportunities and access to environmental services that are particularly important for low-income and informal communities [6,17,18]. While these environments provide socio-economic benefits and ecological services, informal occupation constitutes one of several interacting processes affecting wetland systems. Alongside informal settlement expansion, broader drivers including port development, coastal engineering, watershed sedimentation, municipal waste management, and urban growth have also contributed to hydrological alteration and ecological degradation [19–22]. Informal urbanisation therefore represents an important component of a broader socio-ecological transformation rather than its sole driver.

Globally, the expansion of urban areas has been associated with progressive reduction of natural wetlands. Between 1990 and 2015, wetland coverage decreased by approximately 1.15% in Asia, 1% in Europe, and 0.5% in North America [23]. In the Latin American context, and particularly in Colombia, this loss has been amplified by informal urban growth, weak environmental regulation, and the absence of integrated territorial planning.

Colombia, described as an amphibious country because roughly 26% of its continental area is composed of wetlands, faces increasing tension between urbanisation and ecological conservation [24–26]. The Caribbean region, which contains 82% of the nation's wetlands [27,28], has become a critical setting for studying these conflicts, as informal settlements proliferate around wetland ecosystems and along riverine corridors.

This article focuses on one such case: Las Flores, a neighbourhood located in the northern area of Barranquilla, Colombia, between the Mallorquín Lagoon and the Magdalena River. The area exemplifies an amphibious territory, an environment shaped by the interplay between aquatic and terrestrial systems and by the human communities that have historically inhabited them. Over time, the settlement expanded through processes of self-construction and land reclamation, gradually transforming portions of the wetland into residential land. The informal occupation of the lagoon's edges, together with inadequate waste management, sedimentation, and other interacting environmental processes, has been associated with ecological degradation and increased vulnerability of local residents to flooding and pollution.

The phenomenon of territorialisation provides an analytical lens to interpret these processes. Territorialisation refers to the socio-spatial practices through which individuals and communities appropriate, organise, and transform space to fulfil material and symbolic needs [29]. It involves both the physical occupation of land and the construction of social and cultural identities tied to place [30]. In the context of informal urbanisation, territorialisation expresses the dialectical relationship between survival and exclusion: while communities produce their own forms of urbanity through self-built housing, local organisation, and informal economies, they simultaneously experience marginalisation, lack of recognition, and risk of eviction. This duality is particularly pronounced in amphibious territories, where the human–environment relationship is mediated by water, climate, and ecological dynamics.

The concept of amphibious territories, first introduced by the Colombian sociologist Orlando Fals Borda [31], describes hybrid socio-ecological landscapes that blur the boundaries between land and water. These environments, known locally as playones, are subject to periodic flooding and seasonal climatic variation, shaping the livelihoods, architectures, and spatial imaginaries of their inhabitants [32]. In such settings, time and climate condition the ways of dwelling: communities adapt their housing, productive activities, and mobility patterns according to fluctuations in water levels [33]. Amphibious territories, therefore, represent spaces of coexistence and negotiation between human and natural systems where resilience, culture, and ecology intertwine [34,35]. However, urban pressures, environmental degradation, and climate change have disrupted these historically symbiotic relations, generating new forms of vulnerability and dispossession [36].

In Colombia, the territorialisation of amphibious landscapes has deep historical roots. Since the sixteenth century, rivers and wetlands have structured the settlement patterns and cultural identities of coastal and fluvial communities [37]. During the twentieth century, internal migrations from the Pacific and interior regions towards the Caribbean coast led to the formation of new amphibious settlements, reflecting both economic adaptation and cultural transformation [38,39]. The contemporary challenge lies in reconciling these historical forms of inhabiting water-related environments with the demands of urban development, environmental protection, and social inclusion. The case of Las Flores exemplifies how informal territorialisation in amphibious zones generates overlapping spatial and ecological conflicts: land reclamation, waste accumulation, and deforestation of mangroves have not only altered the hydrological system of the Mallorquín Lagoon but also fragmented the social fabric between formal and informal residents.

Accordingly, this study addresses the following research questions: (1) How have processes of informal territorialisation reshaped the spatial and environmental configuration of the Las Flores amphibious territory? (2) How are these transformations associated with social equity in terms of access to services, livelihoods, participation, and territorial recognition? (3) What conceptual insights does this case provide for developing an exploratory Amphibious Justice framework for informal amphibious settlements?

The present study seeks to analyse the multidimensional interrelations between spatial transformation and social equity in an informal settlement located within an amphibious territory. It explores how processes of informal urban growth and territorialisation in Las Flores have contributed to the transformation of both the physical landscape and the social dynamics of the community. Two analytical dimensions structure the research: (i) the spatial-environmental transformation of the territory, focusing on land-use change, environmental degradation, and settlement expansion; and (ii) for the purposes of this study, social equity is operationalised as differences in access to essential urban services, infrastructure, education, healthcare, livelihood opportunities, participation in decision-making, and social recognition between the formal and informal sectors of the settlement. By examining these dimensions concurrently, the research situates informal urbanisation not only as a spatial phenomenon but also as a question of justice, governance, and sustainability.

The study adopts an integrated methodological framework combining Geographic Information Systems (GIS), aerial imagery obtained from drones, social mapping, and in-depth interviews with community leaders and residents. This mixed approach enables the triangulation of environmental data with social perceptions and local knowledge, generating a holistic understanding of the transformations occurring in the amphibious territory. The voices of the inhabitants and their interpretations of inequality, environmental change, and belonging are central to this analysis, as they indicate the lived experience of informality beyond statistical indicators or planning discourses. Engaging with these perspectives aligns with the principles of participatory and inclusive urban research, which emphasise the co-production of knowledge between researchers and communities [40,41].

From a theoretical standpoint, this article contributes to contemporary debates on urban informality, territorialisation, and socio-ecological resilience. It argues that the study of informal settlements in amphibious territories requires a conceptual synthesis that bridges urban and environmental disciplines. Informal urbanisation in such contexts is not merely a manifestation of socio-economic inequality but also a process of ecological transformation that redefines the boundaries between city and nature. Consequently, the pursuit of sustainable development in amphibious regions must integrate spatial planning, environmental governance, and social justice. Following Corburn [42] and Trudeau [43], equity should be viewed not only as a distributive goal but also as a structural condition for sustainability: equitable access to education, healthcare, and dignified housing strengthens community resilience and fosters the environmental stewardship necessary to sustain amphibious ecosystems.

In alignment with the United Nations' 2030 Agenda for Sustainable Development [44], this study addresses Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable." It contends that promoting social equity in informal amphibious settlements entails recognising their inhabitants as legitimate urban actors capable of contributing to sustainable territorial management. By situating the case of Las Flores within broader regional and theoretical frameworks, the research aims to provide insights into how informality, environmental vulnerability, and governance intersect in the production of urban space. Ultimately, understanding these dynamics is crucial for designing integrated public policies that enhance social inclusion, protect ecological systems, and strengthen resilience in amphibious territories across Latin America and beyond. Building upon these

debates, this article develops an exploratory urban socio-ecological conceptualisation of Amphibious Justice to interpret the dynamics observed in Las Flores. The term Amphibious Justice was previously employed by Chao [45] within a multispecies-justice perspective, where amphibian life provides a basis for conceptualising justice as transversal across species, elements, and ecosystems. The present study does not therefore claim to coin the term. Instead, it develops it in a distinct urban environmental-justice context, focusing on the distribution of environmental risks and urban resources, the recognition of amphibious livelihoods and territorial identities, participation in decisions affecting wetland territories, and governance under changing land–water conditions. Rather than proposing a fully validated theory, this exploratory framework is inductively informed by the empirical findings of the Las Flores case and situated in relation to existing debates on spatial justice, environmental justice, and socio-ecological governance.

2. Materials and Methods

2.1. Study Area

The research was conducted in the city of Barranquilla, the capital of the Atlántico Department, located on the northern Caribbean coast of Colombia (10°53′ N, 74°47′ W). The city covers a territorial area of approximately 154 km^2 and sits at an altitude of 68 m a.s.l. [46]. Barranquilla is a major port and industrial hub that has experienced rapid demographic and spatial growth during the twentieth and twenty-first centuries, largely driven by migration and urban expansion. Its geographical location at the confluence of the Magdalena River and the Caribbean Sea has made it a paradigmatic case of an amphibious urban territory, where the boundaries between land and water are fluid and highly dynamic.

The specific case study selected for this research is the Las Flores neighbourhood, situated in the northern sector of the city. Las Flores is bounded by the Mallorquín Lagoon to the west and the Magdalena River to the east (Figure 1). These two water bodies define its biophysical and socio-economic identity, making it an archetypal amphibious landscape. Historically, the neighbourhood developed as an informal fishing settlement during the early twentieth century. Archival records suggest that by 1925, during the construction of the Tajamares de Bocas de Ceniza, a large-scale hydraulic infrastructure project, temporary workers and migrant families settled in makeshift dwellings near the river delta [47]. The completion of the jetties in 1936 altered the coastal morphology, leading to the formation of the Mallorquín Lagoon, which has since become both a vital ecosystem and a site of urban pressure (Figure 2).

The early inhabitants of Las Flores engaged primarily in fishing, hunting, and small-scale agriculture, developing a symbiotic relationship with the lagoon and the river. Over time, urban expansion and changing land-use pressures increasingly affected the wider Barranquilla hinterland and the relationship between urban development and surrounding environmental systems [48]. The informal construction of dwellings on reclaimed wetland areas represents one of several interacting pressures affecting the lagoon. Other long-term influences include port-related infrastructure, urban expansion, sediment dynamics within the Magdalena River system, and changing patterns of environmental management. The Mallorquín Lagoon, once a thriving wetland, now exhibits diminished depth, ranging from 0.6 to 1.5 m, and fluctuating salinity levels between 8000 and 26,000 μS cm^{-1} depending on the hydrological season [49].

Today, the lagoon is recognised as a Protected Natural Area under the Ramsar Convention, highlighting its ecological significance. Nonetheless, it faces critical challenges related to the compatibility of environmental conservation with socio-economic development [50–52]. The informal settlement at the western edge of Las Flores exemplifies this

conflict: while it provides housing for low-income families excluded from formal urban systems, its location within a sensitive wetland ecosystem has accelerated environmental degradation. The juxtaposition of formal and informal sectors within the same neighbourhood also indicates stark socio-spatial inequalities: differences in infrastructure, service provision, and living standards that reflect broader urban disparities in Barranquilla.



Figure 1. Study Area localisation: Las Flores neighbourhood, Barranquilla (Colombia).



Figure 2. Aerial perspective of Las Flores neighbourhood: between the Magdalena River and the Mallorquín Lagoon.

The case of Las Flores was selected for three main reasons: (i) its representativeness as an amphibious urban territory combining environmental vulnerability with informal urbanisation; (ii) its relevance to ongoing urban regeneration and ecological restoration initiatives in Barranquilla, including the proposed Ecoparque Ciénaga de Mallorquín project; and (iii) its potential to contribute to broader theoretical debates on the interface

between urban informality, environmental governance, and social equity in coastal Latin American cities.

This research examines how informal urban growth interacts with natural systems, producing a spatial transformation that redefines the relationship between urban space, social inclusion, and ecological sustainability.

2.2. Methodology

The study adopts a descriptive and analytical mixed-methods design aimed at characterising the multidimensional interactions between spatial transformation and social equity in the Las Flores settlement. This approach integrates quantitative spatial analysis with qualitative inquiry, enabling a comprehensive understanding of both the physical and social dynamics shaping the amphibious territory. The methodological framework consists of two interrelated components: (i) spatial-environmental transformation, and (ii) social equity. Each component includes specific indicators, data collection instruments, and analytical procedures designed to capture the complexity of informal urbanisation in amphibious contexts.

(a) Research design and data sources rely on a combination of remote sensing, Geographic Information Systems (GIS), aerial photography, social mapping, and in-depth interviews. This triangulation of data sources enhances the validity and reliability of the findings [53].

Spatial analysis was based on a combination of historical imagery from Google Earth Pro, official cartography provided by the Instituto Geográfico Agustín Codazzi (IGAC), and high-resolution aerial photographs acquired using an unmanned aerial vehicle (DJI Phantom 4 Pro (SZ DJI Technology Co., Ltd., Shenzhen, China) equipped with a 20-megapixel CMOS sensor and a 1-inch camera). Historical imagery corresponding to the years 2000, 2007, 2014, and 2021 was used to reconstruct the spatial evolution of the Las Flores settlement and the Mallorquín Lagoon over the study period, while drone imagery provided detailed local-scale validation of current land-use patterns. Image interpretation and GIS processing were carried out between June and August 2022. The use of multiple complementary spatial sources allowed the temporal reconstruction of landscape change while improving the consistency of land-cover interpretation throughout the study period. Table 1 summarises the principal spatial datasets used and their role within the analytical framework.

Table 1. Spatial datasets used for long-term landscape interpretation.

Dataset	Years	Purpose	Interpretation Approach
Google Earth Pro (version 7.3.6) historical imagery	2000, 2007, 2014, 2021	Long-term landscape reconstruction	Manual photointerpretation
IGAC cartography	Current official cartography	Spatial reference and validation	Visual comparison
DJI Phantom 4 Pro imagery	2022	Current field validation	Visual interpretation

All spatial analyses were performed in ArcGIS Pro (version 3.1) and Google Earth Pro using the official Colombian coordinate reference system MAGNA-SIRGAS/Colombia Bogotá Zone, ensuring compatibility with the official IGAC cartography. Settlement boundaries, wetland limits, and land-cover changes were delineated through manual photointerpretation rather than automated image classification. This approach was considered the most appropriate because the study focuses on a small-scale, highly heterogeneous amphibious landscape, where the boundaries between wetlands, reclaimed land, and informal settlements are irregular and difficult to classify consistently using automated

image-classification techniques. Wetland boundaries were delineated through consistent visual interpretation of the interface between permanent water, wetland vegetation, reclaimed land, and built-up areas. Rather than attempting to map short-term hydrological fluctuations, the interpretation focused on identifying broad and persistent landscape transformations that were consistently recognisable across the historical imagery. The interpretation was cross-checked against official cartographic information and subsequently contrasted with the results obtained during the participatory mapping workshops, strengthening the internal consistency of the spatial analysis. Consequently, the mapped boundaries and the derived area estimates should be interpreted as approximate analytical reconstructions of long-term spatial change rather than as exact cartographic representations of permanent environmental conditions.

Because the historical imagery was acquired in different years and under varying environmental conditions, the analysis focused on identifying long-term landscape trends rather than seasonal hydrological fluctuations.

Spatial processing and analysis were conducted using ArcGIS Pro (version 3.1) and Google Earth Pro, through which a series of maps were generated to illustrate the chronological expansion of the settlement (2000–2007, 2007–2014, 2014–2021) and the corresponding environmental transformations. Historical imagery was obtained from Google Earth Pro under Google's standard terms of use, while official cartographic information was provided by IGAC. Key spatial indicators included: (i) extent of informal settlement area; (ii) long-term changes in wetland extent; (iii) changes in land cover and vegetation; and (iv) proximity to risk zones (flood-prone areas and waste accumulation sites). These indicators enabled the characterisation of long-term physical transformations within the amphibious landscape and provided a basis for interpreting associated socio-environmental changes. To support the visual interpretation of proximity to selected public facilities, Euclidean buffer analysis was performed in ArcGIS Pro (version 3.1). Concentric distance buffers were generated around schools, health facilities, and public spaces to provide an approximate representation of spatial proximity. The selected buffer distances were intended as descriptive visual aids rather than as measures of actual travel distance along the street network. Consequently, these maps illustrate relative spatial proximity and should not be interpreted as network-based service areas or travel-time analyses. The overall fieldwork design, including the different data collection activities undertaken during the study, is summarised in Table 2.

Table 2. Summary of fieldwork activities conducted during the study.

Activity	Period	Participants	Purpose
Participatory mapping workshops (n = 3)	April–October 2022	45 participants (28 women, 17 men) from both formal and informal sectors	Identification of environmental risks, territorial boundaries, community facilities and socio-spatial inequalities
Semi-structured interviews	April–October 2022	50 participants (15 community leaders, 20 residents from the informal sector, and 15 residents from the formal sector)	Exploration of territorial identity, environmental change, livelihoods, access to services and perceptions of inequality

The interview and workshop samples were partially overlapping. Several community leaders and residents participated in both the semi-structured interviews and the participatory mapping workshops, whereas others contributed to only one component of the study.

Because each activity pursued different methodological objectives, participant numbers should not be interpreted as representing independent samples.

(b) To complement the spatial analysis, participatory social mapping was conducted with community leaders and residents from both the formal and informal sectors of Las Flores (Table 3). This tool, following Jackson and Bryson [40] and Morren [41], facilitates the identification of local perceptions of territorial boundaries, environmental risks, and social relationships within the community. Three participatory mapping workshops were conducted between April and October 2022, involving a total of 45 participants (28 women and 17 men). Participants included 12 young people (15–25 years), 23 adults (26–50 years), and 10 older adults (over 50 years), with representation from both the informal (25 participants) and formal (20 participants) sectors of the neighbourhood. Workshops were facilitated by members of the research team using printed base maps derived from official IGAC cartography and historical Google Earth Pro imagery. Participants collaboratively identified areas of environmental vulnerability, recurrent flooding, waste accumulation, community facilities (such as schools, recreational spaces, and health centres), territorial boundaries, and other locations considered socially or environmentally significant. The annotated maps were subsequently digitised in ArcGIS Pro and compared with the GIS analysis, field observations, and interview findings as part of the triangulation process. The mapping process therefore served both as a data-gathering technique and as a participatory exercise for community reflection.

Table 3. Participatory mapping procedure.

Component	Description
Workshops	Three participatory workshops (April–October 2022)
Participants	45
Gender	28 women; 17 men
Age groups	15–25 years (12); 26–50 years (23); >50 years (10)
Sector representation	Informal sector (25); formal sector (20)
Base maps	Official IGAC cartography and historical Google Earth Pro imagery
Main mapping topics	Flood-prone areas, waste accumulation, environmental degradation, community facilities, territorial boundaries, socio-spatial inequalities
Digitisation	ArcGIS Pro
Validation	Triangulated with GIS analysis, field observations and semi-structured interviews

Semi-structured in-depth interviews were conducted with 50 participants selected through purposive sampling. The sample comprised 15 community leaders (representing both the formal and informal sectors of Las Flores), 20 residents from the informal sector, and 15 residents from the formal sector. Participants were selected on the basis of their knowledge of the neighbourhood, length of residence, and willingness to participate. This composition enabled the inclusion of diverse perspectives on territorial change, environmental conditions, and everyday experiences across both sectors of the settlement. Community leaders were chosen based on their longstanding involvement in neighbourhood development initiatives, while residents from both the informal and formal sectors were selected to capture diverse perspectives on everyday challenges, urban transformations, environmental risks, and local perceptions of socio-spatial inequalities. This approach allowed for a balanced representation of institutional actors, community leaders, and residents from both sectors of the settlement. To complement the perspectives

of community leaders, younger residents and students were intentionally included in the sample to capture emerging urban imaginaries, perceptions of neighbourhood change, and views on recent institutional initiatives aimed at transforming the area's longstanding social stigma.

The interview guide consisted of 30 open-ended questions covering five thematic areas: (1) territorial identity and amphibious environment; (2) access to education and healthcare; (3) housing conditions and public services; (4) livelihood strategies and informal economy; and (5) perceptions of inequality and risk. Each interview lasted approximately 60 min and was audio-recorded after participants had signed an informed consent form authorising the recording and the scientific use of the anonymised information collected during the study. Interviewing continued until thematic saturation was achieved, that is, when additional interviews no longer generated substantively new themes or analytical categories but largely confirmed patterns already identified across participant groups. This criterion, widely recognised in qualitative research, ensured that the sample size was sufficient to capture the diversity of experiences and perceptions within the study area while maintaining analytical depth.

The working methodology also encompassed three participatory workshops in which community members discussed the principal environmental challenges affecting the neighbourhood, the emergence of new territorialities, and the socio-environmental implications of informal settlement expansion. These workshops also addressed residents' experiences of forced evictions, institutional interventions, and the socio-cultural and environmental risks faced by households occupying areas adjacent to the wetland.

The rapid community surveys were conceived as a complementary descriptive field instrument rather than as a formal statistically representative survey. They were conducted during the same fieldwork period as the interviews and participatory mapping workshops to collect contextual information on household composition, access to basic services, livelihoods, education, and perceived socio-economic conditions. Accordingly, they were used to support the interpretation of the qualitative findings and spatial analyses rather than to generate population-level estimates or inferential statistical results.

Several contextual demographic and socio-economic indicators presented in the Results (e.g., estimated population, number of households, settlement distribution, and selected descriptive characteristics) were not derived directly from the interview sample. Instead, they were compiled from multiple complementary sources, including community-based estimates provided by local leaders, field observations, rapid community surveys, cartographic interpretation, and available municipal information. These indicators are presented exclusively to contextualise the study area and should not be interpreted as statistically representative estimates derived from the qualitative sample. Rather, they provide descriptive background information that complements the qualitative evidence obtained through interviews and participatory mapping. Comparisons between the formal and informal sectors presented throughout the Results should therefore be interpreted as contextual contrasts supported by multiple qualitative and descriptive sources rather than as statistical comparisons between two equivalent survey samples. Throughout the manuscript, interview findings are explicitly distinguished from contextual information obtained through rapid community surveys, field observations, community-based estimates, cartographic interpretation, and municipal sources.

(c) The data analysis involved an iterative process combining quantitative spatial assessment with qualitative content analysis. The GIS outputs (maps, land-cover statistics, and spatial indicators) were cross-referenced with qualitative findings from interviews and social maps. This process of data triangulation [54] allowed the identification of con-

vergences and discrepancies between residents' perceptions and the objectively observed spatial transformations.

The analysis of interview transcripts followed a thematic coding approach using NVivo 14 software. Coding followed a three-stage inductive procedure. First, open coding was used to identify recurring concepts emerging directly from the interview transcripts. Second, related codes were grouped through axial coding into broader thematic categories. Finally, selective coding integrated these categories into the main analytical dimensions guiding the interpretation of the findings. Initial coding was undertaken by the first author and subsequently reviewed by the corresponding author. The review focused on the consistency of code allocation, category development, and interpretation rather than on calculating formal inter-coder agreement, as the objective was to strengthen analytical consistency within an interpretive qualitative framework. Any differences in code interpretation or thematic allocation were discussed until consensus was reached. Thematic saturation was considered to have been achieved when successive interviews no longer generated substantially new codes or analytical categories, but instead reinforced patterns already identified in previous interviews. Particular attention was also paid to identifying divergent or minority perspectives that did not fully correspond with the dominant narratives. These cases were retained during interpretation to avoid overgeneralisation and to better reflect the diversity of experiences within the community. Participant identifiers reported throughout the Results correspond to anonymous codes assigned solely for reporting purposes and are not linked to any personally identifiable information.

The final analytical framework emerged through iterative comparison between the qualitative coding results and the spatial analysis (Table 4). Rather than being predefined, the principal analytical dimensions evolved progressively from the integration of interview themes, participatory mapping, and GIS interpretation. Illustrative examples of the analytical progression from interview extracts to representative codes, themes, and analytical dimensions are provided in Supplementary Table S1. Throughout the analysis, qualitative findings were continuously compared with the results obtained from GIS analysis, participatory mapping, and field observations. This iterative triangulation helped distinguish participants' accounts from researchers' interpretations and strengthened the internal consistency of the analytical framework. The resulting interpretation linked observed patterns of urban expansion with social narratives of adaptation, exclusion, and territorial identity. These analytical dimensions subsequently structured the presentation of the Results and informed the inductive development of the exploratory Amphibious Justice framework discussed later in the manuscript. This integration aligns with recent calls in urban studies for mixed analytical frameworks capable of bridging socio-spatial and ecological dimensions [55,56]. The resulting framework should therefore be understood as an exploratory conceptual synthesis, inductively derived from the empirical evidence of this single case and interpreted in dialogue with the relevant literature, rather than as a universally validated model. Supplementary Table S1 provides representative examples illustrating this analytical progression and the traceability of the coding process.

All interviews were conducted in Spanish. Quotations reproduced in this article were translated into English by the authors and subsequently reviewed by bilingual members of the research team to ensure conceptual consistency with the original meaning. To preserve participants' anonymity, each quotation is identified only by participant type and sector (e.g., Community Leader—Informal Sector, Resident—Formal Sector), without reporting personal identifiers or interview dates.

Table 4. Relationship between representative interview codes, themes, and analytical dimensions.

Representative Codes	Theme	Analytical Dimension	Illustrative Quotation
Flooding, stagnant water, blocked drainage	Hydrological vulnerability	Spatial transformation	"When it rains, the streets become rivers and the water remains for days." (R-IS-11)
Wetland filling, land reclamation, settlement growth	Informal urban expansion	Spatial transformation	"People kept filling the wetland because there was nowhere else to build." (CL-IS-02)
Waste dumping, polluted water, mangrove degradation	Environmental degradation	Spatial transformation	"The lagoon is no longer clean; rubbish and wastewater end up there." (R-IS-09)
Poor roads, lack of drainage, inadequate sanitation	Infrastructure deficits	Social equity	"During the rainy season, we can barely leave our homes." (R-IS-14)
Fishing, recycling, street vending	Informal livelihoods	Social equity	"We survive by fishing, recycling, or selling whatever we can." (R-IS-05)
School access, health services, transport difficulties	Access to public services	Social equity	"The school and the health centre are too far for many families." (R-IS-08)
Community leaders, neighbourhood meetings, collective action	Community organisation	Territorialisation	"When nobody helps us, the community organises itself." (CL-IS-04)
Belonging, identity, attachment to lagoon	Amphibious identity	Territorialisation	"The lagoon is part of who we are." (R-IS-12)
Exclusion, invisibility, unequal treatment	Spatial injustice	Territorialisation	"The municipality only remembers us during elections." (R-IS-03)
Ecoparque, participation, recognition, governance	Amphibious Justice	Policy implications	"They talk about conservation, but they never ask our opinion." (CL-FS-02)

Figures presented in the Results derive from two complementary sources. Together with Figures 1 and 2, they were prepared by the research team using GIS analysis, aerial imagery, field observations, and proximity modelling. Participatory mapping did not directly generate these figures but informed their interpretation by identifying locally perceived areas of environmental risk, community assets, territorial boundaries, and socio-spatial inequalities. Figure 3 summarises the analytical dimensions emerging from the integration of participatory mapping, interviews, and spatial analysis.

(d) Ethical principles were observed throughout the research process. Participation in interviews and participatory mapping workshops was entirely voluntary, and all participants signed an informed consent form prior to taking part in the study. The consent form explained the objectives of the research, the voluntary nature of participation, the recording of interviews, the scientific use of anonymised data, including the possible use of anonymised quotations in scientific publications, for research purposes. Although audio-recorded interviews necessarily involved the temporary collection of identifiable personal information during fieldwork, these data were used solely for research purposes and were removed during transcription and anonymisation. All interview transcripts analysed in this study were fully anonymised prior to coding, and quotations presented in this article cannot be linked to individual participants. All interview transcripts were anonymised prior to analysis, and quotations presented in this article cannot be linked to individual participants. The study involved non-interventional social research addressing territorial dynamics, public-space use, environmental conditions, and community perceptions. It did

not collect sensitive personal information, nor did it address intimate, clinical, or otherwise vulnerable aspects of participants' private lives. Accordingly, the study was conducted following the institutional procedures applicable to this type of non-interventional social research, for which formal ethics committee review was not required.

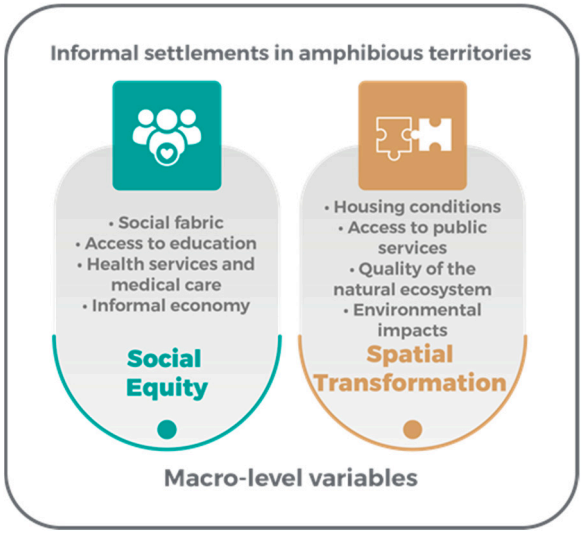


Figure 3. Social equity and spatial transformation macro-variables. Source: Authors' elaboration based on thematic coding of interviews, participatory mapping, and GIS analysis.

(e) This methodological design provides a multidimensional understanding of how informal urbanisation transforms amphibious territories. The integration of geospatial techniques with participatory and qualitative tools allows for the simultaneous observation of macro-level environmental processes and micro-level social dynamics (Figure 3). GIS analysis supports the interpretation of long-term spatial transformations, while interviews and mapping indicate the social meanings, perceptions, and inequities embedded in those changes. Together, these approaches contribute to a holistic comprehension of territorialisation processes in informal amphibious settlements, supporting both scientific analysis and the formulation of evidence-based policy recommendations.

3. Results and Discussion

3.1. Informal Urban Expansion and Spatial Transformation of the Amphibious Territory

The informal expansion of the Las Flores settlement between 2000 and 2021 has been associated with substantial changes in the spatial and ecological configuration of the Mallorquín amphibious territory. Spatial analysis using aerial imagery and Geographic Information Systems (GIS) indicated that the settlement expanded from approximately 7.7 hectares in 2000 to 18.3 hectares in 2021 (Figures 4 and 5). This growth pattern suggests the progressive occupation of the wetland margin and the continuous process of land reclamation through informal filling. These spatial changes coincide with an observed reduction in the interpreted wetland extent and with changes in hydrological connectivity within the Mallorquín Lagoon.

The temporal sequence of settlement expansion indicates three major phases: (i) Initial consolidation (2000–2007): characterised by spontaneous occupation and self-construction near the lagoon's northern fringe; (ii) Intermediate densification (2007–2014): marked by accelerated infilling of the wetland, the emergence of compact housing clusters, and the first signs of environmental stress; and (iii) Recent extension (2014–2021): involving the encroachment of additional 4.5 hectares of reclaimed wetland, accompanied by pronounced sedimentation and degradation of the aquatic ecosystem.



Figure 4. Growth of informal settlements in the Las Flores neighbourhood between 2000 and 2007. Source: Authors' elaboration based on historical Google Earth Pro imagery, official IGAC cartography, and manual photointerpretation. The figure represents an interpreted reconstruction of long-term spatial change and should not be interpreted as a precise measurement of permanent environmental change.

These transformations have taken place in the absence of effective spatial planning or environmental regulation, underscoring how informal urbanisation operates as both a territorialisation process and one component of broader socio-ecological change. Similar trajectories have been documented in other coastal cities of the Global South, where informal settlements expand onto low-lying or flood-prone lands due to economic necessity and lack of affordable formal housing [57–59].

Spatial interpretation of the historical imagery indicates an estimated reduction of approximately 237 hectares in the observed wetland extent of the Mallorquín Lagoon between 2000 and 2021 (Figure 6). This figure represents an interpreted long-term spatial trend derived from manual photointerpretation and should not be interpreted as a direct measure of permanent hydrological or ecological change, as seasonal environmental variability may also influence wetland extent. The reduction should not be interpreted as being exclusively attributable to the expansion of the Las Flores settlement. Rather, it reflects the combined effects of multiple interacting processes occurring across the lagoon during the study period, including sedimentation, informal land reclamation, port and urban development, coastal engineering works, and other interacting anthropogenic and natural dynamics affecting the broader wetland system. The period 2000–2007 accounted for the largest estimated reduction (approximately 164 ha), followed by an additional estimation of approximately 46 ha lost between 2007 and 2014, and 27 ha between 2014 and 2021. Although seasonal fluctuations in water extent are inherent to amphibious environments, the comparison

of historical imagery suggests a persistent long-term trend towards increased terrestrial occupation and wetland transformation. These long-term landscape changes coincide with the current shallow morphology of the lagoon (average depth now 0.6–1.5 m) and the fragmentation of aquatic habitats. These observed spatial patterns are consistent with what Han et al. [20] describe as spatiotemporal compression in informal urbanisation, whereby rapid land-use change may disrupt ecological equilibria faster than environmental recovery can occur.

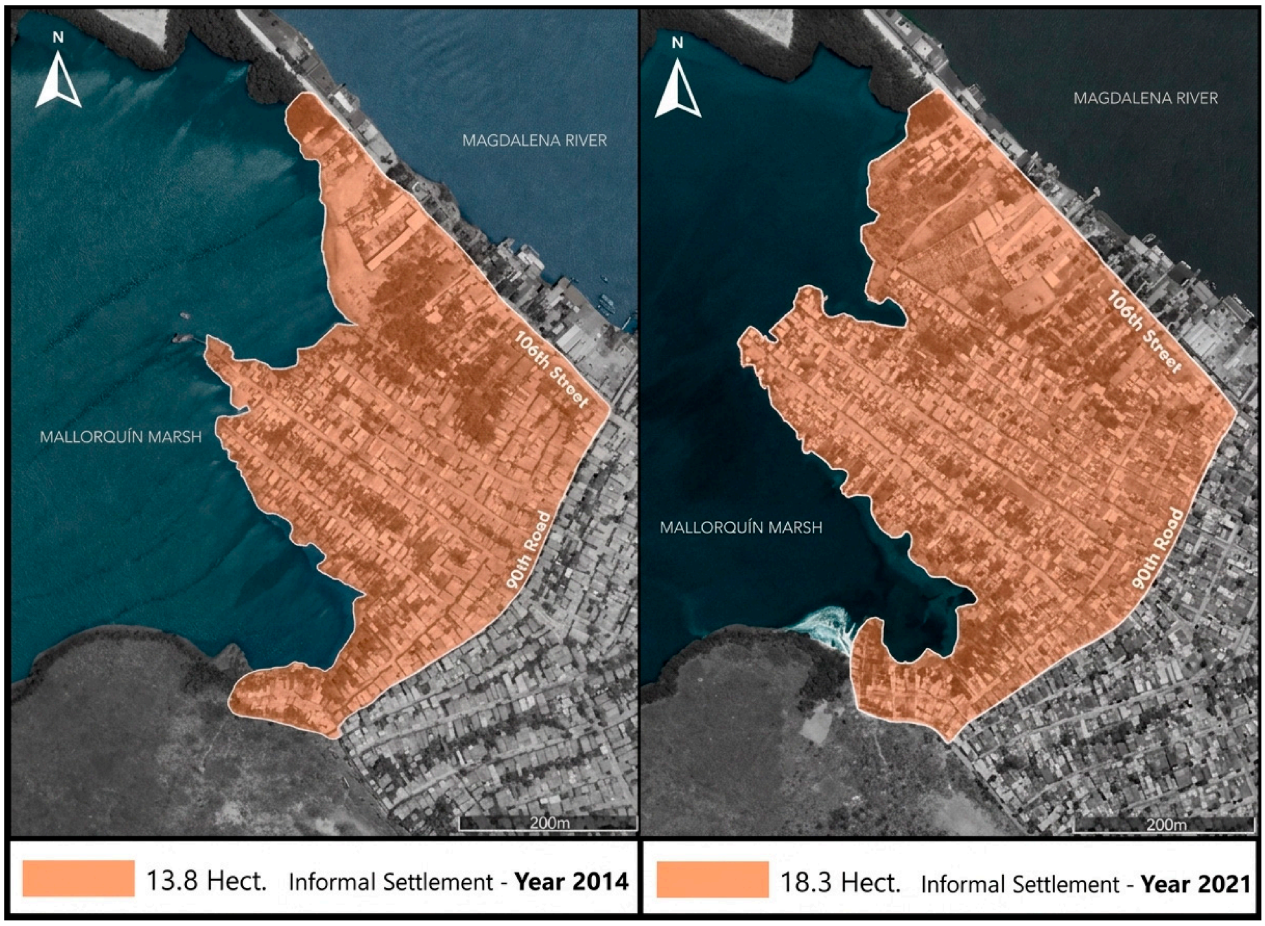


Figure 5. Growth of informal settlements in the Las Flores neighbourhood between 2014 and 2021. Source: Authors' elaboration based on historical Google Earth Pro imagery, official IGAC cartography, and manual photointerpretation. The figure represents an interpreted reconstruction of long-term spatial change and should not be interpreted as a precise measurement of permanent environmental change.

The reduction in wetland surface observed in the Mallorquín Lagoon is symptomatic of broader patterns of urban encroachment into ecologically sensitive zones observed across Latin America. In cities such as Mexico City, Lima, and Guayaquil, informal settlements on wetland margins have reduced flood absorption capacity and increased urban vulnerability [24,57]. In the case of Barranquilla, these processes are compounded by weak enforcement of environmental regulation and limited institutional capacity to coordinate land-use planning with wetland conservation [60].

The following tables (Tables 5 and 6) synthesise the physical-environmental transformations observed in Las Flores, linking quantitative spatial indicators to qualitative observations from fieldwork. The cumulative result of these processes is a progressive erosion of amphibious resilience: the capacity of the ecosystem and the community to coexist with water and adapt to climatic variability [34].

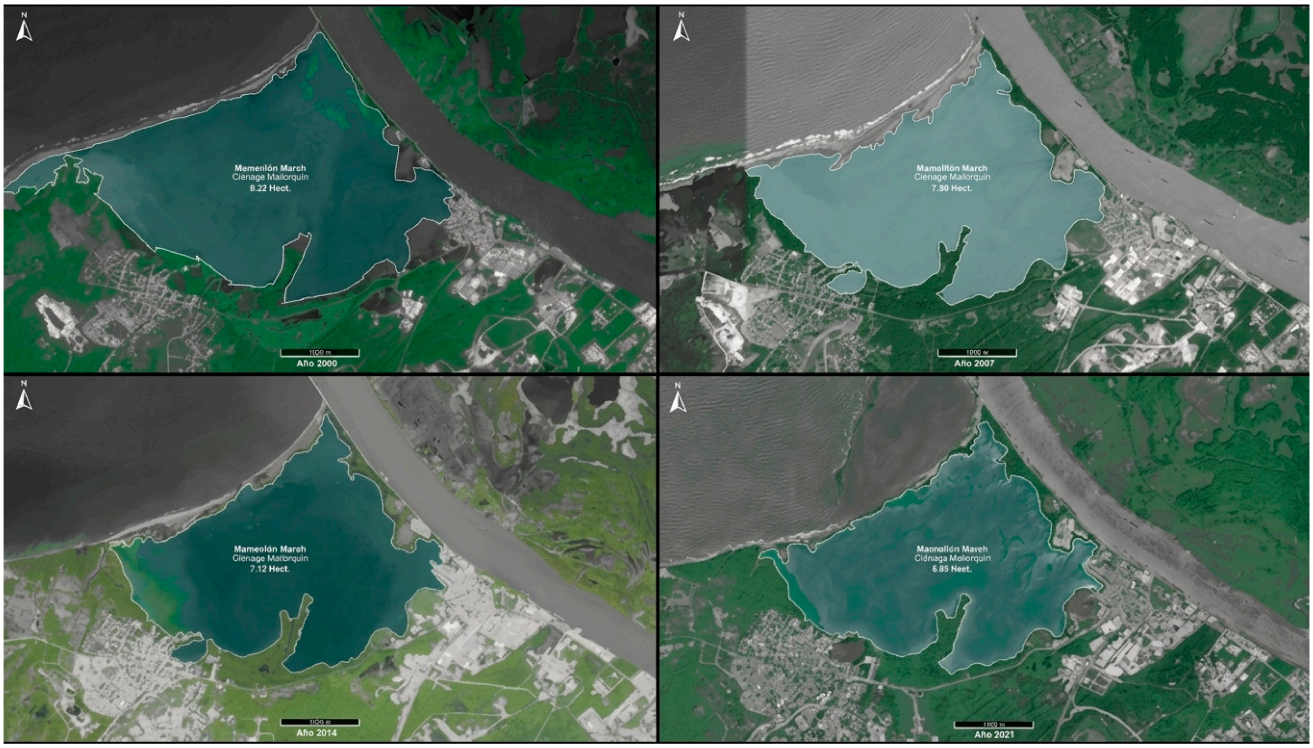


Figure 6. Observed changes in wetland extent within the Mallorquín Lagoon between 2000 and 2021. The figure illustrates the cumulative reduction in wetland surface identified through manual photointerpretation. These changes represent the combined outcome of multiple natural and anthropogenic processes and should not be interpreted as resulting exclusively from the expansion of the Las Flores settlement. Seasonal variability and differences in image acquisition conditions may influence the interpreted wetland boundaries.

Table 5. Environmental Changes Associated with Informal Settlement Expansion.

Indicator of Spatial Transformation	Observed Process/Factor	Implications for the Amphibious Territory
Increase in settlement area (10.6 ha: 2000–2021)	Migration and lack of access to formal housing	Natural vegetation and wetland cover reduction; densification of informal housing
Land reclamation and wetland filling	Self-construction on reclaimed land	Alteration of topography and soil; decreased water infiltration
Reduction of Lagoon (−237 ha, 2000–2021)	Urban encroachment and sediment accumulation	Loss of aquatic biodiversity and ecosystem services
Dumping of waste and mangrove deforestation	Absence of waste management and urban regulation	Associated with sedimentation, water pollution and altered hydrological connectivity
Unpaved and flooded access roads	Lack of drainage infrastructure	Limited accessibility and increased exposure to flooding
Use of precarious building materials	Economic constraints	High vulnerability to storms and extreme weather events
Deficiency of public and recreational spaces	Spatial segregation from formal areas	Limited opportunities for social interaction and community well-being

Table 6. Patterns of Informal Urban Expansion in Las Flores (2000–2021).

Spatial Process	Observed Characteristics	Interpretative Description
Perimeter expansion	Gradual outward growth of dwellings toward lagoon and river margins	Encroachment driven by population pressure and lack of available urban land
Land reclamation	Filling of wetland areas with debris, sediment, and household waste	Community-led strategies to raise terrain and create habitable ground
Densification	Construction of multi-family and attached housing units	Reflects limited land availability and consolidation of informal plots
Functional diversification	Emergence of mixed residential and economic uses (shops, workshops, informal commerce)	Indicates socio-economic adaptation and spatial improvisation
Fragmentation	Spatial and infrastructural separation between formal and informal sectors	Associated with socio-spatial inequality and uneven access to services

Note: Descriptions are interpretative summaries based on aerial imagery analysis, field observation, and community mapping, not on quantitative measurement.

From a morphological perspective, the informal growth of Las Flores displays a linear-radial pattern constrained by the boundaries of the lagoon and the river. The densification process follows the few available dry areas, creating compact clusters of low-rise, self-built dwellings separated by narrow, unpaved pathways. This spatial configuration is consistent with incremental, bottom-up patterns of urbanisation observed in informal-settlement contexts [16].

The territorialisation of the amphibious space in Las Flores occurs through both material and symbolic practices. Materially, residents reclaim land through sediment filling, construction of makeshift embankments, and gradual extension of the built environment into the wetland. Symbolically, they construct an identity linked to the amphibious landscape, a cultural and emotional attachment to the lagoon and its resources, which simultaneously sustains their livelihoods and exposes them to environmental risks. This duality aligns with Fals Borda's [61] conceptualisation of amphibious territories as hybrid socio-ecological systems where land and water coexist in a dialectical relationship.

However, the territorialisation of the wetland through informal processes also entails ecological contradictions. The act of occupying and transforming the lagoon's margins undermines the very environmental conditions that enable amphibious life. Residents' practices of survival (filling, fishing, waste disposal) may contribute unintentionally to the degradation of their habitat. This paradox resonates with [17,21] observation that urban marginality often generates resilient yet self-destructive adaptations to environmental stress.

The spatial expansion of the informal settlement has accentuated the physical and social fragmentation within Las Flores. The absence of paved roads and the prevalence of flooded pathways hinder mobility, particularly during the rainy season. Access to the formal sector of the neighbourhood and to essential services such as schools, health centres, and markets is restricted. This infrastructural isolation reinforces socio-spatial inequality and limits integration with the broader urban fabric of Barranquilla. Previous research has shown that the spatial distribution of green and public spaces, together with inequalities in urban infrastructure provision, is closely associated with patterns of urban equity and exclusion [62–64].

Residents identified the improvement of access roads (Figure 7) and drainage systems as a priority for environmental and social upgrading. The participatory mapping sessions suggested that many of the unpaved roads double as drainage channels, carrying both stormwater and waste directly into the lagoon. This infrastructural deficiency

exemplifies how environmental and social vulnerabilities intersect in informal amphibious settlements [20,24].

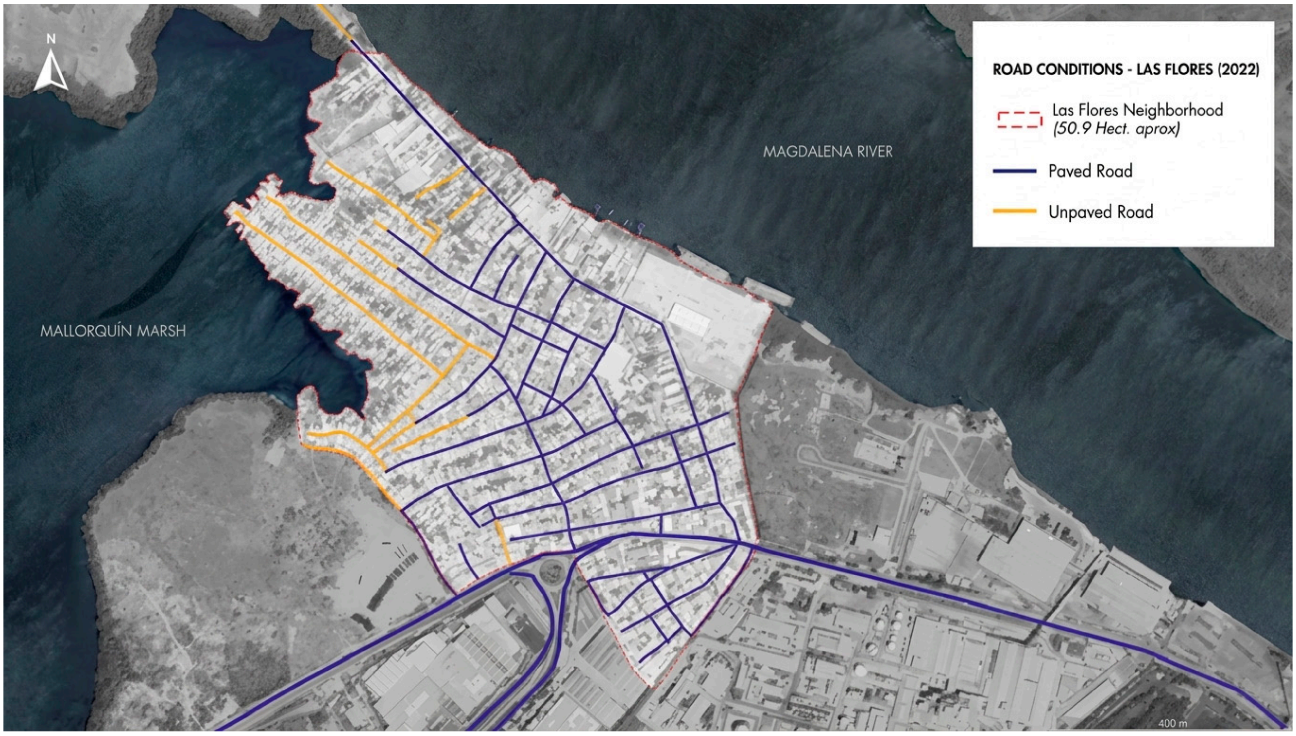


Figure 7. Condition of the roads in the study area.

The lack of effective public space (Figure 8) within the informal sector also emerged as a critical issue. Recreational and cultural facilities are concentrated in the formal part of Las Flores, leaving children and youth from the informal area without safe spaces for leisure or sport. According to local leaders, the absence of such spaces may contribute to the fragmentation of community life and may be associated with greater exposure of young residents to drugs and violence. These findings align with broader literature linking urban exclusion to social disintegration and reduced well-being [65].

The results presented here indicate a strong spatial association between informal urban expansion, environmental degradation, and increasing socio-spatial inequality. Although the expansion of the settlement represents one important component of these transformations, the broader environmental changes observed across the lagoon reflect multiple interacting natural and anthropogenic processes operating at different spatial scales. The progressive reclamation of wetland areas reflects both structural deficits in formal housing provision and the agency of marginalised communities in creating their own urban futures. Yet, this adaptive process may contribute to reinforcing relationships between environmental degradation and social marginalisation within the broader urban socio-ecological system [66].

The case of Las Flores underscores the need to rethink urban informality not as a pathological deviation from formal planning but as a form of territorial production embedded within the broader dynamics of urbanisation and governance. Informal spatial practices in amphibious environments challenge conventional urban categories, such as “land” and “water,” “formal” and “informal”, and invite the development of new conceptual frameworks that integrate social justice, ecological resilience, and adaptive urbanism [43,67].



Figure 8. Proximity and influence of effective public spaces. Proximity to effective public spaces represented through Euclidean buffer analysis in ArcGIS Pro. Buffers illustrate approximate spatial proximity and do not represent accessibility along the street network.

These findings therefore support an interpretation in which informal settlement expansion forms part of a broader set of interacting socio-environmental processes operating across the lagoon rather than acting as the sole driver of observed environmental change.

3.2. Environmental Degradation and Infrastructure Deficits

The amphibious territory of Las Flores illustrates the complex interplay between environmental degradation and infrastructural deficiency that typifies informal settlements in coastal Latin American cities. Wetland occupation, infrastructural neglect, broader urban development, and long-term environmental change interact to shape the current condition of the Mallorquín Lagoon. Environmental degradation appears to be associated with informal land use and may also contribute to social inequity, as deteriorating environmental conditions further marginalise already vulnerable populations [65,67].

The results of the fieldwork and spatial analysis suggest three intertwined dimensions of degradation: (i) hydrological alteration and sedimentation of the Lagoon, (ii) loss of mangrove and wetland vegetation, and (iii) pollution from solid and liquid waste. These processes are consistent with a reduction in the ecological resilience of the lagoon and are associated with increased exposure of residents to flooding, contamination, and infrastructural failure.

Drone-based observations and satellite imagery indicate a progressive shallowing and fragmentation of the Mallorquín Lagoon, driven largely by the deposition of sediments and the construction of informal embankments. Over the past two decades, the lagoon's average depth has decreased from 2.8 m to less than 1.2 m in several areas, while the natural channels that once connected it to the Magdalena River have become partially obstructed. This blockage reduces water circulation and increases stagnation, leading to eutrophication and elevated salinity levels, particularly during the dry season [49].

Residents reported that flooding events have become more frequent and intense, particularly during the rainy seasons of 2010, 2015, and 2020. These floods often coincide

with high tides and storm surges [68], resulting in the backflow of lagoon water into the settlement's unpaved streets. Because drainage infrastructure is almost non-existent, runoff accumulates in open spaces and household surroundings, promoting the proliferation of mosquitoes and waterborne diseases. Similar interactions between wetland occupation, flooding, and infrastructural vulnerability have been documented in informal wetland settlements in Kampala [69] and in other informal-settlement contexts [21].

Visual interpretation of historical imagery, supported by high-resolution drone photographs and GIS analysis, indicates a substantial reduction in mangrove cover surrounding Las Flores between 2000 and 2021. The remaining mangrove patches, mostly Rhizophora mangle and Avicennia germinans, are concentrated along the western edge of the lagoon, near zones of restricted access. Field observations and interviews suggest that mangrove loss is associated with informal land filling, fuelwood extraction, and the use of mangrove trunks as building materials. These practices, while reflecting economic necessity, may undermine the ecological services that mangroves provide, including flood regulation, carbon sequestration, and water purification [39,70].

The environmental implications of mangrove loss extend beyond the local scale. The degradation of the Mallorquín wetland contributes to the loss of biodiversity and the disruption of ecological corridors that connect the Caribbean coastal systems. Mangrove deforestation also reduces the lagoon's resilience to climate change, as it diminishes its capacity to absorb the impacts of sea-level rise and storm surges [35]. Comparable relationships between wetland degradation and socio-ecological vulnerability have been documented in other amphibious and wetland-settlement contexts [24,69].

Field observations and community interviews confirmed that waste disposal constitutes one of the most critical environmental challenges in Las Flores. The absence of an effective municipal collection system in the informal sector has led residents to create improvised dumping areas along the lagoon's margins and at the ends of unpaved streets. These sites accumulate domestic waste, plastics, and construction debris, which are periodically burned to reduce volume, releasing toxic fumes and exacerbating local air pollution.

Liquid waste is equally problematic. Most houses lack connection to a formal sewage system, relying instead on makeshift latrines or direct discharge into open drains that empty into the lagoon. This situation is likely to contribute to microbiological contamination of surface waters, posing serious health risks to residents who use the lagoon for fishing or domestic washing. Findings from Benavides [49] and Jiménez et al. [51] indicated high levels of coliform bacteria and elevated concentrations of nitrogen and phosphorus, consistent with eutrophic conditions. These conditions are consistent with evidence from other informal-settlement contexts showing close relationships between inadequate sanitation, degraded water quality, and environmental-health risks [10,17,71]. The cumulative environmental burden (Table 7), including waste accumulation, contaminated runoff, and deteriorating water quality, illustrates the difficulties faced by settlements where infrastructure is insufficient to safely manage the material outputs of human activity.

The environmental degradation observed in the amphibious territory appears closely associated with infrastructural neglect. The absence of a drainage system is likely to exacerbate flooding during heavy rainfall, while the lack of street paving contributes to soil erosion and stagnant water accumulation. These infrastructural deficiencies represent not merely technical shortcomings but expressions of spatial injustice, as they reflect the uneven distribution of urban services between formal and informal areas [62,64,72].

In participatory mapping sessions, residents identified "water stagnation zones" and "deteriorated roads" as the primary physical risks affecting their well-being. The maps, complemented by drone orthophotos, suggested that many households are located less than 50 m from areas of recurrent flooding. The community's adaptation strategies, raising

the foundations of houses, building makeshift embankments, or using sandbags, reflect a pragmatic but limited form of self-engineered resilience. As noted by Ali et al. [55], such resilience strategies, while effective in the short term, may reinforce long-term vulnerability if not integrated into broader urban management frameworks.

Table 7. Environmental and Infrastructural Impacts of Informal Expansion.

Impact Dimension	Observed Conditions	Interpretative Assessment
Wetland degradation	Loss of natural vegetation, soil compaction, and sediment accumulation	Reduced ecological function and water retention capacity
Mangrove deforestation	Cutting of mangrove patches for housing and access routes	Decline of habitat connectivity and coastal protection
Waste accumulation	Presence of solid waste in drainage channels and wetland edges	Contributes to contamination and blocked drainage
Water quality	Murky, odorous, and stagnant water observed near settlement	Indicates organic pollution and domestic runoff
Infrastructure deficits	Lack of drainage, limited road paving, and absence of green areas	Exposes community to flooding and mobility constraints
Housing vulnerability	Low-lying construction, poor materials, limited structural stability	Increases exposure to flood damage and health risks

Note: All assessments are qualitative and derived from participatory mapping, field observations, and resident interviews, not from quantitative environmental data.

The intertwined processes of environmental degradation and infrastructural neglect in Las Flores exemplify patterns of urban environmental justice, whereby environmental burdens disproportionately affect already marginalised populations [42]. The amphibious setting intensifies this condition, as the community's physical proximity to the lagoon simultaneously sustains their livelihoods and exposes them to its ecological decline.

These results highlight the need for a systemic approach to amphibious urban management, integrating wetland conservation with inclusive service provision. As Dearing et al. [73] argue, achieving sustainability in socio-ecological systems requires addressing both environmental thresholds and social inequalities. In Las Flores, this implies restoring mangrove ecosystems, improving drainage and waste management infrastructure, and recognising residents as legitimate actors in environmental governance.

3.3. Social Equity, Education, Health, and Livelihoods

The social fabric of Las Flores reflects the historical trajectory of exclusion, adaptation, and resilience characteristic of informal settlements across Latin America. The coexistence of formal and informal sectors within the same neighbourhood is connected with contrasts in living conditions, access to public services, and opportunities for education and health. These disparities embody the broader challenge of achieving social equity in amphibious territories, contexts where environmental vulnerability intersects with systemic urban inequality [42,74].

According to community-based estimates corroborated municipal information, the population of Las Flores is approximately 6800 inhabitants, distributed among 1350 households. Community-based estimates suggest that more than half of the neighbourhood population resides in the informal sector. Household rapid surveys and interviews suggest a heterogeneous demographic composition, including long-term residents descended from the original fishing families and more recent migrants from rural areas of Atlántico and Bolívar Departments, many of whom arrived after 2000 seeking affordable housing.

Contextual information compiled from field observations, community-based estimates, rapid community surveys, and interviews consistently indicated lower income levels in the informal sector than in the formal sector. Interviews further suggested that relatively few workers had stable formal employment, with most households relying primarily on informal activities such as fishing, recycling, domestic work, street vending, and small-scale food preparation.

When asked about their perception of inequality, participants described Las Flores as "a divided neighbourhood" (R-IS-07), referring to the spatial and social separation between the formal and informal sectors. Residents associate inequality not only with income but also with access to services, security, and recognition by local authorities. In interviews, several participants emphasised that the informal area is "invisible to the municipality" (R-IS-03), reflecting both administrative neglect and symbolic exclusion. This aligns with the idea of spatial invisibility developed by Brown-Luthango and Arendse [14], whereby informal residents are excluded from the representational and political spaces of the city despite their physical proximity to formal areas.

Education represents one of the most critical dimensions of social equity. Contextual information collected during the fieldwork suggested lower school enrolment levels in the informal sector than in the formal sector. High dropout rates were reported by participants to be associated with economic hardship, the need for children to contribute to household income, and the lack of nearby educational facilities. The closest public secondary school is located 1.8 km from the informal area (Figure 9), an appreciable distance given the absence of reliable public transport and the poor condition of internal access roads.

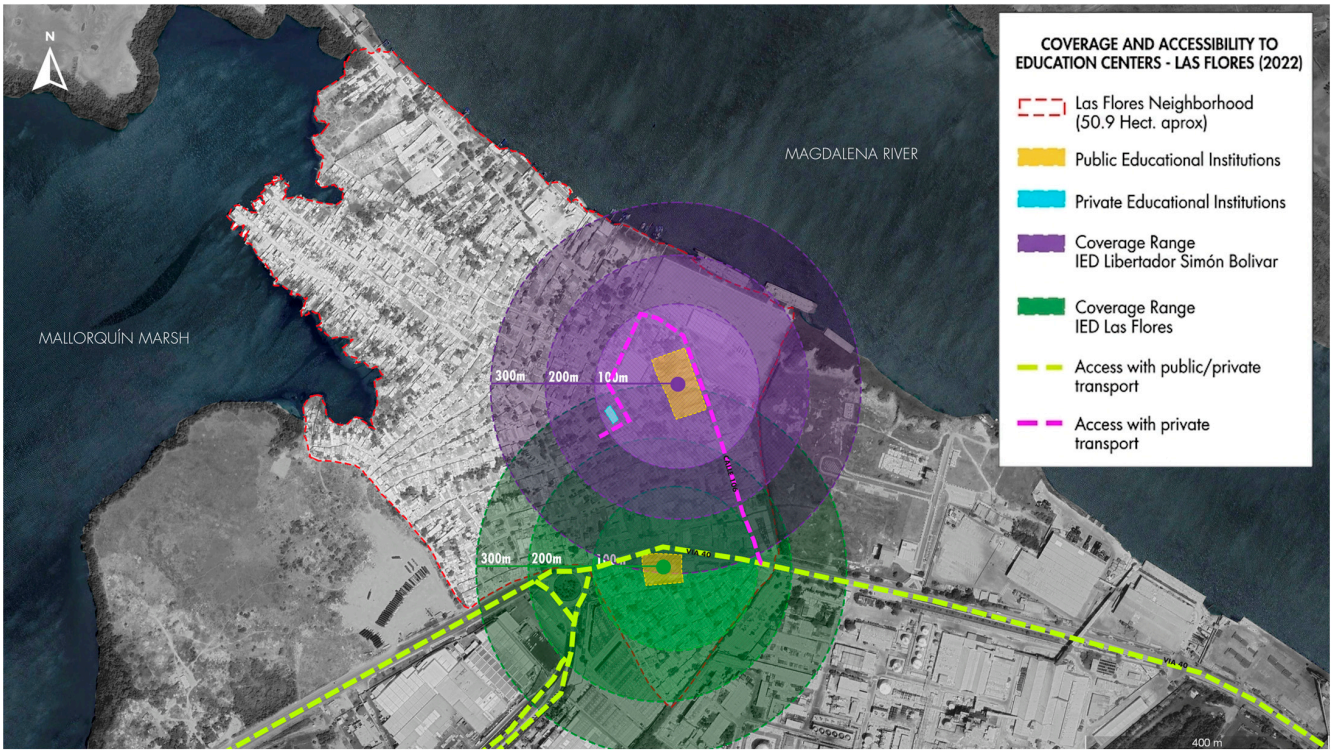


Figure 9. Locations of educational facilities were complemented by information obtained during participatory mapping workshops regarding perceived accessibility barriers. Euclidean buffer analysis was performed in ArcGIS Pro to represent approximate spatial proximity. Buffers do not represent network-based accessibility or travel distance.

Interviews indicated additional barriers: overcrowded classrooms, lack of teaching materials, and limited technological resources. During the last years, the digital divide

became starkly visible; only some households in the informal sector had access to the internet, compared to the vast majority in the formal sector. As a result, many students were unable to participate in virtual classes, deepening existing educational disparities.

These findings resonate with international research highlighting education as both a determinant and an indicator of urban inequality. These findings are consistent with urban environmental-justice perspectives that identify unequal access to quality education and other essential urban resources as dimensions of place-based inequality [42].

Health outcomes in Las Flores are closely linked to environmental conditions and infrastructural deficits. The absence of a local health centre in the informal area forces residents to travel approximately 3 km to the nearest facility, located in the formal sector (Figure 10). This distance, combined with poor transportation, limits preventive care and delays treatment during emergencies.

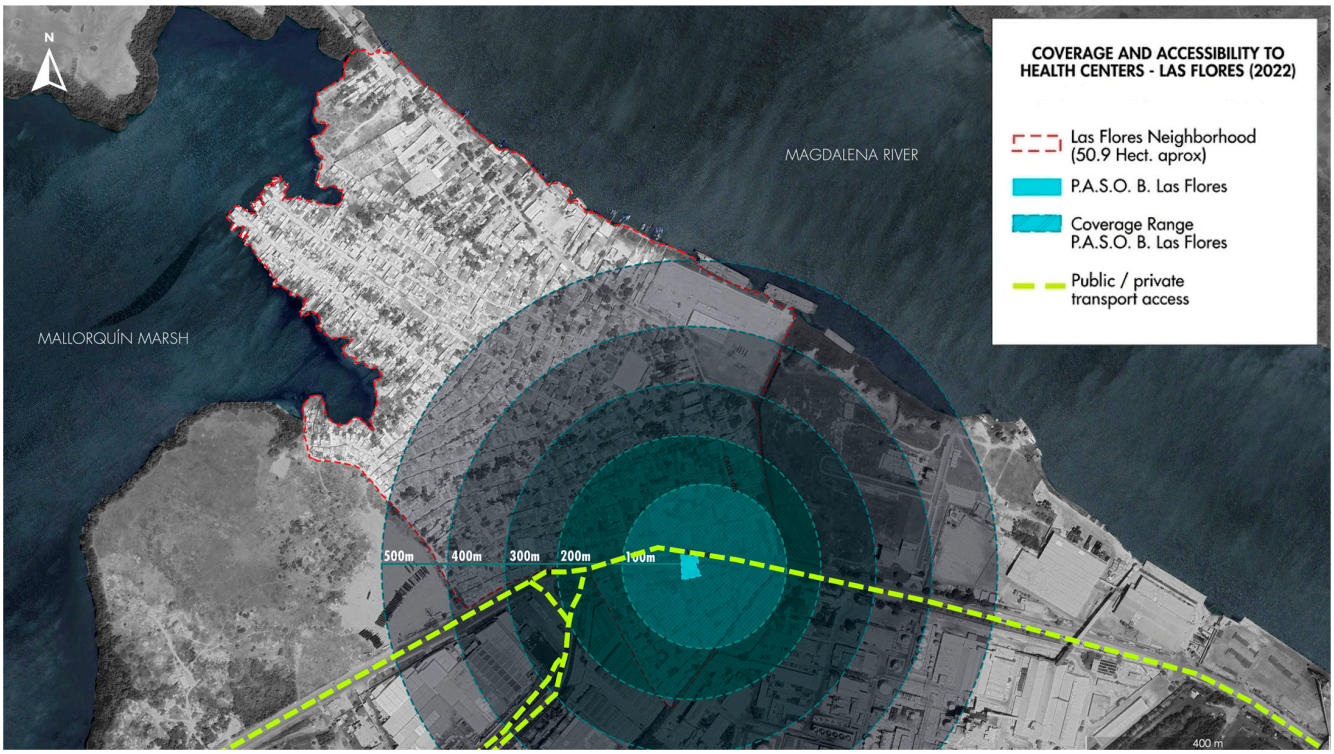


Figure 10. Proximity, coverage and accessibility of the health centre to the informal settlement. Euclidean buffer analysis in ArcGIS Pro illustrating approximate spatial proximity to the health centre. Buffers represent straight-line distance only and should not be interpreted as network-based accessibility.

Participants indicated that most of the residents in the informal sector experienced at least one environment-related health problem during the previous year, including skin infections, respiratory diseases, and gastrointestinal illnesses. Reported cases of dengue and chikungunya were recurrent, particularly during flood periods when stagnant water serves as a breeding site for mosquitoes. These patterns are consistent with previous research highlighting the gendered dimensions of environmental vulnerability in informal settlements, where women frequently experience disproportionate exposure to environmental risks and greater responsibility for household adaptation [74].

The limited availability of clean water and proper sanitation was consistently reported as contributing to health inequalities. Only some households have direct access to piped water, and water contamination from the lagoon further limits safe domestic use. Residents expressed distrust in local health authorities, claiming that "health brigades only come

during elections" (R-FS-05). This perception reflects not only service deficiency but also a lack of institutional continuity and social recognition (Table 8).

Table 8. Dimensions of Social Inequality and Livelihood Vulnerability.

Social Dimension	Observed Situation	Interpretative Discussion
Access to education	Schools located outside informal area; overcrowded classrooms	Limited access and quality, reinforcing intergenerational inequality
Access to health services	Health post insufficiently equipped and distant for some residents	Inadequate coverage and low preventive care
Employment and livelihoods	Predominantly informal activities: fishing, vending, recycling	Reflects economic resilience but perpetuates precarity
Gender roles	Women concentrated in unpaid care work and community organisation	Highlights gendered forms of resilience and vulnerability
Community participation	Uneven involvement between formal and informal sectors	Exclusion of informal residents from decision-making processes
Perceived inequality	Strong local narratives of neglect and marginalisation	Indicates awareness of structural injustice and desire for inclusion

Note: Information based on semi-structured interviews and participatory work-shops; categories express social perceptions rather than statistical indicators.

The informal economy constitutes the main source of livelihood in Las Flores. Interviewees consistently described fishing as one of the principal livelihood activities, with community-based estimates suggesting that approximately half of households depend directly or indirectly on fishing-related activities. However, declining water quality and reduced fish populations have decreased income stability. To compensate, residents diversify into other informal occupations: recycling, domestic labour, petty trade, and small-scale food vending. These activities, while providing short-term income, offer little social protection and are highly vulnerable to market fluctuations.

These livelihood strategies illustrate adaptive responses to economic uncertainty and environmental stress, although they remain constrained by limited access to formal employment and social protection. While these strategies demonstrate resilience, they remain locked within cycles of low productivity and environmental degradation.

Despite material deprivation, the community exhibits strong forms of social capital. Residents rely on neighbourly cooperation for child care, credit, and construction assistance. Local organisations, such as the Las Flores Community Action Board, play a crucial role in mediating between residents and municipal authorities. Nevertheless, participation is uneven: among the interview participants, only a minority of those in the informal sector reported being involved in community organisations, compared to more than half in the formal sector. Interviews suggest that apathy and mistrust have grown over time due to unfulfilled promises from local government and NGOs.

Community leaders emphasised the importance of collective action in improving living conditions. Past initiatives, such as cleaning campaigns, small-scale drainage projects, and community policing, suggest the community's organisational potential. Yet, these efforts appear to be constrained by the absence of institutional support and by socio-spatial divisions within the neighbourhood. These findings resonate with Trudeau's [43] argument that social equity requires not only material redistribution but also recognition and participation, ensuring that marginalised groups have a voice in shaping their environments.

The results highlight the multidimensional nature of social inequity in amphibious informal settlements. Poverty in Las Flores cannot be understood merely as a lack of income; it is an outcome of structural disconnection from urban governance, education, health

systems, and ecological sustainability. The persistence of inequality across generations suggests a path-dependent trajectory, where limited access to services reproduces social disadvantage over time.

3.4. Territorialisation, Social Fragmentation, and Amphibious Resilience

The territorial evolution of Las Flores cannot be fully understood through spatial or socio-economic indicators alone. Beneath the material transformations of informal expansion and ecological degradation lies a deeper process of territorialisation: the socio-spatial production of meaning, identity, and power relations through which the community appropriates and transforms the amphibious environment. This process suggests how residents negotiate belonging, survival, and governance within a landscape simultaneously shaped by nature and exclusion [29,75].

Territorialisation in Las Flores manifests through both physical appropriation of land and symbolic construction of place. Physically, residents engage in continuous acts of land reclamation, raising the terrain with sediment, debris, and domestic waste to prevent flooding and create habitable ground. These practices, while environmentally harmful, can be interpreted as forms of spatial agency, material strategies for survival in the absence of formal urban provision. Symbolically, they construct a sense of ownership and belonging, often expressed in the phrase "this land is ours because we made it livable" (CL-IS-02).

This duality exemplifies Fals Borda's [31,61] notion of amphibious territoriality, where human communities live "between land and water," adapting to hydrological rhythms while asserting cultural identity. In Las Flores, the community's relationship with the lagoon is ambivalent: water is both threat and livelihood, danger and resource. Residents fish from the same lagoon that floods their homes and contaminates their environment, embodying what Ramírez et al. [34] describe as the paradox of amphibious life.

However, territorialisation is also a contested process, shaped by internal hierarchies and external interventions. The formal sector of Las Flores, better connected, serviced, and politically visible, exerts influence over municipal decision-making, while the informal sector remains marginalised. Field interviews suggest that local leaders from the formal area often mediate the distribution of resources and representation, creating tensions with informal residents who feel excluded from participatory processes. This dynamic of "internal fragmentation" expresses how spatial inequality reproduces itself socially within the community.

The coexistence of formal and informal spaces has produced an internal socio-spatial boundary that transcends physical infrastructure. During participatory mapping sessions, residents delineated an "imaginary line" dividing the neighbourhood: "up there is Las Flores proper; down here is the swamp" (CL-FS-01). This symbolic geography reflects what Lefebvre [76] would call the production of space as an expression of power.

The perception of exclusion is reinforced by the uneven distribution of public investments. While the formal sector benefits from paved streets, lighting, and public space improvements, the informal zone continues to lack basic infrastructure. These disparities have eroded trust and cooperation between residents of the two areas. Interviews indicate mutual stigmatisation: formal residents describe the informal sector as "disorderly" or "dangerous," while informal residents perceive the formal side as "privileged" and "unsympathetic."

This fragmentation has practical implications for collective action. Community meetings organised by the Junta de Acción Comunal often experience low participation from the informal area, as residents feel their voices "do not count." Consequently, opportunities for participatory planning and collective problem-solving are limited. The weakening of social cohesion may reduce the community's capacity for collective responses to en-

vironmental challenges, particularly where environmental risk intersects with existing socio-spatial divisions.

Despite fragmentation, the residents of Las Flores have developed a repertoire of adaptive practices that reflect the logic of amphibious resilience. These practices operate at multiple scales (household, community, and environmental) and embody both reactive and proactive responses to risk.

At the household level, residents elevate floors using fill materials, construct makeshift dykes, and design modular housing structures that can be modified seasonally. Some families install wooden walkways connecting houses during floods, reproducing traditional fluvial architectures once common in the Magdalena delta. Others adopt "floating" domestic routines, relocating valuable items during storms and maintaining emergency networks of relatives on higher ground.

At the community level, informal networks organise cleaning campaigns, drainage maintenance, and emergency response during flood events. Women's groups, in particular, play a key role in coordinating these actions, often mobilising through church organisations or school committees. Such grassroots initiatives exemplify the self-organisation that characterises urban resilience in the absence of institutional support [55].

Nevertheless, these forms of resilience remain adaptive rather than transformative (Table 9). They enable survival but do not alter the structural conditions that produce vulnerability: limited service provision, insecure tenure, and environmental degradation. Without institutional engagement, amphibious resilience risks becoming a form of resignation, sustaining the status quo rather than enabling social and ecological transformation [71].

Table 9. Typology of Territorialisation and Resilience Processes in Las Flores.

Dimension	Observed Practices	Function/Rationale	Outcome/Implication
Physical territorialisation	Land filling, construction on reclaimed ground	To create habitable land and prevent flooding	Environmental degradation; reduction in wetland ecosystem
Symbolic territorialisation	Naming of streets, religious landmarks, community rituals	To build belonging and spatial identity	Strengthened cultural cohesion; internal boundary formation
Economic adaptation	Diversified informal livelihoods (fishing, vending, recycling)	To secure income amid environmental decline	Short-term resilience; perpetuation of informal economy
Social self-organisation	Cleaning campaigns, informal governance committees	To manage risk collectively	Limited but effective local coordination; dependence on voluntary labour
Gendered resilience	Women's networks for care and crisis response	To compensate for institutional absence	Increased female agency; burden of unpaid labour
External interaction	Negotiation with municipal authorities, NGOs, Ecoparque project	To seek recognition and support	Fragmented engagement; sporadic institutional presence

This typology captures the multi-scalar nature of territorialisation in Las Flores, highlighting how residents' practices simultaneously produce space, culture, and resilience. The outcomes are ambivalent: while they foster survival and belonging, they also entrench environmental degradation and social inequality.

In recent years, the municipal government has launched urban and environmental initiatives, most notably the Ecoparque Ciénaga de Mallorquín project, aimed at restoring the wetland ecosystem and promoting ecotourism. While these interventions represent

positive efforts toward ecological rehabilitation, they have generated controversy within Las Flores. Residents of the informal area fear that restoration could lead to displacement or restriction of access to traditional fishing grounds.

Interviews with community leaders suggest a widespread perception that the Ecoparque project prioritises tourism and city branding over the rights of local inhabitants. One participant remarked: "They talk about conservation, but they don't include the people who have lived here for decades" (CL-FS-02). This tension raises the distributive and political question of "resilience for whom" highlighted in critical urban-resilience scholarship [77].

For resilience to be socially just, it must address principles of recognition, participation, and redistribution [78]. This implies designing adaptive strategies that not only restore ecosystems but also improve living conditions, tenure security, and access to services for amphibious communities. The Las Flores case thus provides a critical lens through which to assess how resilience policies can inadvertently reproduce inequality when detached from local realities.

Amid these contestations, the amphibious identity of Las Flores persists as a source of cultural continuity. Oral histories collected during the fieldwork recount how early settlers adapted to tidal rhythms, building homes on stilts and navigating the lagoon in small canoes. Although these practices have largely disappeared, their memory endures in narratives of pride and belonging. Residents continue to celebrate annual fiestas patronales and fishing rituals that symbolically link them to the lagoon, reinforcing a collective sense of place.

This cultural resilience is consistent with Gutiérrez and Escobar's [32] analysis of changing relationships between territory, wetland environments, and local communities. In this sense, amphibious resilience is not only a matter of infrastructure or adaptation but also of memory and meaning. It expresses the community's refusal to be erased by urban modernisation or environmental degradation.

The processes described above illustrate that territorialisation in amphibious contexts is inherently paradoxical. It embodies both resistance and degradation, community strength and fragmentation. The informal residents of Las Flores have constructed a lived geography that defies conventional urban categories: their territory is neither fully urban nor fully natural, neither formal nor illegal in the moral sense, but a hybrid socio-ecological system sustained through everyday negotiation.

From a theoretical standpoint, the Las Flores case expands the understanding of territorialisation as a dynamic interaction between material, symbolic, and political dimensions. It explains how informal urbanisation in amphibious settings generates distinctive forms of resilience grounded in local knowledge and collective agency. However, it also exposes the fragility of such resilience when detached from structural support.

Building equitable amphibious urbanism therefore requires bridging the gap between bottom-up territorial practices and top-down environmental governance. Participatory planning, recognition of informal land rights, and co-management of wetland resources are essential to transform adaptive resilience into transformative resilience, capable of reducing vulnerability while enhancing ecological integrity and social justice [55,73].

3.5. Policy and Planning Implications: Towards Equitable and Sustainable 'Amphibious Justice'

The preceding sections have presented the empirical findings and their interpretation. Building upon these results, this section discusses their implications for urban planning and develops the exploratory Amphibious Justice framework.

The results of this study underscore the urgent need to rethink how urban planning and environmental governance engage with informal settlements located in amphibious territories. The case of Las Flores suggests that environmental degradation, infrastructural

deficiency, and social inequality are not isolated phenomena but interconnected expressions of an urban system that has historically marginalised peripheral and ecologically sensitive communities. Addressing these challenges requires a transformative planning approach, one that integrates social equity, ecological restoration, and community participation as inseparable dimensions of sustainable urbanism.

Current policies in Barranquilla, particularly the Ecoparque Ciénaga de Mallorquín initiative, represent important steps towards wetland conservation and climate adaptation. However, their implementation has prioritised technical restoration and tourism development over social inclusion. To move beyond this paradigm, planning must embrace a model of socio-ecological integration, recognising that human and natural systems in amphibious territories are co-dependent. Such restoration should explicitly recognise that wetland degradation was associated with multiple interacting drivers operating across the wider socio-ecological system rather than being attributable to informal settlements alone.

Inclusive upgrading must also be grounded in the principle of spatial justice, redistributing not only infrastructure but also political recognition and representational power. Participation mechanisms that integrate local knowledge and empower informal residents are essential [79]. In amphibious settings, tenure regularisation should be linked to environmental stewardship through conditional agreements that balance human rights with ecological protection.

Institutional coherence remains a challenge. The creation of an inter-agency platform for amphibious governance could strengthen coordination between planning and environmental institutions, supported by spatial monitoring tools such as GIS and community-based mapping. These instruments can foster accountability and adaptive management, ensuring that decision-making is grounded in evidence and inclusion.

The findings of this research indicate that amphibious settlements such as Las Flores are not only sites of environmental risk but also arenas of contested citizenship and uneven recognition. Residents struggle simultaneously for the right to the city and the right to water, negotiating their existence between urban exclusion and ecological vulnerability. In response to these conditions, this study develops Amphibious Justice as an exploratory urban socio-ecological framework for interpreting equity in territories where urbanisation, informality, and land–water dynamics intersect. This formulation should be distinguished from Chao's [45] earlier use of Amphibious Justice within multispecies-justice scholarship. Chao's formulation draws on amphibian beings and their movement across terrestrial and aquatic environments to advance a transversal, more-than-human ethics spanning species, elements, and ecosystems. By contrast, the framework developed here focuses on the socio-spatial and institutional production of justice and injustice in inhabited wetland territories, particularly the distribution of environmental risks and urban resources, recognition of water-dependent livelihoods and territorial identities, participation in planning and restoration decisions, and governance under ecologically dynamic conditions.

The analytical specificity of this framework lies not in the novelty of these individual dimensions, but in the territorial configuration through which they interact. Environmental justice provides the broader concern with unequal environmental burdens, recognition, and participation [78], while spatial justice foregrounds the production and unequal organisation of urban space [80]. Water justice focuses more specifically on contested access to, control over, and governance of water and recognises water as simultaneously material, social, and political [81]. Blue justice has developed particularly around inequities affecting coastal and fishing communities, while its emerging scholarship increasingly encompasses a broader range of coastal justice concerns [82]. Just-adaptation approaches, in turn, examine whether climate adaptation policies redistribute vulnerability or reproduce existing inequalities [83]. Amphibious Justice, as developed here, intersects with all of

these perspectives but addresses a more specific socio-spatial condition: territories in which the boundary between land and water is physically variable, informal urbanisation and wetland-dependent livelihoods coexist, ecological restoration can simultaneously generate environmental benefits and displacement pressures, and residents' claims to urban services, tenure, environmental resources, and political recognition cannot be analytically separated.

Table 10 summarises a set of policy and planning recommendations for developing equitable amphibious justice: integrating ecological restoration, participatory governance, and social inclusion.

Table 10. Policy and Planning Framework for 'Amphibious Justice' and Equitable Amphibious Urbanism.

Policy Dimension	Strategic Actions Proposed	Expected Outcomes
Environmental management	Restore mangrove belts; establish buffer zones; promote community-based waste collection	Reduced flood risk, improved water quality, local employment in conservation
Housing and infrastructure	Implement eco-inclusive upgrading (drainage, elevated pathways, green infrastructure)	Improved living conditions, safer mobility, enhanced amphibious resilience
Social equity and participation	Create participatory councils; integrate community knowledge into planning	Strengthened social inclusion and co-responsibility
Land and tenure security	Develop conditional environmental tenure agreements	Formalisation with ecological safeguards; prevention of forced displacement
Institutional governance	Establish inter-agency amphibious management platform and data observatory	Policy coherence, participatory monitoring, adaptive management
Education and capacity-building	Environmental education programmes, youth training in ecosystem care	Community empowerment and intergenerational sustainability

The formulation proposed here should therefore be understood as an integrative and territorially specific framework rather than as a replacement for existing theories of justice [79,80]. Its analytical value lies in examining how distributive, recognitional, procedural, and governance-related injustices become mutually reinforcing under amphibious conditions. In Las Flores, for example, unequal infrastructure provision cannot be separated from exposure to flooding; livelihood dependence on the lagoon cannot be separated from ecological regulation; tenure insecurity cannot be separated from restoration and redevelopment pressures; and participation cannot be separated from the recognition of residents as legitimate inhabitants and environmental knowledge holders. Amphibious Justice thus focuses on the intersections among these processes rather than treating water, urban space, environmental risk, adaptation, or livelihood justice as separate domains.

To make this conceptual contribution operational, Amphibious Justice can be understood through four interrelated dimensions: recognition, redistribution, participation, and adaptive governance. Recognition refers to the acknowledgement of amphibious livelihoods, local knowledge, and territorial identities as legitimate components of urban planning. Redistribution concerns the fair allocation of environmental benefits, urban services, infrastructure, and risk-reduction measures. Participation implies the meaningful inclusion of informal residents in decisions concerning wetland restoration, upgrading, and resettlement. Finally, adaptive governance refers to institutional arrangements capable of integrating ecological uncertainty, community knowledge, and long-term socio-environmental monitoring. Together, these dimensions operationalise Amphibious Justice for the specific analysis of informal amphibious territories, where urbanisation, water dynamics, ecological regulation, territorial identity, and socio-spatial inequality are inseparably connected (Figure 11). Accordingly, the framework should be understood as an exploratory conceptual synthesis derived from the Las Flores case study rather than as a universally validated model.

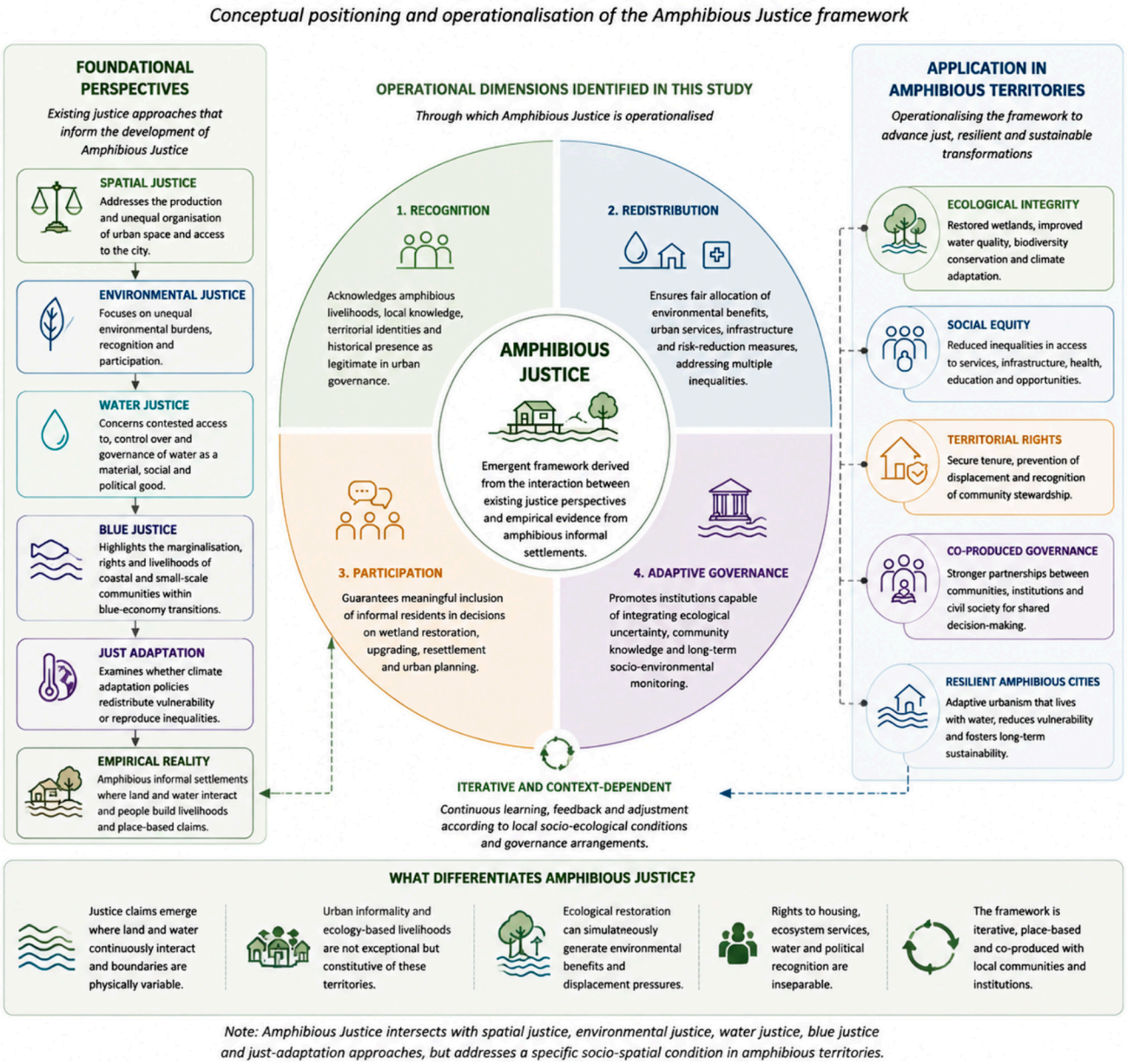


Figure 11. Conceptual framework of Amphibious Justice. The figure illustrates the theoretical foundations, core dimensions, and practical implications of Amphibious Justice. Building upon spatial justice, environmental justice, urban informality, and amphibious territoriality, the framework proposes recognition, redistribution, participation, and adaptive governance as the four pillars for achieving equitable and resilient urban development in wetland settlements. Source: Authors' elaboration.

In amphibious territories, justice cannot be reduced to infrastructure provision or tenure regularisation; it also entails epistemic and territorial recognition acknowledging the knowledge, labour, and historical presence of those who have adapted to live with water. The pursuit of amphibious justice thus implies co-management of ecosystems, participatory governance, and policy frameworks that ensure adaptation processes do not reproduce exclusion.

This notion provides a lens for reinterpreting resilience as a political rather than purely adaptive project: a struggle for visibility, rights, and belonging in the amphibious city.

The future of settlements like Las Flores will depend on whether cities can learn to live with water rather than against it. Building sustainable amphibious futures requires

more than technical adaptation; it requires recognising that ecological resilience and social equity are inseparable foundations of urban sustainability.

4. Conclusions

This study has examined the interrelations between spatial transformation, social equity, and environmental change in the informal amphibious settlement of Las Flores, Barranquilla. Through an integrated methodology combining spatial interpretation, participatory mapping, and qualitative inquiry, it has illustrated how informal urbanisation in amphibious territories is associated with ecological degradation, infrastructural deficiency, and social inequality, while also suggesting the agency and adaptive capacity of communities that inhabit these fragile environments. Three main conclusions emerge:

First, informal territorialisation in amphibious contexts is both a survival strategy and a process of socio-ecological transformation. Residents' acts of land reclamation and self-construction express adaptation to exclusionary urban systems, while also contributing to local environmental pressures within the broader set of natural and anthropogenic processes affecting the Mallorquín Lagoon. The environmental changes documented in this study should therefore be interpreted within the context of multiple interacting natural and anthropogenic processes operating across the wider lagoon system, of which informal urbanisation represents one important component. This duality challenges conventional planning paradigms that separate the social from the ecological, underscoring the need for integrated approaches to urban and environmental governance.

Second, the findings highlight that social inequities are ecologically embedded. Limited access to services and infrastructure is consistent with structural forms of environmental injustice, where marginalised groups bear disproportionate exposure to risk. Addressing these inequities requires policies that link urban upgrading with ecosystem restoration, recognising that sustainability cannot be achieved through purely technical interventions.

Third, the research advances the notion of amphibious resilience, understood as a hybrid capacity rooted in local knowledge, collective organisation, and territorial identity. Yet, this resilience remains fragile in the absence of institutional recognition and support.

From a conceptual perspective, the article contributes to debates on urban informality and socio-ecological justice by developing an exploratory formulation of Amphibious Justice as an integrative analytical framework for territories where informal urbanisation, fluctuating land–water relations, ecological regulation, and socio-spatial inequality intersect. Its contribution lies not in proposing new dimensions of justice, but in articulating how established distributive, recognitional, participatory, and governance concerns interact under specifically amphibious territorial conditions.

The exploratory Amphibious Justice framework proposed in this article emerges from the empirical evidence of a single case study, several limitations should be acknowledged. In addition, the historical imagery analysed in this study was not standardised for seasonality or hydrological conditions. Consequently, the spatial interpretation should be understood as identifying long-term landscape trends rather than precise measurements of permanent hydrological or ecological change. Accordingly, the findings should not be interpreted as universally representative of all amphibious urban contexts. Rather, Las Flores is understood as an analytically informative case through which broader socio-ecological processes can be examined. Furthermore, while the mixed-methods approach enabled the integration of spatial analysis with residents' perceptions, future research could strengthen the proposed conceptual framework by incorporating comparative case studies across different geographical settings, longitudinal analyses of socio-environmental change, and quantitative assessments of the operational dimensions of Amphibious Justice. Such

research would contribute to testing the transferability and broader applicability of the framework proposed in this article.

Ultimately, the future of settlements such as Las Flores depends on whether cities can learn to live with water rather than against it. Sustainable amphibious futures require more than technical solutions; they demand a just, inclusive, and co-produced relationship between society, territory, and ecology.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/land15081521/s1, Supplementary Table S1. Illustrative examples of the analytical progression from interview extracts to representative codes, themes and analytical dimensions.

Author Contributions: Conceptualization, K.T.-N., J.M.-C., M.Z. and A.C.-C.; methodology, K.T.-N., J.M.-C., M.Z. and A.C.-C.; software, J.M.-C., M.Z. and J.G.C.; validation, A.C.-C.; formal analysis, K.T.-N., J.M.-C., M.Z., A.C.-C. and J.G.C.; investigation, K.T.-N., J.M.-C., M.Z., A.C.-C. and J.G.C.; resources, K.T.-N., J.M.-C. and M.Z.; data curation, K.T.-N. and A.C.-C.; writing—original draft preparation, K.T.-N., J.M.-C., M.Z., A.C.-C. and J.G.C.; writing—review and editing, K.T.-N., J.M.-C., M.Z., A.C.-C. and J.G.C.; supervision, A.C.-C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request. Owing to ethical considerations and the need to protect participant confidentiality, interview transcripts, coding files, and other qualitative materials are not publicly available. Spatial datasets generated during the study (including GIS layers, interpreted polygons, and derived spatial analyses) can be made available for research purposes upon reasonable request, subject to any restrictions associated with the original data sources. The interview guide and additional methodological information are also available from the corresponding author upon reasonable request.

Acknowledgments: Funding for open access charge: Universidad de Granada/CBUA.

Conflicts of Interest: The authors declare no conflicts of interest.

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