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Coastal Resilience and Adaptive Housing Strategies in Flood-Prone Areas: A Case Study from Douala 6, Cameroon

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Abstract: The coastline is a major economic driver for coastal countries, but these areas continue to face increasing hazards, particularly more severe flooding. It is becoming imperative to preserve these areas by developing new, adapted housing strategies. This research, based on the case of Douala 6 in Cameroon, proposes a resilient way of living that reduces the risks associated with flooding. The study incorporates local practices, cultural values, and community approaches to improve the living conditions of residents while promoting harmonious coexistence with their immediate environment. Beyond the Cameroonian context, this approach offers an innovative and replicable model of climate adaptation for other vulnerable coastal areas.

Keywords: *Coastal Resilience, Flooding, Housing, Douala 6, Climate Adaptation.*

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I. INTRODUCTION

Nearly half of the global population resides in coastal zones, making them central hubs for trade, fisheries, tourism, and urban development. However, these strategic zones are under increasing pressure from climate-induced hazards: maritime intrusion, coastal retreat, and episodic flooding. The IPCC projects that by 2050, hundreds of millions of people in low-lying coastal areas could be displaced or exposed to severe flooding risks. In Africa, rapid urbanization, unregulated land use, and the degradation of natural buffers such as mangroves amplify these vulnerabilities. Cameroon exemplifies these challenges along its 402 km Atlantic coastline, where urban expansion in the Wouri estuary has intensified environmental degradation and flood risks, particularly evident in Douala 6, the metropolis's only insular district.

While existing research has focused extensively on large-scale infrastructural responses, less attention has been devoted to housing as a critical component of coastal resilience strategies. Conventional building practices, often unsuited to estuarine environments, tend to exacerbate vulnerabilities rather than reduce them. Moreover, policies rarely integrate local community knowledge and adaptive strategies developed through long coexistence with coastal hazards. This gap necessitates innovative approaches to inhabiting coastal spaces that are both technically resilient and socially embedded.

This study addresses this void by examining adaptive housing strategies as resilience mechanisms in flood-prone coastal areas. Using Douala 6 as a case study, the research combines field surveys, architectural analysis, and community perspectives to develop resilient housing models that integrate climate adaptation with local materials and cultural values. Beyond its local application, this framework contributes to global coastal resilience discourse by offering a replicable model for vulnerable coastal territories across Africa and beyond.

II. PRESENTATION OF DOUALA 6

Douala 6th is the only island district of Douala. It is located in the Wouri estuary, facing the Atlantic Ocean, approximately 30 km southeast of the urban center of Douala, with an estimated area of between 300 and 400 km² according to the National Institute of Cartography (INC). Geographically, the district is bounded (see Figure 1):

- To the north, by the mangroves, Wouri estuaries, and wetlands of the Douala-Edéa National Park;

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- To the east, by the Dibamba River and marshy areas separating it from Bonabéri;
- To the south, by a direct opening onto the Atlantic Ocean;
- To the west, by channels and waterways that provide a river connection with the port of Douala.

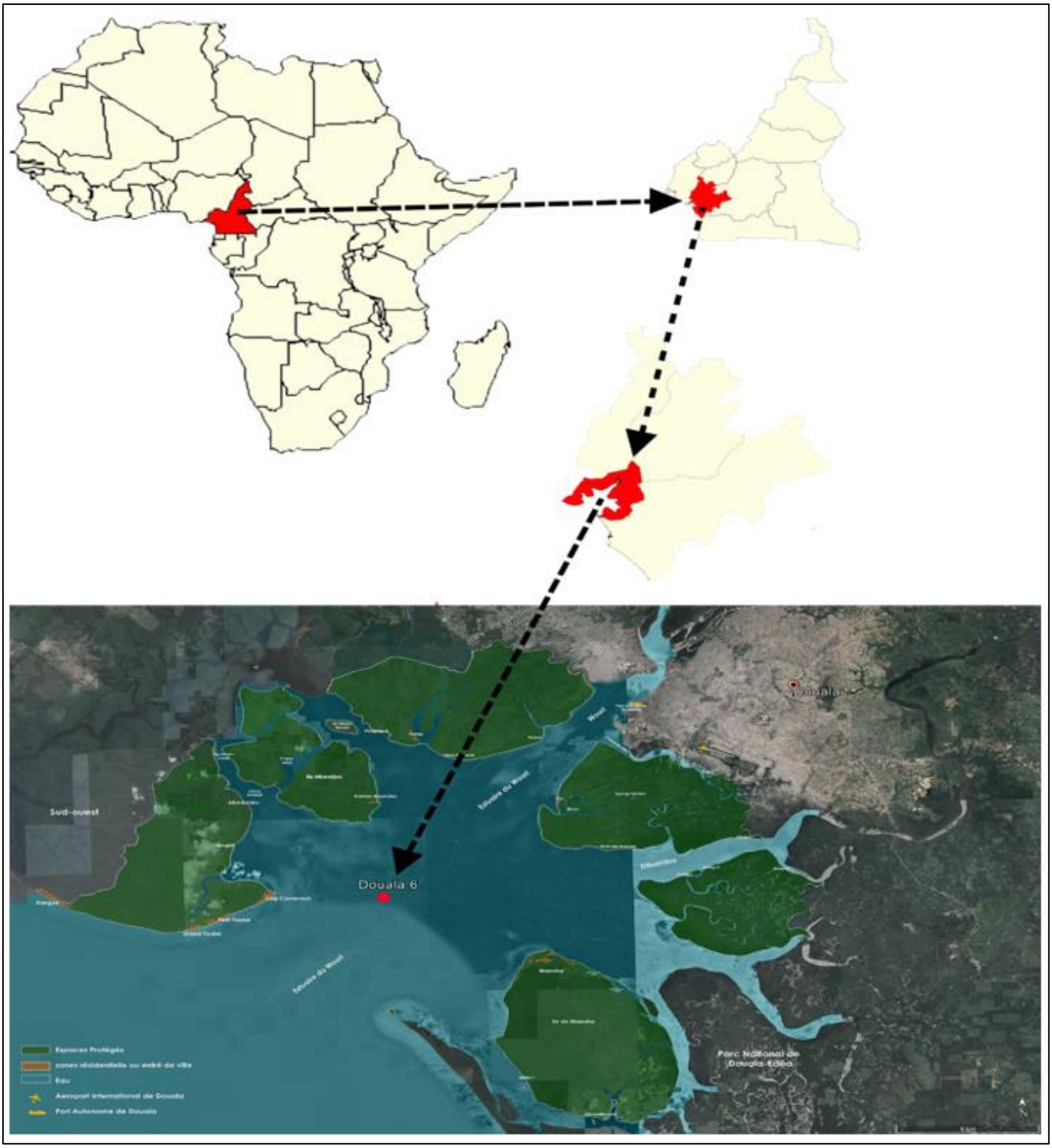

Fig 1 Geographical Location of Douala 6

A. Environmental Analysis

➢ *Climate*

Manoka has a maritime equatorial climate with four distinct seasons. Temperatures range from 24.4°C (August) to 26.9°C (March), with a humidity level of 83-88% (Climate data.org; 2025). The average wind speed is 4.34 m/s (Globalwindatlas.info; 2020). Estimated annual sunshine amounts to 1500-1700 hours, or 4.4 hours/day on average (Figure 2).

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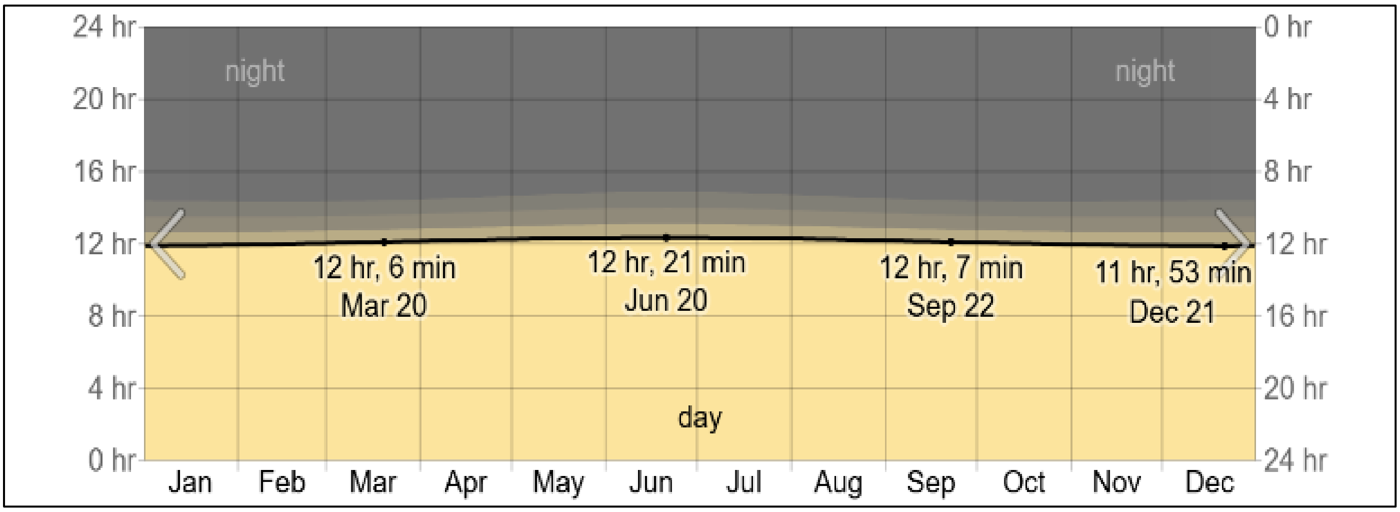

Fig 2 Annual Sunshine in 2024
Source: Weather Spark

➢ *Topography and Vulnerability*

The island's topography is particularly vulnerable: an average elevation of 12 meters, with 70% of the island's land area less than 10 meters above sea level. The highest point reaches 31 meters, while the overall average elevation is only 4.5 meters (Figure 3), directly exposing the majority of homes to the risk of submersion.

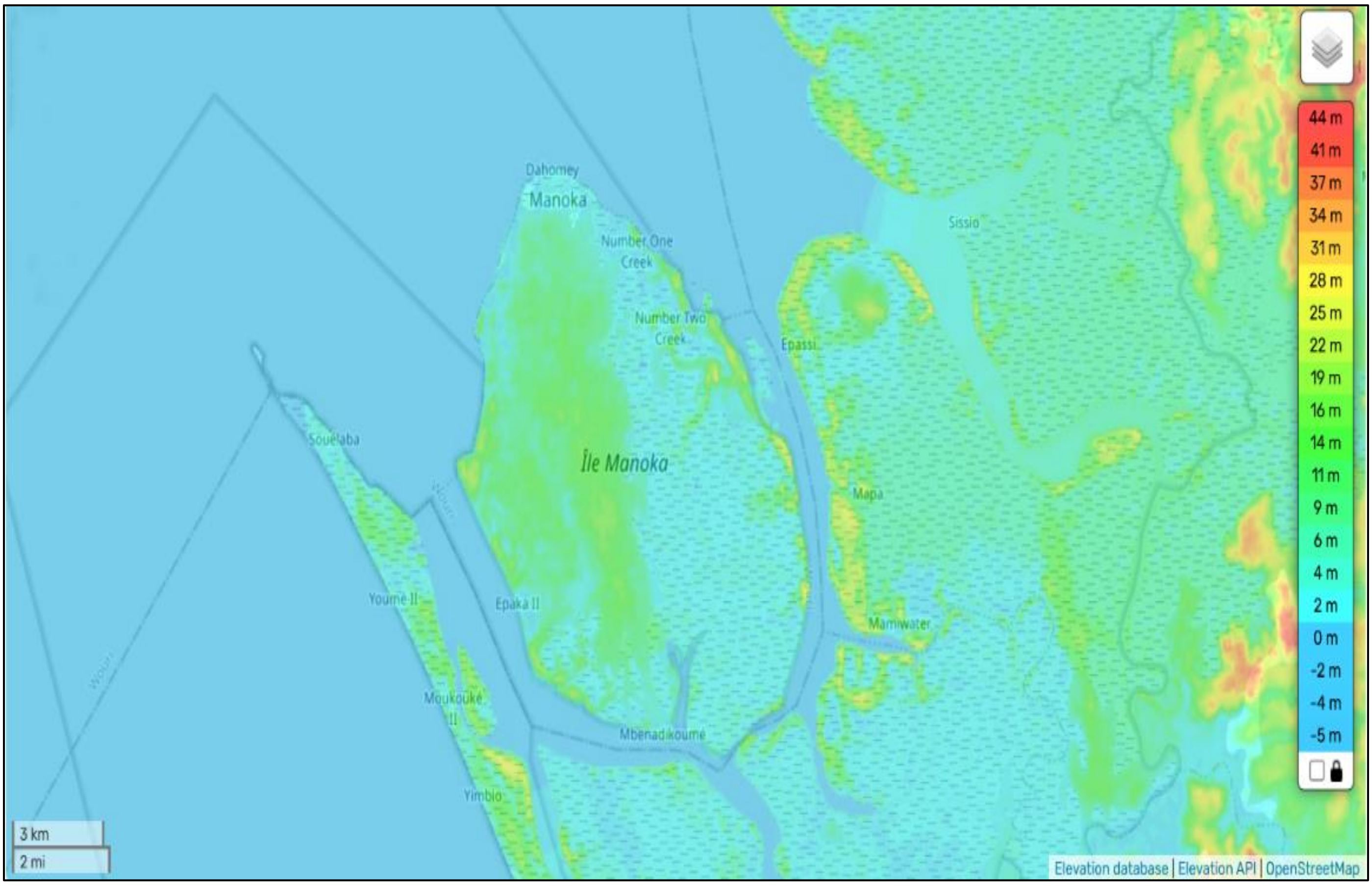

Fig 3 Topography of Manoka
Source: OpenStreetMap

➢ *Environmental Degradation*

Mangrove forest cover declined by 14% between 1986 and 2018, now representing only 56% of the island. This decline is the result of human exploitation: construction of mangrove plank dwellings, canoe manufacturing, and especially fuel for smoking fish (750 m³/year according to Cameroun Ecologie). This degradation accelerates coastal erosion and increases vulnerability to flooding (Figure 4).

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Fig 4 Destruction of a Mangrove Forest

➢ *Basic Infrastructure*

The island has essential facilities: a medical center, two primary schools, a high school and a technical college, administrative structures (sub-prefecture, town hall), security forces, telephone coverage (Orange, MTN), and a few solar power plants. These infrastructures, although present, remain limited in light of the needs of an island population exposed to climate risks.

B. *Socioeconomic Profile*

➢ *Economic Activities*

Manoka's economy is based on a variety of informal activities focused on the exploitation of local natural resources. Our survey of 50 households (300 inhabitants) reveals nine main sectors of activity: fishing (dominant activity), agriculture, hunting, mangrove timber trade, transportation services, fish smoking, small businesses, public services, and tour guiding (Figure 5).

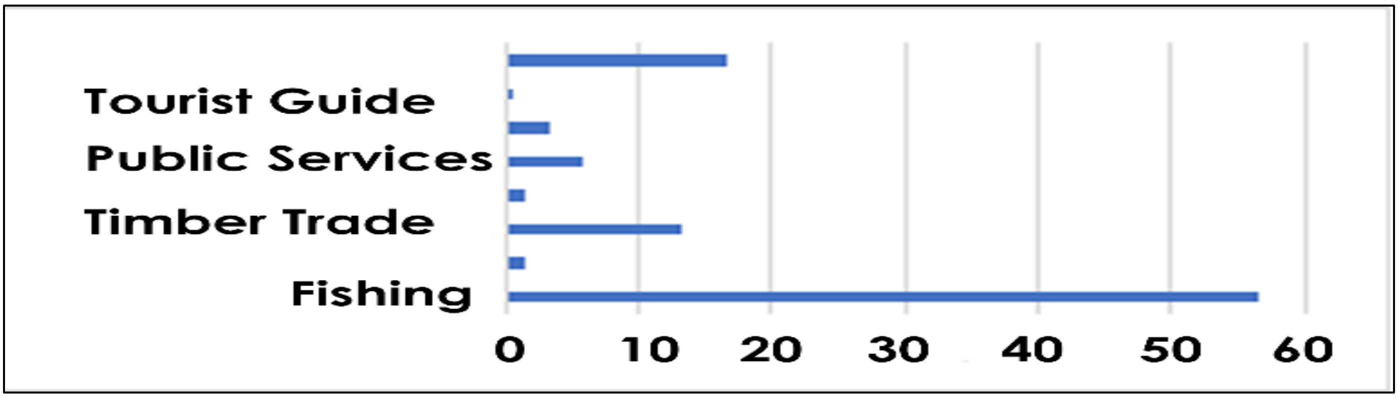

Fig 5 Distribution of Economic Activities on Manoka Island

This subsistence economy illustrates the centuries-old adaptation of island communities to the constraints and opportunities of their estuarine environment, where each family typically combines several activities depending on the seasons and resource availability.

➢ *Revenue Structure*

The income analysis highlights widespread economic insecurity despite this diversification of activities. While 15% of respondents refused to declare their income, the data collected reveal a predominantly vulnerable population: 18% of households survive on less than 30,000 CFA francs/month, 35% have between 30,000 and 70,000 CFA francs, while less than 10% earn more than 100,000 CFA francs per month (Figure 6).

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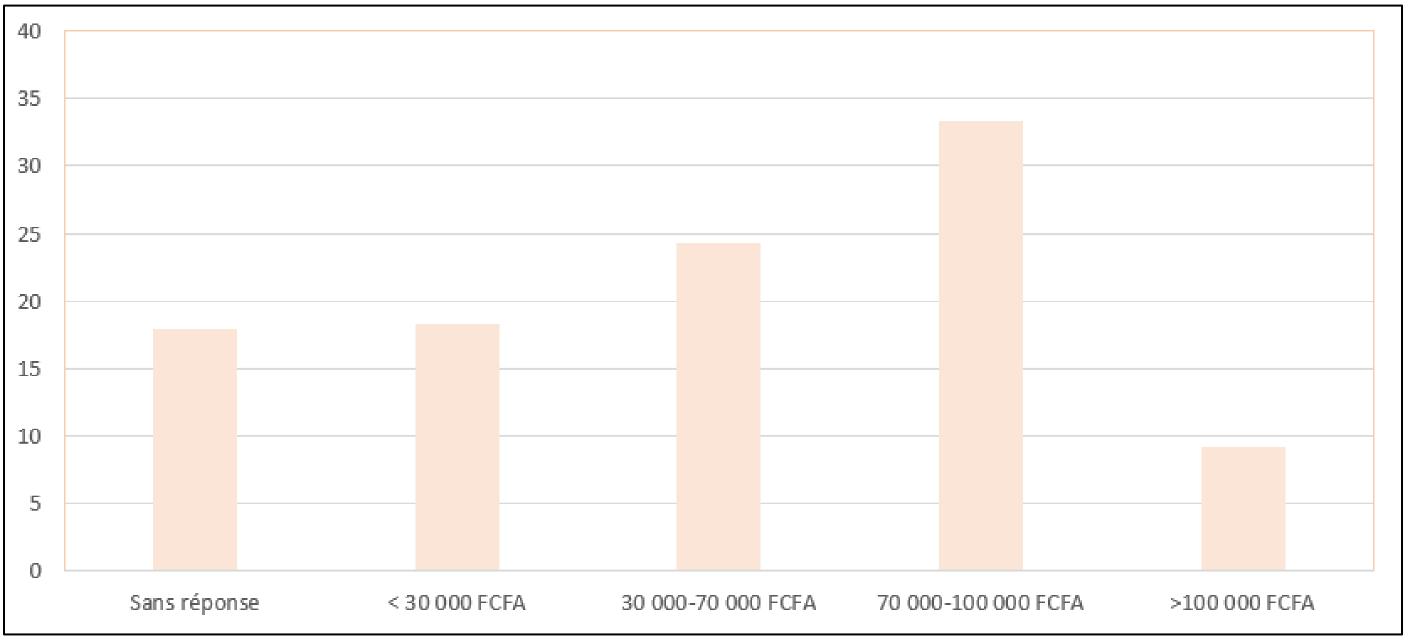

Fig 6 Monthly Household Income

The average income, estimated at 46,000 CFA francs, although slightly higher than the guaranteed minimum wage of 36,720 CFA francs, keeps all families in a situation of chronic financial insecurity, limiting their ability to invest in improving their living conditions in the face of flood risks.

C. Territorial And Demographic Organization

➢ *Population and Growth*

Douala 6 is an archipelago of thirty settlements historically inhabited by the Malimba. With an annual growth rate of 4-5%, the population has increased from 10,000 inhabitants (INS, 2015) to approximately 15,000 in 2023, spread across the settlements of Manoka, Kombo Moukoko, Cap Cameroun, Petit Toube, and Kangue. Projections suggest 30,000 inhabitants in 2035, highlighting the urgent need for appropriate development.

➢ *Hybrid Governance*

The administrative organization combines state authorities (sub-prefect, mayor, security forces) and traditional authorities (island and camp chiefs). This hybrid governance reflects the coexistence of administrative modernity and customary Malimba-Bakoko structures.

➢ *Social Composition*

The population is a mix of indigenous people (Malimba, Bakoko) and regional/international migrants (Nigeria, Benin, Niger) attracted by fishing. Social organization is based on mono-ethnic or regionally affinity camps, horizontal solidarity for daily activities, and informal structures (vigilance committees, associations) ensuring social mediation and security.

➢ *Spatial Occupancy*

Of the 36,800 hectares of municipal land area, only 226.74 hectares (<1%) are inhabited. Manoka accounts for 58.84 hectares of urbanized areas, or 25% of the total land area, as the administrative and economic center. Accelerated urban development (Table 1) shows an increase from 11.18 hectares (2000) to 58.84 hectares (2025), with an urbanization rate reaching 2.61 ha/year.

Table 1 Evolution of Land use

Year	**2000**	**2011**	**2016**	**2025**
Urbanized Area (ha)	11.18	23.62	35.31	58.84
Rate (ha/year)	-	1.14	2.34	2.61

This spatial concentration reveals significant development potential but raises critical challenges of accessibility, vulnerability to flooding and preservation of coastal ecosystems.

D. Critical Analysis of Living Modes

This analysis examines the evolution of housing strategies in the face of flooding constraints on Manoka Island, revealing three distinct models of architectural adaptation.

➢ *Legacy of the German Period (1884-1916)*

During German colonization, Manoka Island experienced a phase of economic prosperity marked by the establishment of the Société Nationale de Commerce du Bois (SNC Bois), specializing in azobé logging. This company attracted thousands of workers in the early 1900s, generating unprecedented urban development. Although their departure occurred, all the buildings on Manoka Island (Figure 7) demonstrate relevant adaptation strategies developed by the Germans:

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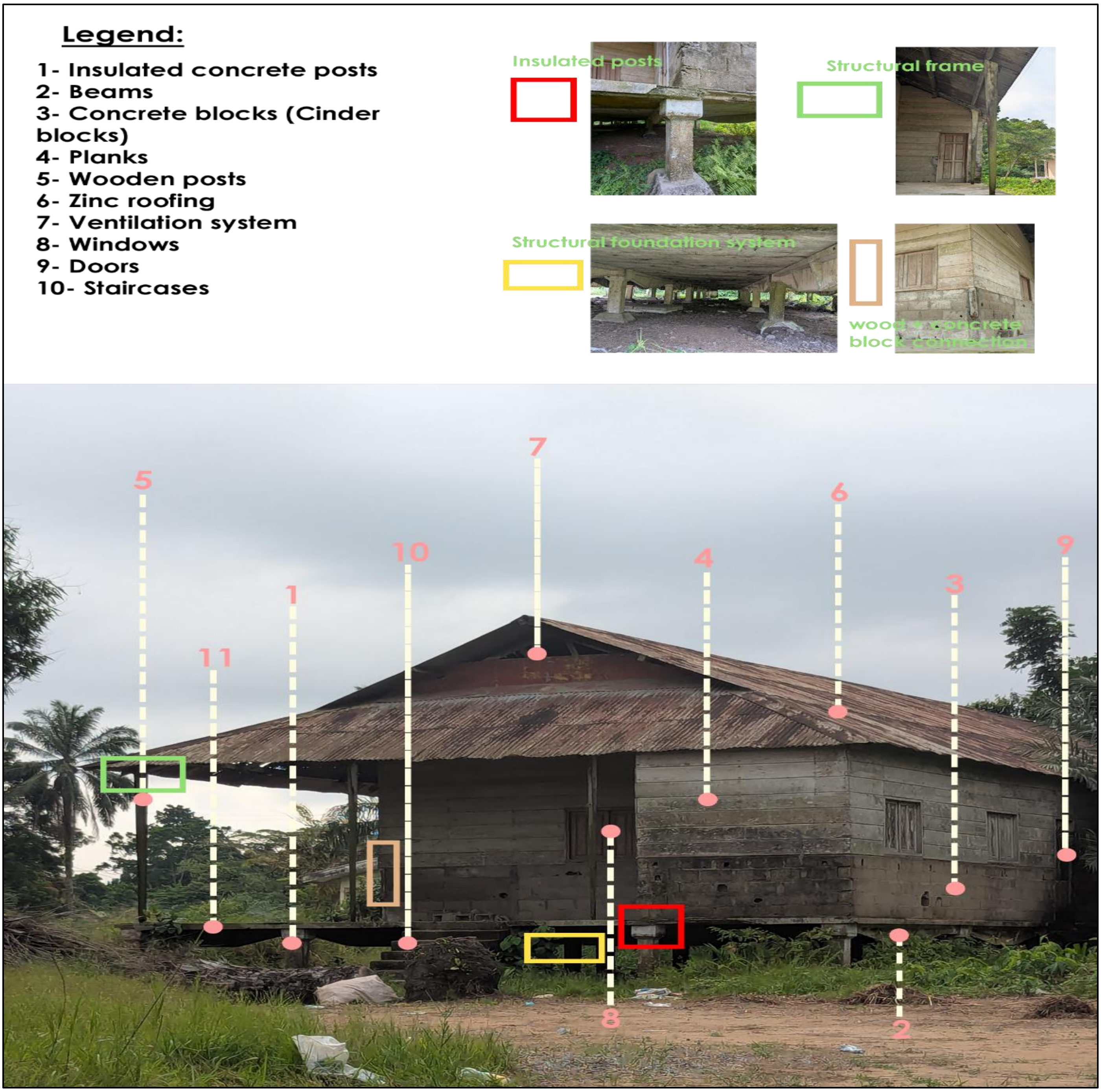

Fig 7 Analysis of a German Building on the Island of Manoka

- *Among these Remarkable Technical Features are:*

✓ Foundations on stilts: made with insulated concrete posts, they allowed for a stable installation on the island's sandy and unstable soils, ensuring sufficient elevation against rising water;
✓ Solid slab floor: contributing to structural strength and limiting the risk of infiltration;
✓ Mixed use of materials: concrete block foundations (cinder blocks) supporting tall wooden structures, a hybridization that reinforced the building's durability while adapting to local resources;
✓ Steeply pitched hipped roofs: facilitating rainwater runoff, typical of resilient architecture in tropical areas;
✓ Zinc sheet roofing: a lightweight and durable material, still widely used today.

➢ *Traditional and Self-Building Housing Styles*

Following the establishment of the Société Nationale de Commerce Bois by the Germans on the island of Manoka towards the end of the 19th century, a paradigm shift took place: the colonial architectural model, which was more massive, taller and more geometric, using so-called 'noble' materials, began to influence local perceptions. Some indigenous families, particularly those in direct contact with the colonial administration or industry, sought to replicate this model, perceiving it as synonymous with progress, respectability and even social advancement.

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However, this imitation was partial and often constrained by economic realities. Lacking the materials or technical know-how of the settlers, these populations developed a hybrid form of housing: houses inspired by the colonial structure but built from raw wood, recycled sheet metal, or salvaged elements. The intention to "build like the settlers" thus evolved into a modernized vernacular self-construction, combining aspiration and adaptation (see Figure 8).

Fig 8 House Based on a Vernacular Self-Build Practice in Manoka

But then, with demographic changes, rural exodus, and the saturation of planned spaces, self-build practices have become widespread in Manoka, outside of any formal framework. These forms of housing rely on locally available resources, the transmission of informal know-how, and immediate use logic, often in response to emergency or precarious situations. Today, two main categories of self-build can be distinguished in the area:

➢ *Self-Construction Inspired by the Colonial Model*

This style aims to imitate German houses built during the colonial period. They have a double-pitched roof, visible basements, compact volumes, and distinct internal divisions. However, due to limited technical and financial resources, the materials used are adapted to the residents' budget (see Figure 9):

- For the elevations, the following are usually used: concrete blocks + planks, nailed planks, and reclaimed wood posts;
- A double-pitched roof with zinc or recycled material sheets and a simple frame;
- Foundations are not very high, rarely reinforced concrete and usually cinder blocks.

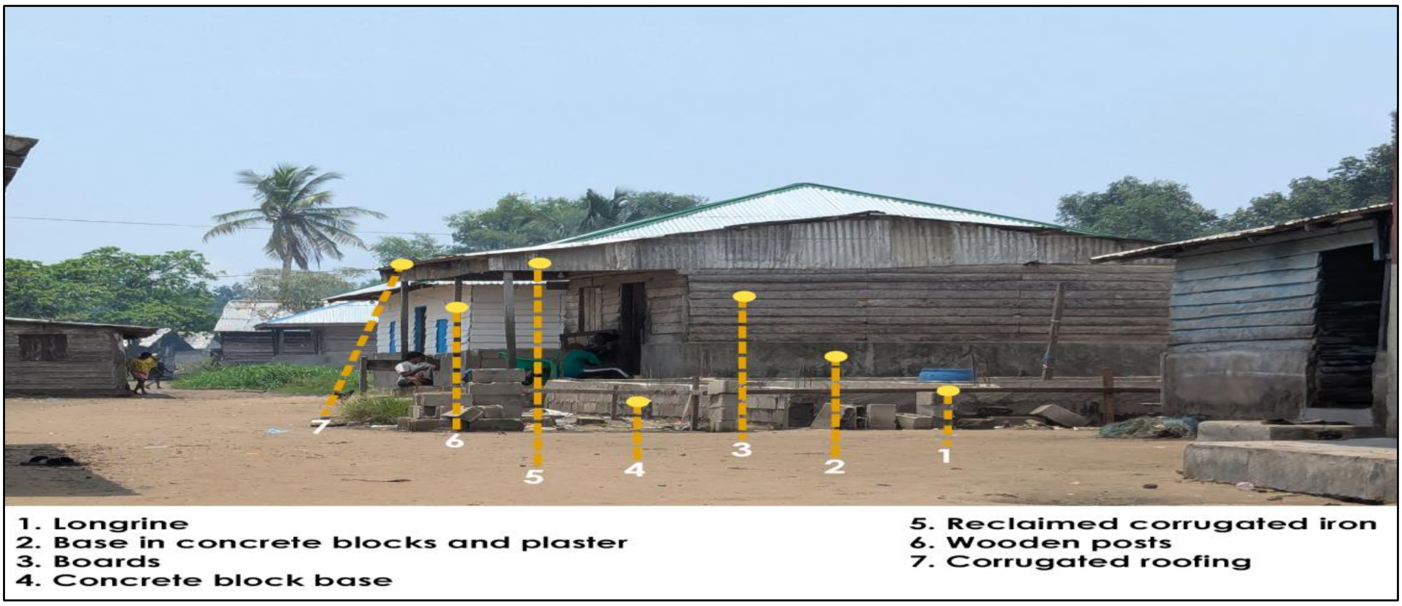

Fig 9 Self-Construction Inspired by a Colonial Model

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➢ *Self-Construction using Recycled Materials*

Alongside these imitative forms, another, more radically pragmatic practice is developing: construction with recycled materials, sourced from the port, the sea, abandoned construction sites, or repurposed elements (see Figure 10). These practices are developed in spaces occupied by immigrant communities. They include:

- Walls made of wood, rusty sheet metal, stretched plastic, or cement bags;
- Roofs made of heterogeneous pieces, often pierced or poorly secured;
- Foundations made of wooden stilts or houses directly in contact with the ground.

Fig 10 Self-Construction using Recycled Materials

Although considered non-compliant, these constructions demonstrate the adaptability of local residents, who themselves develop construction solutions that provide shelter. The Strengths and challenges of these housing models are summarised in Table 2.

Table 2 Advantages and Disadvantages of Self-Construction using Recycled Materials

Type of Self-Build	Advantages	Disadvantages
mitative of the colonial model	Modern appearance, organized structure, social recognition	Unsuitable materials, poor durability, low resistance to weather
Based on recycled materials	Very low cost, quick response to needs, local ingenuity	Unsanitary, high risk of collapse, maximum exposure to hazards

➢ *Regulatory or Modern Housing Styles*

Regulatory or modern housing styles refer to recent constructions, generally resulting from a desire to adapt to urban standards, often under the influence of public policies or external actors (NGOs, private investors, pilot development projects). Although still rare and not widespread in Manoka, these housing forms reflect a growing trend towards formalization and progressive urbanization of the island territory. These constructions are distinguished by the following features :

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- Industrialized materials and more solid foundations: Unlike precarious self-builds, so-called regulatory houses rely on reinforced concrete foundations, using cement blocks, structured reinforcement, and sometimes insulation.
- Standardized roofs and integrated ventilation systems: Gable roofs made of galvanized sheet metal or steel decks are better secured, sometimes equipped with gutters for rainwater collection.
- Functional interior organization: spaces are compartmentalized according to a standardized plan, inspired by formal urban housing.
- Elevation above ground level: some recent houses are raised by 50 to 80 cm, in particular due to technical recommendations or aesthetic needs.

Figure 11 illustrates typical examples of so-called modern housing observed in Manoka, characterized by a complete masonry structure, a sheet metal roof, and reinforced paving. These buildings, although more expensive, are mostly public establishments funded by the State. They reflect a desire to establish minimum safety standards while initiating a dynamic transformation of the local urban fabric towards greater formality and sustainability.

Fig 11 Typical Example of Modern Housing on Manoka Island

However, their accessibility remains limited for a majority of residents due to the high cost of materials and the lack of basic services (water, sanitation, electricity) to support full urbanization. Furthermore, these constructions do not always take into account the island's specific climatic and geotechnical characteristics, which can paradoxically generate new vulnerabilities if they are not properly adapted.

E. Assessment of Local Adaptation Practices and their Limits

Faced with the environmental constraints specific to the Cameroonian coastline, particularly in the municipality of Douala VI, local populations have developed, over time, various adaptation practices to cope with flooding, chronic humidity, and soil instability. These vernacular adaptation strategies demonstrate both empirical knowledge of the environment and an ability to innovate with limited resources.

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However, these practices also exhibit significant limitations, both technically and in terms of sustainability. Among the most common practices are:

- The use of stilts made of local wood or concrete: Inherited from colonial construction and vernacular know-how, this system involves raising homes to limit damage from rising water during the rainy season or high tides. However, this solution has significant limitations in its local implementation: the observed elevation heights rarely exceed 1 meter, which remains insufficient in the face of extreme flooding. Furthermore, anchors are often implemented in a cursory manner, without adequate reinforcement or prior soil studies, exposing the entire structure to instability or even partial collapse during severe weather events;
- Mixed materials or the use of concrete blocks: Aware of the weaknesses of structures built entirely from lightweight or reclaimed materials, some residents with slightly higher economic power opt for hybrid construction solutions. These primarily involve a combination of concrete blocks (at the foundation or base level) and wooden planks at the top. Others, more rarely, prefer construction entirely from concrete blocks. This trend reflects a local attempt at structural consolidation, aimed at improving weather resistance and reducing frequent post-flood collapses. However, these efforts remain limited by the high cost of materials, the lack of technical training, and the absence of institutional supervision for safe construction in flood-prone areas;
- Embankments: Within the island, some occupants choose to fill in naturally wet or flood-prone areas with sand in order to build homes there. This strategy aims to artificially raise the ground to limit the direct impact of stagnant water or rising water during the rainy season. However, this practice, carried out without technical supervision, has many limitations. The backfilling, often partial and irregular, leads to poor load distribution and instability of the foundations, exposing the buildings to the risk of subsidence. In addition, by disrupting the natural functioning of the wet soils within the island, this method worsens the water saturation of the land and can cause delayed flooding in neighboring areas. Finally, the resulting soil depletion and destruction of microfauna weaken the ecological capacity of the site to absorb excess water (see Figure 12);

Fig 12 Construction on Wetlands within the Island

- Construction of a seawall: Faced with rising water levels and recurring flooding, local residents, with the support of municipal authorities, have undertaken the construction of a seawall to limit marine intrusion and coastal erosion. This initiative demonstrates a desire to act collectively in the face of the site's growing vulnerability. However, the structure is now showing visible signs of deterioration (see Figure 13). Poor anchoring to the ground and poor foundation selection are compromising its stability. Without regular maintenance, the seawall is gradually subsiding, significantly reducing its effectiveness in the face of climatic hazards.

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Fig 13 Gradual Collapse of the Seawall on Manoka Island

- Implementation of a drainage system: To limit the stagnation of rainwater inland, local authorities have installed drains to channel water toward the coast (see Figure 14). This system is primarily intended to dry out low-lying inhabited areas by facilitating water drainage toward the banks. However, this system remains ineffective in the long term. Indeed, the canals are rarely maintained and are often obstructed by vegetation. Furthermore, during high tides or seasonal floods, water struggles to flow outward, causing a backflow that worsens the situation and exacerbates flooding along the coast;

Fig 14 Drain, Draining Water from Manoka Plateaux Towards the Coast

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- Cohabitation with hazards: Some residents, having already been victims several times, have resolved to measure the maximum water level at each flood and thus define the height of their riverbed to protect themselves from flooding. This is the case in the Nyangadou and Dahomey neighborhoods of Manoka, which are predominantly occupied by Nigerians. Figure 15 illustrates the situation.

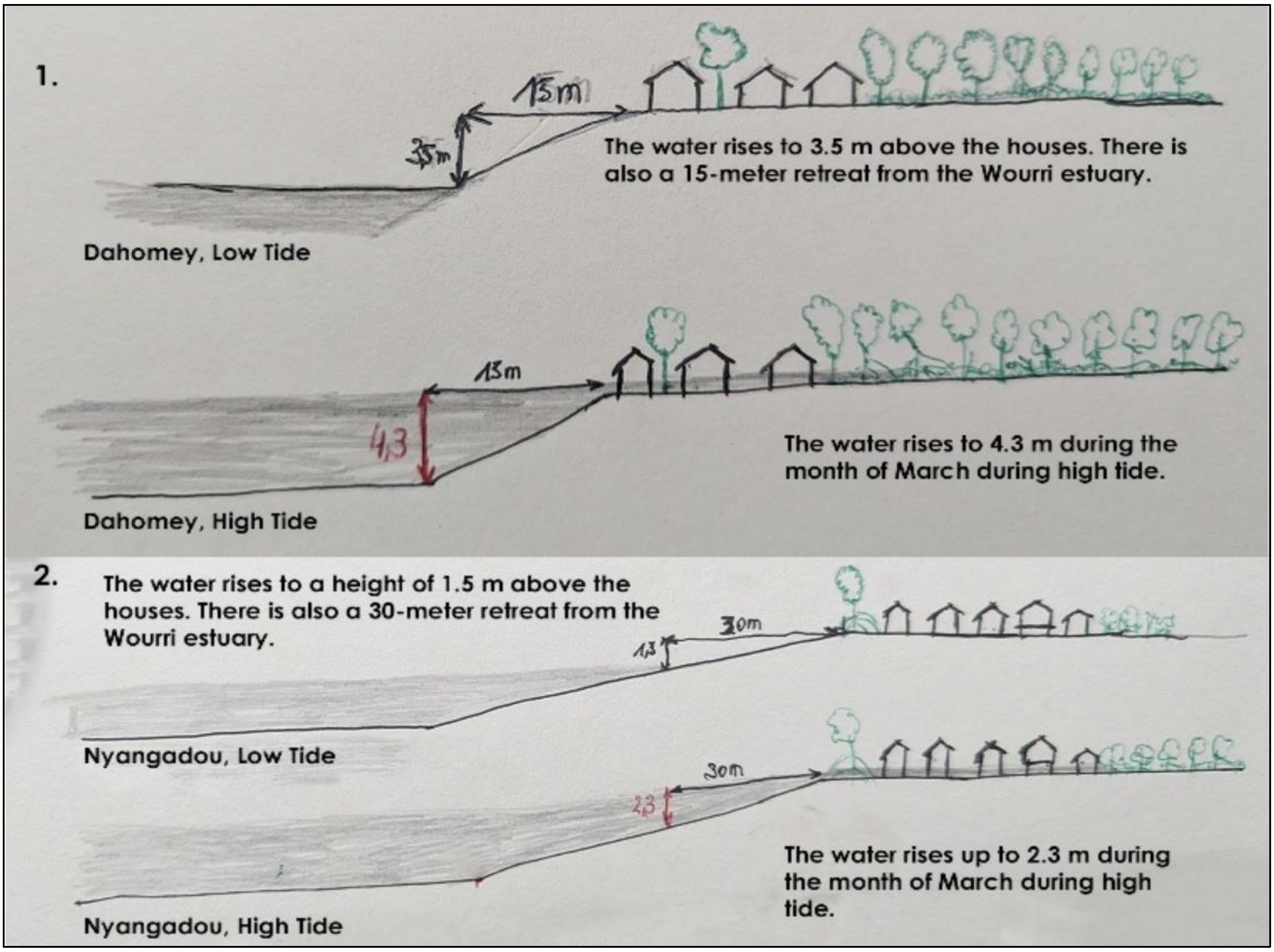

Fig 15 Behavior Adopted by Local Residents During High Tide

III. GUIDING PRINCIPLES FOR RESILIENT HOUSING AND A REGULATORY FRAMEWORK

Given the growing vulnerability of coastal areas such as Manoka Island to flood risks, it is imperative to define guiding principles that can guide the transformation of housing patterns toward greater resilience. These principles must be integrated into the local context, leverage existing socio-spatial dynamics, and align with planning policies and regulations.

A. Design Criteria Adapted to the Local Context

Housing resilience refers to the capacity of a residential system to absorb shocks and adapt to environmental changes. For Manoka, this implies:

- Morphological adaptability: structures that can be adapted to changing water levels;
- Sustainable and accessible materials: treated wood, recycled materials, lightweight structures;
- Spatial flexibility: multifunctional spaces, autonomous systems (water, waste);
- Climate adaptation: orientation, natural ventilation, passive water management.

B. Integration of Vernacular Knowledge and Local Practices

The analysis of self-construction methods in Manoka highlights local resilience logics, albeit sometimes precarious. These practices, often ignored by current regulations, could nevertheless be promoted through:

- Formalization of local best practices: highlighting and regulating construction techniques on stilts, the use of embankments, or natural drainage systems;
- Technical and regulatory support for self-construction: development of resilient construction guides, simplified standards adapted to the island context, and institutional support for the regularization of informal settlements;

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- Recognition of the right to build in specific areas with conditions: definition of flexible building zones subject to the adoption of mandatory resilience measures (light roofs, minimum floor heights, water drainage systems, etc.);
- A revision of the local urban planning code to integrate the realities of the territory, in line with the objectives of the Douala Urban Master Plan (PDU) and the guidelines of the National Territorial Development Plan (SNAT).

C. Technical Innovations and Appropriate Materials

Given the environmental, economic, and social constraints of the Cameroonian coastline, and more specifically of Manoka Island, the adoption of efficient technical innovations and appropriate materials is becoming an essential lever for strengthening housing resilience. These solutions must meet the dual requirements of adaptability to flooding and accessibility for local populations.

➢ *Construction Techniques Adapted to Wetlands*

In coastal areas with high hydrological variability, construction choices must integrate water level management, constant humidity, and the absence of conventional infrastructure. The following techniques address these challenges:

- Modular raised foundations: using adjustable pilings or hybrid platforms combining pilings and floating systems, reduce the impact of rising water, particularly during high tides or seasonal flooding. These foundations, often made from plastic drums, hardwood piles, or raised concrete blocks, offer an accessible and scalable alternative to traditional foundations. They also allow for better soil ventilation, reducing the effects of humidity on structures;
- Ventilated lightweight roofs: The integration of steeply sloped roofs promotes rapid rainwater runoff, limiting infiltration. Made from steel decks, recycled sheet metal, woven plant fibers, or laminated bamboo, these lightweight roofs are compatible with wooden structures. In addition, their design can include natural ventilation features (skylights, high openings), helping to improve interior thermal comfort in hot and humid climates (see figure 16);

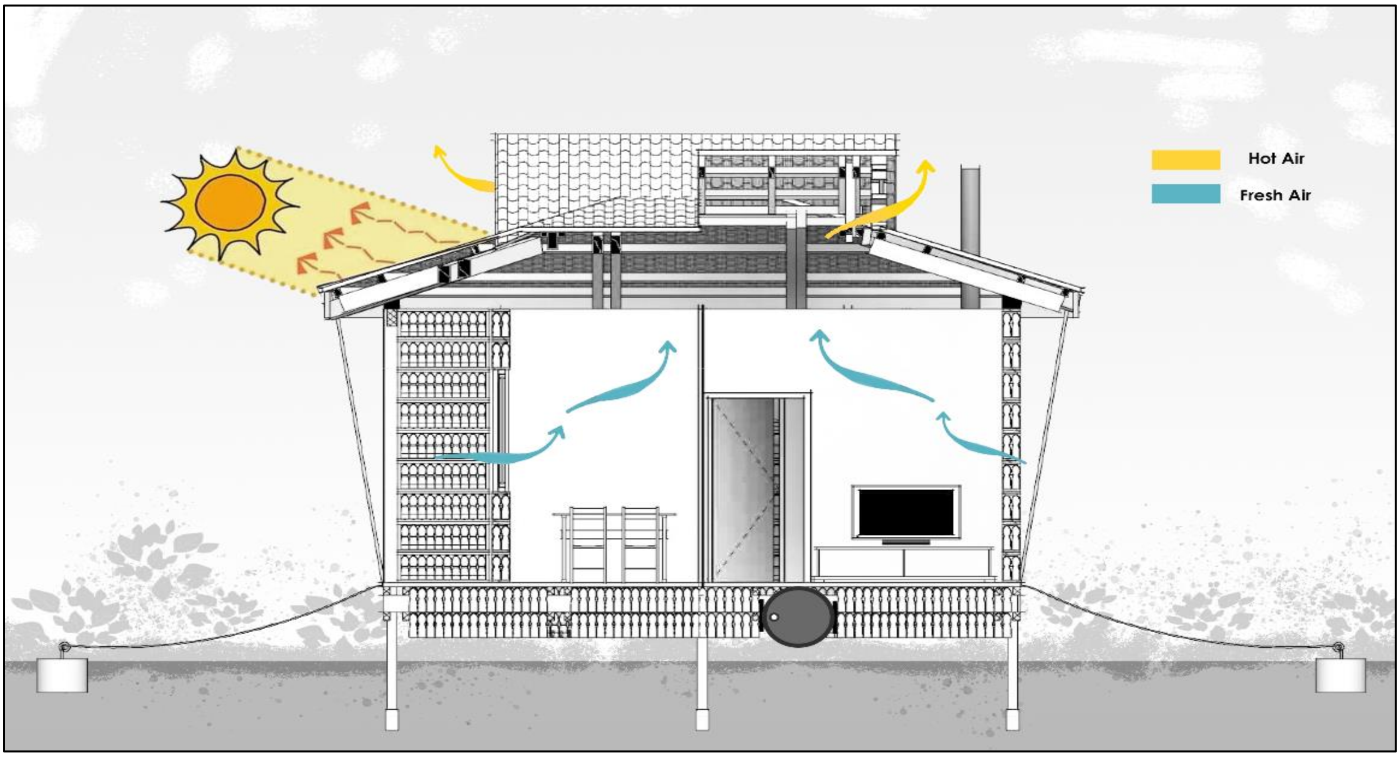

Fig 16 Natural Ventilation System

- Reversible assembly systems: The use of removable assembly techniques (mortise and tenon joints, bolting, doweling) not only facilitates self-construction, but also facilitates maintenance, reconfiguration, or deconstruction of the home as needed. This structural reversibility is particularly relevant in contexts of land instability or frequent resettlement after disasters.

➢ *Local and Recycled Materials*

The adoption of sustainable, locally available or reclaimed materials is an important lever for economical, ecological, and resilient architecture in island areas.

- Treated local woods (iroko, azobé, padouk): These species, naturally resistant to moisture, insects, and fungi, are particularly suited to humid tropical environments like Manoka. Azobé, very dense and rot-resistant, is ideal for stilts and load-bearing frames. To extend their durability, natural treatments such as linseed oil, immersion tanning, or surface carbonization can be applied, thus reducing the use of expensive and unavailable chemicals;
- Recycled materials: Recycling plastic drums, used tires, sheet metal, pallets, and other industrial waste offers accessible alternatives for the construction of non-load-bearing elements, thermal insulation, or the creation of

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integrated furniture. This experimental self-construction approach, widely documented in community initiatives in West Africa, strengthens social resilience while reducing the ecological footprint. In an island context, it also promotes streamlined logistics, reducing dependence on materials imported from the continent.

➤ *Integration of Resilience Equipment*

Improving living conditions in flood-prone areas requires the integration of simple, autonomous technical systems adapted to the access constraints and vulnerability specific to island environments. This equipment helps reduce dependence on centralized infrastructure, which is often absent or dysfunctional in Manoka.

- Rainwater collection and storage systems: In a context marked by the absence or insufficient access to drinking water, the installation of rainwater harvesting systems is a relevant supplementary solution. The installation of gutters coupled with storage tanks, as well as the integration of rudimentary filters made from sand or activated carbon, make it possible to ensure a minimum domestic water supply, particularly during the rainy season. These systems, inexpensive, easy to maintain, and adaptable to lightweight construction, meet the basic needs of coastal populations(See Figure 17);

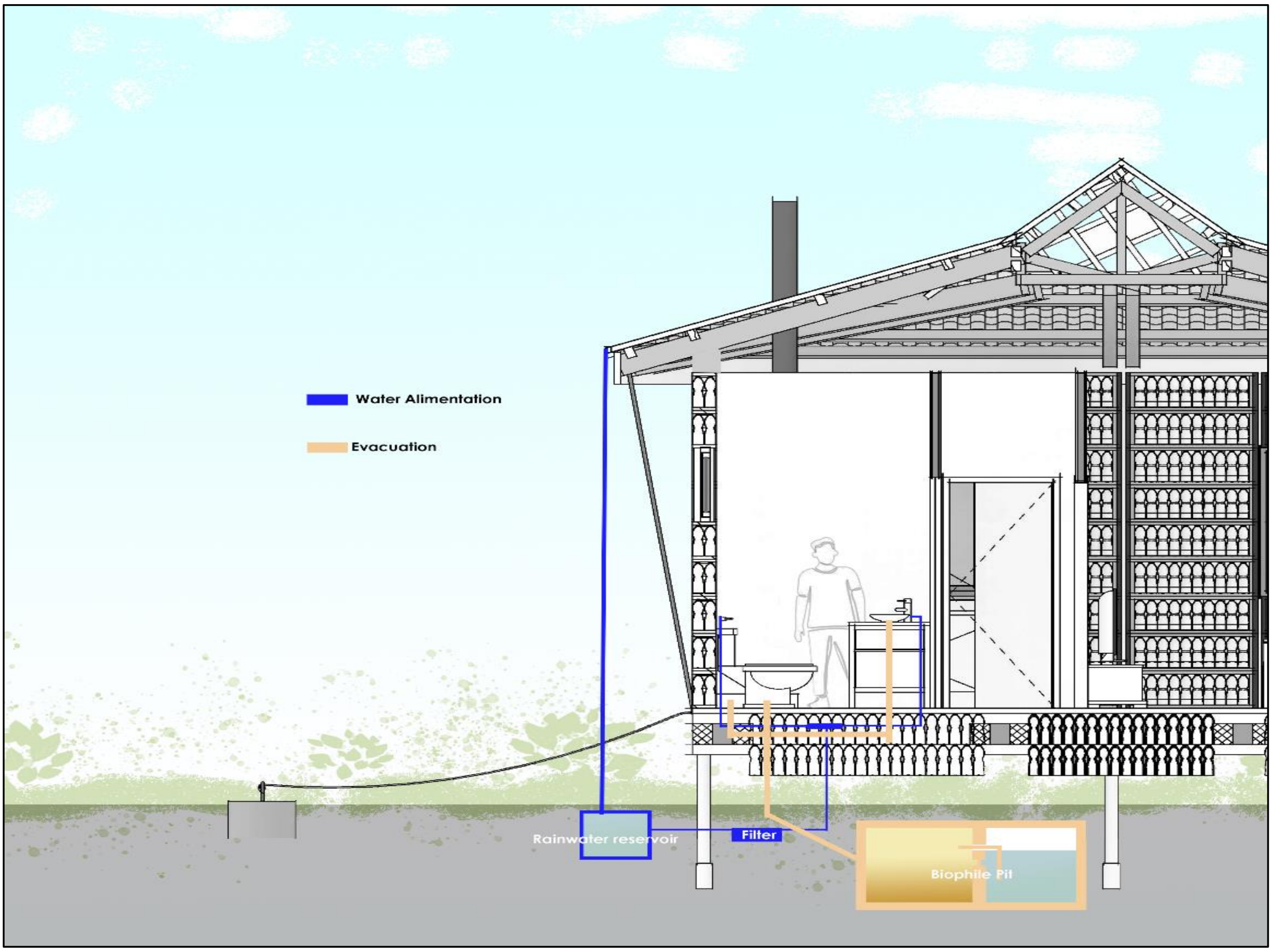

Fig 17 Eco-Friendly Water Management

- Above-ground ecological sanitation: The installation of dry toilets, improved ventilated pits, or raised latrines makes it possible to maintain minimum sanitary conditions while preventing the infiltration of fecal matter into waterlogged soils. These solutions, already tested in island or marshy areas (such as Benin and Bangladesh), contribute to the preservation of the water table and the reduction of waterborne diseases ;
- Solar microgrids and autonomous lighting: In isolated areas such as Manoka Island, access to electricity remains limited or nonexistent. The integration of low-power photovoltaic solar kits (5 to 100 W) makes it possible to cover essential energy needs such as domestic lighting, charging mobile devices, and powering small equipment. These devices, easy to install and maintain, strengthen the energy autonomy of households while improving night-time safety. Their efficiency can be optimized by a renewable backup source, such as a micro-wind turbine, thus contributing to resilient and decentralized energy management (see figure 18).

Fig 18 Solar Energy Autonomy

IV. PROPOSALS FOR LOCAL REGULATIONS FOR THE OPERATION OF FLOOD ZONES

In a context of increased vulnerability to flooding, particularly in island areas such as Manoka, regulatory oversight of land use is becoming an essential condition for building resilient housing. Appropriate regulation should guide urbanization practices, reduce risks, and preserve environmental balances. The following proposals aim to lay the foundations for a local, contextualized, and operational regulatory framework:

➢ *Regulatory Zoning of Vulnerable Areas*

Zoning is a fundamental lever for regulating land use based on vulnerability levels. In the specific case of island areas such as Douala VI, this zoning must not only integrate natural risks, but also the protection of ecosystems and the viability of living spaces. The following are proposed:

- The establishment of a municipal zoning plan, based on detailed mapping of altitudes, slopes, historical flood levels, and tidal dynamics. This zoning should distinguish between high-, moderate-, and low-risk areas and serve as the basis for all urban development decisions;
- The establishment of ecological zoning specific to the islands, identifying areas with high biodiversity or high environmental value (mangroves, wetlands, spawning grounds, etc.) and strictly protecting them from any human occupation or exploitation. This zoning should balance habitat and conservation, placing the environment at the heart of development decisions;
- The restriction or prohibition of permanent construction in very high-risk areas, in favor of removable, elevated, or floating structures, specifically designed to minimize human and material losses during flooding. Any intervention in these areas must demonstrate strong environmental and social relevance;
- The definition of non-buildable buffer zones along banks, rivers and natural canals. These spaces, left free of any development, will allow for better water flow, reduce pressure on the banks and help prevent coastal erosion.

➢ *Mandatory Construction Standards in Floodplains*

Regulating construction in floodplains requires the adoption of rigorous technical standards specific to local hydrological and climatic constraints. These standards must guarantee the safety of occupants, the durability of structures, and the environmental compatibility of the materials and systems used. To this end, the following are recommended:

- Imposing a minimum elevation height for all new construction located on land identified as floodplains. This elevation, defined according to local topographical and hydrological data, aims to protect homes from rising water and seasonal flooding;
- Promoting hybrid foundations and modular construction systems, combining piles, floating platforms, and removable elements, to provide flexibility of use and gradual adaptation to changing water levels. These solutions also allow for easy maintenance and reduced reconstruction costs;
- Encouraging the use of materials suitable for humid environments, such as treated tropical wood (azobé), galvanized steel, or recycled composites, which offer good resistance to corrosion, humidity, and mechanical shock, while remaining accessible to local communities;
- Incorporating into building permits the obligation to install rainwater collection and storage systems, as well as ecological wastewater treatment systems. These systems strengthen household autonomy in times of crisis and

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reduce the environmental impact of human settlements.

➢ *Supervision of land use and occupation*

In a context of increasing vulnerability to climate hazards, rigorous supervision of land use in flood-prone areas is becoming a fundamental lever for territorial resilience. Urban planning must articulate land use logic, ecological preservation, and community safety through the following actions:

- The establishment of a simplified local land registry, adapted to the realities of island and peri-urban areas, to identify land status, formalize usage rights, and prohibit informal subdivisions in areas identified as high-risk. This registry could be developed with the participation of local communities and supported by participatory mapping tools;
- The encouragement of forms of collective or semi-collective housing, incorporating shared facilities and shared structures (elevated storage spaces, traffic walkways, water access points), in areas deemed suitable for urbanization. Such controlled densification optimizes the use of secured land, limits land use, and facilitates the maintenance of protective structures;
- The conditionality of public aid and development permits on compliance with local environmental standards, resilience requirements (elevation, materials, ecological devices), and consistency with the municipal zoning plan. This principle aims to strengthen territorial governance and encourage project leaders to adopt sustainable solutions adapted to the local context.

➢ *Governance and Community Participation*

The resilience of flood-prone areas cannot be effective without inclusive and appropriate local governance. It requires strong local roots and collective ownership of the issues by the communities concerned. To this end, several levers can be mobilized:

- The creation of local risk management committees, including traditional authorities, municipal elected officials, technicians (urban planners, architects, engineers), and resident representatives. These multi-stakeholder bodies would promote the coordination of initiatives, concerted decision-making, and the continuity of prevention and adaptation actions;
- The development of ongoing community awareness, through the organization of participatory workshops, development simulations, demonstrations of adapted housing models, and targeted information campaigns. These approaches strengthen local capacities, reduce institutional mistrust, and help embed resilience in daily practices;
- The implementation of participatory monitoring of the territory's development, based on regular field surveys, analysis of flood dynamics, and the capitalization of feedback after each critical episode. This mechanism allows for the gradual adaptation of standards, developments, and behaviors, incorporating residents' memories and local knowledge.

The proposals made regarding zoning, construction standards, and local governance aim to sustainably regulate the occupation of flood-prone areas while strengthening community resilience. This territorial regulation, combined with appropriate architectural choices, constitutes an essential lever for limiting risks along Cameroon's coastline. With this in mind, it becomes relevant to examine how these principles can be applied concretely in the specific context of Douala VI.

V. ARCHITECTURAL AND URBAN PLANNING PROGRAM

Faced with the resilience challenges identified in Douala VI, developing a suitable architectural program requires an integrated approach that combines local needs, environmental constraints, and innovative technical solutions.

A. Identified Needs and Specifications

The field analysis reveals priority needs that structure the project. First, housing must be flood-resistant while providing residents with minimal comfort. At the same time, energy and water autonomy are crucial in this island context. Furthermore, permanent accessibility is imperative, even during flooding. Finally, sustainable management of natural resources and construction flexibility based on user means complement these fundamental requirements.

➢ *The Technical Specifications are Based on Five Pillars:*

- Flood resilience: raised site or hybrid foundations, local moisture-resistant materials (treated wood, bamboo, recycled materials), permeable soils, and drainage systems.
- Resource autonomy: rainwater harvesting and filtration, renewable energy production (solar, wind), ecological sanitation (dry toilets, phytoremediation).
- Accessibility and mobility: raised walkways and paths, inclusive public spaces, continuity of communication with Douala VI.
- Functionality and comfort: modular spaces adapted to households and activities, natural ventilation, passive lighting, and solar protection.
- Scalability and local participation: expandable modular structures, supervised self-construction, and resident training.

B. Adapted Functional And Spatial Organization

The spatial organization is based on a micro-neighborhood structure, grouping housing units into blocks of eight housing units around central community spaces and vegetated buffer zones for water absorption. The project is structured according to a three-pronged zoning:

- Residential center: raised housing in compact blocks, protecting households from flooding;
- Economic hub: commerce and accommodation, located in flood-safe areas;
- Natural hub: mangroves and wetlands preserved as water regulators.

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Connectivity is ensured by a network of stilt-mounted footbridges linking the neighborhoods, a central landing stage capable of accommodating 20 boats, and elevated roads above the 100-year flood level to ensure mobility in all seasons.

C. Sizing and Integrated Programming

The project includes a minimum of 50 modular housing units with surface areas ranging from 36 to 80 m², accommodating 3 to 12 people. These scalable modules are installed on hybrid foundations incorporating stilts and a float. Community amenities include a 45 m² clinic, a 345 m² covered market with 23 stalls, a 135 m² school with three classrooms, and a water and energy station sufficient for at least 150 people. The wooden walkways, with a span of 6 m and resistant up to 300 kg/m², and 3 to 5 m³ tanks will be integrated into each module for water self-sufficiency. Designed to accommodate up to 300 residents, this amphibious model will integrate autonomy, resistance to climate change, and local anchoring**.**

VI. MORPHOLOGICAL DESIGN OF THE PROJECT

A. Project Concept and Philosophy

The project's architectural concept cannot be separated from its founding philosophy, which places community and resilience at the heart of its design. Inspired by the association between community and the movement of waves, which is a fundamental element for Cameroonian coastal fishermen, the project develops an architecture that follows a logic of balance, adaptation, and return, like the fisherman who reads the sea to better return to land. In the local culture, knowing how to observe the waves, understanding their rhythm and signals, is a condition of survival. This ancestral knowledge has become our architectural metaphor: it symbolizes listening to the territory, anticipating hazards (such as floods), and the ability to adapt collectively. Thus, the project's philosophy is based on several key principles:

- Listening to the territory: Understanding natural rhythms (water, wind, tides) to guide spatial choices, minimize the impact of flooding, and integrate into the island landscape.
- Community resilience: Designing spaces that foster solidarity, collective resource management, and the adaptability of residents in the face of environmental changes.
- Spatial flexibility: Implementing modular, scalable structures capable of transforming themselves according to family needs, natural hazards, and social dynamics.
- The centrality of social connections: Anchoring architecture around shared spaces (courtyards, platforms, footbridges), true crossroads of "lifelines" where exchanges, learning, and mutual support intersect.
- Hybridization of vernacular knowledge and innovation: Integrating local materials and traditional construction practices with contemporary technical systems adapted to climate challenges.

Like a boat guided by collective intelligence, it aims to reconnect people, their habitat, and their environment, by proposing architecture that is at once poetic, functional, and resilient. We can therefore say “Lines of life: an architecture anchored in the rhythms of the territory, woven around the community, and designed to sustainably inhabit uncertainty.”

B. Implementation Strategy and Site Consideration

In Manoka, the current layout is based on a rigid linear grid (see Figure 19), suitable for accessibility but unsuitable for the coastal context because it increases erosion and vulnerability to flooding.

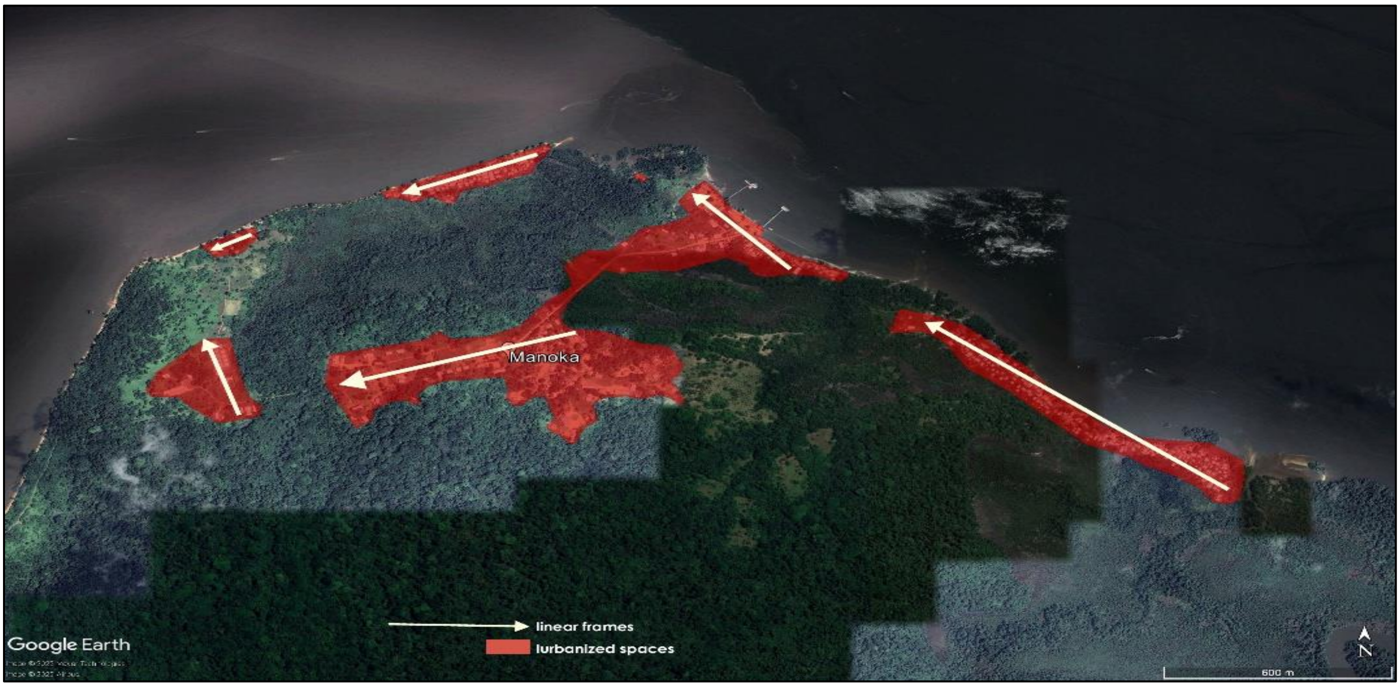

Fig 19 Spatial Organization Following a Linear Grid
(Source: Google Earth)

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➢ *The Project Proposes a Reinterpretation in an Undulating Grid, Inspired by the Movement of Waves. this Strategy:*

- Connects housing, service, and public space hubs around a structuring axis.
- Promotes gentle flow management by integrating buffer and planted areas.
- Increases spatial resilience through a fragmented and porous built fabric.

From this main grid, organic ramifications, comparable to tree branches, extend into the housing units. Each house becomes a "fruit" connected to the community's common core, illustrating a vision of space as a living system, anchored in the soil, water, and local knowledge. As show in Figure 20.

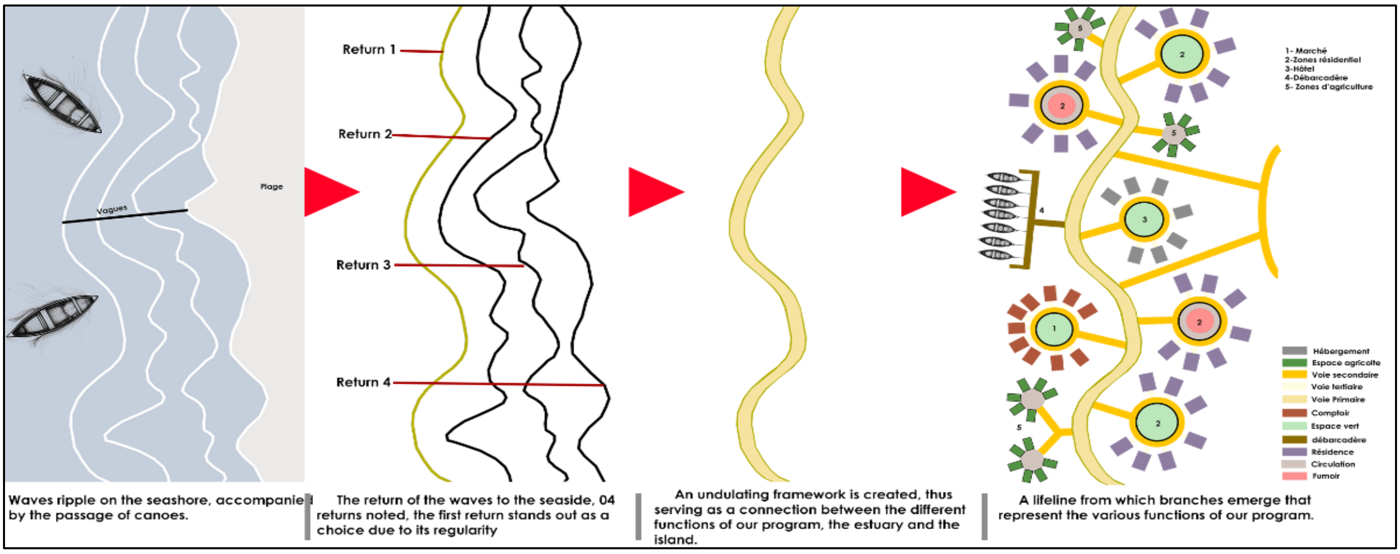

Fig 20 Conceptual Approach

C. Proposed Habitat Typologies

The proposed housing typologies are of three types, namely:

- Typology 1: 36 m², it has a living room, a bedroom, a shower, a kitchen and a porch. It is designed for single people or families of up to three people. This typology favors compactness and constructive simplicity, while ensuring minimal comfort. It is an accessible solution for low-income households or first-time buyers. Figure 21 illustrates this typology;

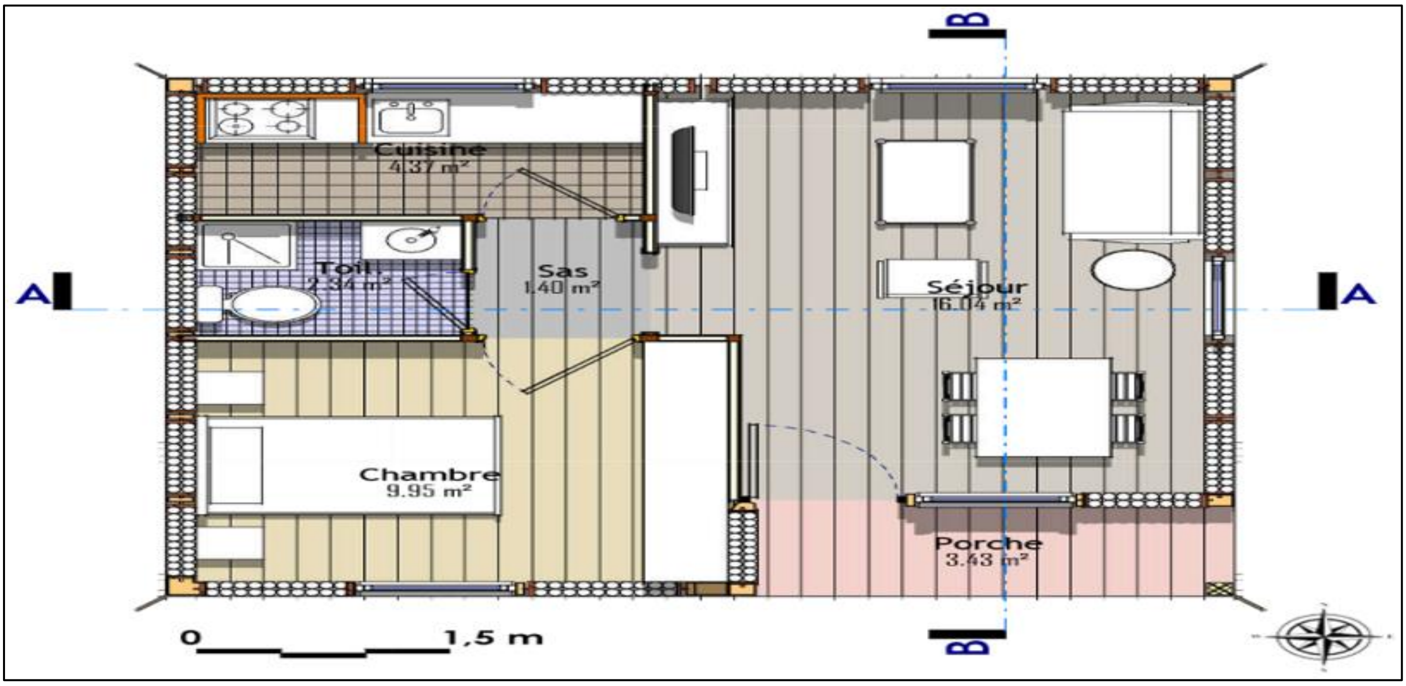

Fig 21 Floor Plan Typology 1
Source: Author

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- Typology 2: 80 m², it is proposed for families with up to 6 people and has a living room, two bedrooms, a kitchen, two toilets, a porch. This typology is suitable for stable families with moderate resources. See figure 22 for the spatial representation;

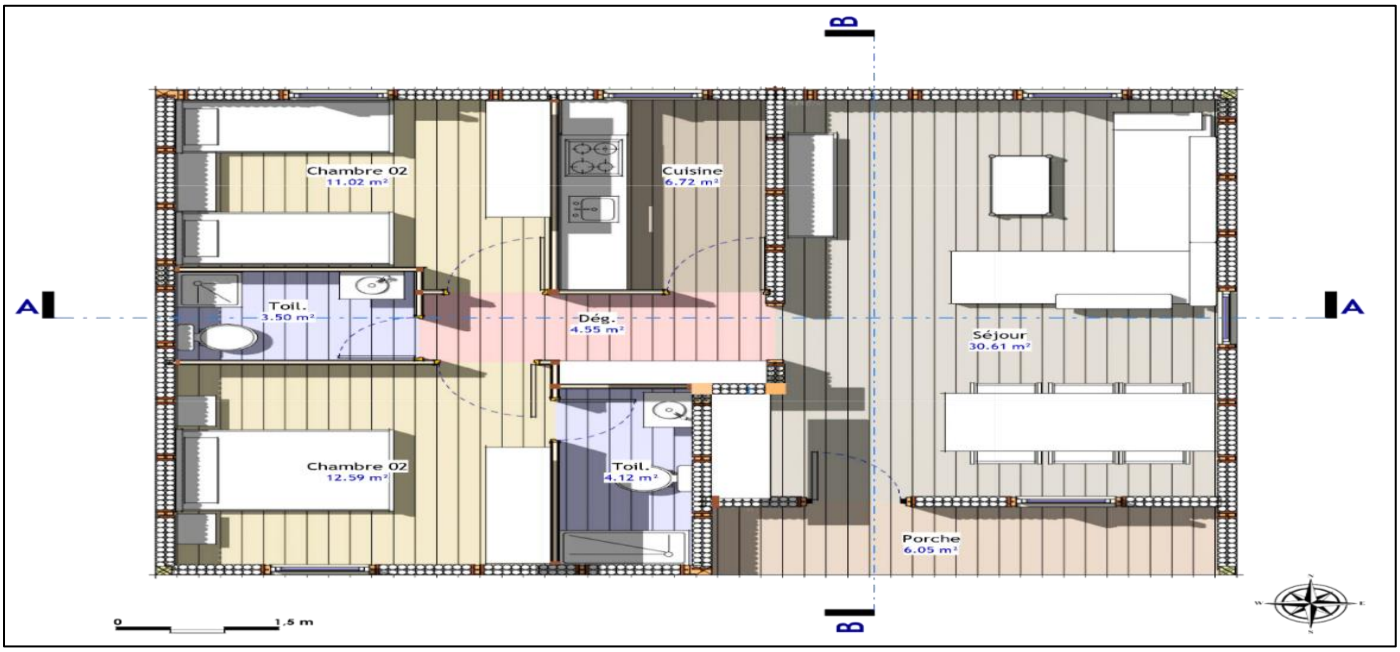

Fig 22 Floor Plan Typology 2

- Typology 3: having a base of 80 m², it is made to be evolving and adapted to families with a little more means, its program changes according to the economic level of these buyers. It has a kitchen + pantry, vertical circulation, 04 toilets, a living room, a porch, a terrace and a number of bedrooms which goes from 03 to 05 because it is scalable and on two levels, i.e. a total area of 160 m². Figure 23 presents the spatial development of this typology.

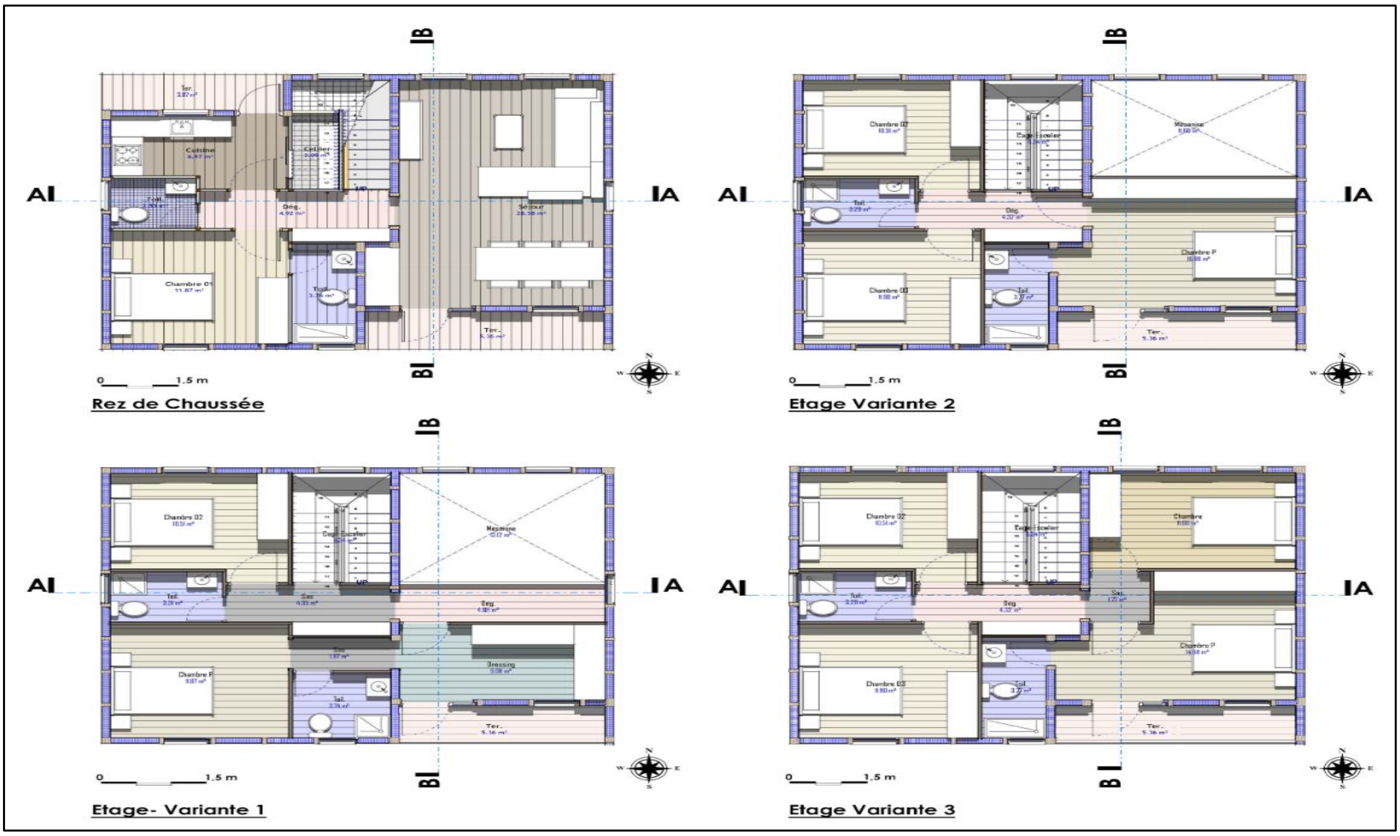

Fig 23 Floors Plans Typology 3

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All of these types are self-sufficient in water and electricity, have a natural ventilation system, a waste management system, and all have hybrid foundations and can easily be combined with an urban planning model.

D. Construction Systems And Specific Flood-Resistance Provisions

➢ *Construction Systems*

In keeping with a focus on resilience and resident empowerment, the project favors a system of assisted self-construction, based on prefabricated and adaptable modules. This approach not only reduces construction costs, but also facilitates the participation of local communities in the manufacturing and assembly process, thus strengthening their ownership of the site.

- Use of Bottle Cinder Blocks: Unlike the plastic bottle walls developed by Robert Bezeau, our system adapts to the local context by using locally available materials. Each household consumes an average of six bottles of water per day, or approximately 2,160 bottles per year, making it possible to build a Type 1 house without producing plastic waste in the estuary. The construction system is based on a load-bearing wooden frame combined with a plastic bottle cinder block filling. All elements are prefabricated and standardized, facilitating assembly, reproduction, and maintenance. Each module is designed to be repeatable, allowing for wide and effective dissemination within the community. Figure 24 illustrates this constructive principle.

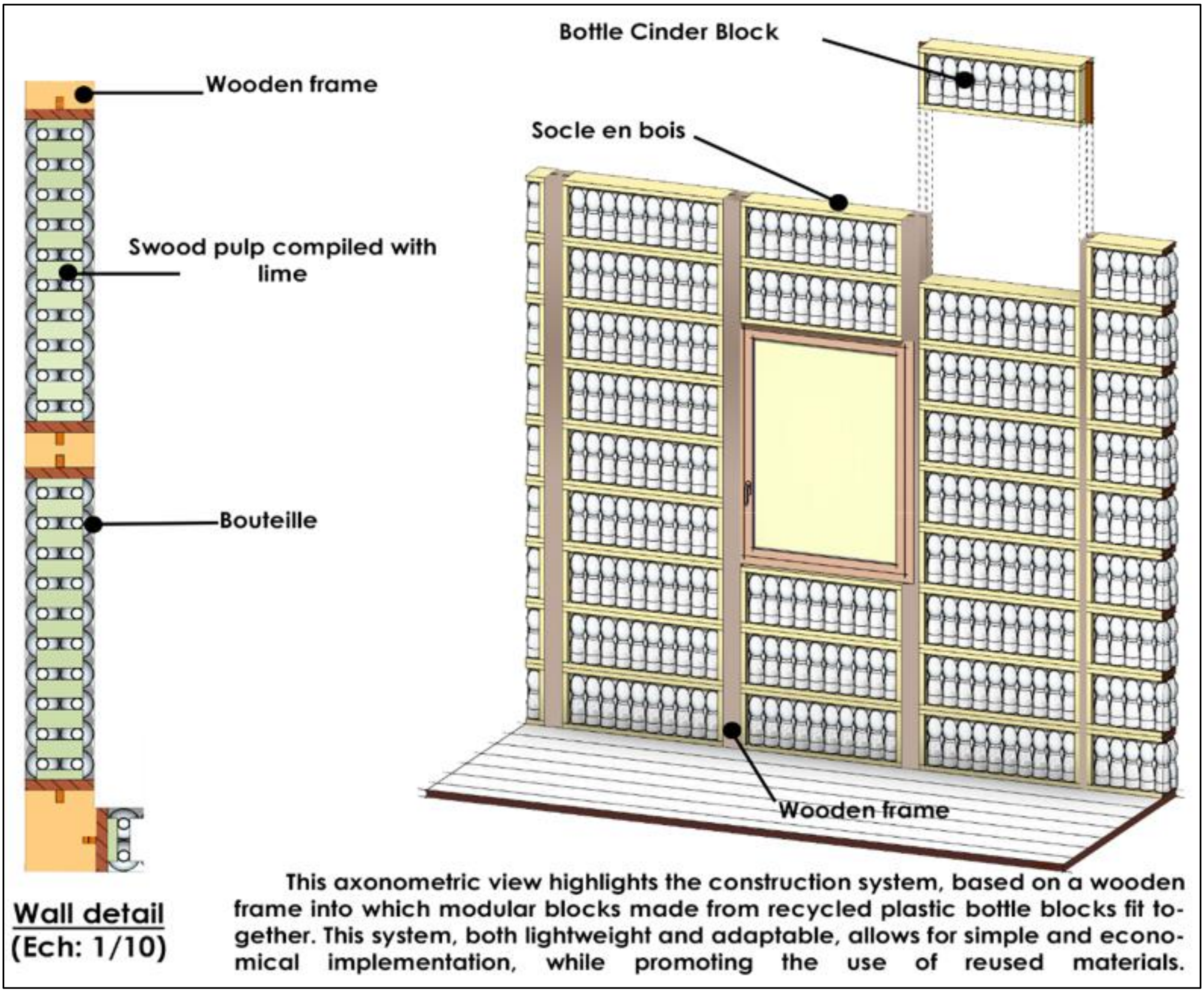

Fig 24 Construction System

- 8 cm partition: The interior partitions consist of a wooden rafter frame (50 × 70 mm), filled with wood soot or shavings, forming a light and ecological insulating mattress. Each side is covered with 5 mm plywood, ensuring rigidity and finish (figure 25). This modular system meets the requirements of comfort, lightness and promotes the use of local materials with a low carbon footprint.

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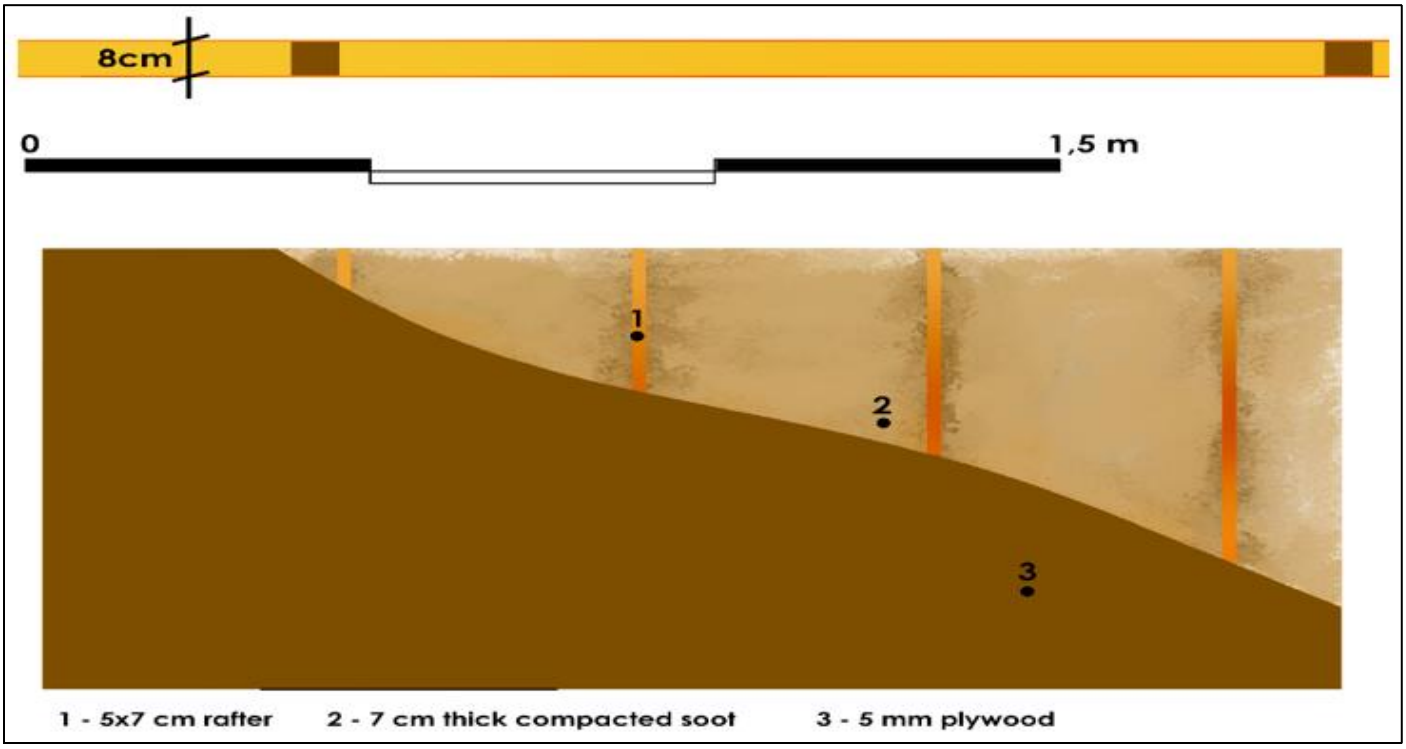

Fig 25 Technical Diagram of an 8 cm Partition

- Floating system: Inspired by projects such as the Makoko Floating School in Nigeria, this device incorporates a flotation system designed from recycled plastic bottles.

Unlike more technological projects such as Oceanix or Maldives Floating City, this solution remains economically accessible and technically reproducible on a local scale. Figure 26 shows how it works.

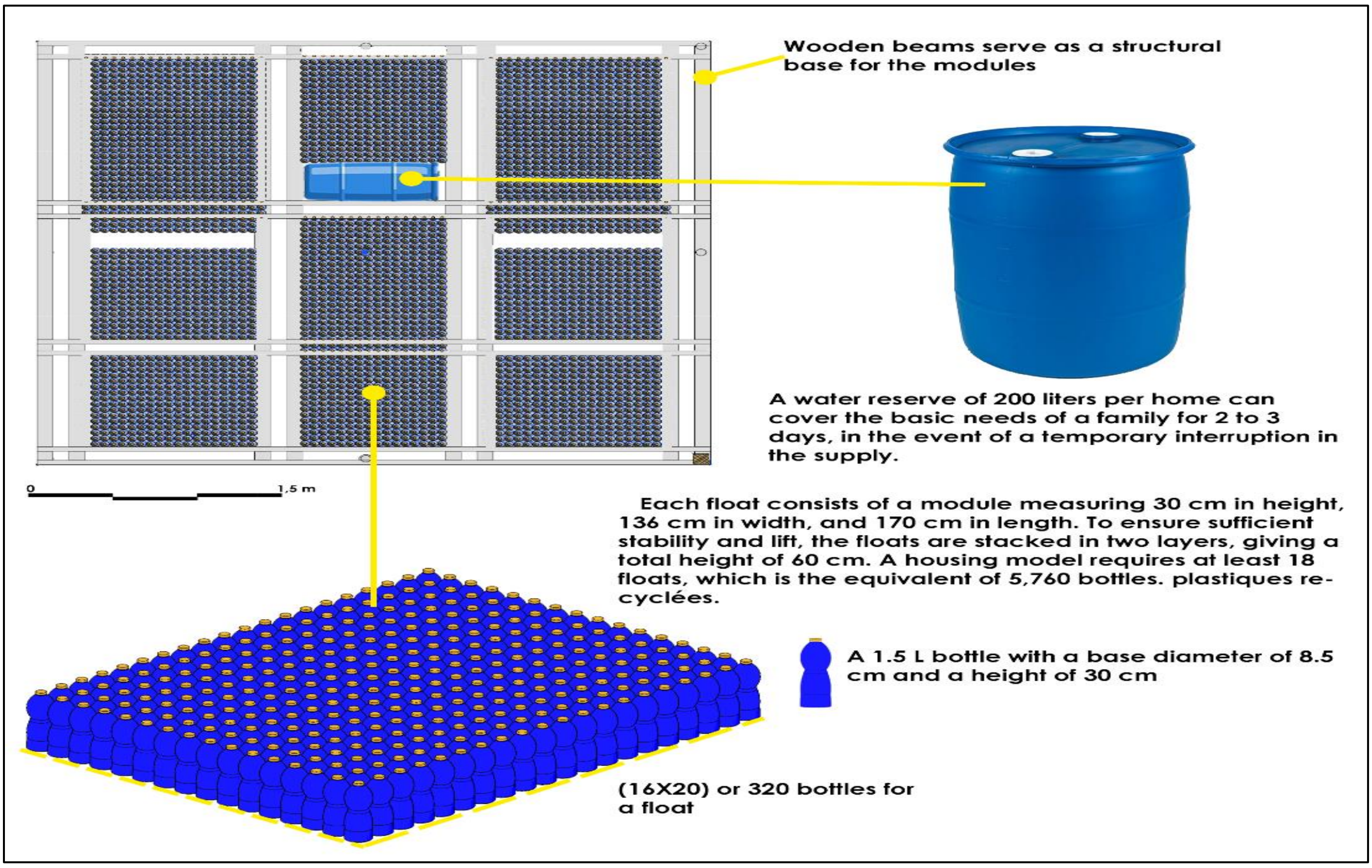

Fig 26 Float System

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- Hybrid foundation: The foundation developed combines structural stability and resilience to water level variations. Figure 27 illustrates this principle. The hybrid foundation of our architectural design is based on a synergy of heterogeneous materials, where each component plays a specific role in ensuring resilience to climatic hazards: Cables (ensure the lateral stability of the habitat during water level fluctuations, preventing any drift), Wooden beams (provide flexibility and lightness), Floats (allow partial buoyancy of the habitat), Concrete pylons (form the fixed base of the system, receiving the anchor cables and ensuring stability even in the event of heavy or prolonged flooding), Nuts (facilitate maintenance and scalability of the system).

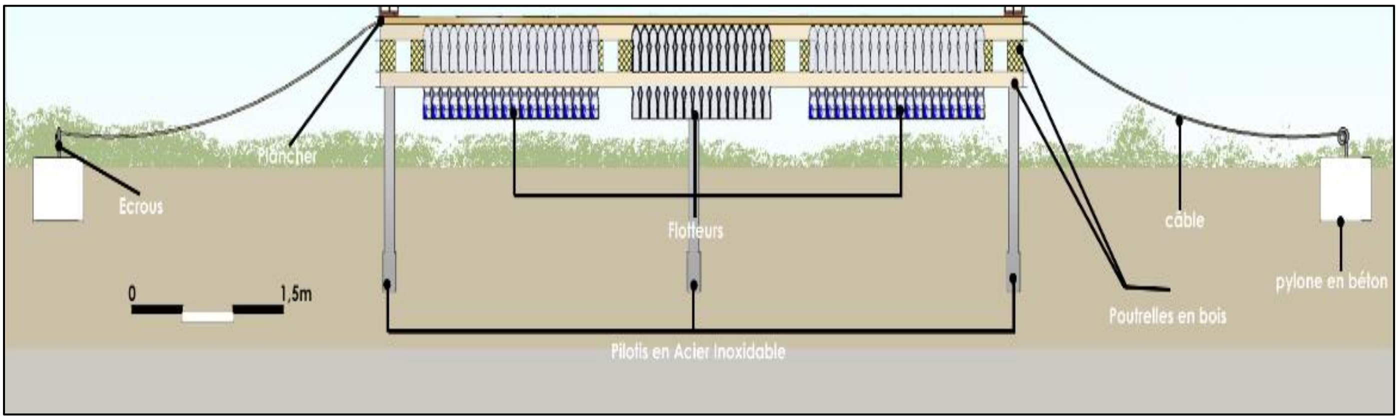

Fig 27 Hybrid Foundation

It allows the habitat to remain elevated during flood periods while adapting to water level drops during low water seasons. This system demonstrates that it is possible to coexist with water through an adaptive approach rather than direct confrontation. Figure 28 illustrates how these foundations work: under normal conditions, the structure rests on steel piles anchored in the ground that protect it from capillary rise and minor floods. During water level rises, the floats generate upward buoyancy controlled by the piles that serve as vertical guides, while cables fixed to concrete pylons absorb lateral forces and maintain stability.

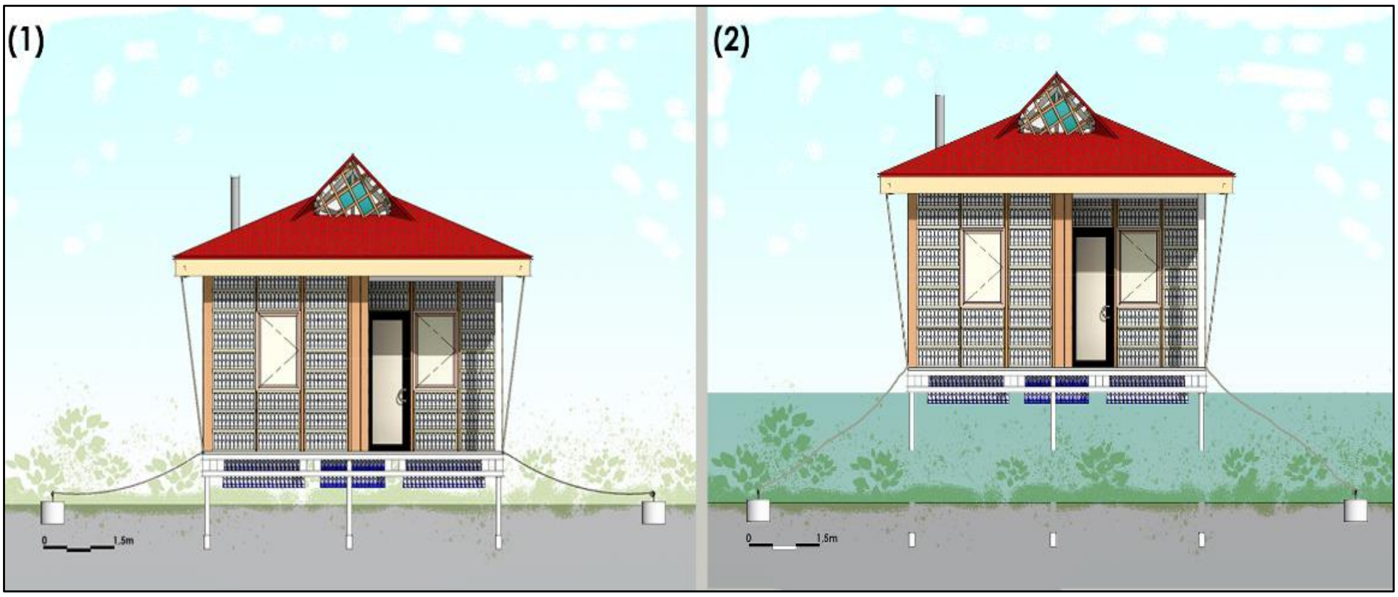

Fig 28 A Description of how our Foundations Operate

➢ *Specific Flood-Responsive Provisions*

The project for Douala 6 incorporates a series of flood resilience measures, combining architectural adaptation, urban planning, and the development of local resources. It includes gentle dikes to limit erosion and wave impact, stilt or floating housing to promote coexistence with the water, water recovery and treatment infrastructure, and local social facilities (schools, clinics) to maintain access to essential services. The strategy also includes economic diversification through markets and eco-tourism, energy self-sufficiency through renewable energy, and the creation of green spaces and ecological buffers to filter water and preserve biodiversity. Finally, the urban fabric follows the site's topography and promotes community ties, resource pooling, and the transmission of local knowledge, providing a coherent and integrated response to flood risks while strengthening the social and ecological resilience of the area, as shown in Figure 29.

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Fig 29 Urban Scale Development Plan

This entire integrated approach to resilience and urban planning cannot fully function without a master development plan, which serves as a strategic framework to guide the future development of the area. This plan defines spatial orientations, areas to be protected, buildable areas and traffic routes, ensuring coherence between infrastructure, public facilities and natural spaces. It thus helps to prevent uncontrolled urbanization, optimize flood risk management and ensure that interventions respect local ecological and community dynamics, as illustrated in Figure 30.

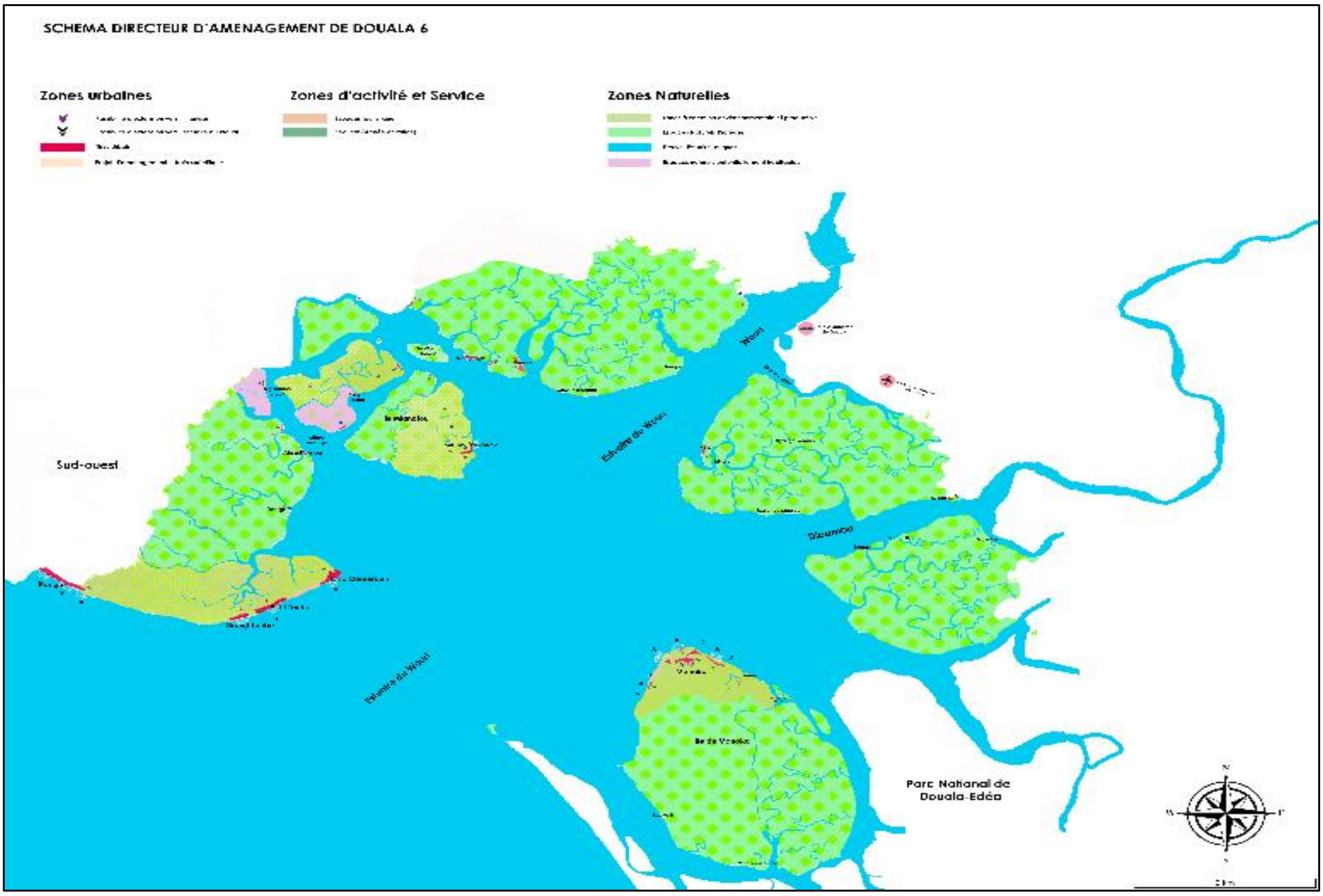

Fig 30 Douala 6 Master Plan

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VII. PHASING, ESTIMATED COSTS, AND FINANCING OPTIONS

➢ *Implementation Phasing*

The project is structured into three phases, as shown in Table 3, with an estimated total implementation period of 39 months.

Table 3 Project Phasing

Phase	Designation	Duration	Main content
Phase 1	Technical studies and awareness	3 to 6 mois	Diagnostic Participatory diagnosis and local training
Phase 2	Pilot module and adjustments	6 to 9 months	Construction of an inhabited prototype, user feedback
Phase 3	*Progressive community-scale deployment*	1 to 2 years	Replication of units, adaptation to needs

➢ *Estimated Project Costs*

The estimated project cost will be calculated using the FCFA 100,000 per square meter as the gross cost. We will first calculate the estimated cost for each type (Table 4) and then the estimated cost for urban development (Table 5).

Table 4 Estimated cost of different housing types

Typology / Parameters	Typology 1	Typology 2	Typology 3
Area (m²)	36	80	160
Gross floor area value (FCFA)	3 600 000	8 000 000	16 000 000
Labor cost (FCFA)	1 080 000	2 400 000	4 800 000
Contingencies (FCFA)	468 000	1 040 000	2 080 000
Studies and project supervision (FCFA)	231 660	514 800	1 029 600
Estimated Cost (FCFA)	5 379 660	11 954 800	23 909 600

Table 5 Estimated Budget Urban Model

Urban model / Parameters	Ligne de vie
Area (m²)	25 000
Gross floor area value (FCFA)	2 500 000 000
Labor cost (FCFA)	750 000 000
Contingencies (FCFA)	325 000 000
Studies and project supervision (FCFA)	160 875 000
Estimated Cost (FCFA)	3 735 875 000

Our urban model covering an area of 25,000 m² is estimated at three billion seven hundred and thirty-five million eight hundred and sixty thousand FCFA (3.735.875.000 FCFA).

➢ *Financing Options*

As with the operational phasing, three main complementary financing options have been selected to ensure the project's economic feasibility:

- Institutional support: This component relies on public subsidies from government agencies such as FEICOM, as well as decentralized local authorities, including the Littoral Region, the Douala Urban Community, and the Douala VI District Municipality. These institutions can support the project through housing improvement, urban resilience, or natural hazard mitigation programs;
- Partnerships with NGOs or international cooperation agencies: Several development organizations and international donors can be mobilized for pilot projects or action research. Actors such as UNDP, GIZ, UN-Habitat, and AFD have technical and financial support mechanisms targeting climate adaptation, sustainable housing, and social innovation projects;
- Local participatory model: This option favors the direct involvement of residents, through a contribution in labor, collection of recycled materials, or by integrating self-construction cooperatives. Solidarity micro-credit mechanisms can be considered, in partnership with community mutuals or local microfinance structures, to facilitate financial accessibility for the most vulnerable households.;

VIII. MULTI-CRITERIA ASSESSMENT AND ADAPTATION PERSPECTIVES

A. *Multicriteria Assessment*

To analyze the relevance of the architectural proposal in a vulnerable coastal context such as Manoka, a multi-criteria evaluation grid was applied. This analysis combines environmental, social, technical, and economic performance criteria, taking into account natural risks, local realities, and the region's adaptive capacity.

➢ *Performance in the Face of Flood Risks*

The project's performance in the face of flooding is based on a combination of avoidance, adaptation, and absorption strategies. The hybrid foundation system allows the building

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to temporarily rise during floods, while returning to a stable position during low water levels. This system ensures continuity of use of the habitat even during high water levels.

➢ *Environmental and Economic Sustainability*

The project is based on a recycling and recovery approach for local resources. The use of plastic bottles to make concrete blocks, as well as local wood for the structure, significantly reduces the carbon footprint associated with imported industrial materials. From an economic perspective:

- Material costs are significantly reduced thanks to community-based plastic collection;
- Modular prefabrication lowers labor costs and facilitates future expansions;
- The model can be replicated without extensive technical expertise, facilitating its adoption by the local population.

However, questions remain regarding the long-term sustainability of plastic materials in a humid tropical climate, as well as how to manage the aging of these components without a structured recycling system.

➢ *Cultural and Social Acceptability*

The proposal fully integrates local living practices. It respects vernacular construction principles (wooden structures, simple volumes, natural ventilation) while incorporating progressive innovations. The choice of materials is based on what the residents produce themselves (bottles, wood, palm leaves) or can easily collect. The community's involvement in participatory design, collective construction, and management of shared spaces (yards on stilts, floating platforms) allows for strong social ownership, an essential condition for the project's sustainability. In addition, the modularity of the habitats responds to changing family needs, which strengthens their legitimacy over time.

➢ *Limitations*

The approach adopted is highly consistent with the territorial resilience challenges of Cameroon's coastline. The use of simple yet innovative technical solutions, such as hybrid foundations or bottle blocks, ensures both local anchoring and project sustainability. Community involvement strengthens social ownership, an essential condition for the project's success. However, some limitations remain, including :

- The need to train residents in certain specific techniques (modularity, prefabrication).
- Uncertainty regarding the long-term sustainability of certain recycled materials (e.g., plastics).
- The need for a regulatory framework more favorable to experimentation in high-risk areas.

B. *Adaptation Perspectives*

➢ *Reproducibility in Other Coastal Contexts*

The architectural and urban planning proposal developed for Douala 6, although anchored in this specific context, is transposable to other coastal areas facing similar challenges: rising sea levels, erosion, recurrent flooding, informal urbanization and the fragility of coastal ecosystems (Figure 31). This reproducibility is based on several elements:

- Integrated territorial approach: diagnostic based on analysis of the site, social dynamics, and morphology, adaptable to other coastal areas.
- Adaptive architectural principles: timber frame and recycled materials (plastic bottles, wood soot) offering flexibility, economy, and adaptability to different soil types.
- Functional autonomy: solar and wind energy, floating permaculture, and rainwater treatment guaranteeing infrastructure resilience independent of urban networks.
- Integration of indigenous knowledge: traditional practices and community logics promoting local ownership and cultural adaptation.
- Modularity and phasing: project scalability based on available resources and population growth.

Fig 31 Integration of the Prototype into an Urban Environment

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Reproducibility therefore lies in the transferability of methodological and constructive principles, requiring local contextualization, community involvement and strong political commitment.

➢ *Recommendations for Coastal Development Policies*

- Integrate resilient architecture into planning documents: Urban Master Plans and Development Plans must provide for demountable, elevated, or floating structures suitable for flood-prone areas.
- Promote local materials: Encourage the use of bio-sourced and recycled materials, while supporting local processing sectors.
- Strengthen community participation: Institutionalize citizen participation through chiefdoms, associations, and cooperatives for sustainable ownership of urban projects.
- Create a regulatory experimental framework: Establish legal test zones for pilot projects, enabling experimentation and action research on new forms of housing.
- Implement a national coastal resilience strategy: integrate climate mobility, environmental justice and urban resilience to avoid fragmented and reactive interventions.

IX. CONCLUSION

The in-depth analysis of Douala 6, and more specifically of Manoka Island, revealed a territory that is both vulnerable and endowed with underutilized adaptive dynamics. Despite heightened exposure to flooding, exacerbated by urban pressure and socio-economic precariousness, local knowledge and empirical adaptation strategies demonstrate a resilience potential that can be harnessed. Based on these findings, an innovative architectural approach was developed through the concept of "lines of life," inspired by the ancestral knowledge of fishermen who read the sea. This project philosophy abandons the rigid linear grid logic in favor of a wavy organization reproducing the movement of the waves, materializing concretely in three modular housing typologies (36, 80, and 160 m²) incorporating remarkable construction innovations: adaptive hybrid foundations, recycled plastic bottle blocks, and floating systems.

This participatory approach emphasizes local materials (azobé wood, wood soot) and bioclimatic principles suited to the humid tropical climate, while integrating resilience measures (soft dikes, energy self-sufficiency, social infrastructure) to form a comprehensive territorial adaptation system that respects natural dynamics. Multi-criteria evaluation confirms the project’s relevance, with high performance in flood resilience, local technical feasibility, and social acceptability, while the budget estimate (3.7 billion FCFA for 25,000 m²) and a 39-month phasing demonstrate its economic realism.

Beyond the specific case of Manoka, this research proposes a methodology transferable to other African coastal contexts and provides policy recommendations for incorporating resilient architecture into planning documents, demonstrating that a credible alternative to conventional urbanization is possible by reconciling climate adaptation, social justice, and environmental sustainability through an architecture “anchored in the rhythms of the territory, woven around the community, and designed to sustainably inhabit uncertainty,” coexisting with water rather than fighting it.

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