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Flood-Adaptive Planning Model for Mid-River Islands in Hanoi Based on Green Corridor and BGI Theory

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Abstract

Mid-river islands in the Red River hold significant ecological and cultural value but remain poorly integrated into Hanoi's green infrastructure. This study addresses the gap by examining the current conditions of the largest mid-river island and proposing a flood-adaptive development model grounded in the Green Corridor framework. The methodology combines policy review, hydrological and elevation analysis using long-term official datasets, spatial assessment of morphological change, field surveys, and SWOT evaluation. Results indicate a trend toward greater geomorphological stability alongside major management challenges. Five thematic park zones are proposed using modular, non-permanent, and flood-resilient structures compliant with the Law on Dikes, contributing a scientifically grounded model for sustainable river-corridor planning.

1. Introduction

Hanoi is a city defined by its rivers and lakes, with the Red River being the longest and largest waterway running through the capital [1]. This river stretches approximately 120 km within Hanoi's territory, from Ba Vi District in the northwest to Phu Xuyen District in the southeast. The Red River plays a crucial role in flood control, irrigation for agriculture, and waterborne transport for the entire Red River Delta region. Together with the Thai Binh River, it drains a basin of nearly 90,000 km^2 and affects the lives of around 32 million people (about 10 million of whom are directly impacted in the delta area) [2].

Within the Hanoi urban area, the Red River's changing flow has created many mid-channel alluvial islands. Notably, the stretch from Trung Ha Bridge to Thanh Tri Bridge contains alluvial islands totaling roughly twice the area of Hoan Kiem District [3]. These undeveloped green islands lie along the central Red River corridor, which functions as a vast linear open space threading through the city. This corridor has been envisioned in Hanoi's master plans as a "green spine" comprising parks, landscaped areas, cultural sites, recreational zones, and ecological reserves, all integrated with the city's flood control and dike system [4]. In effect, the Red River corridor provides a critical environmental and spatial structure for the capital metropolis.

However, rapid urbanization and population growth in Hanoi have put intense pressure on land resources and the environment. The Red River corridor's water surface area has been shrinking over the past decades - from

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about 25.8 km^2 in 1985 down to 14.7 km^2 by 2021, a loss of 11.1 km^2 [3]. At the same time, informal settlements and uncontrolled construction have encroached into the floodplain, narrowing the river's flow and impairing its ecological functions. Water quality has deteriorated due to pollution, and the rich cultural heritage associated with the river remains underpromoted. Economic activities in the corridor have been predominantly limited to sand mining, rudimentary agriculture, and fishing, rather than sustainable ecotourism or cultural services.

Based on a preliminary assessment, five key challenges must be addressed for the Red River section through Hanoi: (1) maintaining the natural river flow and protecting water resources; (2) safeguarding and restoring the ecological environment; (3) conserving and integrating cultural heritage values; (4) unlocking green economic development potential; and (5) controlling haphazard urban development in the riparian zone. Addressing these issues is essential for Hanoi's goal of becoming a "Civilized - Cultural - Modern Capital" in a sustainable manner [5].

The mid-river islands offer a unique opportunity to tackle the above challenges by serving as core elements of Hanoi's green infrastructure. To date, their role has not been clearly positioned in urban plans, due in part to regulatory constraints and a lack of strategic vision. This study aims to fill that gap by exploring how Hanoi's mid-river islands can be developed under a sustainable framework. In particular, we apply the Green Corridor theory to the Red River context to guide the planning orientation for these islands. The objective is to propose a development model that transforms the islands into a multifunctional "ecological-cultural park" system that is adaptive to flooding, while remaining compliant with legal regulations.

The remainder of the paper is structured as follows: Section 2 introduces the theoretical background and related work, including the Green Corridor concept and recent approaches to river corridor planning. Section 3 outlines the study area and methodology. Section 4 presents the results of the current status analysis of the mid-river island. Section 5 is a discussion of the proposed development model's feasibility, limitations, and comparisons with similar projects. Finally, Section 6 concludes the study and highlights recommendations for implementation.

2. Literature Review

2.1 Green Corridor Concept

The concept of a “Green Corridor” in urban planning refers to a linear and interconnected network of green spaces that link natural areas, parks, and open spaces to preserve biodiversity, maintain ecological processes, and provide recreational and cultural benefits. Historically, the concept can be traced to early landscape planning precedents such as Frederick Law Olmsted’s Emerald Necklace in Boston, and it gained wider prominence through the late twentieth-century greenway movement [6]. Over time, planners and scholars have used related terms-greenways, ecological corridors, green belts, linear parks-but they consistently emphasize two defining characteristics: (1) linear connectivity that links fragmented landscapes; and (2) formal planning designation or protection that secures these connections [7]. Hellmund and Smith (2006), in their foundational text Designing Greenways, documented several families of concepts-including parkways, riparian buffers, and wildlife corridors-and argued that effective green corridors integrate ecological, recreational, and cultural functions within a unified landscape system [8].

International planning practice demonstrates the adaptability of the Green Corridor concept. Herz and Wolff (2010) highlighted diverse applications ranging from California’s “Green Technology Corridor” to Singapore’s “Urban Park Corridor,” each using linear green systems to structure sustainable urban development [9]. In Vietnam, the concept has been embedded within major strategic plans for Hanoi. The Hanoi Capital Construction Master Plan to 2030 and the Capital Region Plan (2016) designate Green Corridors and green wedges to manage urban expansion and protect agricultural land, heritage landscapes, and ecological assets [10]. Within this structure, the Red River corridor functions as a principal axis, connecting natural zones, cultural clusters, and recreational spaces through continuous green infrastructure [7].

Contemporary planning theory further expands the Green Corridor concept by aligning it with Blue–Green Infrastructure (BGI), Nature-Based Solutions (NbS), and urban resilience frameworks. These perspectives emphasize multifunctional green networks that integrate hydrology, ecology, and social benefits while enhancing a city’s capacity to adapt to climate-related disturbances. Incorporating these principles strengthens the conceptual foundation for treating the Red River corridor-and its mid-river islands-as dynamic ecological systems capable of supporting biodiversity, cultural identity, and flood-adaptive development.

2.2 Urban River Corridors and Flood-Adaptive Design

Urban river corridors are increasingly recognized as multifunctional ecological infrastructures that enhance biodiversity, strengthen ecosystem services, and support long-term climate resilience. Recent studies demonstrate that well-connected riverine green corridors can mitigate habitat fragmentation by enabling species movement and maintaining ecological continuity across dense urban areas. A recent study showed that ecological

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 15-29

corridor planning based on local species distribution significantly improves urban bird diversity, reinforcing the value of continuous riparian green networks for sustaining ecosystem functions [11].

Beyond biodiversity benefits, contemporary planning practice highlights the critical role of river corridors in flood-adaptive urban design. A global shift is underway away from rigid, hard-engineered flood control toward Nature-Based Solutions (NbS) that restore natural hydrological processes. The Netherlands' "Room for the River" program exemplifies this approach, using spillway parks, widened floodplains, and restored wetlands to increase flood safety while creating recreational landscapes [12]. International evidence from 29 floodplain restoration projects shows that NbS, such as riparian forest recovery, wetland rehabilitation, and floodable parks, can simultaneously enhance flood protection, ecological health, and social well-being [13].

Asian precedents further demonstrate how river landscapes can be designed to accommodate, rather than resist, seasonal flooding. China's "Sponge City" initiative integrates permeable surfaces, wetlands, and floodable public spaces into dense urban districts. Yanweizhou Park in Jinhua, designed to safely flood during the monsoon season, illustrates how terracing, resilient vegetation, and flexible pathways create a landscape that remains functional despite repeated inundation [14]. Similarly, Seoul's Seonyudo Park transformed an abandoned industrial islet in the Han River into an ecological water park, showing how mid-river islands can be repurposed as resilient green infrastructure.

Recent scholarship further emphasizes that Blue–Green Infrastructure (BGI) provides a unifying framework for river-island planning by integrating water systems, wetlands, vegetation networks, and open spaces into a multifunctional ecological system that mitigates flood risk, enhances habitat quality, and supports urban livability [15]. In parallel, urban and climate resilience theory highlights the capacity of landscapes to absorb shocks, adapt to hydrological variability, and recover without losing core ecological or social functions [16]. The combined lens of BGI, NbS, and resilience theory underscores the importance of flexible, reversible, and flood-adaptive interventions, especially in mid-river islands where permanent construction can obstruct flood conveyance or degrade ecological processes. Incorporating these contemporary theoretical frameworks, therefore strengthens the scientific foundation of the development model proposed for Hanoi's Red River islands.

3. Methodology

3.1 Study Area

The study focuses on the largest mid-river island of the Red River in central Hanoi. This island is situated within the administrative boundaries of four urban districts (Before July 1, 2025): Hoan Kiem, Ba Dinh (on the west bank), and Long Bien, Tay Ho (on the east bank). It stretches approximately 5.7 km in length, with a maximum width of about 1.1 km, covering an area of around 310 hectares as of 2024. Fig. 1 shows the location and extent of this island. The island's northern tip lies near the historic Long Bien Bridge, and it extends southward toward the Chuong Duong and Vinh Tuy Bridges. The terrain consists of flat alluvial deposits with an elevation generally between 9-12 meters above sea level. The highest natural levees locally exceed the Alarm Level III level (11.5 m), but large portions of the surface remain within the Alarm II zone [17]. The island's surface is characterized by sandy soil with grasses, shrub thickets, and some cultivated plots. A smaller secondary islet and sandbanks adjoin the main island depending on seasonal water levels.

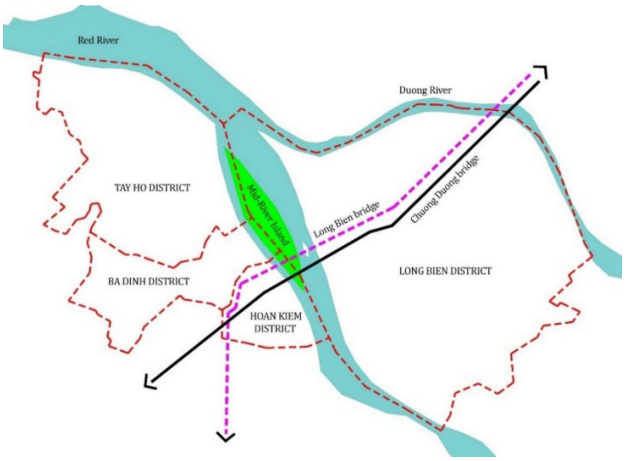


Fig. 1 *The mid-river island within four districts (before July 1, 2025)*

3.2 Research Methods

The study adopted an integrated qualitative–quantitative methodological framework to assess the current status of the mid-river island and to propose an appropriate development model. First, a comprehensive literature review and policy analysis were conducted to establish the theoretical and institutional basis for the research. Scientific publications, planning reports, and legal documents related to the Red River, green corridor development, and floodplain management were examined. Particular emphasis was placed on Vietnamese regulatory documents, most notably the Law on Dikes and Hanoi's river corridor planning regulations, to clarify the legal restrictions governing construction and landscape modification within the Red River floodplain [4, 18]. This analysis ensured that subsequent planning propositions were aligned with national and municipal statutory frameworks.

Second, field surveys were undertaken during both the dry and rainy seasons of 2021–2022 to observe seasonal variation in hydrological conditions and environmental characteristics. GPS points, photographic records, and descriptive notes were collected to document land-use patterns, vegetation cover, wildlife presence, informal settlements, agricultural activities, and areas showing evidence of erosion or sediment deposition. These observations served as essential ground-truth information to validate the secondary datasets and improve the accuracy of morphological interpretation.

Third, map analysis and geospatial assessment were carried out using a schematization-based approach. Historical satellite images and topographic maps (1980s, 2000s, 2020s) were analyzed to delineate morphological changes. The island's outline was digitized for the years 1984, 2000, 2005, 2015, and 2021 to visualize variations in area and geometry over time. Available elevation datasets were then compared with historical flood records covering 100 years to identify zones susceptible to inundation during different flood stages. Land-cover patterns derived from recent high-resolution imagery allowed further interpretation of ecological characteristics [18, 20].

Finally, a SWOT analysis was conducted to synthesize internal attributes-such as ecological richness, cultural significance, and management limitations-with external opportunities and threats, including tourism trends and climate-related hydrological variability. This integrative methodological approach provided a rigorous foundation for establishing the development vision and model presented in subsequent sections.

Advanced GIS-based quantitative modelling was considered; however, consistent cloud-free Landsat/Sentinel imagery across all historical periods was unavailable, limiting the reliability of automated geomorphological extraction. Therefore, officially published hydrological datasets and topographic map series were used as the primary quantitative basis, ensuring methodological transparency without overinterpreting incomplete GIS data.

4. Survey Results and Current Status Analysis

4.1 Hydrological Regime

The Red River in Hanoi exhibits a tropical monsoonal hydrological pattern with two distinct seasons: a dry season from November to April, and a flood (wet) season from May/June to October. Peak water levels typically occur in late summer (August). Upstream dams and reservoirs now regulate the river's base flow, but heavy rainfall events can still produce sudden large floods. Over the last century, about 73% of years recorded flood-season water levels reaching Alarm Level I-III (approximately 9.5-11.5 m at the Hanoi gauge) as shown in Fig. 2. The highest flood on record was on August 20, 1971, which reached 14.13 m - roughly 2.6 m above the Alarm III level. Such extreme floods are rare. Water levels above Alarm III occurred on average only 1.7 days per year, with the maximum being 14 days in 1971 [18].

These data indicate that the mid-river island is periodically exposed to inundation during extreme events, although in many years the floods do not submerge the highest parts of the island. In recent decades, the lowering of the Red River's water levels (due to upstream flow regulation and sediment extraction) has somewhat reduced the frequency of moderate flooding, but it has also led to riverbed incision. The hydrological regime's variability underscores the need for any development on the island to withstand flood pulses and adapt to changing water levels, especially as climate change may alter flood intensity.

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 15-29

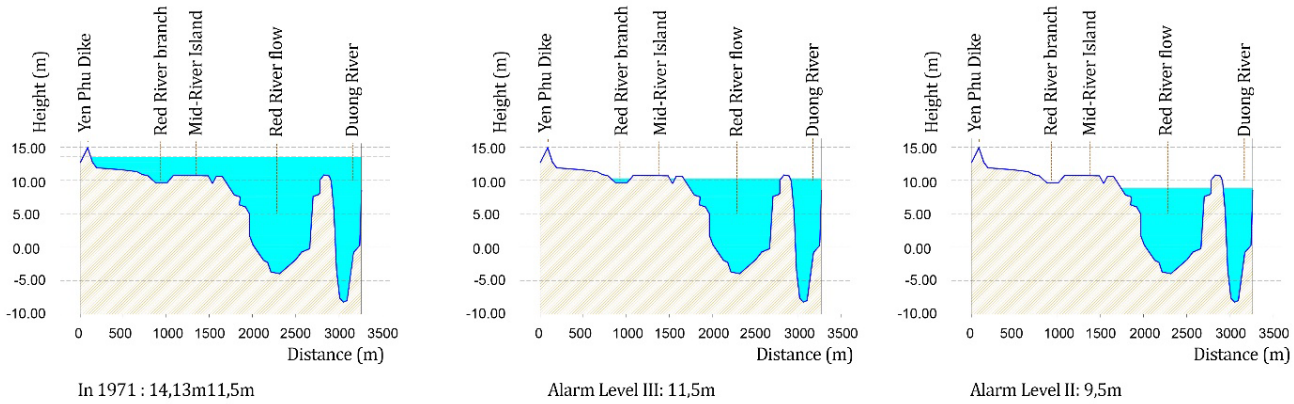


Fig. 2 *Conceptual diagram of Red River flood alarm levels based on historical hydrological data*
Data sources: Hanoi Hydrometeorological Station (1920–2023); Red River–Thai Binh Basin Planning Management Board.

4.2 Morphological Changes

The mid-river island is a dynamic landform created by the deposition of alluvium over time. It is an inseparable geomorphological part of the Red River, evolving with the river's channel shifts. Historical imagery reveals distinct phases of the island's growth:

- Pre-1985: The Red River's course was braided with many small sandbars. A proto-island existed but had not accreted significantly near Long Biên Bridge, and the river flowed in two roughly equal branches around it (hence the old name "Nhi Ha" or "Two Rivers") [21].
- 1985-2000: This period saw the most dramatic expansion. The island rapidly extended southward, reaching the area under Chương Dương Bridge by around 2000. Sediment deposition was high, enlarging the land area.
- 2000-2005: Lateral growth became apparent. The island's eastern and western edges spread, and its length stabilized. By 2005, the island had a substantial continuous landmass.
- 2005-2015: Continued sedimentation and human impacts (e.g., sand mining altering flows) caused the western channel (adjacent to Hanoi's main urban districts) to narrow significantly. The eastern bank of the island stabilized, while the western bank kept pushing outward toward the city's dike line. The Long Biên (west) branch of the river became shallower and slower.
- 2015-Present: The island's overall morphology has stabilized in recent years. Climate change and excessive upstream sand extraction have lowered normal flow levels, slowing further accretion. The western side of the island is now so close to the mainland that in the dry season, one can practically wade across in places. The western branch is at risk of silting up entirely, which could eventually connect the island to the mainland if sedimentation continues unchecked.

Overall, the island has grown in size and become more stable in position compared to decades past. Its highest elevation areas (10-12 m) are now above most annual flood levels, though still below historic flood peaks. The morphological stability provides a foundation for considering more permanent land uses, provided they can accommodate lateral erosion or deposition at the shores.

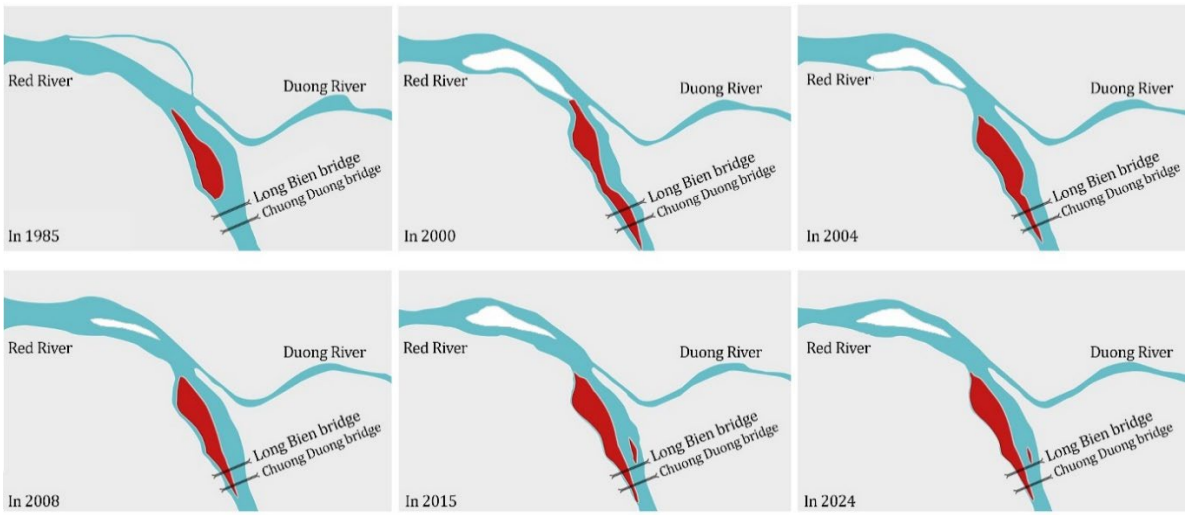


Fig. 3 *Natural morphological changes of the mid-river Island from 1985 to Present*

Table 1 quantitatively summarizes morphological evolution across five temporal milestones. The island expanded from approximately 120 ha (1984) to 310 ha (2024). This 2.6-fold increase, combined with reduced lateral channel shifts in the past decade, confirms that the island has reached a state of morphological semi-stability. These results complement the qualitative observations in Fig. 3 and strengthen the empirical basis for evaluating long-term development feasibility.

Table 1 *Area variations of the mid-river Island over time*

Year	Area (ha)	Morphological Characteristics
1984	120	Fragmented sandbars; proto-island structure
2000	240	Rapid southward accretion; merging of sandbars
2005	280	Lateral expansion, stabilization of island geometry
2015	305	Western channel narrowing; eastern edge stabilized
2024	310	Morphologically stable; minimal accretion

4.3 Terrain Characteristics

Due to continuous alluvial deposition, the island's elevation has gradually increased. On average, the terrain lies around 10-12 m above sea level, sloping gently from north to south [20]. This means that some higher parts of the island approach or slightly exceed the typical Alarm III level (11.5 m) but remain lower than extreme flood crests by a few meters. The highest natural point on the island still sits roughly 3 m below the 1971 record flood level.

The lowering of normal river levels in the past decade (owing partly to upstream dam retention and riverbed mining) has likely reduced overbank flooding frequency, which in turn slows the natural buildup of sediments on the island [22]. There are minor undulations in the terrain, including natural levees along the riverbanks and depressions in the interior where water can pond. During major floods, it is expected that only treetops and any tall structures would remain above water, while moderate floods might inundate low-lying southern parts. This topographic understanding is crucial for planning - any infrastructure must either be placed on the higher ground or be flood-resilient by design.

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 15-29

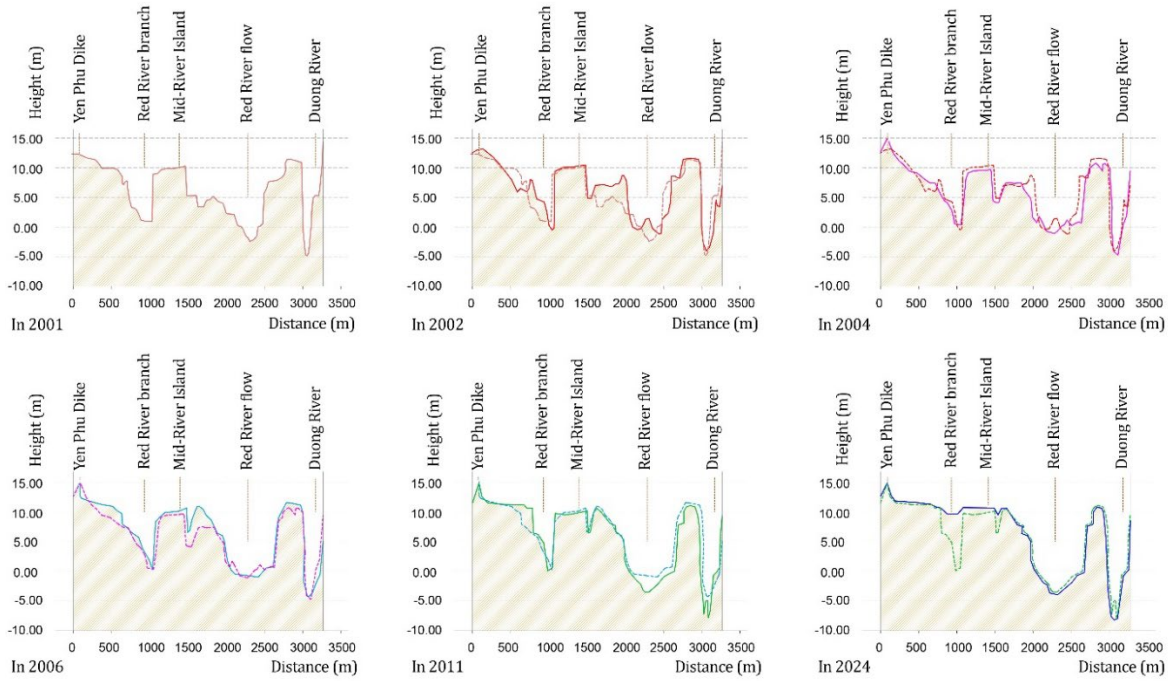
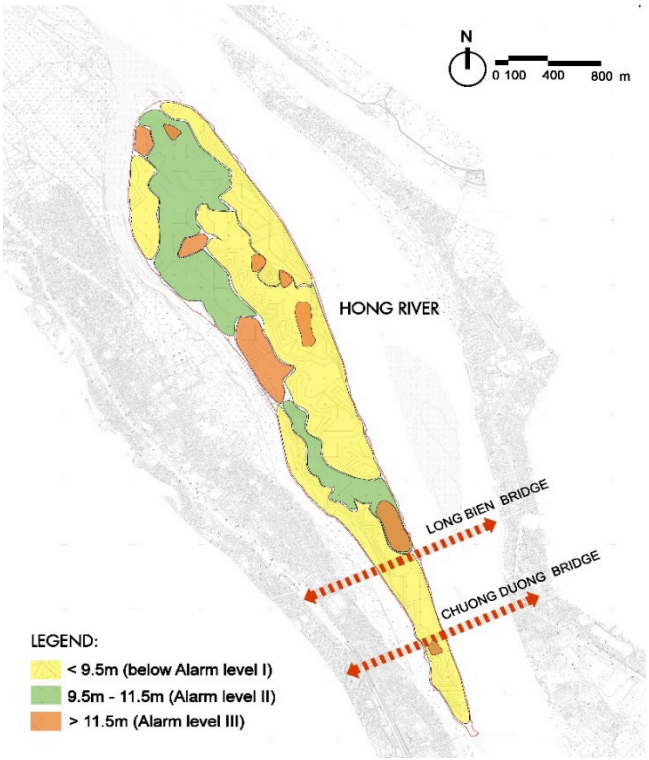


Fig. 4 *Conceptual diagram of morphological changes of the mid-river island (2001–2024)*
Data sources: Topographic map series of the Ministry of Agriculture and Rural Development; published Red River planning reports (2001–2024).

Fig. 4 shows the conceptual diagram of morphological changes of the mid-river island (2001–2024). Fig. 5 presents the flood risk zoning map of the mid-river island, developed based on the official alarm levels of the Red River (Alarm I: 9.5 m; Alarm II: 10.5 m; Alarm III: 11.5 m). The map clearly illustrates the relationship between topographic elevation and inundation risk, showing that large areas of the island fall within Alarm Level II, while only limited higher terraces remain above Alarm Level III. This zoning provides the scientific basis for evaluating spatial vulnerability and informs the placement of adaptive design interventions discussed in Section 5.1.



4.4

Fig. 5 *Flood risk zoning map of the mid-river island based on Red River alarm levels I–III (source: author)*

4.4 Ecological Characteristics

The Red River's mid-channel island has been dubbed an ecological jewel in the heart of Hanoi [20]. Its mix of wetland and terrestrial habitats supports remarkable biodiversity, especially given its proximity to dense urban districts. The island has long functioned as one of the largest and most unique bird sanctuaries of the capital [23]. Recent surveys in 2021-2022 recorded at least 232 bird species on and around the island, including 192 migratory species, with several categorized as endangered or threatened [24]. This indicates the island's crucial role in migratory flyways and as a refuge for avian fauna amidst the urban matrix.

Flora on the island ranges from pioneering grass and reed species on newly deposited sandbanks to shrubs and some mature trees (e.g., willows, bamboo groves) on older, higher parts. The vegetation provides feeding and nesting grounds for birds, and the surrounding waters likely harbor fish and aquatic invertebrates that sustain wading birds and other wildlife.

Despite its ecological value, the island's environment has suffered in the last 5-10 years from human disturbance. Activities such as illegal sand mining (dredging around the island), agricultural encroachment (clearing natural vegetation for crops), and hunting/trapping of wild birds have degraded the habitat [25]. There is evidence of a decline in certain bird populations due to these pressures. Conservation of this biodiversity hotspot is a major argument for limiting development and instead promoting the island as an urban nature reserve or park.

4.5 Cultural Characteristics

Culturally, the mid-river island is intertwined with Hanoi's heritage. Most prominently, it lies just beside the iconic Long Bien Bridge - a 120-year-old historic cantilever bridge that is a symbol of Hanoi [26]. Long Bien Bridge is often considered an "urban heritage" landmark with significant architectural and historic value (associated with colonial-era engineering and Vietnam's 20th-century wars). The island directly under and around this bridge effectively forms a natural-cultural landscape in combination with the structure. Together, the bridge and the river's alluvial islets create a picturesque scene that has inspired local art and literature, symbolizing the resilience and identity of Hanoi [27].

Beyond the bridge, the island can be seen as a "connecting space" linking the dense cluster of heritage sites in the Old Quarter and French Quarter south of the river with those to the north, like Co Loa and Soc Temple. Historically, the Red River is central to the Red River civilization - an indigenous culture dating back to the Dong Son drum era and through the Dai Viet period of Vietnamese history [28]. The fertile banks and islands of the river have always been part of the city's cultural landscape, associated with legends, agriculture, and traditional riverside settlements.

Recognizing this, the development of the island could celebrate and interpret these cultural layers. For instance, any park or public space on the island could include references to the Long Bien Bridge history, Vietnamese river folklore, and the agrarian heritage of the Red River Delta. This aligns with findings that community-driven river-based activities can enhance local resilience and strengthen human–river interactions.

4.6 Policies and Management

The legal status of the mid-river island is a critical factor. According to Vietnamese law and Hanoi's regulations, this island lies within the Red River's flood drainage corridor, which is classified as a non-construction zone. Specifically, pursuant to the Law on Dike Management, areas such as these islets are generally subject to construction projects approved by the Prime Minister. Structures built on alluvial islets must not reduce the design flood discharge beyond permissible limits; must not increase the design flood water level beyond permissible thresholds; and must not adversely affect the flow regime of adjacent, upstream, or downstream areas [16]. Hanoi's recent urban zoning plans (e.g., the Red River 1/5000 Plan approved in 2022) also label much of the mid-river area as either conservation or restricted-use space [4]. The island can be used for certain open economic and social activities (e.g., agriculture, tourism, recreation) as long as they do not obstruct flood flows or reduce flood storage capacity. Any use must also ensure no harm to the river's flow, no exacerbation of flood risks, and compliance with environmental protection laws. Only very limited types of structures are allowed by law in the flood corridor - mainly those serving flood control, irrigation, or navigation (e.g., pumping stations, embankments) and small ancillary facilities, and even those require special permissions.

In terms of administrative management, the Red River and its islets fall under multiple jurisdictions. The overall planning and flood management of the Red River basin is overseen by the Ministry of Agriculture and Rural Development (specifically, the Red River - Thai Binh River Basin Planning Management Board) [19, 29]. Meanwhile, Hanoi City People's Committee is responsible for local land use and enforcement within the city's territory, under the guidance of national agencies. In practice, this has led to overlapping responsibilities and sometimes insufficient enforcement. The island has suffered from weak management manifesting in issues like illegal land reclamation, unpermitted construction of shacks, and dumping of waste, as city inspectors struggle to

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 15-29

monitor these transient activities [27]. Strengthening the governance framework - possibly by establishing the island as a special managed park or protected area - will be important for any future development model.

4.7 Land Use and Landscape

Land Use: At present, land use on the island is informal and mixed. There are pockets of small-scale agriculture; local farmers from nearby neighborhoods have planted maize, vegetables, or fruit trees on parts of the fertile alluvial soil. No official land titles exist, but encroachment has been ongoing, with some semi-permanent shacks or storage sheds erected [30]. In recent years, a number of unplanned residential structures (essentially squatter houses) have appeared, particularly on higher ground safe from regular floods. There are also areas where construction debris and waste have been dumped illegally, gradually raising the ground in spots. These activities not only violate regulations but also pose environmental hazards (pollution, habitat destruction).

Landscape: Despite human impacts, large portions of the island remain natural in appearance, characterized by open grasslands, aquatic habitats, and panoramic views of the city. The combination of the lush green island, the spanning bridges, and the flowing Red River - especially at sunrise or sunset - creates a scenic landscape unique to Hanoi. The site has become an attractive spot for urban residents seeking recreation: on weekends one can find people camping on the sandy beaches, fishing in the shallow waters, or even swimming in calm river sections. The fresh air and retreat-like environment so close to the city center is a major asset.

However, intermixed with these idyllic scenes are many "gray zones" of disorder. In certain pockets, one encounters piles of construction materials (sand, gravel) that have been stored by private businesses. Some makeshift yards for construction equipment or boat landings are scattered along the shoreline. There are also a few illegal floating houses moored in the river near the island's banks, serving as informal housing or fishing bases. These detract from the visual landscape and raise concerns about water pollution (sewage discharge, etc.).

4.8 SWOT Analysis

From the above findings, we derive the following SWOT factors (summarized for clarity):

- Strengths (S): Exceptional natural heritage in an urban context (diverse ecosystem, bird sanctuary); fertile alluvial land and scenic landscape; adjacency to major urban heritage (Long Biên Bridge, Old Quarter) giving it cultural significance; geomorphologically stabilizing (the island now coexists with the river's regime rather than being ephemeral).
- Weaknesses (W): Strict legal limitations on development (no permanent structures allowed); lack of infrastructure and accessibility (no official bridges or services to the island currently); ongoing environmental degradation from illegal activities (sand mining, poaching, dumping); absence of an established management mechanism or clear ownership leading to chaotic land use.
- Opportunities (O): Huge potential to develop an ecological park or nature-based tourism given the island's natural assets; possibility to create a flexible urban innovation space (e.g., for creative, scientific, or agricultural experimentation) that aligns with Hanoi's vision as a "Creative City"; support from broader policies promoting green development and climate adaptation - e.g., integration into Hanoi's Green Corridor strategy and access to funding for urban resilience projects.
- Threats (T): The ever-present risk of flood damage to any intervention (structures could be destroyed or projects undone by a major flood if not properly designed); potential conflicts with aggressive real estate pressures on the urban banks (e.g., developers eyeing dike relocation or riverbed land for expansion - which could undermine the island if not controlled); and climate change scenarios that could bring more extreme floods or droughts, complicating stable land use. Additionally, bureaucratic and regulatory hurdles pose a threat - any development concept might stall without high-level support and legal adaptations.

Translating Analysis into Planning: The above SWOT analysis indicates that the island's best future lies in leveraging its strengths (nature and culture) and opportunities (policy support for green space) to overcome weaknesses and mitigate threats. In the next sections, we build on these insights to propose a development orientation. The goal is to enhance the island's ecological and cultural value through planning models that are flexible, flood-adaptive, and legally feasible.

5. Discussion

In light of the analysis, we propose that Hanoi's mid-river islands be developed as a network of Ecological, Cultural, and Creative Thematic Parks integrated into the Red River Green Corridor. This section discusses the feasibility of the proposed development model, addresses the apparent contradictions with current legal constraints, and compares our approach with relevant international cases.

5.1 Feasibility and Adaptive Design Strategies

A major concern is the legal status of the mid-river island as a non-construction zone. Our proposal directly tackles this by advocating flood-adaptive and flexible design instead of conventional construction. All planned facilities on the island would employ lightweight, removable, or amphibious structures that do not qualify as permanent buildings under the Law on Dikes [16]. For instance, small visitor pavilions, observation decks, or cafes could be made from modular prefabricated units that are bolted to foundations in the dry season and easily disassembled or relocated before major floods. Elevated boardwalks and viewing platforms could be built on stilts or floatable pontoons that allow floodwaters to pass beneath. Critical infrastructure (e.g., toilets, kiosks) might be housed in structures designed to withstand submersion or quickly evacuate (similar to campsite facilities in floodplains). These approaches have precedents: in the Netherlands and the United States, amphibious architecture has been used for housing in flood-prone areas - such buildings rest on the ground normally but rise with floodwaters on guideposts [31]. By adopting amphibious and floating design principles, the island's development can "live with the water", ensuring that even a 50-year or 100-year flood would not catastrophically damage the park, but rather temporarily inundate it in a controlled manner [32].

Another strategy is to zone the island's surface by flood frequency. As hinted in our model notes, we envision a tiered circulation system: pathways and access roads at different elevations corresponding to floods of various return periods. For example, a primary walkway might be built at the 20-year flood level (perhaps 12 m elevation), secondary trails at the 5-year flood level (11 m), etc. When lower paths submerge, visitors would be restricted to the higher routes. Vegetation selection is also crucial - planting mostly native flood-tolerant species (such as river reeds, lotus in wetland spots, and fast-growing trees that can survive occasional inundation) ensures the landscape recovers quickly post-flood.

From a financial and technical standpoint, the proposed park model is plausible if phased appropriately. Initially, minimal investment could create basic eco-trails and viewpoints, capitalizing on the island's natural appeal. Over time, and contingent on regulatory approvals, more features (like a small environmental education center or floating cafés) could be added. It's important to highlight that no dikes or major land-fill will be done - the island will retain its natural form, which keeps costs lower and maintains compliance with flood conveyance requirements. Engaging stakeholders, such as city authorities, local residents (e.g., farmers currently using the land), and environmental groups, early in the planning process will help refine these ideas and build consensus. The success of this model will depend on effective management (possibly a special management board for the river park) to enforce rules (e.g., seasonal removal of structures, ban on private development) and coordinate flood response.

To operationalize the adaptive design approach, the proposed thematic parks incorporate five typologies of flood-resilient structures: (1) floating pavilions for seasonal activities, (2) elevated stilt walkways allowing free passage of floodwaters, (3) modular prefabricated units that can be removed before major floods, (4) temporary platforms for events or ecological viewing, and (5) amphibious decks capable of rising with water levels. These designs comply with the Law on Dikes by ensuring reversibility and non-obstruction of the flood conveyance corridor. Under Alarm Level I (9.5 m), most activities remain functional, with only low-lying ecological areas affected. At Alarm Level II (10.5 m), agricultural and wetland zones are inundated while elevated cultural and scientific zones remain operational. Under Alarm Level III (11.5 m), only high-elevation routes and floating structures remain accessible; modular units are seasonally removed or secured. This system ensures that the proposed model remains safe, adaptable, and compatible with the hydrological dynamics of the Red River.

A conceptual cross-section (see Fig. 6) illustrates the flood-adaptive behavior of modular composite units, amphibious decks, and elevated stilt walkways. The diagram shows structural responses under Alarm II (10.5 m) and Alarm III (11.5 m) water levels of the Red River. Floating modules rise along anchoring posts, while elevated walkways maintain hydraulic clearance. All structures comply with flood-conveyance requirements and demonstrate engineering feasibility. These configurations are suitable for deployment on mid-river islands.

Int. J. Sustain. Constr. Eng. Technol. Vol. 17 No. 1 (2026) p. 15-29

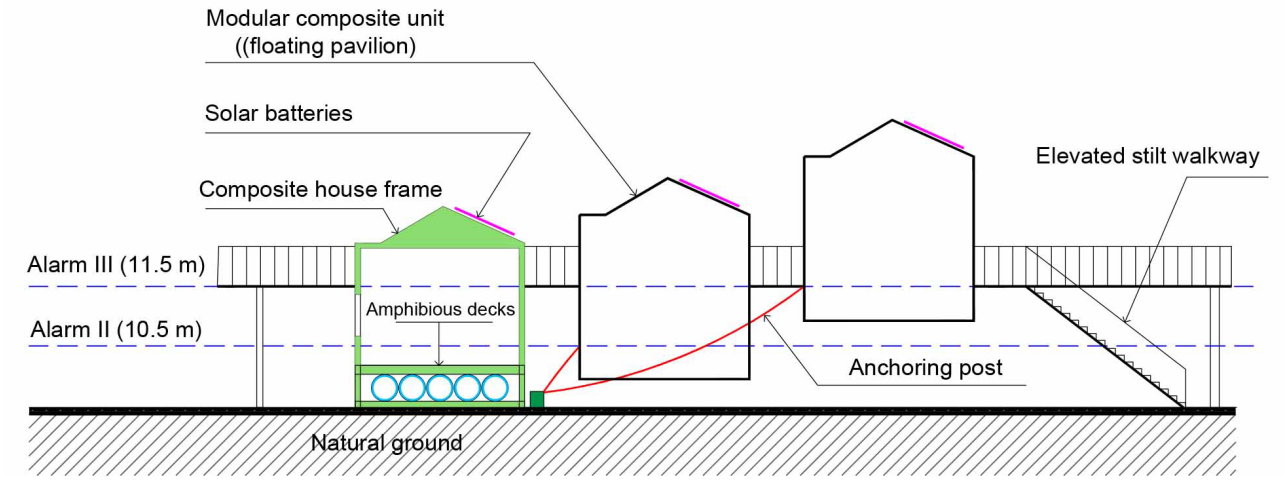


Fig. 6 *Conceptual cross-section illustrating the flood-adaptive structures (source: author)*

Integrating Blue–Green Infrastructure, Nature-Based Solutions, and climate-resilience principles ensures that the proposed model functions not only as an ecological park system but also as a hydrologically adaptive landscape. These frameworks reinforce the island's capacity to accommodate floods while maintaining ecological performance and long-term social value.

5.2 Legal and Institutional Considerations

The contradiction between the island's protected status and the development proposals is indeed sensitive. However, our approach can be framed not as urban "construction" but as landscape enhancement and floodplain management, which is consistent with policy goals. We recommend that Hanoi explore legal mechanisms such as:

- Special Zoning or Pilot Status: The city could designate the mid-river island as a special planning zone (an "urban ecological park" zone) where certain lightweight constructions are permitted as exceptions, subject to stringent design codes. Pilot projects in flood-adaptive design could be allowed here by obtaining waivers or amendments to current regulations. Given that the Prime Minister's decisions on Red River zoning already allow for recreational use, a well-justified plan might gain central approval [4, 32].
- Inter-agency Agreements: A memorandum of understanding can be made between the water management authority and the city to implement the island park as a flood-friendly use that improves flood safety (for instance, by stabilizing soils and providing better flood overflow channels). If the project is seen as supporting the objectives of the flood control plan (Decision 257/QD-TTg, etc. [32]), it is more likely to be approved.
- International Partnerships: Hanoi could partner with organizations experienced in nature-based solutions for rivers. Support or sponsorship from bodies like the World Bank or Asian Development Bank for a "Resilient Rivers Program" might provide both funding and an external mandate to reconcile development with safety. Such partnerships often come with technical assistance to address legal barriers by updating local guidelines in line with global best practices [17].

In summary, while current laws are restrictive, they are not insurmountable obstacles. By positioning the project as an ecological restoration and public space initiative rather than commercial development, it aligns with the intent of regulations (which is to prevent harmful construction in the floodplain). Small, non-permanent structures serving public interest can be argued as allowable or can be newly authorized through the proper channels. A careful legal feasibility study would be the next step, but comparative examples (e.g., parks on river islands in other countries) show it is indeed possible to navigate these constraints. The current lack of unified coordination in the Red River corridor means that development activities are fragmented and often unregulated, increasing risks to flood safety and ecological stability.

5.3 Comparison with Similar Projects

To validate our development model, it is useful to compare it with similar projects globally and regionally:

- Urban River Island Parks: As mentioned, Seoul's Seonyudo Park is a prime example of turning a mid-river island into a thriving public park. Seonyudo faced challenges of access (solved by a pedestrian bridge) and environmental cleanup (it was a former filtration plant), but today it's celebrated for its harmonious

design with water and native landscaping. Our proposal for Hanoi shares a similar vision of repurposing an island for public benefit, though our context has a stronger flood and legal component. Another example is New York City's Governors Island (though technically in a harbor, not a river): once a military base, it is now a public park and cultural venue accessible by ferry. It demonstrates how an island can host art installations, educational centers, and festivals without permanent residents, somewhat akin to our idea of an "innovation park" theme for part of the island.

- Flood-Adaptive Parks: The Yanweizhou Park in China, as previously noted, offers lessons in design - terracing, use of flood-resistant vegetation, and integrating pedestrian infrastructure that can be submerged [13]. The proposed Red River island park can adopt similar techniques, such as terraced riverbanks at the island's edges to dissipate flood energy and create wetlands. Another case is Praca das Aguas in Curitiba, Brazil, where a former floodplain was turned into a park with seasonal lakes that fill in the rainy season. Such designs treat flooding as a feature, not a bug. Our model's emphasis on flexible structures and multi-level pathways aligns well with these international practices for resilience [12, 17].
- Cultural Heritage Integration: Many cities incorporate cultural heritage into park design - for example, in Singapore's Bishan-Ang Mo Kio Park, an old concrete canal was naturalized into a river park that also celebrates local history through art and signage. We envision interpretive trails or small open-air museums (Long Biên Bridge) on the island that could host exhibitions about Hanoi's riverine culture. This approach is akin to parks like Boston's Emerald Necklace, where historical elements (old structures, references to indigenous history) are part of the experience [6].

Comparatively, what Hanoi's mid-river island project would demonstrate is a synthesis of multiple thematic parks in one: ecological, historical, agricultural, and scientific. This multi-themed approach is somewhat unique. While examples exist of single-theme parks (eco-park, heritage park, etc.), combining them requires careful zoning within the island. Our proposal divides the island into zones (for ecotourism, culture, agriculture, science, and health) as outlined in Section 6. This could serve as a model for multi-functional green corridors, illustrating how one continuous space can support diverse but complementary uses. It will be important, as we implement this, to ensure the themes indeed synergize rather than conflict - something our Discussion highlights as both an opportunity and a management challenge.

5.4 Limitations and Future Work

It is important to acknowledge the limitations of our study and proposal. Firstly, the research has been largely qualitative. We did not conduct new quantitative measurements of biodiversity (aside from compiling existing records) or hydraulic modeling of flood scenarios with the proposed interventions. Such data would strengthen future planning - for example, precise flood modeling could identify how elevated walkways might slightly alter flow, or ecological surveys could pinpoint critical nesting sites to leave undisturbed. A more detailed environmental impact assessment will be needed in the next phase.

Secondly, our SWOT analysis and planning recommendations were formulated by the authors' team and would benefit from broader stakeholder input. Perspectives of local communities, city officials, and potential investors were not formally surveyed in this study. Their input could reveal additional strengths (e.g., community support), weaknesses (e.g., funding constraints), opportunities (e.g., tourism demand), or threats (e.g., competing land-use interests) that we might have overlooked. Before implementation, holding public consultations and expert workshops will be essential to refine the model.

Lastly, implementation will face practical challenges that our paper can only briefly touch on: securing financing for park development and maintenance, phasing construction to sync with dry seasons, providing access (perhaps via pedestrian bridges or boat ferries), and coordinating among multiple government agencies. These challenges are surmountable but require further study. We suggest future work should include developing a phased master plan for the island, including designs for pilot projects (like a demonstration "floating pavilion"), as well as policy dialogues to adapt existing regulations. Monitoring and evaluation frameworks should also be established from the start, to document how the island's environment and usage change once the project is initiated - contributing valuable lessons for other river cities.

In conclusion of this discussion, the mid-river islands of the Red River present a complex yet promising case for innovative urban green planning. By learning from global best practices and carefully addressing local constraints, Hanoi can turn what was once considered off-limits into an exemplar of sustainable, resilient urban design.

6. Conclusions

The mid-river islands of the Red River possess significant ecological, cultural, and climatic value, positioning them as strategic nodes within Hanoi’s emerging Green Corridor. Based on the comprehensive assessment conducted in this study, the islands demonstrate both high biodiversity potential and substantial management challenges,

confirming the need for a scientifically grounded and policy-aligned development approach. Applying the Green Corridor framework allowed us to conceptualize the Red River corridor as a linear ecological spine integrating natural, cultural, and economic functions [7], while simultaneously reinforcing its role within a broader system of Blue–Green Infrastructure (BGI) and Nature-Based Solutions (NbS). Within this multidimensional framework, the mid-river island is envisioned as a flexible ecological park capable of enhancing Hanoi's resilience to climate variability.

The proposed vision positions the islands as adaptive green spaces that can accommodate seasonal flooding, support biodiversity, and celebrate cultural identity, contributing to Hanoi's aspiration for a "Green – Cultural – Civilized – Modern" capital [1]. To operationalize this vision, five planning criteria were developed: flood-adaptive flexibility, ecological conservation, cultural interpretation, green economic innovation, and intelligent management, ensuring that any intervention remains sustainable, reversible, and resilient under dynamic hydrological conditions.

Building on these criteria, we introduced a Development Planning Model consisting of five thematic park zones: an Ecotourism Park emphasizing ecological restoration; a Cultural Park showcasing the Long Bien Bridge and heritage landscapes; an Agricultural Park demonstrating urban agriculture and native species; a Science and Innovation Park for environmental research and community creativity; and a Health and Wellness Park oriented toward nature-based therapeutic experiences. All zones prioritize minimal permanent construction and employ modular, lightweight, and flood-resilient design strategies consistent with best practices in BGI and NbS, as well as Vietnamese regulatory requirements [29], [30].

This study has certain limitations, such as the unavailability of high-resolution hydrodynamic modelling and full GIS-based flood risk analysis. Future research should focus on integrating remote sensing, hydraulic simulation, and community-based assessments to validate and refine the proposed development model for wider application.

This integrated model suggests a viable pathway for harmonizing conservation and development within Hanoi's river corridor. If implemented, the island system could simultaneously function as a biodiversity sanctuary, a public recreation destination, a cultural landmark, and a living laboratory for climate-adaptive innovation. Its open and permeable landscape would also strengthen flood safety by providing space for water dispersion and improving environmental quality through habitat creation and natural filtration.

Overall, this study contributes a context-specific example for urban river revitalization, illustrating that even cities with stringent flood-control regulations can activate river islands as resilient public assets. Successful implementation will depend on design and policy flexibility, multi-stakeholder collaboration, and a steadfast commitment to ecological integrity. We recommend that city authorities initiate small-scale pilot projects, such as seasonal eco-camps or floating cultural stages, to test and refine the proposed solutions. Continuous monitoring, community engagement, and iterative learning will be essential to unlock the full natural and cultural potential of Hanoi's Red River islands and to establish a replicable model for sustainable river-corridor planning.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

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