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Developing a Triple Landscape Network Model for Multi-Hazard Urban Resilience: Evidence from the Maltepe–Dragos Coastal Area, Istanbul

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ABSTRACT

Coastal metropolitan areas increasingly face overlapping seismic, hydrological, and climate-related hazards, requiring spatial frameworks that integrate risk reduction with everyday urban performance. This study develops a Triple Landscape Network Model for the Maltepe–Dragos coastal area of Istanbul to translate multi-hazard vulnerability into actionable landscape planning strategies. Using a research-by-design and scenario-based spatial assessment approach, the study overlays ecological, hydrological, topographical, land-use, accessibility, and industrial-heritage layers to identify strategic transformation zones. The proposed model integrates three interconnected systems: an ecological network for coastal–stream–hill continuity, a circulation network for redundant evacuation and pedestrian mobility, and a recreational-cultural network for adaptive reuse and public life. Results identify a 390 m² critical flood-prone zone along Dragos Stream, central nodes located within 5 minutes of the coastline and 15 minutes of the rail system, and the potential conversion of 30–35% of impermeable industrial surfaces into absorptive landscapes. The model also positions post-disaster gathering spaces to serve approximately 60% of nearby residential fabric within 5–10 minutes. By combining nature-based solutions with adaptive reuse, the study demonstrates how resilient landscape infrastructure can reduce disaster costs, enhance urban attractiveness, stimulate local investment, and support sustainable urban economic vitality.

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Highlights:	Contribution to the field statement:
- Proposes a landscape-based resilience framework for multi-hazard coastal areas. - Converts environmental and disaster risks into spatial planning strategies. - Integrates ecological, circulation, and recreational-cultural networks. - Applies a multiscale approach from master plan to detailed design.	This study advances landscape architecture and urban resilience planning by proposing a multiscale framework for coastal adaptation. It demonstrates how ecological, mobility, and recreational networks can enhance resilience while generating urban economic benefits through increased place attractiveness, tourism potential, local investment opportunities, and reduced long-term disaster-related costs.

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1. Introduction

In recent years, the escalating frequency and severity of climate-related hazards, compounded by the persistent seismic vulnerability of many metropolitan regions, have profoundly challenged conventional urban planning paradigms. Particularly in tectonically active coastal cities where earthquakes, floods, and climate-induced risks frequently co-occur and interact, relying solely on engineering-based structural solutions or post-disaster intervention strategies is increasingly insufficient. Consequently, contemporary discourse has shifted from defining resilience merely as a static capacity for shock resistance to conceptualizing it as a complex, dynamic, and evolving process (Amirzadeh et al., 2022). Comprehensive reviews of the literature affirm that building resilient cities necessitates multi-disciplinary, holistic frameworks capable of addressing an array of complex threats (Büyüközkan et al., 2022). Within this evolutionary perspective, cities are increasingly regarded as complex social-ecological-technological systems (SETS) that must preserve their core functions, respond to rapidly changing conditions, and adapt in the face of compounded crises. True resilience is therefore characterized not only by the ability to withstand disruptions but also by inherent capacities for learning, reorganization, and transformation (Meerow et al., 2016; Elmqvist et al., 2019; Sharifi, 2023), positioning urban resilience as an essential condition for achieving long-term urban sustainability goals (Bautista-Puig et al., 2022).

This theoretical transformation repositions open space systems and landscape architecture from purely aesthetic or recreational disciplines into strategic fields of planning that mediate between ecological processes, spatial organization, and societal needs. To effectively address multi-hazard realities—including the persistent threat of sudden-onset disasters like earthquakes—cities must be evaluated not only on their holistic preventive planning but equally on their preparedness capacity for effective response and recovery (Türer Başkaya, 2023). In this context, Green Infrastructure (GI) and green-blue networks emerge as fundamental tools bridging the reduction of urban vulnerabilities with enhanced environmental and social performance. GI conceptualizes natural, semi-natural, and urban open spaces not as isolated elements, but as an interconnected network supporting urban ecology and social well-being (Wang & Banzhaf, 2018). Evaluated through the lens of nature-based solutions, these systems simultaneously provide multiple ecosystem services, such as climate regulation, air quality improvement, and surface runoff control (Yao et al., 2025). Furthermore, while a comprehensive review indicates that urban GI concentrates heavily on regulatory and cultural services (Yao et al., 2025), this multifunctionality is often not consciously incorporated into planning processes (Cook et al., 2024), leaving significant gaps regarding how it should be evaluated and integrated into spatial planning (Korkou et al., 2023).

Particularly in compact cities where spatial constraints are a determining factor, leveraging this multifunctional capacity of green spaces is a critical necessity (Hansen et al., 2019). Viewing landscape as a "medium" enables the integration of spatial, ecological, and social components across different scales, thereby structuring public spaces as adaptive entities (Wu & Liu, 2023). Recent studies on post-industrial coastal areas demonstrate that resilience is robustly enhanced through designs that integrate spatial continuity, ecological restoration, and social inclusivity (Wu & Liu, 2023). Such landscape-oriented transformations of industrial areas go beyond the adaptive reuse of physical spaces; they strengthen social sustainability, reconcile cultural heritage with present-day needs (Cırık & Haştemoğlu, 2024), and convert isolated sites into multi-layered landscape systems integrated with the city (Tırnakçı, 2020). The critical necessity of these connected systems becomes undeniable during disasters, proving that evaluating risks solely through singular hazards is profoundly inadequate. Sudden disasters like earthquakes cause massive accessibility losses and infrastructure collapses that drastically delay emergency response, demonstrating that resilience is strictly tied to spatial continuity (Ghasemi et al., 2025). In both risk reduction and recovery stages (Türer Başkaya, 2023), linear landscape configurations that develop in harmony with circulation networks and topography assume an effective role in reintegrating fragmented urban fabrics (Sağlık, 2021).

Despite the advanced theoretical discourse on green-blue infrastructure and urban resilience, a significant research gap remains regarding how multi-hazard vulnerabilities can be explicitly translated into actionable spatial decision-making models. Frequently, critical dimensions of urban resilience—such as ecological continuity, post-disaster accessibility, and socio-cultural adaptive reuse—are conceptualized and managed as entirely separate systems. In response to this gap, this study departs from rigid quantitative engineering simulations and conventional mixed-method approaches, instead adopting a scenario-based spatial assessment and research-by-design methodology. The unique contribution of this study is the development of a "Triple Landscape Network Model." By systematically integrating the ecological network, circulation network, and recreational-cultural network layers into a cohesive decision-making matrix, this model provides a transferable, multiscale spatial strategy that unites isolated resilience systems.

The concrete manifestation of this theoretical and methodological framework is examined in the Istanbul Maltepe–Dragos region. With its coastal location and overlapping risks of earthquakes and flood hazards, this area simultaneously embodies vulnerability and transformation potential through fragmented land uses, abandoned industrial traces, and degraded water systems. Through these characteristics, Dragos presents a critical focal area where the proposed triple landscape network model can be spatially tested and evaluated. Driven by the necessity to explicitly link multi-hazard problems with actionable landscape frameworks, the study is guided by the following research questions:

1. How can multi-hazard vulnerabilities (e.g., flood risks and seismic accessibility loss) be systematically translated into spatial planning priorities using a scenario-based landscape assessment?

2. How does the proposed "Triple Landscape Network Model"—integrating ecological, circulation, and recreational-cultural layers—improve the multifunctionality and adaptive capacity of compact coastal cities?

3. How can abandoned industrial landscapes be physically transformed into resilience assets that simultaneously support ecological restoration, daily public use, and emergency post-disaster functions?

By addressing these questions through a multiscale (1/2000 and 1/500) design framework, the study aims to contribute to current discussions on resilient urban landscapes, adaptive reuse, and disaster-sensitive public space design, proposing a transferable methodology for vulnerable coastal urban areas.

2. Materials and Methods

2.1. Research Design

This study aims to develop a landscape-based approach to enhance urban resilience under multiple hazard conditions in the Istanbul Maltepe–Dragos region (Figure 1).Addressing the need for measurable spatial evaluation without relying on rigid quantitative engineering simulations, the research departs from conventional mixed-method claims and instead adopts a 'Research by Design' and 'Scenario-Based Spatial Assessment' methodology. Accordingly, the research process proceeds through a structure integrating multi-layered spatial analyses, the development of a literature-based conceptual framework, and design-oriented synthesis stages. The study is grounded in the understanding that landscape architecture can function not only as a design discipline, but also as an analytical and strategic framework addressing issues of urban risk and socio-economic resilience.

In this direction, the study brings together environmental reading, spatial analysis, and design synthesis in order to develop a landscape proposal that responds both to everyday urban needs and post-disaster conditions. This approach conceptualizes the design process not merely as a result-oriented production, but as a data-driven, multi-layered, and iterative research process, based on shaping spatial decisions through proxy analytical outputs.

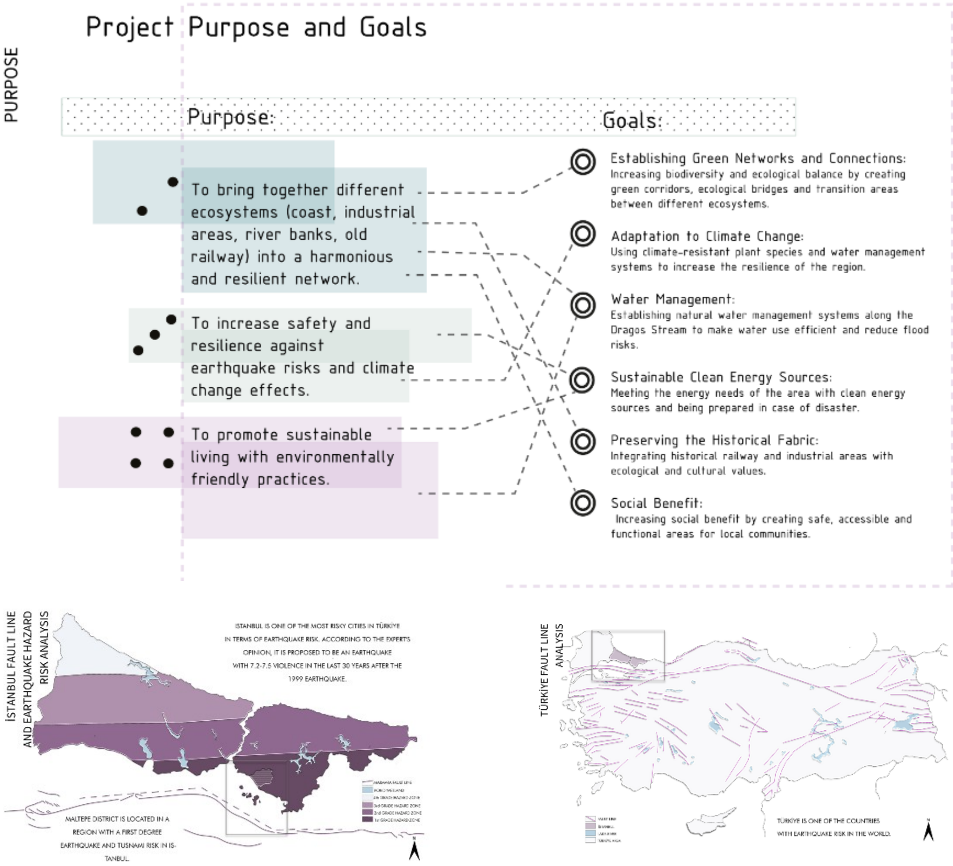

Figure 1. Structure of the Study, Study area and Project Purpose (Developed by the Authors).

The methodological structure follows a layered process consisting of (1) contextual reading, (2) spatial and environmental analysis, (3) synthesis of risks and potentials through a decision-making matrix, and (4) design development stages. This structure reflects the project's transition from diagnosis to intervention and from site vulnerability to an adaptive spatial strategy. Within this framework, the design process is addressed as a spatial response to environmental constraints, infrastructural discontinuities, and ecological potentials identified through analyses. This process also includes data generation and interpretation at different scales (regional–urban–local); while risk and system relationships are analysed at the macro scale, the spatial correspondences of design interventions are detailed at the micro scale. Thus, the methodology constructs not a linear but a multidirectional transition from analysis to design.

2.2. Study Area

This study focuses on the Maltepe–Dragos region located along the Marmara Sea coastline on the Anatolian side of Istanbul. The area is characterized by the coexistence of coastal edges, stream corridors, sloped topography, industrial remnants, and residential urban fabric. Dragos Stream, former industrial parcels, transportation infrastructure, and protected natural areas together form a spatially and ecologically complex landscape. This layered structure reflects not only the coexistence of physical components but also the interaction between ecological systems, infrastructure networks, and socio-spatial processes. The relationship between the coastline, stream corridor, and topography enables the interaction of multiple ecosystem types, making the area both vulnerable and highly significant in terms of urban resilience.

The study area was selected for four main reasons. First, the area is exposed to multiple hazards, including sea-level rise, flooding, and seismic risks. Second, it contains fragmented yet ecologically valuable systems associated with coastal and stream habitats. Third, the area preserves historical and infrastructural traces, such as former railway lines and industrial structures, which provide opportunities for adaptive reuse and economic viability. Finally, the presence of open and transformable spaces creates a suitable basis for resilience-oriented public landscape planning. These characteristics make Dragos an appropriate case for investigating how landscape planning can respond to layered urban vulnerabilities. Moreover, the area's direct relationship with the Marmara Sea and its proximity to active fault lines establish it as a critical context in which multiple hazard scenarios can be evaluated simultaneously. In this respect, the site functions as an "interface" where both theoretical discussions and design-based interventions can be tested.

2.3. Data Collection and Spatial Analysis

The study is based on a multi-layered analytical framework supported by cartographic interpretation, spatial mapping, visual reading, and contextual environmental assessment. Environmental, ecological, and urban datasets were superimposed to identify the spatial conditions influencing resilience and vulnerability within the area (Figure2). Accordingly, the analytical framework was approached not only as a descriptive method but also as an interpretive and decision-support tool. The overlay of multiple datasets revealed the relationships between risks and spatial potentials and informed the overall design process. This approach demonstrates that planning analyses should address physical data as part of an integrated system guiding spatial decision-making processes. In the Dragos area, spatial planning requires an integrated assessment of natural, social, and physical thresholds, rather than treating these dimensions as separate layers. Within this framework, land use, transportation, protected areas, existing tree texture, hydrological conditions, and risk analyses were evaluated interactively in order to identify spatial relationships, vulnerability zones, and potential intervention areas.

2.3.1. Hazard and Climate Analysis

The broader environmental and hazard context of the area was examined through climate change trends, fault-line impacts, and earthquake risk assessments conducted at both national and metropolitan scales. Climate analyses indicated increasing environmental pressures associated with changing precipitation regimes and rising temperatures, while fault-line mapping highlighted the seismic sensitivity of Istanbul and the Maltepe district. These findings demonstrate the necessity of a risk-sensitive spatial framework that considers multiple interacting hazards rather than isolated risks. In particular, the spatial consequences of earthquake–flood interactions were examined. This approach corresponds with the concepts of "complex problematic areas" and "zones requiring precaution" identified in the planning report, which defines alluvial soils and reclaimed lands as highly vulnerable areas.

Flood analysis, water-flow direction analysis, and sea-level rise projections were evaluated together, revealing that low-lying coastal and stream corridor areas are exposed to overlapping risks. These analyses clarified the spatial distribution of vulnerabilities and contributed to determining intervention priorities. Urban vulnerability literature further emphasizes that climate-related risks often interact and generate cascading effects throughout urban systems. In the context of Istanbul, rapid and dense urbanization, horizontal building density, and a lack of green coverage significantly intensify the surface urban heat island (SUHI) effect, which alters the local microclimate and exacerbates environmental pressures (Okumus & Terzi, 2021). Furthermore, these intersecting climate impacts, such as coastal flooding and increasingly severe heatwaves, disproportionately threaten socially and economically marginalized populations (Williams et al., 2022). This demonstrates that physical vulnerabilities created by dense urban fabrics (Okumus & Terzi, 2021) are directly compounded by systemic socio-economic inequalities, underscoring the critical need for urban adaptation justice and the active inclusion of vulnerable communities in spatial planning and climate resilience strategies (Williams et al., 2022).

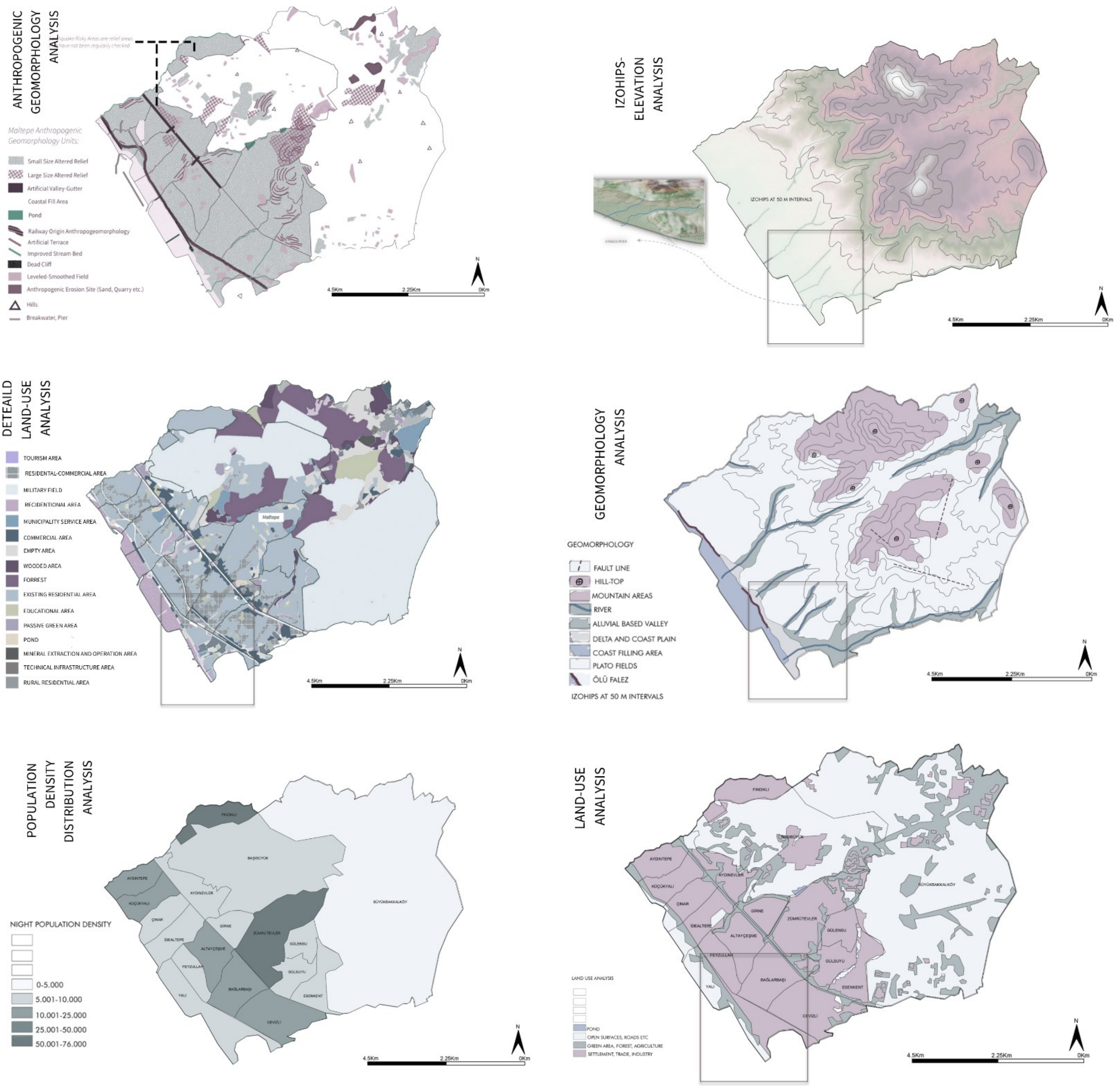

Figure 2. Spatial Analysis (IBB datasets and reports; analysis by Authors).

2.3.2. Land Use and Urban Fabric Analysis

Land-use mapping was conducted to examine residential areas, industrial zones, vacant parcels, infrastructure corridors, and coastal uses. The analyses revealed a fragmented urban morphology, particularly in areas where industrial remnants and extensive gray infrastructure interrupt ecological and social continuity. The conversion of natural green spaces into highly developed, impervious surfaces is a primary driver of coastal landscape fragmentation and spatial complexity (Kim et al., 2021). This analytical layer was essential for identifying conflict zones, transition areas, and adaptive reuse potentials. Addressing these discontinuities is critical, as integrated and connected landscape patterns perform significantly better in restoring spatial continuity and mitigating urban vulnerabilities compared to isolated, fragmented patches (Kim et al., 2021). Furthermore, the multiscale land-use analysis revealed severe discontinuities between coastal and inland areas, exacerbated by spatial thresholds created by dense urban and transportation infrastructure. Such concentrated linear developments hinder natural spatial transitions and lead to "coastal squeeze," emphasizing the critical need for designated inland accommodation spaces (Romero-Martín et al., 2025). These findings corroborate the perspective that coastal spaces should be evaluated not only through the immediate shoreline itself but also by holistically incorporating their broader settlement, socio-economic, and spatial-environmental dynamics (Ayan, 2019; Romero-Martín et al., 2025). Ultimately, resolving these spatial discontinuities requires comprehensive strategies where land-use and adaptive measures are deeply integrated into local, multiscale planning processes to ensure long-term sustainability and resilience (Olazabal & Ruiz De Gopegui, 2021).

2.3.3. Geomorphology, Elevation, and Topographical Reading

Topography was considered a primary analytical layer in understanding the spatial vulnerabilities and design potentials of the study area. Geomorphological interpretation, contour reading, and elevation analysis enabled the identification of hillside formations, valley-like drainage corridors, coastal plains, low-lying flood-sensitive zones, and terrain-based spatial thresholds. These readings were particularly significant for determining the location of water-sensitive design interventions, post-disaster open spaces, and pedestrian circulation routes. By clarifying the relationships between elevation, surface runoff, water movement, and accessibility, the topographical analysis directly informed the spatial organization of the proposed design.

The combined evaluation of geomorphology and anthropogenic topography further revealed the distinction between natural landforms and human-induced terrain modifications. This distinction demonstrated that topography should not be interpreted solely as a physical site condition, but also as a factor shaping spatial vulnerability, risk exposure, and planning decisions. In this context, low-elevation coastal areas, alluvial ground conditions, filled surfaces, and slope-sensitive zones were assessed as critical spatial thresholds that require careful consideration in resilience-oriented landscape planning.

2.3.4. Ecological and Biodiversity Analysis

The ecological structure of the area was examined through protected area mapping, existing tree cover analysis, and fauna-based assessments. The ecological significance of the stream corridor, vegetation cover, and bird movement patterns played a decisive role in the development of the ecological network strategy. These analyses revealed both habitat potential and fragmentation pressures, identifying the area as a critical transition zone in terms of ecological continuity. Accordingly, spatial continuity strategies were proposed to strengthen ecological connectivity. Due to its natural landscape value, Dragos Hill and its immediate surroundings require a planning approach that prioritizes the conservation of existing vegetation cover and the continuity of the area's landscape character. Protected area analysis, tree texture analysis, and fauna assessments collectively demonstrated the ecological continuity of the area and clarified its role within the regional ecological system through bird movement and habitat relationships. These findings are consistent with biotope studies conducted in Maltepe, which identify high floristic diversity and multiple habitat types, including parks, forested areas, roadsides, and coastal fill zones (Ünal, 2016). Furthermore, studies conducted on the Princes' Islands reveal the ecological and ecotourism potential of the region, particularly regarding birdwatching and nature-based activities (Solak, 2023).

2.3.5. Hydrology, Flooding, and Water Level Rise Analysis

Hydrological vulnerability was evaluated through stream behaviour analysis, flood-risk mapping, and sea-level rise projections. Dragos Stream and adjacent low-lying coastal areas were identified as critical hydrological zones requiring integrated water-sensitive planning approaches. These analyses directly informed the location of retention landscapes, bio ponds, permeable surfaces, and runoff management strategies. In this context, water was addressed not only as a risk factor but also as a guiding element for ecological restoration and spatial organization.

In areas where stream corridors intersect with alluvial ground conditions, settlement suitability should be assessed with particular caution, and planning decisions should be supported by risk-sensitive engineering and ground-stabilization measures. Flood and water-level rise analyses together demonstrated that risks are concentrated particularly around stream–coastal intersections, revealing that water should be understood as a multi-layered urban system rather than merely a linear flow structure. This approach corresponds with water-sensitive urban design and blue-green infrastructure literature, which advocates managing water at its source and integrating stormwater systems into broader ecological networks (Eşbah Tunçay, 2021; 2022). Such approaches contribute to reducing flood risks, controlling surface runoff, and strengthening urban ecosystem services (Arslan, 2022). Furthermore, developing sensitivity toward water dynamics within urban systems requires the reconfiguration of relationships between natural and built environments and constitutes a central component of climate-responsive and nature-based design approaches (Eşbah Tunçay, 2021).

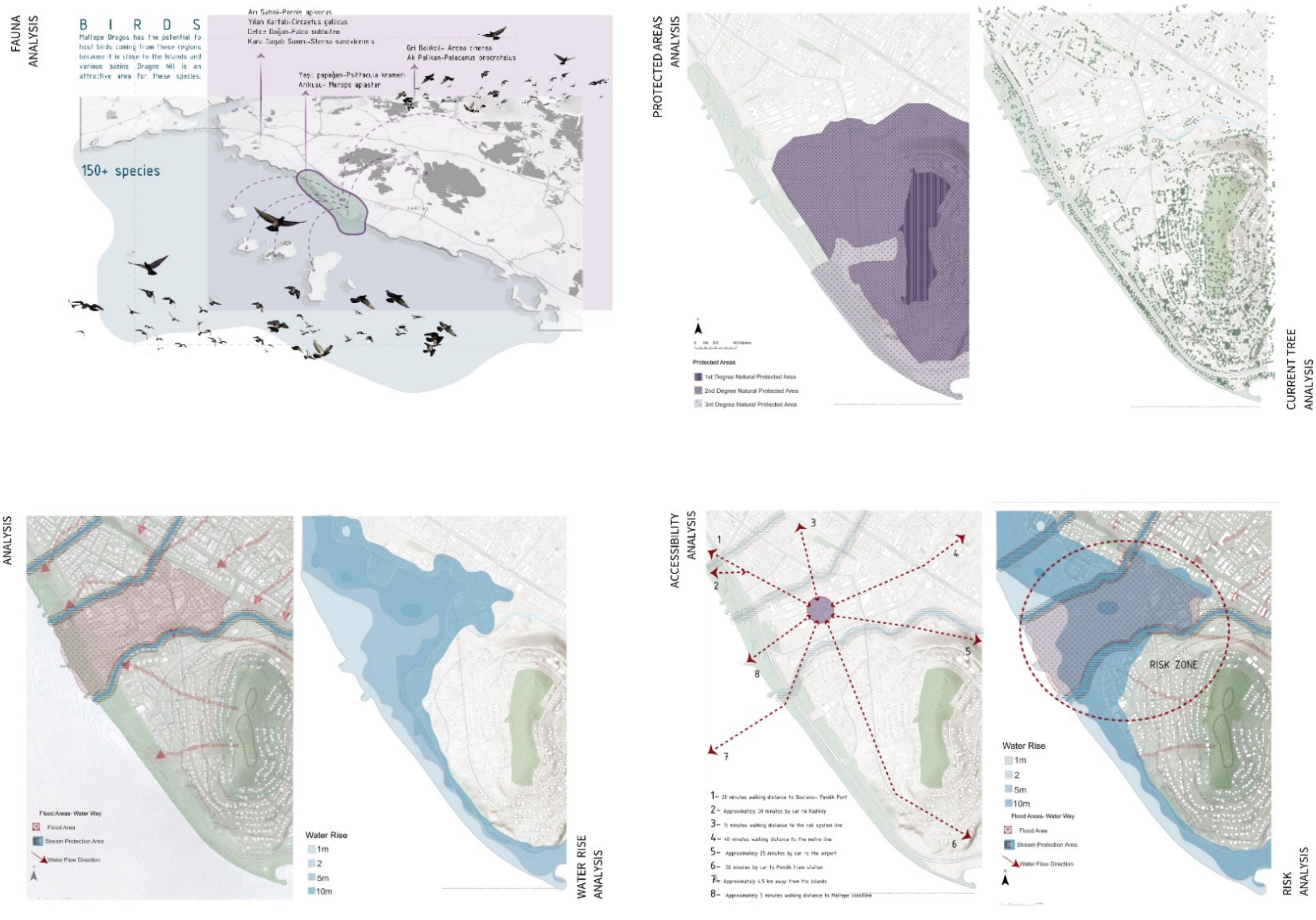

Figure 3. Data Collection and Spatial Analysis (Developed by the Authors using ArcGIS Pro and Google Earth).

2.3.6. Accessibility and Risk Overlay

Accessibility mapping was conducted to evaluate pedestrian routes, proximity relationships, and spatial accessibility within and around the study area. These datasets were overlaid with hazard-sensitive zones to identify spaces that could function as safe and accessible public areas under both daily use and emergency conditions. This analysis played a critical role in determining suitable locations for post-disaster gathering spaces and low-impact mobility networks (Figure 3).

The findings demonstrated that accessibility is closely linked to spatial resilience, particularly in relation to the multifunctional use of public open spaces. Major transportation infrastructures, including highway, coastal, and rail corridors, were interpreted not only as mobility systems but also as spatial thresholds that shape connectivity, permeability, and access to safe open areas. Evaluating accessibility together with risk layers clarified the distribution of areas that could support both everyday circulation and post-disaster evacuation or gathering scenarios. In this context, transportation duration, pedestrian connectivity, and proximity analyses informed the strategic positioning of open spaces, while pedestrian- and bicycle-oriented mobility networks were considered essential components of a resilient and accessible urban landscape.

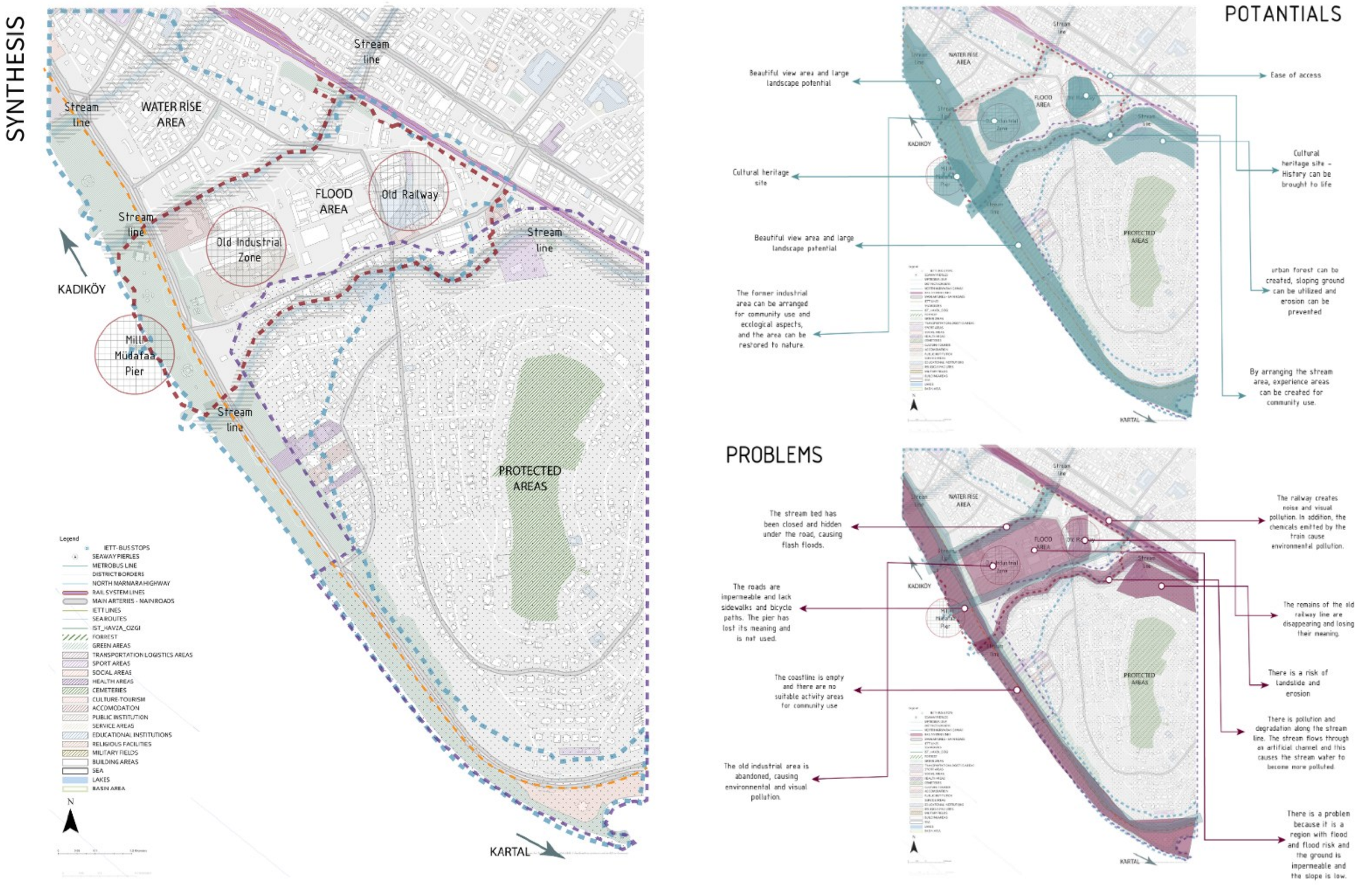

Figure 4. Synthesis Map (Developed by the Authors).

2.3.7. Bridging Data to Design: The Synthesis Mechanism

To systematically translate abstract spatial data into tangible design interventions, this study utilized a Suitability and Conflict Analysis matrix as a critical methodological interface, ensuring that subsequent decisions were grounded in empirical evidence rather than subjective intuition. The progression from analysis to spatial formulation was executed through a cohesive workflow, beginning with the superposition of digitized thematic layers—encompassing hazard susceptibility, topographical variations, ecological corridors, and accessibility parameters. By spatially cross-referencing these datasets, specific "Strategic Transformation Zones" were delineated at the intersections of restrictive conditions, such as severe flood risks or limited access, and advantageous site features, like potential ecological nodes and historical assets. Following this spatial conflict identification, a targeted weighting system was applied in alignment with the overarching research objectives. For instance, inundation-prone sectors were heavily prioritized for the integration of nature-based solutions, whereas derelict industrial parcels were earmarked for adaptive reuse to bolster socio-economic resilience. Ultimately, these weighted priorities were synthesized into a comprehensive spatial program where analytical findings directly dictated morphological responses: high-vulnerability zones necessitated the implementation of permeable landscapes, spatial ruptures demanded cohesive circulation networks, and heritage footprints guided the formulation of adaptive socio-cultural nodes. Through this rigorous filtering mechanism, the proposed design transcends mere layered observations, culminating in a robust, evidence-driven spatial strategy tailored to the multifaceted environmental and socio-spatial constraints of the study area (Figure 4).

2.4. Synthesis and Design Development

Following the analytical phase, the collected spatial data were synthesized in order to identify the main potentials, constraints, and strategic intervention areas of the site. The critical question of how to transition from abstract spatial analyses to concrete design decisions was addressed through a systematic, GIS-based overlay technique. By cross-referencing topographic elevation models, historical hydrological data, and current land-use maps, specific vulnerability hotspots were extracted. The synthesis maps produced within the project demonstrate a clear overlap between ecological opportunity areas, flood-sensitive low-lying zones, circulation discontinuities, and abandoned industrial parcels. These spatial overlaps formed the foundational logic for generating the "Triple Landscape Network Model," which acted as the primary methodological bridge translating multi-hazard vulnerabilities into a structured design response. The design development process was structured through the transformation of these analytical findings into a three-component spatial framework. Within this scope, the ecological network was addressed with the aim of strategically re-establishing coastal-stream-hill ecological connectivity, strengthening water-sensitive systems, and enhancing biodiversity; the circulation network focused on creating redundant, pedestrian- and bicycle-oriented evacuation movement systems integrated with existing and reinterpreted infrastructural traces. The recreational-cultural network, on the other hand, was structured as a macro-system that transforms obsolete zones into adaptive reuse nodes, supports everyday public life, encourages social participation, and incorporates post-disaster gathering functions. This holistic framework was first conceptualized through strategic planning decisions in a 1/2000 scale master plan (Figure 5), dictating where and why systemic relationships are established. It was then deepened at the spatial level through 1/500 scale detailed intervention areas, sections, and material strategies, answering *how* these systems are implemented (Figure 6). In this regard, the design proposal evolved beyond being an abstract conceptual approach and gained the character of an integrated response producing spatial correspondences based on the environmental, social, and hazard-oriented conditions of the site. By bringing multiple spatial data layers together, this approach highlights the need for a holistic planning framework that strengthens decision-making processes and supports more integrated spatial outcomes. Furthermore, the use of geographic information systems and spatial analysis tools (ArcGIS-ESRI) ensures that this multi-layered evaluation process is grounded on scientific foundations.

3. Results

3.1. Spatial Vulnerability and Accessibility Results

The initial phase of the scenario-based spatial assessment revealed a critical overlap between hydrological vulnerabilities and the existing urban fabric. According to the flood and waterway analysis, a highly vulnerable flood area encompassing approximately 390 m^2 was pinpointed along the primary water flow direction of the Dragos Stream. This precise area was calculated by integrating a high-resolution Digital Elevation Model (DEM) with local precipitation data, surface runoff coefficients, and existing infrastructure capacities in ArcGIS, simulating peak flow scenarios to delineate the low-lying depressions most susceptible to immediate inundation. This critical zone dictates the sizing and capacity of the proposed blue-green infrastructure. Conversely, the accessibility analysis provided measurable travel-time thresholds to determine the strategic positioning of post-disaster gathering areas. The central focal node exhibits a high degree of connectivity, offering a 5-minute walking distance to the Maltepe coastline (a primary open-space evacuation corridor) and a 15-minute walking distance to the rail system line. These quantitative accessibility metrics ensure that the proposed landscape interventions function not only as daily recreational spaces but as rapidly accessible emergency hubs during seismic events

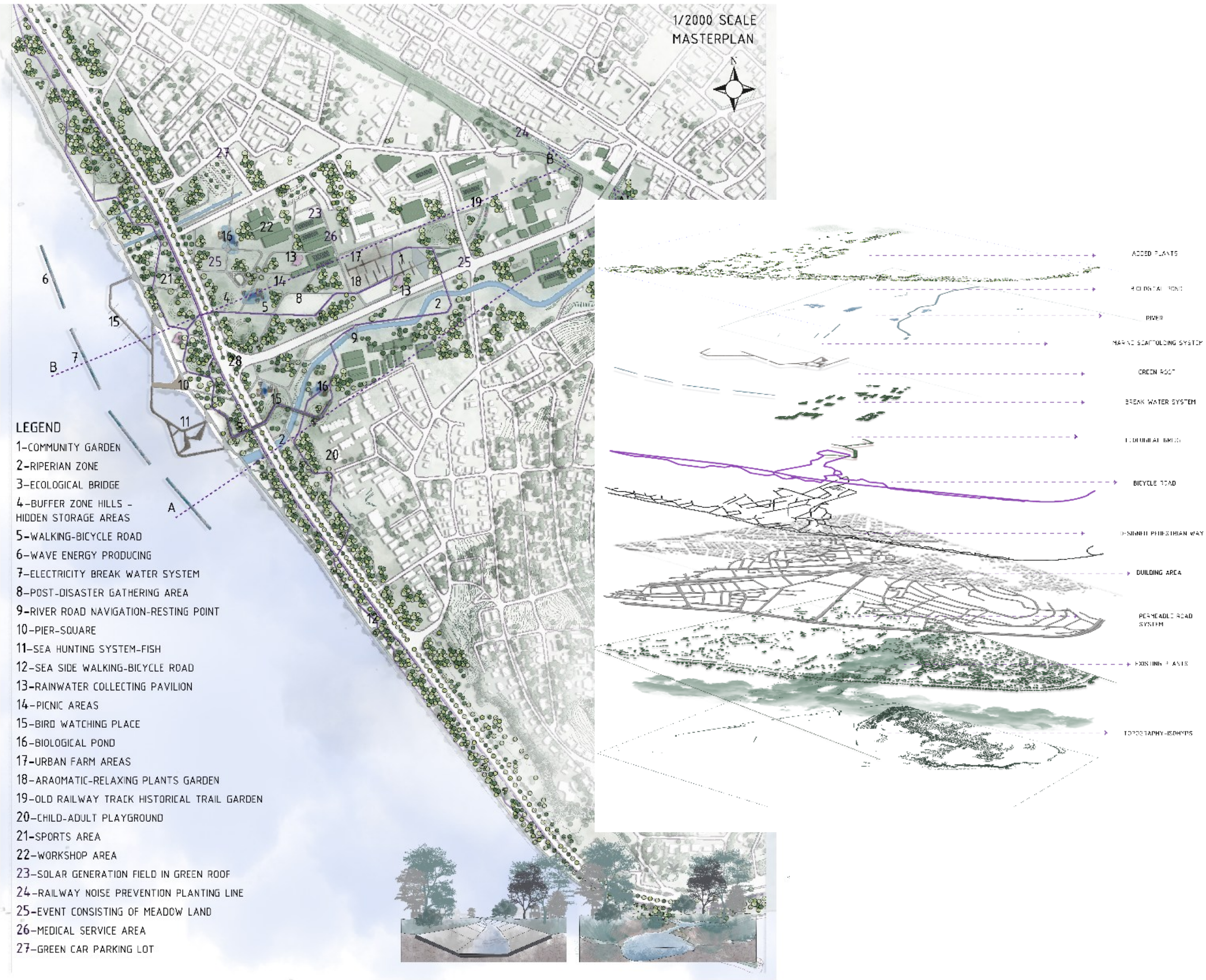

Figure 5. 1/2000 Masterplan (Developed by the Authors).

3.2. Evaluation of Existing Industrial Heritage and Socio-Economic Constraints

The assessment of existing industrial heritage revealed that the former industrial parcels in the area consist largely of impermeable concrete and asphalt surfaces, contributing significantly to surface runoff and urban heat island effects. While legally available for municipal transformation, the physical degradation of these structures necessitates adaptive reuse strategies rather than complete demolition. Transforming these parcels addresses socio-economic constraints by providing low-cost, high-impact public spaces that foster community engagement and economic vitality without the financial burden of massive grey infrastructure projects.

3.3. Decision-Making Matrix for Spatial Interventions

To systematically translate the spatial vulnerabilities into landscape architecture strategies, a decision-making matrix was developed (Table 1). This matrix prioritizes interventions based on the intersection of multi-hazard risks and existing site potentials, forming the foundational logic for the multiscale master plan.

Table 1: Decision-Making Matrix for the Maltepe-Dragos Landscape Framework.

Spatial Component / Zone	Hazard & Vulnerability Level	Evaluated Metric / Threshold	Primary Landscape Intervention (Decision)
Dragos Stream Corridor	High (Intersection of flood areas and urbanization)	390 m² identified critical flood area; 1m - 10m projected water rise.	Conversion of the 390 m² high-risk zone into biological retention ponds and riparian bioswales to absorb surface runoff.
Former Industrial Parcels	Medium-High (Soil degradation, high impermeability)	High ratio of concrete/asphalt surfaces exacerbating flood risks.	Adaptive reuse of abandoned structures; breaking hardscapes to introduce rainwater harvesting systems.
Central Focal Nodes	Low Vulnerability (Safe zones with high connectivity)	5-min walk to coast; 15-min walk to rail system.	Designation as primary post-disaster gathering areas integrated with everyday community gardens.

3.4. Landscape Framework and Multiscale Design Approach

The design proposal is structured through a multiscale framework that operates at both 1/2000 and 1/500 scales. Within this framework, the 1/2000 master plan is not treated simply as a physical arrangement of land uses, but as a strategic spatial model that guides the broader ecological, infrastructural, and socio-spatial relationships of the area. . At this scale, the proposal defines where key connections should be established, why these relationships are necessary, and how they contribute to strengthening urban resilience (Figure 6). In this context, the fragmented relationship between the coastline, stream corridor, and surrounding urban fabric is reorganized through an integrated landscape strategy. The macro-scale decisions focus on improving green infrastructure continuity, enhancing accessibility, supporting water-sensitive spatial organization, and increasing disaster preparedness. These strategic decisions are derived from the Triple Landscape Network Model and form the basis for the transition from broad planning principles to more detailed design interventions. The main macro-level strategies developed through this model are summarized in Table 2.

Table 2: Strategic master plan decisions derived from the Triple Landscape Network Model (1/2000 Scale).

Network Layer	Strategic Master Plan Decision (Macro-Scale Objectives)
Ecological System	- Re-establishing coastal-stream-hill ecological connectivity. - Transforming flood-prone zones into adaptive retention landscapes. - Increasing the permeability of former industrial areas to manage surface runoff.
Mobility (Circulation) System	- Creating redundant pedestrian evacuation routes to ensure continuous post-disaster mobility. - Connecting coastal evacuation corridors directly with dense residential fabrics.
Socio-Cultural System	- Transforming obsolete industrial zones into adaptive reuse nodes. - Integrating daily recreational uses with post-disaster emergency gathering functions.

This comprehensive framework is structured along three interconnected macro-systems: the ecological network, circulation network, and recreational-cultural network.

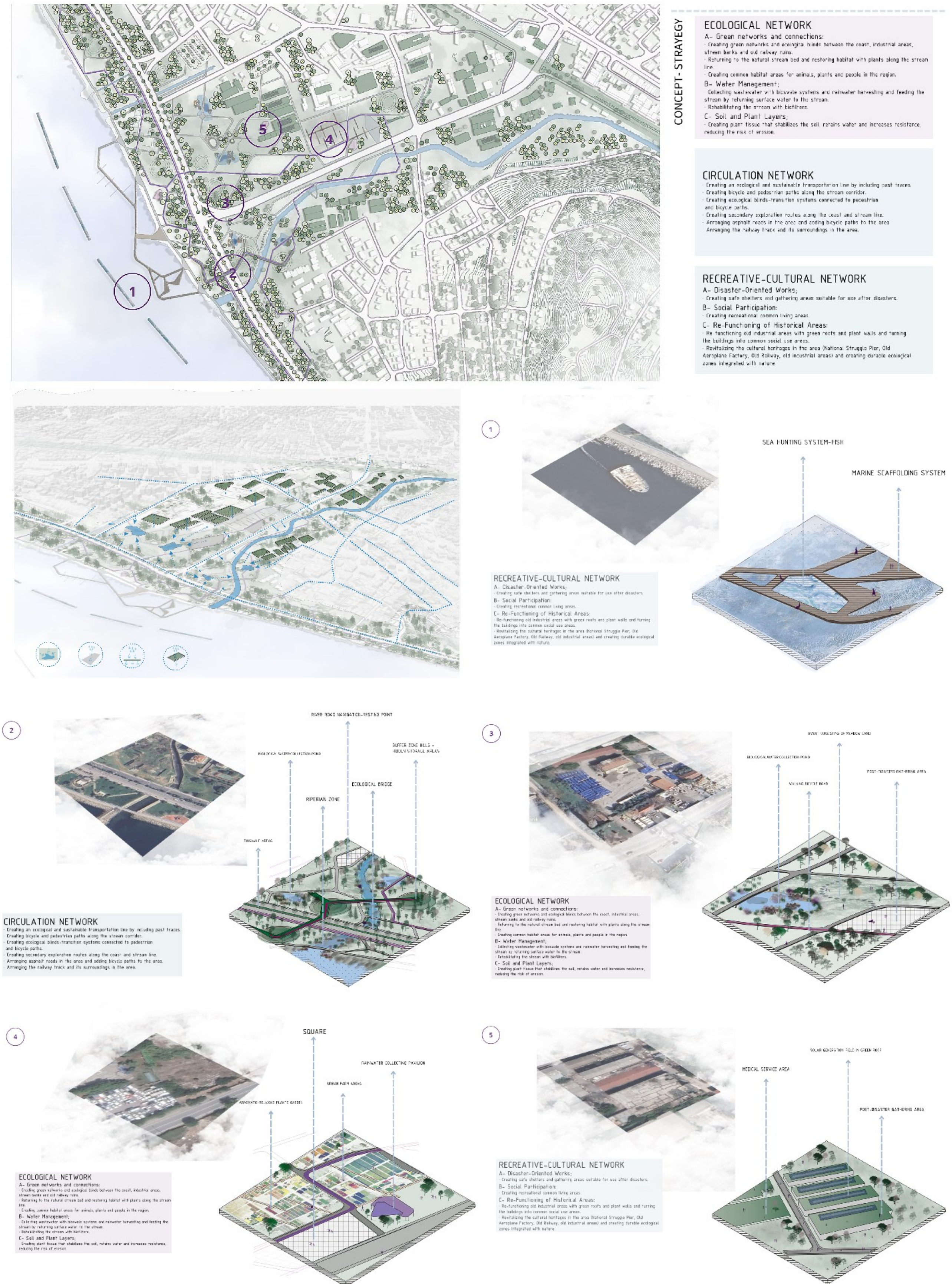

Figure 6. Multiscale landscape framework illustrating the ecological, circulation, and recreational-cultural network systems and resilience-oriented spatial interventions in the Maltepe–Dragos region. (base imagery: Google Earth Developed by the Authors).

3.4.1. Ecological Network

The ecological network acts as the project's environmental spine by strategically re-establishing coastal-stream-hill ecological connectivity, linking the disconnected habitats of the coastline, Dragos Stream, green spaces, and open lands. The stream corridor is strategically designated to be transformed into an ecological corridor. Specifically, the 390 m² high-risk flood zone—calculated through GIS-based topographical modelling and flood risk scenarios—is assigned to function as a primary retention landscape within this network. This is coupled with the macro-strategy of converting approximately 30-35% of the existing impermeable industrial surfaces—a target proportion determined by spatial analyses of current land-cover ratios and the required hydrological retention capacities—into highly absorptive adaptive landscapes. These systemic decisions hold critical value for macro-level water quality improvement, habitat conservation, and the resuscitation of natural hydrological processes across the urban fabric.

3.4.2. Circulation Network

The circulation network structurally recuperates the fragmented spatial organization of the site by creating redundant pedestrian evacuation routes spanning the stream corridor, coastal recreation axes, and linear routes following the former railway trace. At the master plan scale, this system connects coastal evacuation corridors directly with residential areas, ensuring uninterrupted mobility during seismic events. In addition to serving as a critical transport and evacuation system, it establishes an experiential continuum, linking users to ecological and cultural stratifications while maintaining historical continuity. The strategic placement of transition zones closes the strict separation between hard infrastructure and the urban surface, establishing a more permeable, sustainable, and navigable spatial matrix.

3.4.3. Recreational-Cultural Network

The recreational-cultural network is the strategic social layer of the project, designed to accommodate both everyday public use and critical post-disaster needs. Guided by the accessibility analysis, the master plan strategically positions designated post-disaster gathering areas to serve approximately 60% of the surrounding residential fabric within a 5-to-10-minute pedestrian reach. By fundamentally deciding to transform obsolete industrial zones into adaptive reuse nodes, the plan structurally reinforces cultural continuity and public accessibility. Using recreational space and coastal arrangements as connective tissue, the National Struggle Pier is strategically repositioned as an intersection point between historical memory and contemporary urban life.

3.5. 1/500 Scale Detailed Design Approach

While the 1/2000 master plan establishes the broader systemic framework of the proposal, the 1/500 scale translates these strategic relationships into specific spatial and design interventions. At this scale, the emphasis shifts from defining macro-level connections to demonstrating how resilience-oriented systems are physically implemented within the landscape. Therefore, the detailed design functions as the operational layer of the master plan, revealing the tangible spatial tools through which ecological, social, infrastructural, and post-disaster strategies are applied on site (Figure 7).

The 1/500 design incorporates a range of targeted interventions, including biological water collection systems, rainwater harvesting pavilions, urban agriculture areas, therapeutic gardens, ecological bridges, green roofs, solar energy systems, and platforms designed for social interaction. These components are not treated merely as architectural features or recreational amenities; rather, they are conceived as active landscape elements that support water management, habitat formation, climate adaptation, social use, and emergency functionality. In this sense, the detailed scale demonstrates how the strategic objectives of the master plan are transformed into performative spatial systems.

Through planting strategies, topographical adjustments, micro-scale spatial organization, and localized infrastructural solutions, the 1/500 design makes resilience visible and operational. This scale shows that urban resilience is not limited to a conceptual planning principle, but can be materialized through precise, site-specific design decisions that respond to environmental risks, social needs, and future adaptive capacities.

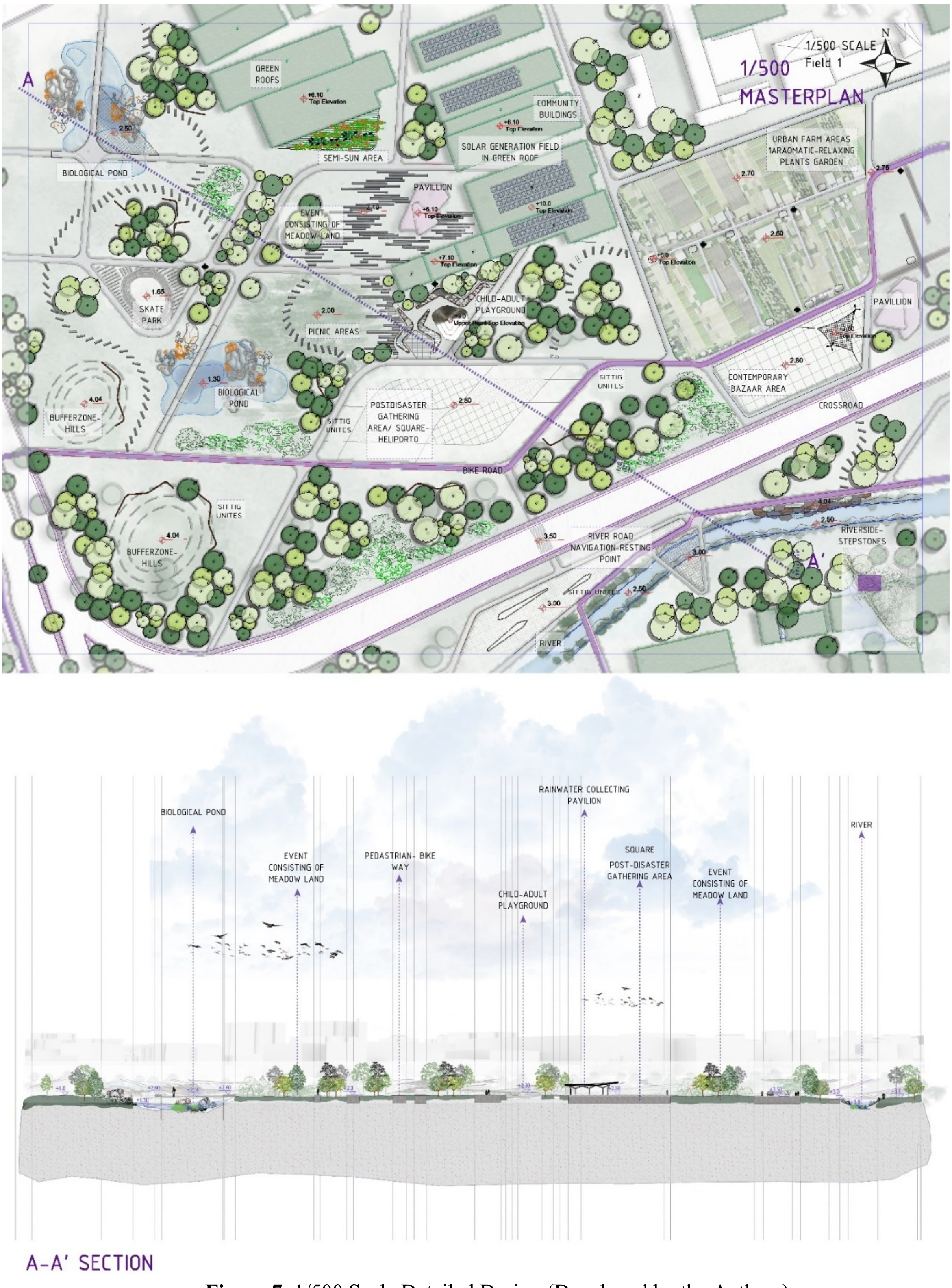

Figure 7. 1/500 Scale Detailed Design (Developed by the Authors).

3.6. Material and Section Findings

Structural and material studies illustrate how ecological, circulation, and public use layers can be physically integrated at the human scale. The use of tactical materials—such as permeable concrete, bio-filtration substrates, rainwater harvesting, and renewable energy systems—supports the project's aim to embed resilience into the physical environment. Ultimately, these analyses suggest that, rather than remaining an abstract concept, resilience can be fostered through ecological continuity, hydrological sensitivity, and multifunctional adaptive reuse (Figure 8).

Figure 8. 1/500 Scale Detailed Design (Developed by the Authors).

4. Discussion

4.1. Interpretation of Findings within the Context of Resilience Theory

The findings demonstrate that the Maltepe-Dragos region operates as a complex, multi-scalar system composed of interacting social-ecological-technological networks (SETS) under multi-hazard conditions. Rather than conceptualizing resilience through a static equilibrium model that aims to "bounce back to normal" following a disaster, this study adopts non-equilibrium and evolutionary paradigms. These paradigms emphasize the capacity of the system to adapt to changing conditions and transition toward new developmental trajectories (Fu et al., 2021). In this context, risk is reinterpreted as a productive spatial layer that informs the urban design process. Integrating flood-vulnerable areas and abandoned industrial zones into multifunctional green infrastructure through nature-based solutions (NBS) such as rain gardens and permeable surfaces, represents a paradigm shift. It moves away from traditional, defensive planning approaches based strictly on "resistance" toward a flexible and transformative spatial adaptation (Castellar et al., 2021; Lourdes et al., 2022). This conceptual shift is of critical importance; systems that focus exclusively on robustness can become locked into specific technological or physical features (lock-in), which inherently undermines flexibility and perpetuates unequal or undesirable urban configurations. Consequently, managing urban resilience necessitates deliberate structural transformations cantered on equity. Such transformations are essential to ensure the fair distribution of ecosystem services, accessibility, long-term sustainability, and enhanced adaptive capacity (Grabowski et al., 2023).

4.2. Conceptual and Spatial Contribution of the Triple Landscape Network Model

Although the benefits of green infrastructure and nature-based solutions are widely acknowledged in the existing literature, the practical implementation of their multifunctionality in compact cities in response to urban challenges remains a significant difficulty (Castellar et al., 2021). The proposed multiple landscape network model advances traditional planning approaches by spatially analysing and integrating ecosystem services rather than relying on isolated interventions (Lourdes et al., 2022). Unlike conventional models that merely segregate conservation and recreation, this framework integrates various urban ecosystem services and human well-being to ensure efficient land use (Castellar et al., 2021; Lourdes et al., 2022). By overlapping these networks, the model generates a multifunctional landscape infrastructure that supports biodiversity, mitigates multi-hazard and disaster risks such as flooding through the lens of urban resilience (Fu et al., 2021), and centers social justice and equity in access to public spaces (Grabowski et al., 2023). This strategic integration offers a concrete spatial response to the demand for multifunctionality, ensuring that limited urban spaces deliver a wide range of ecological, socio-economic, and resilience benefits simultaneously (Fu et al., 2021; Grabowski et al., 2023).

4.3. Socio-Economic Implications and Economic Viability

A critical dimension of resilience-oriented urban landscape planning is its economic feasibility and socio-economic impact (Kapucu et al., 2024). The adaptive reuse of former industrial parcels and the implementation of nature-based solutions (NBS) offer a highly viable alternative to capital-intensive grey infrastructure. Recent studies indicate that integrating green infrastructure into densely built environments reduces long-term maintenance costs, lowers urban heat accumulation, and decreases energy consumption for building cooling (Salimi et al., 2025). Furthermore, urban parks and multifunctional green spaces stimulate local economic welfare by enhancing real estate values, attracting investment, and reducing healthcare costs through improved physical and mental public health (Dizdaroğlu, 2022). In the context of Dragos, transforming abandoned industrial zones into productive public landscapes minimizes potential land ownership conflicts by utilizing existing public or obsolete assets. This low-cost, adaptive strategy provides equitable climate mitigation benefits without requiring massive land acquisitions, thereby strengthening both the economic and social resilience of the community (Dizdaroğlu, 2022; Salimi et al., 2025).

4.4. Adaptive Reuse, Historical Continuity, and Spatial Memory

Addressing industrial remnants as carriers of spatial memory, this study expands resilience beyond ecological adaptation to include cultural continuity and place identity. Landscape functions as an active mediation system that bridges ecological processes with urban space, and historical industrial heritage with future public use. In the case of Dragos, the reinterpretation of railway traces and industrial parcels contributes to the development of a design language that is both site-specific and adaptable to the future. Thus, adaptive reuse is evaluated not merely as a strategy of physical transformation, but as a mechanism establishing continuity between past industrial networks and future ecological functions.

4.5. The Role of the Multiscale Approach in Design

One of the strongest methodological aspects of the study is the combined use of 1/2000 and 1/500 scales. Adopting a multiscale approach ensures that strategic, city-wide green infrastructure goals are effectively translated into site-specific design interventions using multiple ecosystem service models and multicriteria analysis (Lourdes et al., 2022). While the macro scale reveals the general framework of ecological networks and the continuity of nature-based solutions developed to address urban challenges, the micro scale demonstrates how classified multifunctional typologies such as rain gardens, bioswales, permeable surfaces, and floodplains are operationalized through spatial programming and topographical arrangements (Castellar et al., 2021). This alignment bridges the frequent disconnect between high-level urban planning and local implementation, allowing multifunctionality discussions that incorporate dimensions of equity, accessibility, and social justice to be directly reflected in the field (Grabowski et al., 2023). Consequently, resilience-oriented design strategies and post-disaster functions—which evaluate green infrastructure performance through a resilience lens do not remain solely at the conceptual level but find a practical and actionable counterpart (Fu et al., 2021).

4.6. Limitations of the Study and Future Research

Despite its conceptual and spatial contributions, this study adopts a scenario-based spatial assessment rather than relying on quantitative engineering simulations. The performance of the proposed networks was evaluated using proxy spatial metrics and design logic rather than advanced hydraulic modelling, seismic vulnerability assessments, or empirical economic cost-benefit analyses. Furthermore, the complexities of multi-stakeholder governance and long-term institutional maintenance require deeper investigation. Future interdisciplinary research should incorporate quantitative simulation tools to test the operational performance of these landscape interventions under specific climate and disaster scenarios. Additionally, empirical studies focusing on the economic life-cycle and social inclusivity of the proposed models will be essential to validate their transferability to other coastal cities.

5. Conclusion

This study suggests that urban resilience under multi-hazard conditions can potentially be restructured through an integrated, landscape-based approach. Analyzed as a complex socio-ecological system rather than merely a degraded urban void, the Maltepe-Dragos region highlights significant intersections between ecological degradation, infrastructural discontinuities, and simultaneous flood and seismic risks. A primary outcome of this research is the proposed application of the "Triple Landscape Network Model." By structurally overlapping the ecological, circulation, and recreational-cultural networks, this model demonstrates a potential capacity to transform highly vulnerable areas—such as the 390 m^2 flood-prone stream corridor and impermeable industrial parcels—into multifunctional resilience nodes. Furthermore, the systematic integration of 1/2000 macro-scale planning with 1/500 micro-scale spatial interventions aims to bridge the gap between abstract resilience strategies and concrete, site-specific physical applications.

The theoretical and practical implications of this study advocate for a paradigm shift from traditional, defensive urban planning toward an adaptive, transformation-oriented framework. Theoretically, the findings support the perspective that environmental and seismic risks should not be viewed merely as constraints, but as productive spatial inputs that can help guide urban morphology. Practically, this research seeks to reposition landscape architecture from a passive aesthetic or recreational discipline into a central, strategic planning instrument with the potential to mediate complex urban vulnerabilities. By embracing nature-based solutions and adaptive reuse rather than capital-intensive gray infrastructure, these spatial strategies may offer economically viable and socially equitable pathways for compact coastal cities. Ultimately, the study implies that the urban landscape can function as a vital infrastructural interface, seamlessly integrating daily socio-cultural needs with critical post-disaster response capacities.

Despite its comprehensive spatial framework, this study contains several methodological limitations. The research fundamentally relies on a design-oriented, scenario-based spatial assessment rather than empirical, quantitative engineering simulations. Consequently, the operational capacity and structural performance of the proposed landscape networks under acute disaster stress were evaluated using proxy spatial metrics and design logic, rather than advanced hydraulic modeling or seismic vulnerability assessments. Additionally, while the study addresses spatial and socio-economic adaptability, it does not explicitly analyze the multi-stakeholder governance structures, long-term financial feasibility, or institutional maintenance requirements necessary to sustain these multifunctional green infrastructures over time.

To build upon the spatial framework established in this study, future interdisciplinary research could benefit from focusing on empirical validation. To better understand the on-site performance of the nature-based solutions presented in this study, supporting subsequent research with site-specific hydrological simulations and climate tests could make a significant contribution to the process. Furthermore, empirical investigations into the economic life cycle and cost-benefit analyses of the Triple Landscape Network Model would be valuable to assess its economic viability against traditional infrastructure. Finally, exploring the policy frameworks and collaborative governance models required to implement and maintain these hybrid socio-ecological systems may be important for transferring this methodology to other multi-hazard, post-industrial coastal cities.

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Conflicts of Interest
The authors report no conflicts of interest.

Data Availability Statement
The data supporting the findings of this study are derived from publicly available planning reports, institutional publications, spatial analyses, and literature sources cited within the manuscript. Additional design drawings, analytical mappings, and research materials generated during the study are available from the corresponding author upon reasonable request.

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