Athens Journal of Sciences 2025, 12: 1-34
https://doi.org/10.30958/ajs.X-Y-Z

Evaluating the Multi-Functional Benefits of Urban Green Infrastructure for Climate Adaptation: A Nature-Based Approach in Konak District, Izmir

By Birsu Kambur[*] & Stefano Salata[±]

Climate change is a reality, and the entire world is experiencing its effects. Coastal areas are highly affected by climate change. In addition to effects such as heat waves, floods, droughts, and decreased biodiversity, coastal areas are threatened by sea level rise and erosion. Türkiye, one of the most exposed countries, has struggled with an average temperature increase of 1 °C in the last decade. The coastal city of Izmir, Türkiye's third largest city, has become vulnerable under increasing population pressure, causing massive urbanization of the fringe. This research investigates the feasibility and effectiveness of implementing Nature-Based Solutions (NBS) in the Konak district, which represents one of the city's most ecologically vulnerable urban areas due to limited green space and high density. Within Konak, Alsancak, being one of its most historical neighborhoods, is used as a pilot site to test spatial interventions. The study aims to enhance coastal resilience and reduce vulnerability to climate change impacts. To achieve this, Geographic Information System (GIS) and InVEST tools were employed to evaluate key ecosystem services including carbon sequestration, urban heat island mitigation, air quality, and habitat quality. The vulnerability of Izmir, particularly Konak, to sea level rise, storm surges, and erosion was analyzed. Potential NBS suitable for adaptation were identified through parametric analysis. The socio-economic and environmental benefits of NBS were compared with traditional engineering-based solutions under two scenarios. Based on the findings, a comprehensive design proposal was developed to integrate NBS into the urban context. The reuse of post-industrial sites, such as the Sümerbank Factory, is proposed to enhance ecosystem connectivity and resilience. This research aims to serve as a roadmap for other coastal cities facing similar climate challenges.

Keywords: *climate change, nature-based solutions, ecosystem services, coastal resilience, urban heat island effect*

Introduction

Climate change poses serious global threats, including heatwaves, floods, droughts, biodiversity loss, sea-level rise, and coastal erosion. The Intergovernmental Panel on Climate Change (IPCC) notes that limiting warming to 1.5°C instead of 2°C could prevent millions from losing their homes due to sea-level rise (IPCC 2022). Climate change affects not only the environment but also ecosystems and human communities.

[*]Graduate Student, Polytechnic of Milan, Italy.
[±]Associate Professor, Polytechnic of Milan, Italy.

The Mediterranean is amongst the world's most climate-exposed areas, likely to undergo systemic breakdown in the face of rising temperatures, water scarcity, and degradation of ecosystems (UN Environment 2017). Reducing exposure and enhancing the resilience of the marine and coastal environment using ecosystem-based and Nature-Based Solutions (NBS) is important.

NBS have gained more support globally due to being eco-friendly, low-cost interventions with many benefits, including urban cooling, flood control, and biodiversity improvement (McPhearson et al. 2023).

Izmir, the third-largest city in Türkiye, is most exposed to climate change due to the fact that it is coastal, urbanized, and expanding rapidly. The Konak district, for instance, has a low runoff retention capacity (46%) and not enough green infrastructure, increasing such vulnerabilities as urban heat and flash flooding. Alsancak, being an old district of Konak, is most exposed due to lower adaptive capacity and protection constraints. This study was developed within the MSc thesis work of the first author in the Sustainable Architecture and Landscape Design program at Politecnico di Milano. The research builds upon the strategic urban resilience vision outlined in İzmir's Green Infrastructure Strategy (2017) and İzmir Sustainable Energy and Climate Action Plan (2020), further extending their framework through spatial analysis and ecosystem modeling (using InVEST and GIS tools) to evaluate the climate adaptation potential of green infrastructure in Konak District. Even though the above policy reports present a broad outline for enhancing urban resilience and ecological integrity, this paper completes their vision through spatially rich and model-based research based on ecosystem service evaluation tools, e.g., InVEST. The focus is placed on the Konak District, being a model representative for the application of nature-based solutions towards mitigating climate-related urban vulnerabilities.

However, Alsancak provides a location to test NBS integration in urban development, particularly for services like water harvesting, carbon sequestration, and cooling. The main purpose of this study is to evaluate the multifunctional ecosystem services of existing and proposed green infrastructure elements in the Konak District of Izmir, including carbon sequestration, urban heat island mitigation, habitat quality, and air purification. Using GIS-based spatial analysis and InVEST modeling tools, the research aims to assess the environmental performance of nature-based solutions and inform integrative design strategies that enhance urban climate resilience, ecological connectivity, and public well-being in Mediterranean coastal cities.

Literature Review

Climate change is a pressing global issue, with warming of 1.1°C above pre-industrial levels already observed (IPCC 2022). The Mediterranean is particularly vulnerable, experiencing rising temperatures, droughts, and more extreme events (MedECC 2020, UN Environment 2017).

Coastal cities like Izmir are exposed to sea-level rise, storm surges, and heat stress. Rapid urbanization and weak green infrastructure exacerbate these risks, especially in historic neighborhoods such as Alsancak within Konak (İzmir SEİEP 2020, Salata et al. 2022).

Nature-Based Solutions (NBS) are increasingly used to enhance urban resilience. Defined by the IUCN (2016) as actions to restore and manage ecosystems to address societal challenges, NBS provide co-benefits such as climate regulation, improved air quality, and enhanced community well-being (McPhearson et al. 2023, Epelde et al. 2021). Green roofs, permeable surfaces, and urban forests are examples applied in urban contexts (Coutts et al. 2013, Manso et al. 2021).

Ecosystem services, classified as provisioning, regulating, cultural, and supporting, play a central role in NBS planning. Including them in urban decision-making enables better outcomes (Eggermont et al. 2015, Palta et al. 2017). In this study, InVEST was used to quantify key services, including habitat quality, carbon storage, and urban cooling, in Alsancak, highlighting weaknesses in Izmir's current strategy.

However, NBS performance depends on local socio-ecological factors such as governance, density, and participation (Dorst et al. 2019, Haase 2017). Therefore, integrating NBS into İzmir's planning framework is crucial for achieving long-term success.

Methodology

Climate change vulnerability is here quantified for Izmir and NBS capacity to build resilience is experimented with for the Konak municipality, focusing specifically on the Alsancak quarter. Spatial analysis and ecosystem modeling platform was used through GIS and InVEST platforms (Kambur 2025).

Study Area and Data Sources

Izmir, located on the Aegean coast, is Türkiye's third largest city. The historical heart of the city is Konak (which includes Alsancak), which has high-density development and a low amount of green space (6%) but significant heritage value, and faces significant ecological challenges associated with urbanization (i.e. pressures on biophysical systems).

The datasets used are:

- **LULC**: Landsat 9 imagery (July 2024) via EarthExplorer
- **Tree Cover**: Copernicus (2018 raster)
- **Building Height**: Urban Atlas (2012)
- **Air Quality (PM10)**: Stations in Bayraklı, Alsancak, Güzelyalı (Oct 2023–2024)
- **Carbon Values per LULC Class**: Natural Capital Project

All spatial data were projected in UTM Zone 35S (Datum: WGS84).

Green Infrastructure Analysis

Green infrastructure within Konak was evaluated based on Izmir Municipality's 2017 strategy document (İzmir Yeşil Altyapı Stratejisi 2017). GIS analysis identified key green spaces, such as Kültürpark and Kadifekale, as well as the presence of proposed green corridors along the Meles River. Tree cover density statistics were used to calculate spatial distribution and vegetation gaps. The results show that there is very little green space, and the existing green spaces are fragmented, therefore, do not adequately support climate adaptation efforts and require concurrent planning of integrated ecological approaches to urbanism.

Ecosystem Service Models Using InVEST

Four ecosystem services were modeled using InVEST software (v3.14.2):

- Carbon Sequestration
- Habitat Quality
- Urban Heat Island Mitigation
- Air Pollution Mapping (via ArcGIS)

Carbon Sequestration

The InVEST Carbon Sequestration model (v3.14.2) calculates carbon storage using LULC data and four values of carbon pools: aboveground, belowground, soil, and dead organic matter. A Landsat 9 image (July 2024) was utilized to produce a LULC map using ArcGIS software and grouped into six classes: water, artificial, bare land, forest, agriculture, and shrubland.

Accuracy was validated by 300 random points and ground truthing. Classification was 0.856 kappa coefficient, verifying sufficient reliability to use in carbon calculations.

Habitat Quality

The InVEST Habitat Quality model assesses biodiversity via threats, sensitivities, and LULC. The data needed include LULC maps, sensitivity tables, raster of relevant threats, and information on protected areas. We selected data for threats and sensitivity from Salata et al. (2022). We also used the same LULC data as in our carbon modeling. We used the type of threat and sensitivity data together with threat intensity and adjusted intensity of threat depending of distance from threats and habitat type. Our output captured habitat vulnerability and quality.

Urban Heat Island Mitigation

To assess urban heat mitigation, the InVEST Urban Cooling Model was used. It estimates the cooling effect of land uses via evapotranspiration, shade, albedo, and proximity to green areas.

The input data included LULC, reference temperature, UHI values, and biophysical parameters. This model helped evaluate how nature-based interventions reduce heat vulnerability in urban areas.

Air Pollution Mapping

Annual PM10 concentrations (October 2023–2024) for the survey area were interpolated using ArcGIS IDW at the 3 monitoring stations in Alsancak, Güzelyalı, and Bayraklı into a single map based on monitoring data. Due to their ability to penetrate the deep tissues of the lungs, PM10 is one of the most hazardous air pollution components (Türkmen 2019). The developed map reflects the spatial variability of air quality throughout Konak.

Model Validation and Processing

All InVEST outputs were validated against peer-reviewed data and local records. Reclassification, normalization, and raster overlays were made in ArcGIS Pro 3.4.2 for the data's integration and visualization.

Environmental Impact Assessment and Analytical Tools

Environmental performance of tree-planting strategies at the Sümerbank site was assessed using species-specific ecological coefficients.

- **Carbon Sequestration:** 1,036,678 kg CO_2 projected lifetime storage.
- **Annual CO_2 Assimilation:** 83,647 kg/year.
- **Pollutant Removal:** 91.5 kg O_3, 80.82 kg NO_2, 72.4 kg SO_2, 48.22 kg PM10 annually.

Species like *Celtis australis* and *Quercus ilex* were key contributors. Results were contextualized through equivalents such as flight emissions and diesel usage. Google Earth imagery was also utilized to confirm land-use changes in the Meles Delta (2002–2025) and validate design strategies, such as wetland creation and riparian restoration.

Results

Green Infrastructure

These were also validated against peer-reviewed data and local records for the InVEST results. Reclassification, normalization, and overlay inspection through raster were performed in ArcGIS Pro 3.4.2 to be incorporated and visualized.

Konak, which is one of İzmir's older districts, has been urbanized to a great extent, and green space expansion was behind. Inner green areas such as Kültürpark and Kadifekale are unused, with green space coverage at only ~6%, which is considerably below the recommended 10 m^2 per capita (Türker & Gül 2022) (Figure 1).

In response, İzmir Green Infrastructure Strategy (2017) proposed holistic ecological measures like transitional spaces, recovery of ecosystem services, and corridor planning, especially along the Meles River for connecting fragmented locations and balancing urban growth with ecological requirements.

Key measures include:

- Large-canopy trees to reduce urban heat.
- Buffer zones and height regulations.
- Tiered conservation in biodiversity hotspots.
- Conversion of idle lands into green infrastructure.

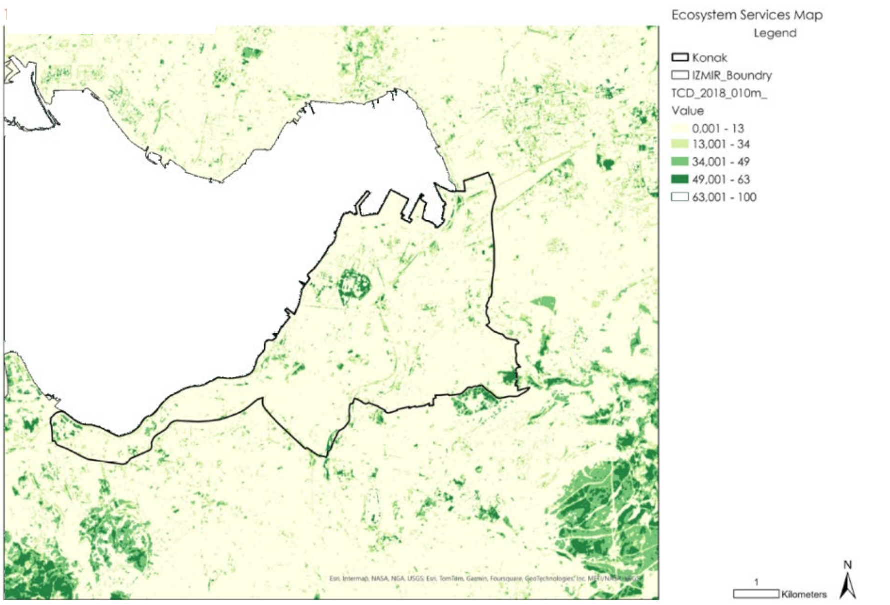
Figure 1. *Izmir Municipality Green Infrastructure Strategies*

Source: İzmir Büyükşehir Belediyesi 2017.

Tree Cover Density

The tree cover is scant in Konak, having emerged in patches surrounding Kültürpark and on parts of the Meles River. Urban environments, such as Alsancak, lack vegetation with occasional street trees scattered outside the Akdeniz and Konak regions (Figure 2). The urban forest canopy needs to be improved to improve ecological resilience. There would also be benefits from integrating the Meles corridor into a connected urban green network, reducing spatial fragmentation, and encouraging the sustainability of the city.

Figure 2. *Tree Cover Density 2018 (raster 10 m) of the Konak District*

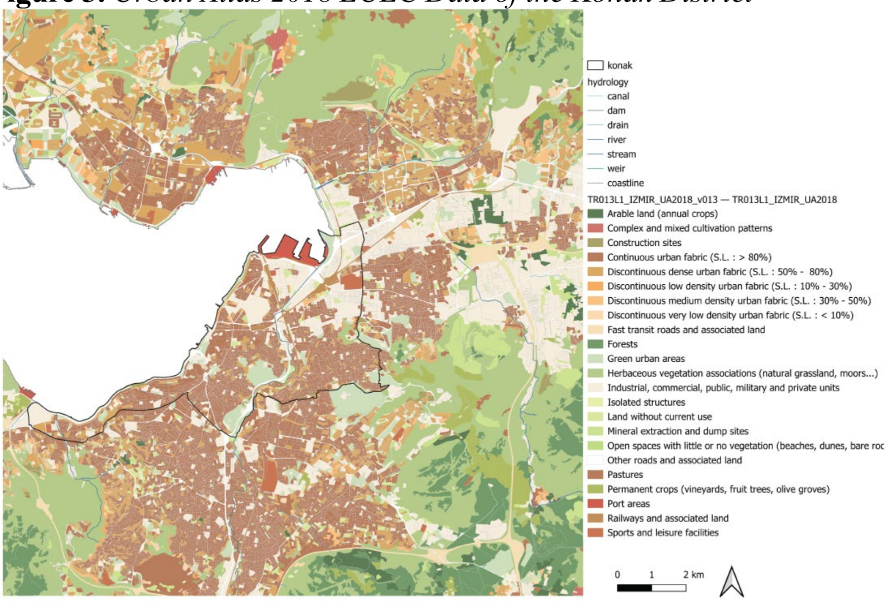


Source: author's elaboration using Tree Cover Density 2018 raster file, UTM Zone 35S, Datum WGS 84.

Land Use/Land Cover (LULC)

Over 80% of Konak's land is covered by urban uses, reflecting dense residential, commercial, and administrative development (Figure 3). Alsancak Port further intensifies industrial land use nearby. While the historical fabric contributes cultural value, the dominance of impermeable surfaces reduces green coverage and climate resilience.

Figure 3. *Urban Atlas 2018 LULC Data of the Konak District*

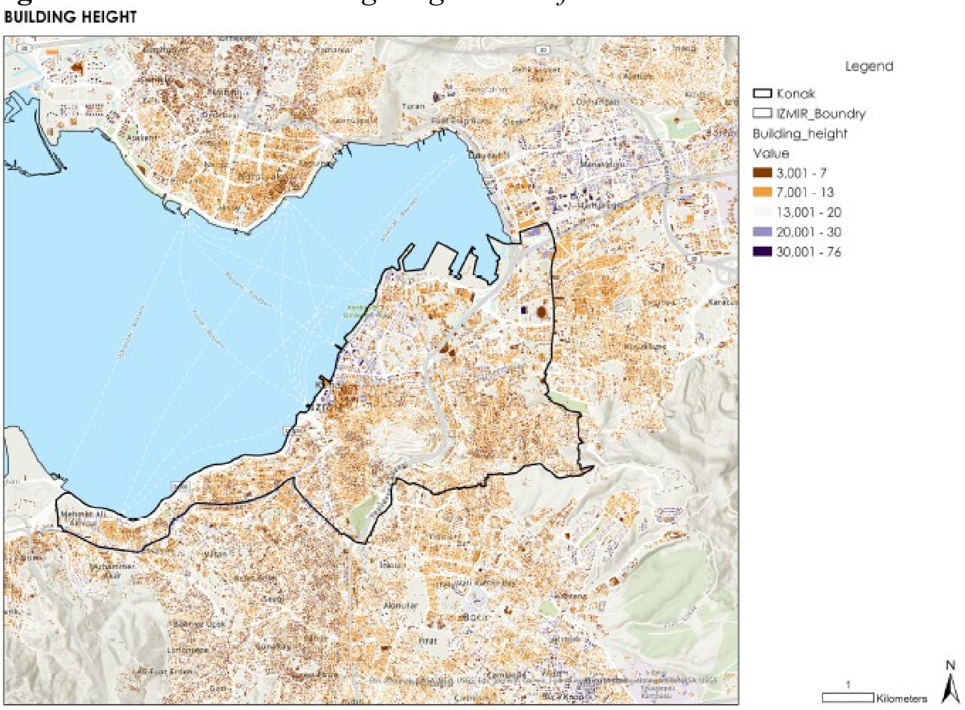


Source: author's elaboration using Urban Atlas 2018 vector file, UTM Zone 35S, Datum WGS 84).

Building Height

Konak building heights range from 3 to 76 meters (Figure 4). Alsancak and Mimar Sinan districts are represented with higher buildings (20–30 m), indicating densification, but conserved areas like Kemeraltı maintain low-rise buildings due to cultural heritage constraints. These are spatial distinctions emphasizing various urban pressures and needs for conservation.

Figure 4. *Urban Atlas Building Height 2012 of the Konak District*



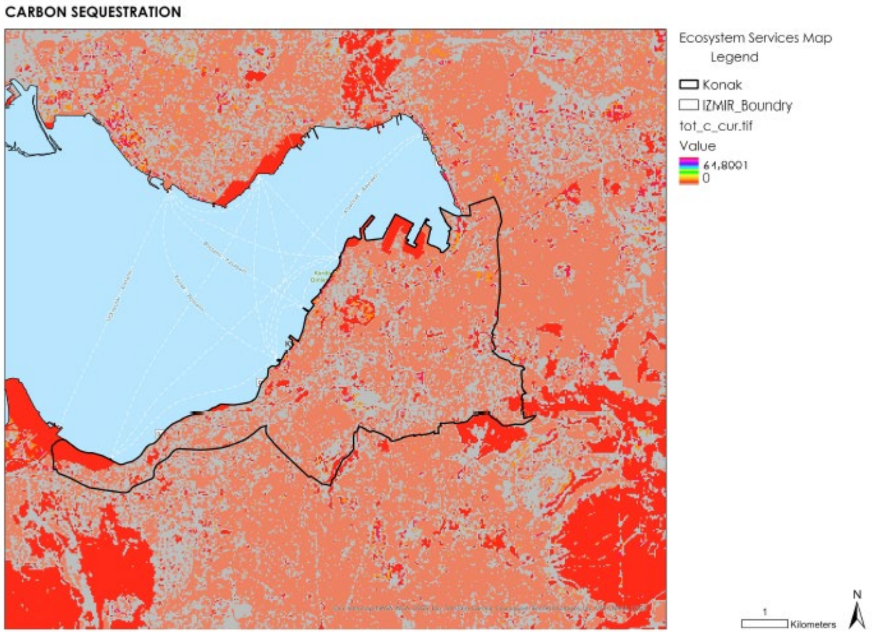
Source: author's elaboration using Urban Atlas 2012 vector file, UTM Zone 35S, Datum WGS 84.

Ecosystem Service Modeling

<u>Carbon Sequestration</u>

Carbon stock is critically low in urbanized areas of Konak, with only green zones like Kültürpark and Kadifekale retaining moderate values (~64.8Mg C/ha) (Figure 5). This emphasizes the need for NBS to be implemented (e.g., green roofs and vertical gardens). The opportunity to turn abandoned plots into vegetated areas, as well as supporting green mobility (e.g., bike lanes through Kültürpark into Alsancak), adds to the sequestration potential.

Figure 5. *Carbon Sequestration Map of Konak*

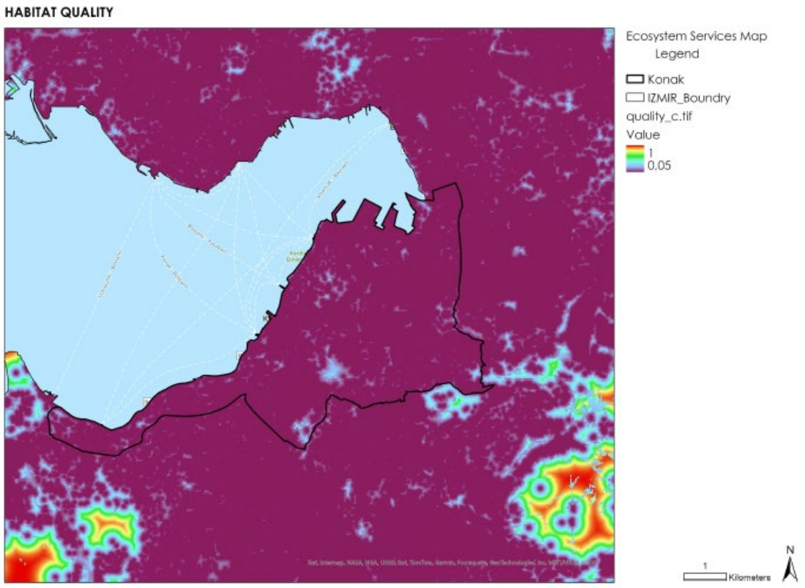


Source: author's elaboration with InVEST.

Habitat Quality

Over 90% of Konak exhibits low habitat quality (below 0.3 on a 0–1 scale) as a result of urban and agricultural expansion, and only a small number of patches above 0.6, indicating medium or high ecological value (Figure 6). Habitat fragmentation threatens biodiversity across the globe, and is reducing climate resilience (Admasu et al. 2023).

Figure 6. *Habitat Quality Map of Konak*

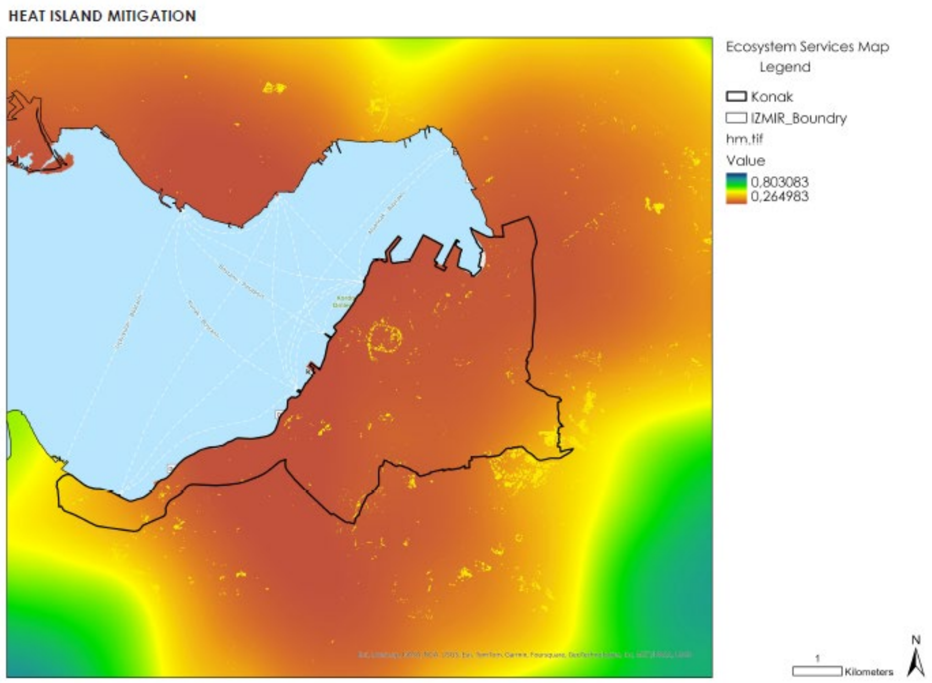


Source: author's elaboration with InVEST.

Urban Heat Island Mitigation

Konak is at high risk from UHI effects, and some areas are only showing substantial cooling values such as dense vegetation in areas like Mehmet Ali Akman, Güzelyalı, Göztepe, and Kültürpark which produced cooling values of 0.803 (on a normalized scale) (Figure 7). It will be especially critical to implement NbS such as green roofs and tree planting- especially in high-density areas. Increasing tree coverage by 10% can reduce local UHI intensity by (55) in the summer (Rogers et al. 2020).

Figure 7. *Heat Island Mitigation Map of Konak*



Source: author's elaboration with InVEST.

Environmental Vulnerabilities in Konak

The spatial analysis showed some significant environmental gaps. The area south of Alsancak Harbour shows the extent of flood vulnerabilities and the subsequent risks posed by climate exacerbation. The fragmented green infrastructure greatly deterrents mobility has been central to UHI, low habitat and carbon sequestration and pollutant exposures, which suggests that there is significant health risks related to populations exposed in areas like the Meles Stream corridor given the poor biodiversity and lack of vegetated barriers to pollution allergies. These vulnerabilities are spatially visualized in Figure 8, which highlights the key environmental weaknesses of Konak district, including flood risk, fragmentation, and low biodiversity.

Design interventions must focus on areas identified as most vulnerable, and think holistically to integrate NBS and planning for a regional scale for long-term climate adaptation.

Figure 8. *Weakness Map of Konak*

Design Proposal: Integrating Nature-Based Strategies for Urban Resilience in Alsancak, Izmir

Green and Blue Infrastructure Integration

The ecological integrity of Izmir increasingly depends on the agricultural basins and sustainability of its green corridors. In the context of a Blue Growth Strategy for the sustainability of the Gulf of Izmir, a reformed green network system has an increased importance to the Central Green Belt. The long-term vision of the municipality of Izmir (Izmir Sustainable Energy and Climate Action Plan 2020) proposes a continuous green corridor that follows the Meles Stream. This would be enterprising that can re-establish some ecological connectivity around the urban core (see Figure 9). The proposal to connect some of the fragmented green areas (e.g., Kültürpark and the coastal edge) with green infrastructure and street trees will provide connectivity solutions. In support of this, the proposed Green Infrastructure Strategy contains specific urban interventions based on the mapping of ecosystem services (Figure 10). The order is sequential and prioritized:

- **Ecological Bridge in Tabakhane Area:** Reconfigured a road to convert a highway into an underpass that is topped with a green bridge to reconnect disjointed green and facilitate wildlife movement.
- **Vegetation at Highway Intersections:** Taking usually neglected intersections and using them as a way to create more public green spaces to mitigated urban heat islands and increase biodiversity.
- **Green Corridor Expansion**: A new corridor is proposed along the Melta Stream, extending the existing green framework.

- **Urban Terraces**: Designed to improve vertical and functional connectivity between **Kadifekale** and the urban core.
- **Air Quality Enhancements**: Green façades, roofs, and permeable pavements are introduced in **Alsancak** and **Kordon Promenade** to mitigate air pollution.

These interventions constitute a multifunctional ecological network that enhances climate adaptation while promoting biodiversity and human well-being (Figure 11).

Figure 9. *Green Network Proposal*

Figure 10. *Green Infrastructure Strategy*

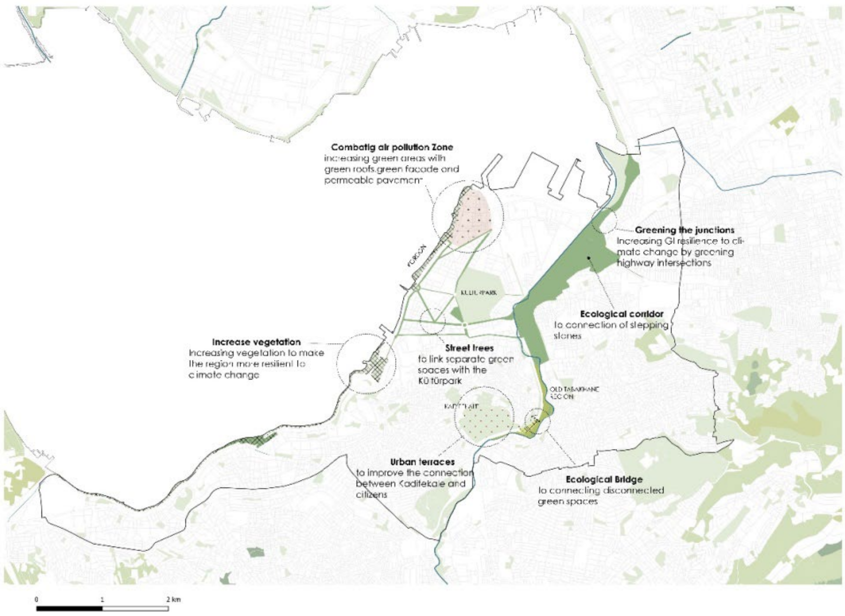


Figure 11. *Air Pollution Mitigation Strategy Map*

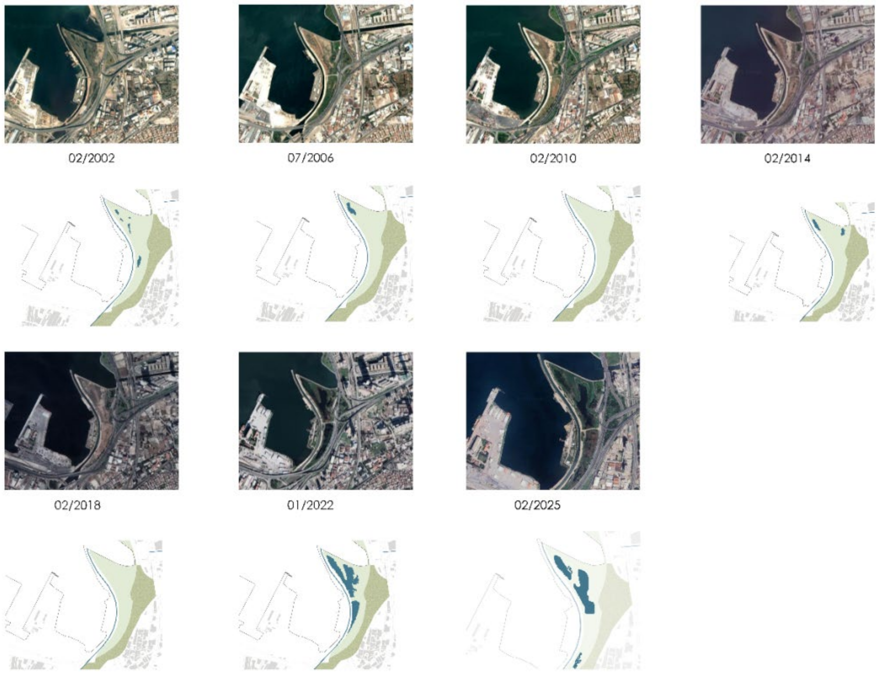
Blue Infrastructure and Coastal Adaptation

The Meles Delta is an ecologically sensitive and flood-prone area. Examination through Google Earth reveals that incredible changes are occurring (e.g., urbanization, altered river discharge, drought) from 2002 to 2025 (Figure 12). To restore hydrological balance and ecological integrity, a **Blue Infrastructure Strategy** (Figure 13) has been integrated, including:

- **Floodplain Wetlands**: Designed to store excess water during peak flows, enhancing resilience and biodiversity.
- **Wetland Restoration in Former Industrial Zones**: The vacated site near **Mandra Stream** is repurposed to restore natural water filtration.
- **Floating Wetlands & Filtration Ponds**: Improve water quality using phytoremediation.
- **Fish Passages and Buffer Zones**: Address flow interruptions and enhance aquatic biodiversity.
- **Groundwater Recharge Surfaces**: Along the **Meles Stream**, green and permeable surfaces improve infiltration and reduce runoff.

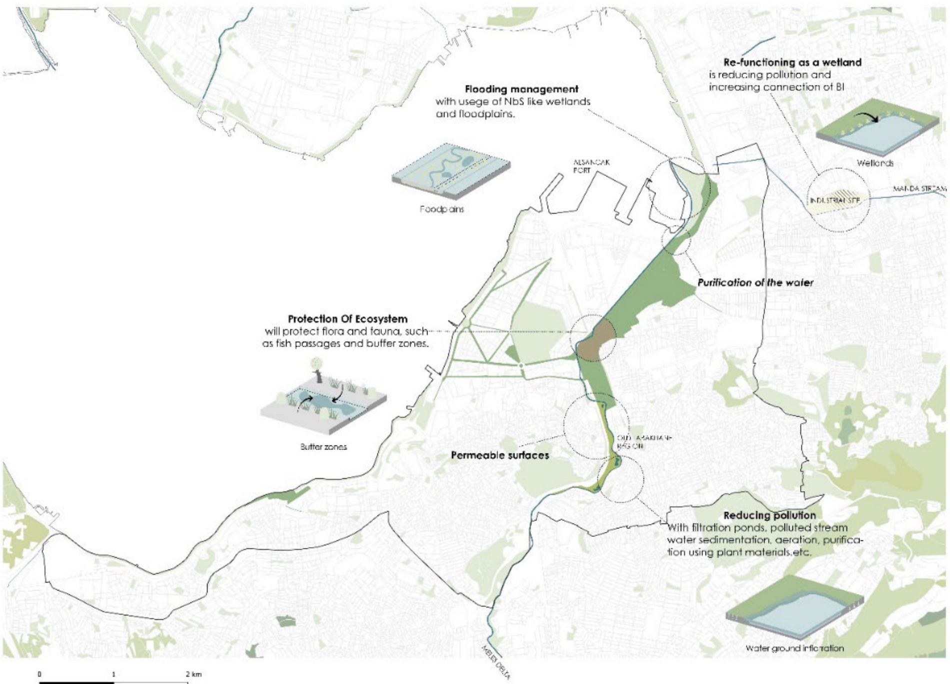
Together with the green strategy, this approach forms a hybrid urban ecosystem resilient to both climate and anthropogenic pressures.

Figure 12. *Evolution of the Coastal Area and the Meles Delta*



Source: Author's elaboration based on satellite imagery analysis (Google Earth, 2002–2025).

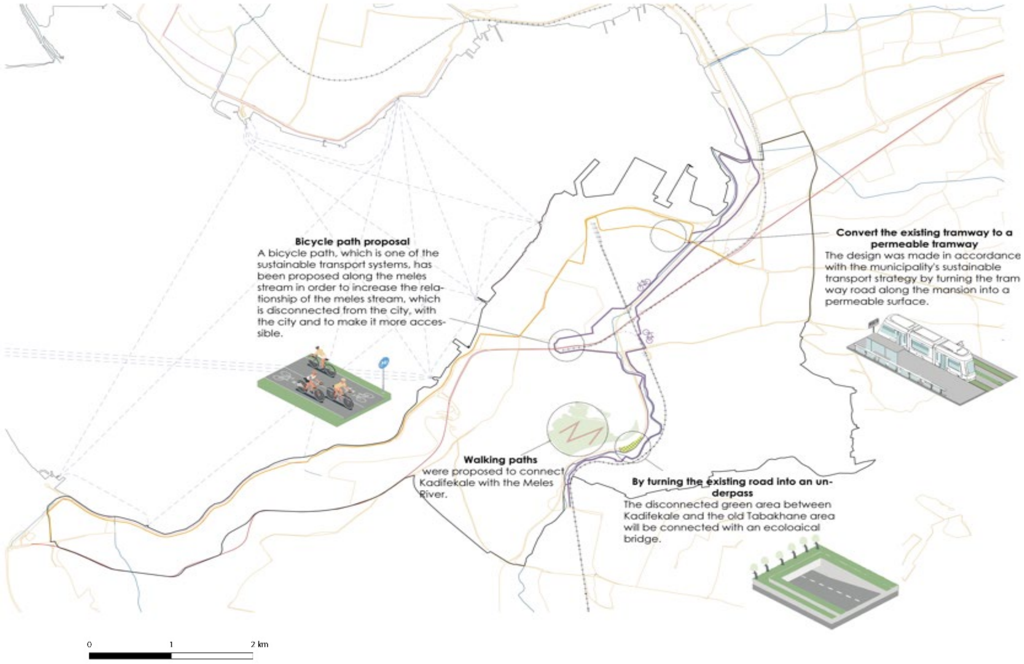
Figure 13. *Blue Infrastructure Strategy Map*



Mobility and Climate-Compatible Transport

The purpose of transportation redesign is to connect urban energy and mobility with the ecological system (Figure 14). It includes: - Bicycle and Pedestrian Paths: New bicycle and pedestrian paths are proposed along the Meles Stream and Kadifekale providing public space that is also linked to the ecological systems. - Permeable Surfaces on Tramway: In particular, a redesigned tramway with permeable surfaces proposed for the Kordon waterfront reduces run-off: These mechanisms indicated a strong link between humans and natural corridors and improved environmental quality.

Figure 14. *Transportation Strategy Map*



Strategic Vision and Master Planning for the Ecological City

<u>Conceptual Framework: The Ecological City Model</u>

Through thorough spatial, environmental, and vulnerability assessment, a strategic mechanism was created before the whole master plan was finalized (Figures 15-16). This strategic mechanism integrates green, blue, and transport systems into one unified planning vision, featuring the Ecological City Concept as the philosophical and spatial foundation of design. The concept has three pillars:

- **Climate Resilience:** enhancing the city's capacity to adapt to extreme weather, floods, and heat waves.
- **Social Equity**, ensuring that green and blue infrastructure benefits all populations, particularly vulnerable groups.

- **Ecological Integrity** conserves biodiversity and restores degraded ecosystems through green networks and sensitive land use.

The Meles Delta was identified as a priority zone due to its ecological value and vulnerability to climate impacts. In this regard, protecting the habitats is essential for the endemic fauna and urban biodiversity. Being one of Izmir's climate-threatened provinces and districts, Fazil Konak emphasizes the importance of Nature-Based Solutions as primary tools for adaptation and mitigation.

Other determining factors for this model's success would include awareness of civil society and the stakeholders.

Understanding how urban ecosystems operate helps a community build support, strengthen stewardship, and promote long-term viability.

Figure 15. *Concept Diagram*

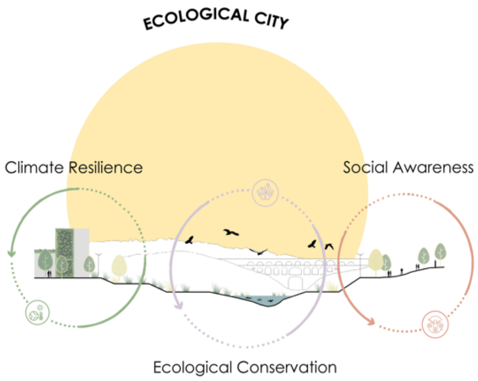
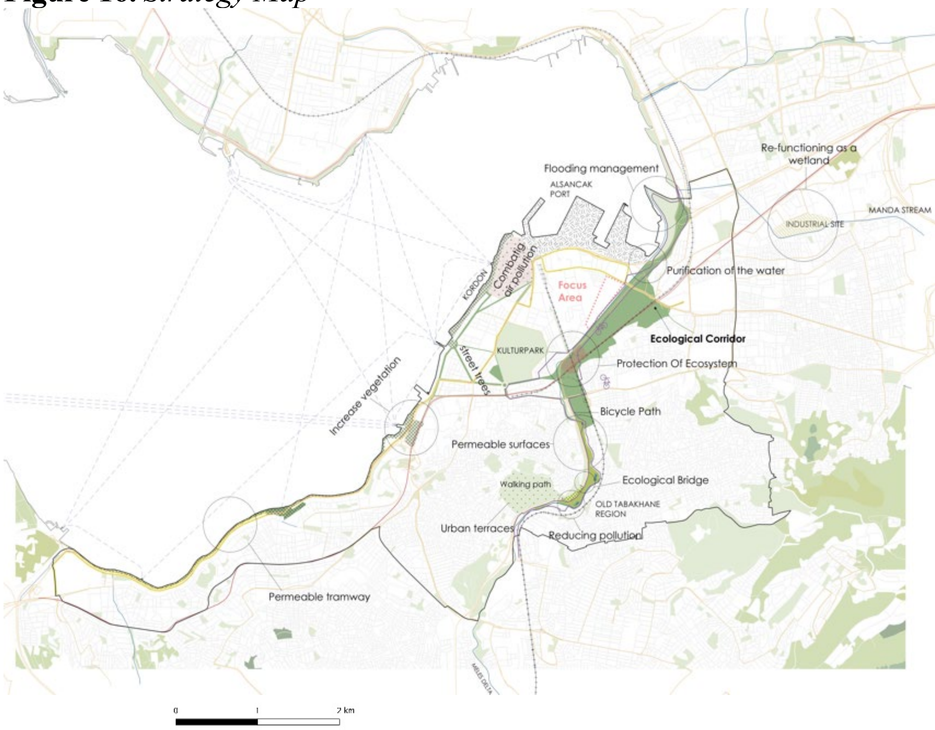


Figure 16. *Strategy Map*



Master Plan: Integrating Green-Blue Networks in Alsancak

Building on the strategic concept, the Master Plan (Figure 17) integrates site-specific interventions across green, blue, and transportation domains, especially within Alsancak Port, where the Meles Stream meets the Gulf of Izmir. Seasonal analyses (Figure 12) revealed that parts of this area exhibit wetland characteristics during rainy periods, offering an opportunity for ecological enhancement and water-sensitive design.

The site is reimagined as a functional wetland system that respects natural hydrology. Enhanced green and tree-canopied spaces are introduced to capture stormwater, reduce flooding, and cool the local urban microclimate. A continuous boardwalk connects the spine of the intervention's three:

- Observation decks for environmental education and recreation.
- Pedestrian walkways and bike paths to promote sustainable mobility.

This structural intervention provides an ecological and circulation opportunity to connect the Meles Stream corridor to Kültürpark while connecting the community with the waterfront. The three land-use changes derive the transformation from:

- Vacant lands to green spine.
- Parking lots are redesigned as permeable green areas.
- New street trees reinforce ecological corridors along highways.

The green corridor from Kültürpark to the coast is divided into four landscape typologies:

1. Public Areas – for cultural events and civic gatherings.
2. Ecological Protection Areas – with restricted access to conserve sensitive habitats like the Meles Delta.
3. Recreation Areas – for walking, nature viewing, and low-impact leisure.
4. Sport Areas – with jogging and cycling routes and fitness equipment, surfaced with permeable materials to manage runoff and reduce heat.

This typology, based on ecological sensitivity and spatial analysis, ensures a balanced landscape that supports climate adaptation, strengthens ecological connectivity, and harmonizes urban development with environmental stewardship.

Figure 17. *Master Plan*

Ecological Conservation and Biodiversity Enhancement

The ecological conservation plan supports a sustainable, urban vision for the overall planning of Konak by enhancing protected areas, buffer zones, ecological corridors, permeable networks, and publicly available participatory spaces. This multiservice platform provides biodiversity benefits while supporting Konak's climate resilience. Although the Meles Delta has many kinds of flora and fauna, the previous industrialization and riverbed alteration has led to widespread habitat degradation. The plan proposed a master ecological plan based on local biodiversity, which aimed to restore ecological integrity through select interventions. The design proposes:

- **Protected Zones** to restrict access and allow natural regeneration.
- **Buffer Zones** to mitigate urban disturbances and prevent habitat fragmentation.
- **Observation Areas** for education and research, maintaining ecological integrity with controlled access through walkways and decks.

Species-focused strategies include the planting of **Olea europaea** (olive tree) to provide food and shelter, and habitat enhancements for birds like **Halcyon smyrnensis** (White-throated Kingfisher) and **Carduelis carduelis** (European Goldfinch).

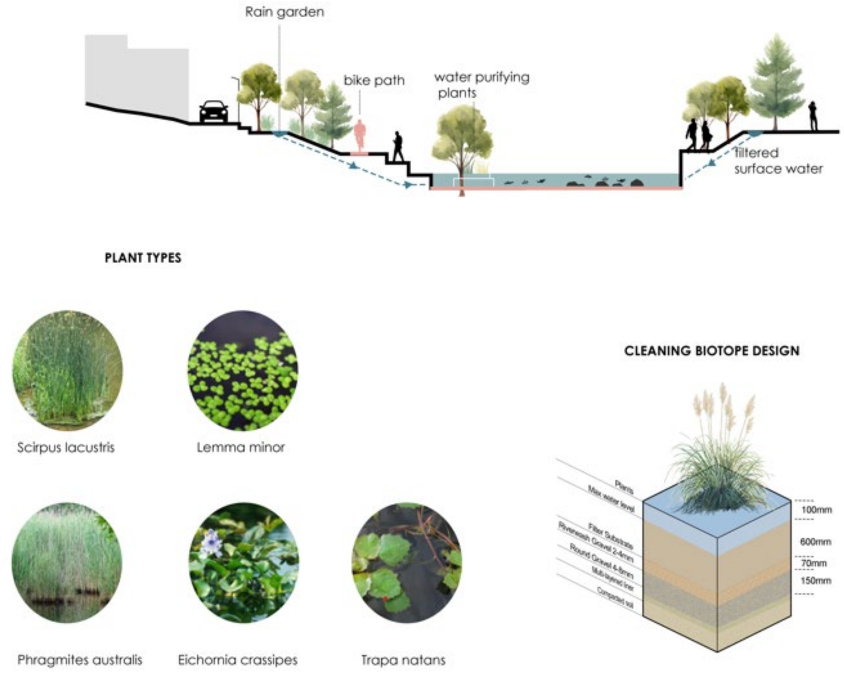
Water quality restoration in the Meles River is a significant objective. For this, phytoremediation is introduced using aquatic plants with pollutant-removal capabilities (Figure 18):

- *Lemna minor* (duckweed): absorbs nutrients and heavy metals.
- *Trapa natans* (water chestnut): reduces pollutants and provides habitat.

- *Scirpus lacustris* (bulrush): stabilizes sediment and filters water.
- *Eichhornia crassipes* (water hyacinth): removes organics and heavy metals.
- *Phragmites australis* (common reed): improves oxygenation and filtration.

These nature-based solutions promote habitat recovery, improve water quality, and strengthen the coexistence of urban and natural systems in the Meles Delta. Importantly, this combined approach also coincides with international frameworks that promote climate-resilient approaches integrating natural ecosystems with built heritage, enhancing the ecological and cultural value of the Sümer Bank Factory and its environment, in accordance with ICOMOS (2019).

Figure 18. *Water Quality Improvement Strategy*



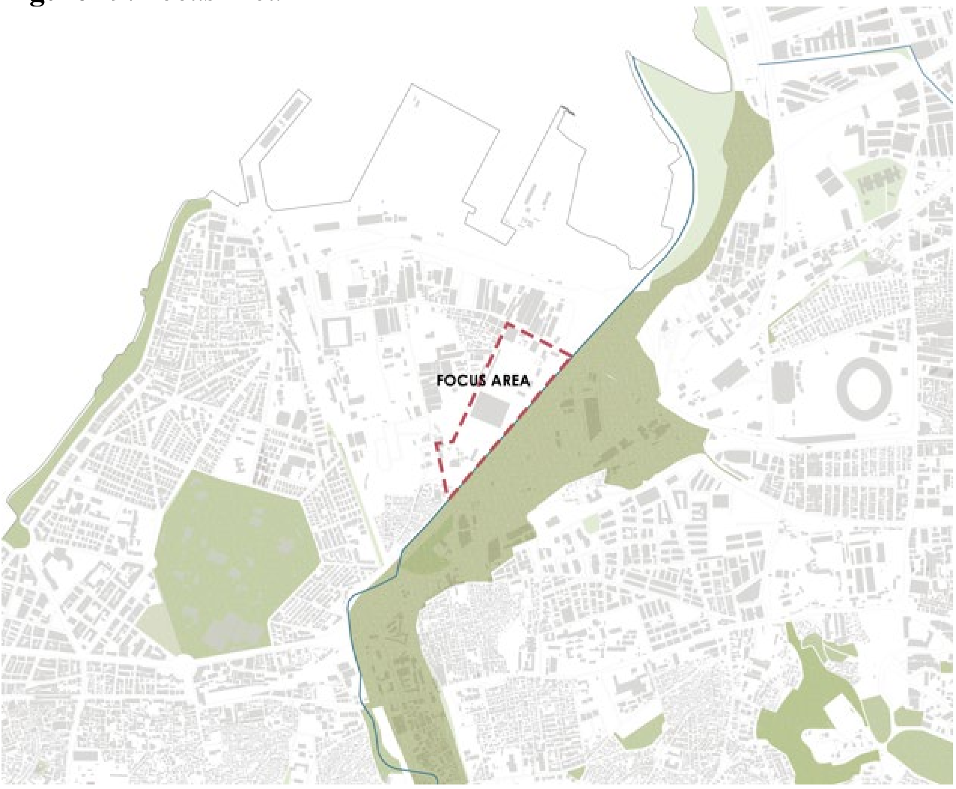
Focus Area: Sümerbank Factory as a Catalyst for Urban Regeneration

<u>Rationale for Selection and Urban Context</u>

The Sümerbank Factory was selected as the primary focus area within the Alsancak green corridor project due to its historical, spatial, and ecological significance (Figure 19). The tradition of early Turkish industrialization follows another that carries the collective memory of Izmir's heritage of manufacturing. Its current abandonment brings about urban fragmentation, in turn disrupting the ecological and cultural continuum of the city. Integrating the site along the green corridor will allow the project to rehabilitate it as a multifunctional ecological and social node, enhancing biodiversity as well as public interest.

Situated adjacent to green spaces and transportation axes, Sümerbank could serve as a spatial anchor, strengthening ecological connectivity for the Meles River. The adaptive reuse supports sustainable renewal by way of heritage conservation and climate resilience. Allowing the site to return to a natural state reclaims a disused industrial site and creates living infrastructure that fuses-built heritage with eco-system restoration.

Figure 19. *Focus Area*



Historical Trajectory of Sümerbank Factory

Founded in 1933, Sümerbank emerged as both a **state-owned industrial and financial institution**, inheriting the functions of the earlier Industrial and Mining Bank, established in 1925. It was established to manage textile factories, support local industry through credit, and regulate the Turkish economy during its period of modernization (Toprak 1988). Following the closure of the State Industry Office and the Industry and Credit Bank due to structural inefficiencies, Sümerbank unified these roles and became instrumental in constructing major textile, chemical, and mining facilities under the First and Second Five-Year Industrial Plans (Arıtan 2004).

The Sümerbank Factory was chosen as the leading focal point of the Alsancak green corridor project because of its significant importance historically, spatially, and ecologically (See Figure 19). Sümerbank's influence extended all across Turkey with factories located in Kayseri, Nazilli, and other cities dependent upon raw materials, development emphasis, and military potentiality (Uğrasal 2011). Although it was fully privatized by 1993 and operations ceased by the early 2000s, Sümerbank's factories remain critical to the history of Turkey's industrial architecture and socio-economic development (Köksal & Ahunbay 2006).

Site Analysis and Design Approach

The spatial organization of the İzmir Sümerbank Basma Sanayi Complex, which is organized in spaces effective for operation as a place with separate areas for production, administration, housing, and public facets (See Figure 20). The entrance on Şehitler Street marked the starting point of a well-defined circulation axis (Axis 1), which connected all primary functions of the site, facilitating both secure factory operations and public access to social areas.

Today, although some buildings are used for educational purposes (e.g., Nevvar Salih İşgören Campus), many original industrial structures have fallen into disrepair. Despite the conservation decisions made in 1998 and 2001 by İzmir's Cultural Heritage Board, which registered the steam power plant, social facility, and other elements as second-degree cultural assets (Uğrasal 2011), much of the complex remains underutilized. The present-day disjointed state of the site represents the need for a design-based type of intervention to reinstate the operational and ecological functioning of the site. As seen in Figure 21, the Sümerbank Factory is physically disjointed, decayed, abandoned, and lacks any sort of maintenance. This ground-level photograph highlights the site's vulnerability and reinforces the necessity of nature-based strategies to rehabilitate its cultural and ecological assets.

Figure 20. *The Functional Zoning of the Sümerbank with Entrances*

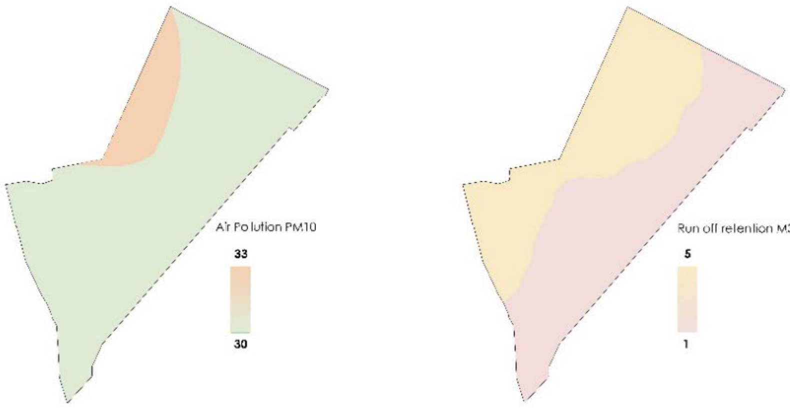
Source: Uğrasal, 2011.

Figure 21. *Current State of the Sümerbank Factory Site Showing Structural Decay and Abandonment*

Source: Gerçekİzmir 2018.

Understanding the place's historical importance, a series of analyses was conducted before engaging in the process of design. Flooding, as well as studies on air pollution, revealed that the area is critically prone to floods, and notably, the area with the five schools is most at risk. The rate of air pollution was also observed to be quite intense along 1525 Street. Therefore, the design process addresses these environmental conditions so that development will be environmentally friendly and responsive.

Figure 22. *Air Pollution and Flooding Risk Maps*



<u>Sümerbank Factory Design Proposal</u>

The Sümerbank Factory site, located near the Meles River, is designed as part of the river's green corridor with a focus on expanding green areas. The aim is to develop a network of contiguous green spaces to enhance flood resilience, improve water absorption, and establish ecological continuity between natural and urban environments.

Flood Risk and Educational Facilities

As earlier analyses revealed (Figure 22), five schools on-site face flood risks. Their position will be shifted into a safer zone, and in place of various scattered schools, an integrated educational complex shall be developed.

Wetlands for Flood Mitigation and Biodiversity

Wetlands are proposed to be established in flood-prone areas for the temporary storage of excess water and for mitigating the effects of water. The location of the site near the Meles River supports the wetlands in increasing biodiversity and habitat functions.

Reconnecting the City to the River

Viewpoints and recreational areas are integrated along the riverbank to reconnect the public with the Meles River, thereby enabling new social and environmental interactions.

Heritage Conservation and Adaptive Reuse

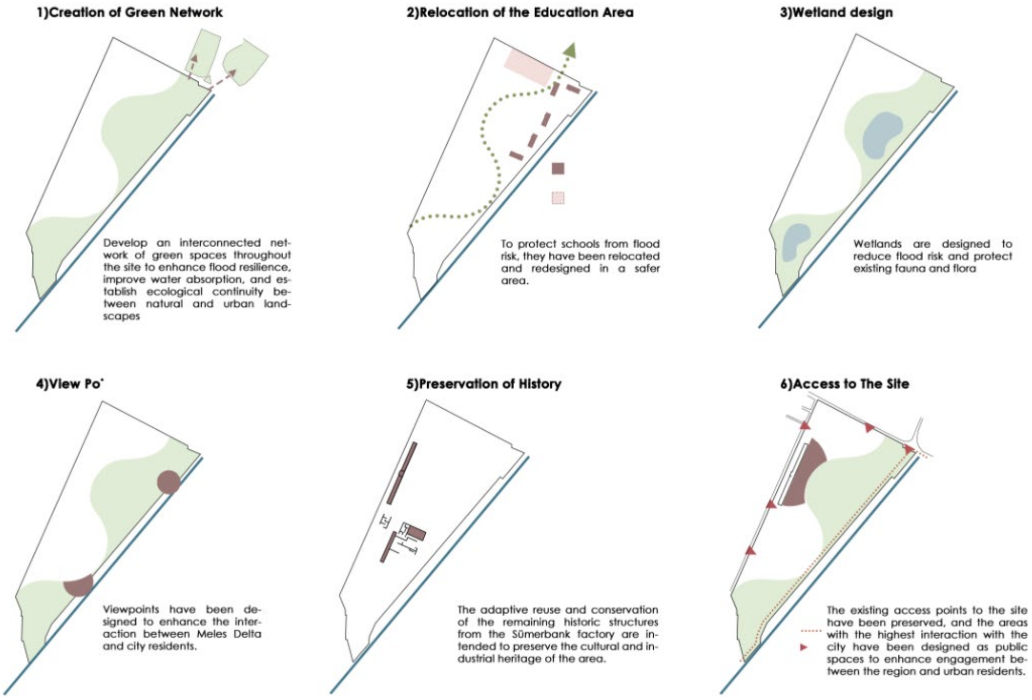
To conserve the heritage of the area, the important buildings are retained and converted for further use. While 80% of the Printing Processing Factory was demolished, the remaining structures will become an open museum. The Yam Weaving Building will serve as social facilities, and the original factory entrances are retained to preserve spatial identity.

Integrated Mobility and Green Transportation

A bicycle route along the Meles River passes through the area, promoting access and sustainable transport. Cycling infrastructure supports urban mobility and environmentally friendly commuting.

As shown in Figure 23, the design process followed a series of ecological assessments, conceptual zoning strategies, and interventions informed by a variety of stakeholders to achieve a climate-responsive transformation of this industrial site.

Figure 23. *Sümerbank Factory Site Design Process*



<u>Circulation Strategy</u>

The circulation system constructed for the Sümerbank Factory site provides a full-fledged experience by merging architecture and nature. Prioritizing pedestrian access, walkers enjoy views over the wetlands, heritage buildings, or public spaces, and their path elevates their experience and environmental consciousness. Protected bird zones are distinguished by observation points to the extent that visitors can observe wildlife without detracting too much from the ecosystems. The network also interlinks cultural and ecological facets, such as museums, social hubs, and bioswales, to unite sustainable environments alongside constructed ones. The bicycle path ushers connectivity to the larger Meles River green corridor, while sunlit pathways and their adjoining public facilities promote entrance, sustainability, and continuity. Figure 24 demonstrates the comprehensive master plan that serves this integrated vision and illustrates how blue-green infrastructure, adaptive reuse strategies and pedestrian connectivity combine to create a climate-resilient cultural landscape.

Figure 24. *Master Plan*

<u>Ecological Restoration</u>

To support the wider initiative for urban regeneration of the site, Sümerbank will also employ ecological restoration to reverse the previous and significant forms of environmental damage resulting from industrial activity in relation to soils, vegetation, and habitats. The principle of restoration here incorporates notions of biodiversity, habitat diversity and complexity, and ecological resilience using nature-based and adaptable landscape design approaches. Approaches will include:

- Protection/translocation of mature trees
- Seed banking for grassland recovery
- Faunal-assisted seed dispersal
- Shaded microclimates with targeted planting
- Accelerated succession through diverse planting
- Native species use, in-situ tree conservation, and reuse of removed vegetation (e.g., logs for insects/seating)

These strategies support a self-sustaining, biodiverse, and climate-resilient ecosystem.

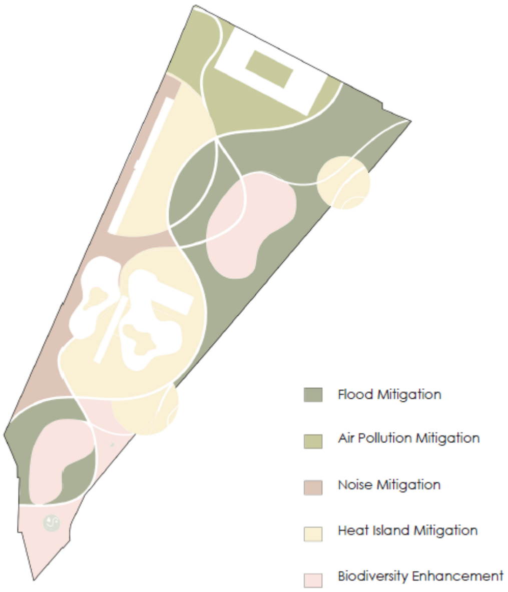
Vegetation is selected for mitigating air/noise pollution, reducing UHI, and supporting biodiversity. Species are urban-adapted and ecologically functional (Figure 25).

Tree species include: Celtis australis, Acer campestre, Fraxinus excelsior, Tilia platyphyllos, Platanus × acer folia, Quercus ilex – chosen for drought resistance, pollution absorption, and shade.

Shrub species include: Lavandula, Rosmarinus, Pittosporum, Phillyrea, Juniperus, Sambucus – selected for air purification, adaptability, and habitat support.

Planting locations are based on vulnerability, including road proximity, flood-prone zones, and solar exposure.

Figure 25. *Climate Resilience Intervention Map*



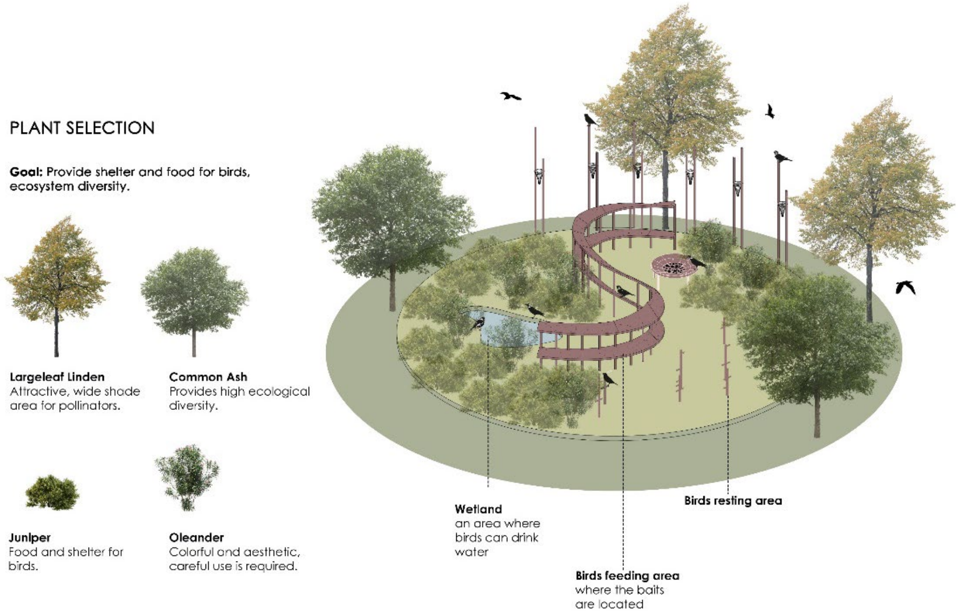
Zoning for Ecological Processes and Education Three ecological zones support functioning with minimal intervention:

- Protected Zones –limit human access for natural regeneration
- Buffer Zones – shield core areas and support edge species
- Observation Areas – allow public learning without disturbing ecosystems.

This structure ensures a balance between preservation, education, and recreation.

Enhancing Urban Biodiversity and Habitat Suitability Bird habitat creation is prioritized. Tilia platyphyllos and Fraxinus excelsior offer shelter and food for birds and pollinators. Juniperus and Nerium oleander provide additional food sources and cover. Wetlands provide fresh water and nesting grounds (Figure 26). These create year-round microhabitats for ecosystem continuity.

Figure 26. *Biodiversity Enhancement Strategy*



Mitigating Urban Heat Island Effect

The proposed biodiversity strategy includes key zones for habitat, pollinator plantings, and the reinstatement of native species. With summer temperatures exceeding 40°C in İzmir, key strategies will include planting shade trees and trees that transpire large amounts of water i.e. Platanus × acerifolia, Tilia platyphyllos and Fraxinus excelsior. Cooling at ground level will be provided by reflective species i.e., Pittosporum tobira and Phillyrea latifolia to ensure climatic comfort and resilience.

Air and Noise Pollution Mitigation Strategies

Pollution levels along the busy 1525 Street are very high, and intervention is desperately needed. For example, tree species as Platanus × acer folia, Celtis australis, and Acer campestre will help capture pollutants.

Noise is reduced with multi-layer vegetation. Carpinus betulus acts as a sound buffer, especially along roads. Acer campestre and Viburnum tinus support year-round acoustic absorption.

This ecological restoration approach transforms Sümerbank into a resilient urban ecosystem. Strategic planning, functional zoning, and nature-based mitigation enhance biodiversity, reduce environmental stress, and build a climate-adaptive landscape.

Water Management Strategy

The Sümerbank site faced growing challenges associated with flooding given its proximity to the Meles River; consequently, it needed a water management plan that considered Nature-Based Solutions (NBS) to address hydrological vulnerabilities, restore ecological function, and enable better quality public space with nature-based elements. NBS interventions include rain gardens, bioreactors, wetlands, riparian buffers, rainwater harvesting, and greywater reuse systems. Figure 27 shows these interventions across the site and with the potential for green infrastructure capturing stormwater, reducing flooding, and improving ecosystem connections. Rain gardens, are vegetated basins that temporarily intercept shallow stormwater, filter surface contaminants, improve infiltration, and increase biodiversity. Constructed wetlands, located in low-lying zones, store floodwater and purify it through phytoremediation. Species like *Phragmites australis*, *Typha latifolia*, and *Juncus effusus* stabilize soils and support aquatic life.

Bioswales, vegetated linear channels, guide runoff through open spaces along a corridor, allowing sediments and pollutants to filter through gravel base layers and bio-retention layers. As depicted in Figure 28, they are located to filter runoff, facilitate groundwater recharge, and create microhabitats as part of the activities on the Sümerbank green corridor. Plantings include *Acer campestre* and *Fraxinus excelsior* for shade and evapotranspiration, while *Rosmarinus*, *Juniperus*, and *Lavandula* spp. Contribute to both purification processes and the visual character of the green infrastructure system.

The rainwater harvesting system on the educational campus collects runoff via green roofs and permeable surfaces, channeling it to underground tanks for irrigation and non-potable reuse. The surface doubles as a public plaza with sculpted topography for recreation and cultural events. As illustrated in Figure 29, the multifunctional design integrates water-sensitive urban design (WSUD) with landscape architecture, where form, slope, and paving patterns facilitate runoff collection while also creating vibrant, community-oriented public spaces.

Greywater reuse systems are proposed, particularly in green zones, to maximize water efficiency. Riparian buffers along the Meles River are restored with native vegetation to stabilize banks, reduce erosion, and connect the river with interior green spaces.

Together, these water-sensitive urban strategies make the Sümerbank site climate-adaptive, ecologically functional, and socially vibrant, demonstrating how post-industrial areas can evolve into resilient ecological infrastructure for future cities.

Figure 27. *Water Management Strategy*

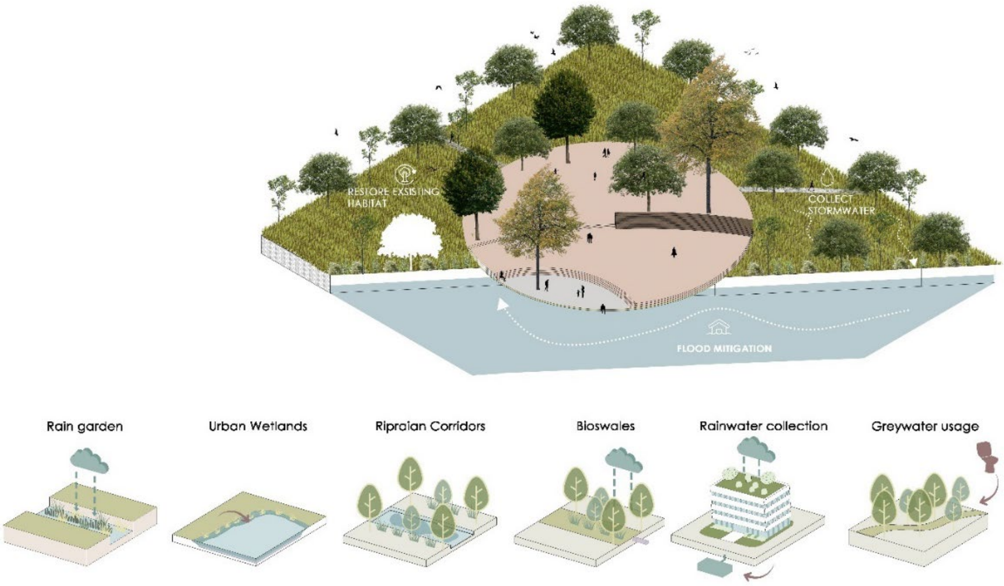


Figure 28. *Bioswale Design*

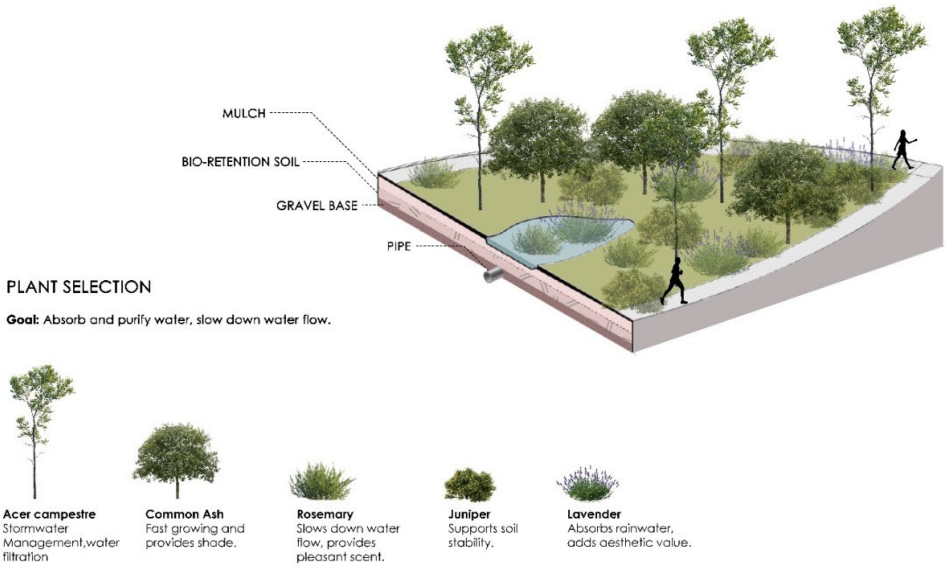
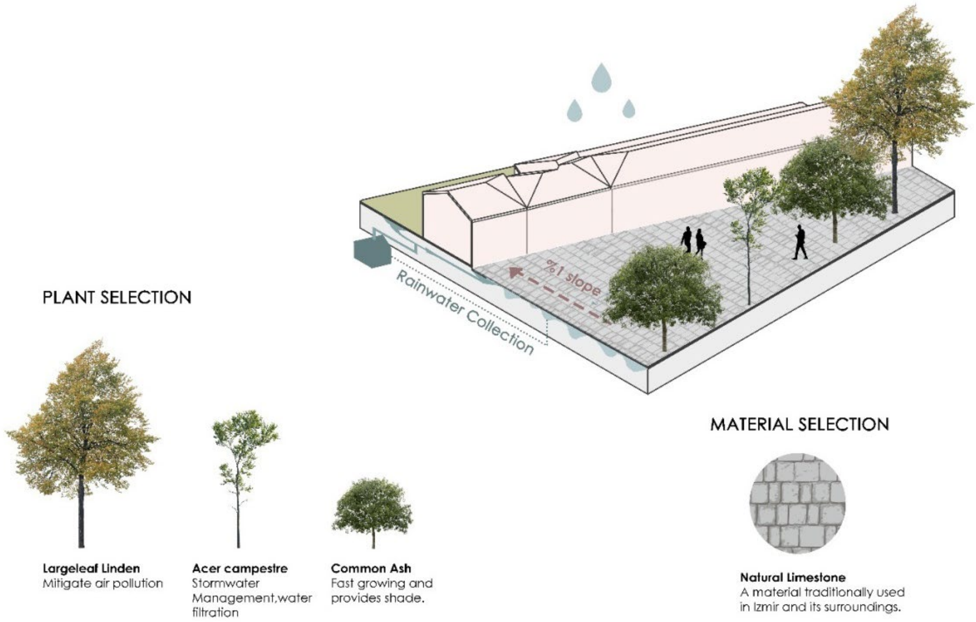


Figure 29. *Rainwater Collection*



Adaptive Reuse and Environmental Performance of Urban Greening

The Sümerbank regeneration project is based on adaptive reuse and circular design principles. The elements were designed for reuse, from the abandoned building structures and relocated schools, all aimed at reducing construction waste and embodied carbon. Crushed aggregates from demolished buildings were incorporated into the museum plaza elements, while providing a means for stormwater to permeate and contribute to management. Corten steel was applied to museum walls for its low maintenance and visual continuity between past and present. Permeable paving supports both water management and climate resilience.

Environmental Impact Assessment of Urban Tree Planting

To evaluate these approaches, a performance assessment of urban greening and tree planting was undertaken. The design added 342 new native trees and 64 784 m² of new vegetated area, preservation and increase of natural biota and overall connectivity and exchange between environments, ecosystem functions and ecology were improved and ecological connectivity level was improved due to these new reintroduced and preserved biodiversity along with preservation and increase of urban vegetation. In addition to the trees, 21 faunal species and 15 native plant species were reintroduced.

The environmental benefits of the project were measured and modelled with respect to: carbon sequestration, CO_2 assimilation and pollution removal. The trees planted are expected to sequester 1,036,678 kg CO_2 by the natural life of the trees, equating to 83,647 kg annually. Our urban greening and tree planting will also remove: ozone (O_3) and nitrogen dioxide (NO_2), Sulphur dioxide (SO_2) and particle pollution (PM_{10}). Species-specific reductions were outlined as:

Celtis australis: 13.1 kg O_3 26.2 kg NO_2 and had the ability to intercept and retain 39.3 kg SO_2 annually. Quercus ilex: was shown to retain 5.2 kg PM_{10}. In terms of equivalent real-world amounts:

CO_2 = 237 short trips from Izmir –Milan
PM_{10} = 3.2 million km worth of car trips
SO_2 = amount from burning 3.8 tons of coal
NO_2 = amount from 84,188 liters of diesel
O_3 = amount filtered from 2,287 mature trees

These results provided tangible, measurable results for air quality, climate resilience, and environmental justice measures. The inclusion of native trees and plant species, as well as recycled materials and design thinking, transformed the Sümerbank design from an industrial area considered to be in "a state of anthropogenic vulnerability", into an estimated sustainable, resilient, low-carbon, ecologically and environmentally enriched urban ecosystem.

Discussion

This study highlights the critical role that Nature-Based Solutions (NbS) play in enhancing climate resilience, particularly in dense urban coastal cities like Izmir. Through the integration of NbS into ecological and socio-spatial contexts, the study illustrates how urban planning and ecosystem recovery can come together through adaptive, multifunctional methods.

The interventions proposed for Alsancak and Sümerbank are not only spatial compositions but also ecological infrastructures. The study discovers that fragmented green spaces, historic forms, and vacant industrial lands can be redesigned as regenerative landscapes with measurable ecosystem values.

One of the notable observations is the potential for NbS stacking, such as combining rain gardens and open spaces, or leveraging adaptive reuse materials that allow both stormwater infiltration and thermal comfort. The Sümerbank Factory is a good example of how climate mitigation, historic preservation, and community use can all be integrated into a single location.

Quantifiable outcomes, such as sequestering 237 flights' worth of CO_2 or removing 3.8 tons of coal worth of SO_2, take intangible sustainability objectives and make them tangible results critical when making the case for NbS over traditional grey infrastructure.

There are, though, challenges. Success with NbS depends on political will, routine maintenance, and inclusive governance. Involvement by the government and multi-stakeholder cooperation are essential to preventing underuse or degradation in the long term.

Finally, tools such as GIS, InVEST, and Google Earth facilitated the development of a solid approach towards prioritization, ecosystem service modeling, and adjusting the design to site-specific conditions. This approach can be replicated in other Mediterranean cities along the coastline that face similar challenges.

In total, the research offers both a blueprint and proof for NbS as part of a larger urban resilience agenda. Situating climate action within landscape architecture and environmental simulation, it represents a replicable model for data-driven, community-based, and ecologically regenerative city change.

Conclusion

This article discusses the intensifying impacts of climate change on urban coastal cities, with a special focus on Izmir, Türkiye. As a Mediterranean city already experiencing heatwaves, droughts, floods, and sea-level rise, Izmir is exposed to intensifying environmental pressures. Qualitative assessment of exposure to the city indicates the need for adaptive measures to improve resilience.

Centered to this approach are Nature-Based Solutions (NbS), offering a means to address climate risk while generating ecosystem services like flood protection, air filtration, and carbon sequestration. The research recommends integrating NbS from the regional scale to site-level interventions with an emphasis on their role in contributing to systemic resilience.

Barcelona and Izmir case studies show NbS's capability in addressing both socio-economic and environmental issues in coastal regions. The green planning and infrastructure gaps in Konak were discovered by mapping ecosystem services, including low vegetation cover, poor air quality, and inadequate flood control, placing importance on ecologically based urban design.

The proposed NbS intervention for Konak, including its pilot site, Alsancak, consists of increasing tree cover, restoring river-edge ecosystems, creating permanent green and blue corridors, and adaptively reusing post-industrial sites, such as the Sümerbank Factory.

In addition to their environmental and physical benefits, the success of NbS also depends on governance, public participation, and facilitatory policy. Their participatory approach, which includes citizens, planners, and authorities, is crucial to long-term success.

Lastly, whereas climatic change is an ongoing challenge, in this case, it is clear that NbS offer a strong rationale for the marriage of climatic adaptation, urban regeneration, and nature protection. Using the natural processes to synergize with development, NbS can allow for the creation of healthier and more resilient cities if augmented by sustained policy and community support.

References

Admasu S, Yeshitela K, Argaw M, Bloor M (2023) Assessing habitat quality using the InVEST model in the Dire and Legedadi watersheds, central highland of Ethiopia: Implications for watershed management. *Sustainable Environment* 9(1).

Arıtan Ö (2004) *Kapitalist-sosyalist modernleşme modellerinin erken Cumhuriyet dönemi mimarlığının biçimlenişine etkileri – Sümerbank kit yerleşkeleri üzerinden yeni bir anlamlandırma*. (The effects of capitalist-socialist modernization models on the

formation of early Republican architecture – A new interpretation through Sümerbank kit campuses). Doktora tezi. Dokuz Eylül Üniversitesi.
Babbar D, Areendran G, Sahana M, Sarma K, Raj K, Sivadas A (2020, August 5) Assessment and prediction of carbon sequestration using Markov chain and InVEST model in Sariska Tiger Reserve, India. *Journal of Cleaner Production* 278(Jan): 123333.
Balık Sanlı F, Kurucu Y, Esetlili MT (2009) Determining land use changes by radar-optic fused images and monitoring its environmental impacts in the Edremit region of western Turkey. *Environmental Monitoring and Assessment* 151(1–4): 45–58.
Berberoğlu S, Çilek A, Ünlükaplan Y (2019, Mart) Dirençli kentler için bir çerçeve: Yeşil odaklı uyarlama. (A framework for resilient cities: Green-focused adaptation). *Türkiye Sağlıklı Kentler Birliği*. https://www.skb.gov.tr/wp-content/uploads/2019/07/Izmir-Buyuksehir-Belediyesi-Yesil-Odakli-Uyarlama-Kilavuzu.pdf
Chen Y, Qiao F, Jiang L (2016) Effects of land use pattern change on regional-scale habitat quality based on the InVEST model: A case study in Beijing. *Acta Scientiarum Naturalium Universitatis Pekinensis* 52: 553–562.
Coutts AM, Tapper NJ, Beringer J, Loughnan M, Demuzere M (2013) Watering our cities: The capacity for water-sensitive urban design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography: Earth and Environment* 37(1): 2–28.
Eggermont H, Balian E, Azevedo JMN, Beumer V, Brodin T, Claudet J, et al. (2015). Nature-based solutions: New influence for environmental management and research in Europe. *Gaia* 24(4): 243–248.
Epelde L, Mendizabal M, Gutiérrez L, Artetxe A, Garbisu C, Feliu E (2021) Quantification of the environmental effectiveness of nature-based solutions for increasing the resilience of cities under climate change. *Urban Forestry & Urban Greening* 67(Jan): 127433.
Gerçek İzmir (2018, March19) İzmir'in ve Cumhuriyet tarihinin simge fabrikası viraneye döndü (The iconic factory of Izmir and the history of the Republic has been reduced to rubble). [Fotoğraf]. *Gerçek İzmir*. https://www.gercekizmir.com/haber/Izmir-in-ve-Cumhuriyet-tarihinin-simge-fabrikasi-viraneye-dondu/42242.
Hu X, Cao J, Qian Y, Zhou W, Zheng Z (2024) Extreme heat events in mainland China from 1981 to 2015: Spatial patterns, temporal trends, and impacts of urbanization. *Sustainable Cities and Society* 100: Article 104999.
ICLEI (2017) *IUCN European Regional Office in Brussels*. ICLEI.
ICOMOS (2019) *The future of our pasts: Engaging cultural heritage in climate action*. International Council on Monuments and Sites. https://www.icomos.org/en/what-we-do/focus/climate-action.
IPCC (2022) *Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by H Pörtner, D Roberts, M Tignor, et al. Cambridge University Press.
İzmir Büyükşehir Belediyesi (2017) *İzmir Yeşil Altyapı Stratejisi*. (Izmir Green Infrastructure Strategy). https://izmirdoga.izmir.bel.tr/CKYuklenen/İzmirYeşilAltYapıStratejisi.pdf.
İzmir Büyükşehir Belediyesi (2020) *İzmir Sürdürülebilir Enerji ve İklim Eylem Planı*. (Izmir Sustainable Energy and Climate Action Plan). http://skpo.izmir.bel.tr/content.aspx?MID=112.
Kambur B (2025) *How Cities Adapt to Climate Change? The Example of Izmir, Türkiye.* Master's Thesis. Politecnico di Milano, MSc in Sustainable Architecture and Landscape Design.
Köksal TG, Ahunbay Z (2006) İstanbul'daki endüstri mirası için koruma ve yeniden kullanım önerileri. *TÜ Dergisi* 5(2): 125–136.

Lau TK, Lin TP (2024) Investigating the relationship between air temperature and the intensity of urban development using on-site measurements, satellite imagery, and machine learning. *Sustainable Cities and Society* 100: Article 104982.

Manso M, Teotónio I, Silva CM, Cruz CO (2021) Green roof and green wall benefits and costs: A review of the quantitative evidence. *Renewable and Sustainable Energy Reviews* 135: 110111.

McPhearson T, Frantzeskaki N, Kabisch N, Seto KC (2023) Foreword II. In *Nature-Based Solutions for Cities*, 13. Edward Elgar Publishing.

McPhearson T, Kabisch N, Frantzeskaki N (2023, August 15) *Nature-based solutions for cities*. Elgar Online. https://www.elgaronline.com/edcollbook-oa/book/9781800376762/9781800376762.xml.

MedECC (2020) *Climate and environmental change in the Mediterranean Basin – Current situation and risks for the future*. Edited by W Cramer, J Guiot, K Marini.. Union for the Mediterranean, Plan Bleu, UNEP/MAP.

Natural Capital Project (n.d.) *Carbon storage and sequestration model*. Stanford University. https://naturalcapitalproject.stanford.edu/invest/carbon.

Oke TR (1982) The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society* 108: 1–24.

Ossola A, Lin BB (2021) *Making nature-based solutions climate-ready for a 50°C world*. ResearchGate.

Oukawa GY, Krecl P, Targino AC, Batista LFA (2024) Advantages of modeling the urban heat island intensity: A tool for implementing nature-based solutions. *Sustainable Cities and Society* 102: Article 105204.

Palta MM, Grimm NB, Groffman PM (2017) "Accidental" urban wetlands: Ecosystem functions in unexpected places. *Ecology and the Environment* 15(5): 248–256.

Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas (2017) *UN Environment/MAP*. Athens, Greece.

Salata S, Velibeyoğlu K, Baba A, Saygın N, Couch VT, Uzelli T (2022) Adapting cities to pluvial flooding: The case of İzmir (Turkey). *Sustainability* 14(24): 16418.

Sharp R, Douglass J, Wolny S, Arkema K, Bernhardt J, Bierbower W, et al. (2020) *InVEST User's Guide*. Natural Capital Project: Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund.

Toprak Z (1988) *Sümerbank*. İstanbul: Creative Yayıncılık.

Türker BH, Gül A (2022) Kentsel açık ve yeşil alanlarının niceliksel analizi ve irdelenmesi: Uşak kent merkezi örneği. (Quantitative analysis and examination of urban open and green spaces: Uşak city center example). *Kent Akademisi Dergisi* 15(4): 2088–2109.

Türkmen Ü (2019) Temiz hava solumak tüm vatandaşların temel hakkıdır. (Breathing clean air is the fundamental right of all citizens). *TMMOB Kimya Mühendisleri Odası*. https://www.kmo.org.tr/genel/bizden_detay.php?kod=4557&tipi=3&sube=6.

Uğrasal S (2011) *Tarihi yapıların yeniden işlevlendirilmesi: İzmir Sümerbank Basma Sanayi Yerleşkesi örneği*. (Re-functioning of historical buildings: The example of the Izmir Sümerbank Printing Industrial Campus). Yüksek lisans tezi. Dokuz Eylül Üniversitesi.