

Waterfront 4.0: Landscape and Coastal Regeneration

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INTRODUCTION & AIM

Coastal areas are complex territorial systems where natural processes and anthropogenic pressures interact, generating vulnerable yet culturally significant landscapes. However, while remaining attractive for tourism and urban development, they are among the areas most exposed to the impacts of climate change. This dual condition requires resilient and adaptive planning approaches. A central element of the analysis is the integration of Nature-Based Solutions (NBS) as tools for climate adaptation, environmental mitigation, and landscape regeneration within a "Waterfront 4.0" framework that combines ecological and digital innovation, participatory governance, and smart resource management. The study aims to suggest interventions based on NBS to support the coastal urban regeneration project already implemented in the Portici Maritime Park, Italy.

METHOD

The Portici Maritime Park is one of the key initiatives implemented in the Naples coastal area. The project involved the redevelopment of the seafront and the pier of the Pietrarsa Railway Museum. These interventions exemplify the integration of recreational infrastructure and ecological restoration. However, the implemented project does not explicitly include climate adaptation or ecosystem protection measures (Fig.1). To this end, this study proposes a design framework based on the implementation of integrated NBS interventions, aimed at enhancing ecosystem services, improving environmental performance, and strengthening adaptive capacity (Tab. 1).



Figure 1. Waterfront redevelopment project underway; on the right, a detail of the completed intervention.

Table 1: NBS interventions	
Type	Description of interventions
Ecological nourishment	Shift from static to dynamic nourishment, allowing the beach to self-adapt Use compatible sands, without associated rigid structures
Draining pavements and SuDS along the park's paths	Replace or supplement impermeable pavements with: • permeable surfaces • rain gardens • vegetated bioswales Direct rainwater toward green areas
Multifunctional green strips featuring halophilic and Mediterranean vegetation.	Establish strips of salinity-tolerant vegetation between the beach and recreational areas Use Mediterranean species that are resilient to heat and drought

RESULTS & DISCUSSION

The proposed NBS interventions enhance the environmental and functional performance of the Portici Maritime Park waterfront through an integrated coastal adaptation strategy (Fig.2). Ecological nourishment measures transform the shoreline from a static system into a more dynamic and self-adaptive coastal environment by using compatible sediments and reducing reliance on rigid coastal barriers. Along the pedestrian paths, impermeable pavements are partially replaced with permeable surfaces, rain gardens, and vegetated bioswales, thereby reducing surface runoff and urban flooding risks. In addition, multifunctional green strips composed of halophilic and Mediterranean plant species are introduced between the beach and urban recreational areas to improve ecological connectivity, mitigate the urban heat island effect, and increase shading. Following the proposed interventions, the waterfront assumes the character of a resilient and ecologically integrated public landscape, where green infrastructure is combined with recreational facilities and coastal ecosystems, while maintaining its social and cultural function as a public urban waterfront.



Figure 2. NBS scenario for the redevelopment of the coastal waterfront. The intervention preserves the existing coastline and integrates permeable green surfaces, shade trees, and multifunctional green spaces to improve climate resilience and environmental quality. The project area is outlined in red, while the lower photograph provides a detailed view of the selected coastal stretch.

CONCLUSION

The Waterfront 4.0 framework promotes a shift from conventional coastal redevelopment toward integrated, adaptive, and ecosystem-based regeneration strategies, fostering resilient coastal territories through approaches that combine environmental sensitivity, technological innovation, and inclusive governance.

FUTURE WORK / REFERENCES

Pérez G, et al. A conceptual framework to help choose appropriate blue nature-based solutions. *J Environ Manage.* 2024 Feb 14;352:119936. doi: 10.1016/j.jenvman.2023.119936.
Collier, Marcus J., et al. An integrated process for planning, delivery, and stewardship of urban nature-based solutions: The Connecting Nature Framework. *Nature-Based Solutions* 2023, 3, 100060.