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Beyond Conventional Green Walls: A Modular Nature-Based Solution Framework for Climate-Resilient Cities

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Abstract

Urban areas are increasingly exposed to the impacts of climate change, including rising temperatures, urban heat islands, extreme rainfall events, air pollution, biodiversity loss, and declining environmental quality. Nature-based Solutions (NBS), particularly green walls and green roofs, have been widely recognized as effective strategies for improving urban resilience. However, their large-scale implementation is frequently constrained by structural limitations, installation requirements, permitting procedures, maintenance costs, and the lack of flexibility to adapt interventions to changing urban needs. Consequently, existing green infrastructure often remains restricted to permanent installations with limited applicability in densely built Mediterranean cities. This paper proposes a modular Nature-based Solution framework based on portable green wall systems designed to enhance the adaptability, scalability, and operational flexibility of urban green infrastructure. The proposed concept integrates modular green wall units with renewable energy technologies, rainwater harvesting and recirculation, Internet of Things (IoT)-based environmental monitoring, and intelligent operational management into a self-contained urban greening system. Beyond its engineering characteristics, the framework incorporates plant selection strategies adapted to local microclimatic conditions, biodiversity enhancement, environmental monitoring, and comprehensive sustainability assessment using Life Cycle Assessment (LCA), Social Life Cycle Assessment (S-LCA), and techno-economic analysis. Unlike conventional green walls that primarily function as static architectural elements, the proposed framework emphasizes mobility, modularity, rapid deployment, and real-time environmental assessment under actual urban conditions. This enables the strategic placement, relocation, and scaling of green infrastructure according to seasonal demands, urban redevelopment priorities, emergency climate adaptation needs, or temporary interventions in public spaces. Furthermore, the integration of smart monitoring technologies facilitates continuous evaluation of environmental performance, resource consumption, and ecosystem services, providing quantitative evidence for decision-making and future urban planning. The proposed framework is currently being implemented and validated under Mediterranean climatic conditions through the development of a modular portable green wall platform. By integrating circular water management, renewable energy, digital technologies, and Nature-based Solutions within a unified system, this approach provides a scalable pathway towards more resilient, adaptive, and climate-responsive cities while supporting future urban sustainability and climate adaptation strategies.

Keywords: Nature-based Solutions, Green walls, Climate adaptation, Urban resilience, Modular green infrastructure, Smart cities, Internet of Things, Life Cycle Assessment

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