https://doi.org/10.15302/J-LAF-0-020052 Received Date | 2025-06-06 Accepted Date | 2025-08-22

Sponge Planet:
Nature-based Infrastructure for Climate Adaptation Beyond Concrete

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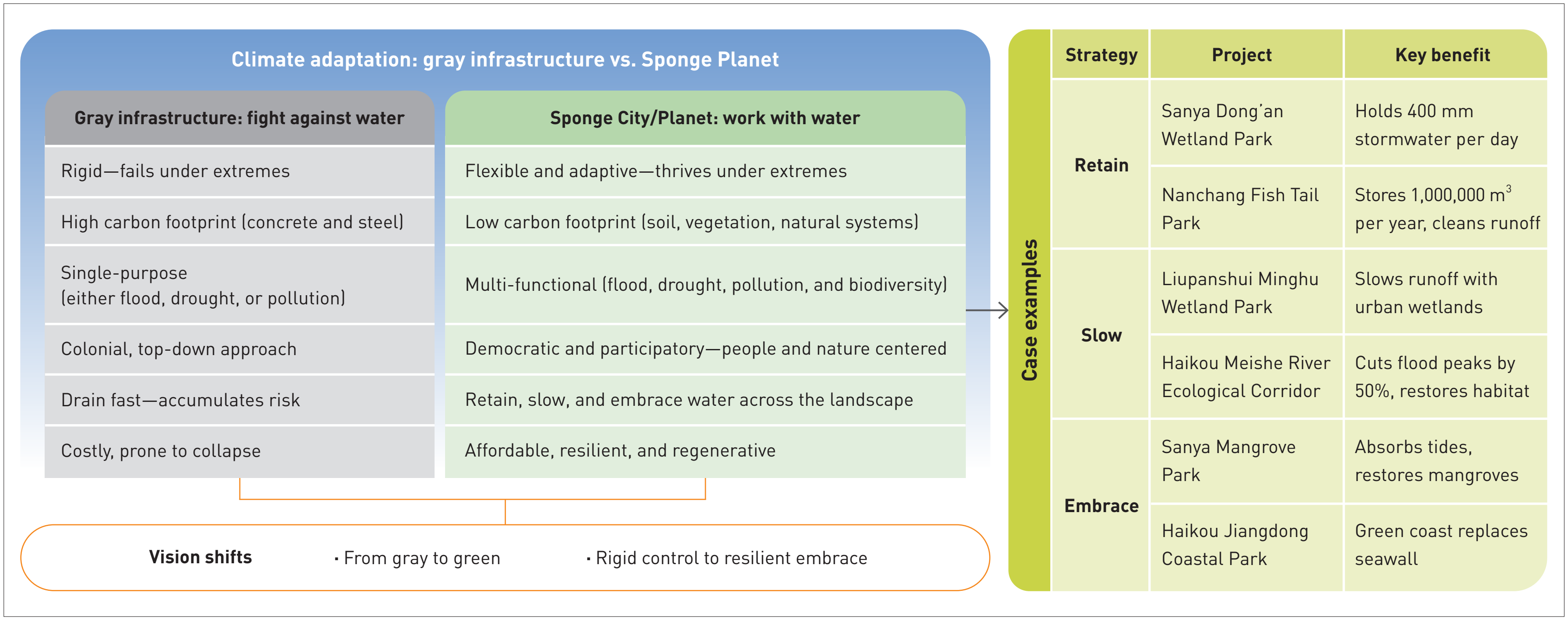
GRAPHICAL ABSTRACT



Climate adaptation: gray infrastructure vs. Sponge Planet

Gray infrastructure: fight against water	Sponge City/Planet: work with water
Rigid—fails under extremes	Flexible and adaptive—thrives under extremes
High carbon footprint (concrete and steel)	Low carbon footprint (soil, vegetation, natural systems)
Single-purpose (either flood, drought, or pollution)	Multi-functional (flood, drought, pollution, and biodiversity)
Colonial, top-down approach	Democratic and participatory—people and nature centered
Drain fast—accumulates risk	Retain, slow, and embrace water across the landscape
Costly, prone to collapse	Affordable, resilient, and regenerative

Vision shifts · From gray to green · Rigid control to resilient embrace

Case examples

Strategy	Project	Key benefit
Retain	Sanya Dong'an Wetland Park	Holds 400 mm stormwater per day
	Nanchang Fish Tail Park	Stores $1,000,000\ m^3$ per year, cleans runoff
Slow	Liupanshui Minghu Wetland Park	Slows runoff with urban wetlands
	Haikou Meishe River Ecological Corridor	Cuts flood peaks by 50%, restores habitat
Embrace	Sanya Mangrove Park	Absorbs tides, restores mangroves
	Haikou Jiangdong Coastal Park	Green coast replaces seawall

ABSTRACT

As the impacts of climate change intensify and ecological degradation accelerates, the inadequacies of carbon-centric and concrete-dependent infrastructure have become increasingly evident. This article introduces the "Sponge Planet" paradigm—a transformative, landscape-based framework for climate adaptation and ecological restoration grounded in hydrological logic and nature-based urbanism. Synthesizing insights from decades of research and implementation across more than 600 projects worldwide, the work critiques the systemic failures of gray infrastructure, highlighting its historical, cultural, and material dissonance with ecological principles. In contrast, the Sponge Planet model is structured around three foundational strategies—retaining, slowing, and embracing water—thereby reimagining urban and rural environments as porous, adaptive systems capable of mitigating floods, droughts, sea-level rise, and urban heat. Through case studies from China, Thailand, and other countries and regions, the article illustrates how modular design, local materiality, and GIS-based precision can be employed to construct deep forms of ecological infrastructure. It ultimately advances a planetary design framework that integrates scientific knowledge, cultural heritage, and landscape architecture to restore Earth's regenerative capacity and promote scalable resilience in the face of climate crises.

KEYWORDS

Sponge Planet; Climate Resilience; Nature-based Solutions; Hydrological Design; Gray Infrastructure; Flood Adaptation; Indigenous Wisdom

HIGHLIGHTS

- Provides a critical reassessment of gray infrastructure's failures in addressing climate risks
- Introduces the Sponge Planet paradigm as a transformative nature-based framework for resilience
- Demonstrates how indigenous wisdom and modern science converge in scalable water-sensitive design
- Presents global case studies showcasing ecological, social, and economic co-benefits of Sponge Planet practices

RESEARCH FUNDS

- Project of "Integration and Demonstration of High-Efficiency Low-Carbon Utilization Technologies for Urban Sewage," National Key Research and Development Program of China (No. 2016YFC0401108, 2016YFC0401105)
- Project of "Landscape Approaches to Building Urban Water Adaptation Capacity in China Under Global Climate Change," National Natural Science Foundation of China (No. 51078004)
- Project of "Hydrological Regulation Mechanisms and Performance Evaluation of Urban Water-Adaptive Landscapes," General Program of the National Natural Science Foundation of China (No. 51678002)
- Project of "Theoretical Methods and Strategic Research for Building Safety and Resilience in Xiong'an New Area," Emergency Management Project of the National Natural Science Foundation of China (No. 71741042)
- Project of "Research on Key Technical Issues of Land Ecological Design," Key Research of the Ministry of Science and Technology of China (No. 2004BA516A18)
- Project "Key Technologies and Protection Strategies for Constructing China's National Land Ecological Security Pattern," Environmental Protection Public Welfare Industry Scientific Research (No. 201209027)

EDITED BY Ying WANG

1 The Planet Is in Crisis

The contemporary global environmental landscape is marked by an unprecedented existential crisis, which is precipitated by the interplay of climate change, rampant unsustainable urbanization, and widespread ecological degradation. Over the past three decades, despite concerted international policy efforts and substantial financial investments aimed at mitigation, global carbon emissions have not only persisted but continued to escalate at an alarming rate. Empirical evidence from recent climate analyses underscores this trajectory: data from Berkeley Earth indicate that 2023 marked the warmest year on record since 1850, with a global mean temperature rise of approximately 1.54 ± 0.06 °C above the 1850–1900 baseline, exacerbating phenomena such as intensified droughts, catastrophic floods, devastating wildfires, and accelerated sea-level rise across diverse geographical contexts[1]. This warming trend has manifested in extreme weather events that disrupt ecosystems, economies, and human societies worldwide.

In coastal regions, the vulnerabilities are particularly acute. Along China's extensive coastline, projections reveal that a significant proportion—estimated at around 45% of major cities—are experiencing moderate to severe subsidence, compounded by rising sea levels, potentially placing up to a quarter of urban coastal land below sea level within the next century[2]. This subsidence, driven largely by groundwater extraction and urban development, threatens not only physical infrastructure but also the livelihoods of millions and the integrity of coastal ecosystems. Such patterns are not isolated; they mirror global trends where deltaic regions, home to dense populations, face compounded risks from both anthropogenic subsidence and climatic forcings.

This spatial distribution of economic and demographic assets in high-risk areas is a recurring theme globally, as evidenced in similar vulnerabilities in low-lying megacities such as Jakarta, Dhaka, and New Orleans. Yet, despite these clear indicators, international investment priorities remain profoundly misaligned with the imperatives of ecological resilience. Annual global financial flows into infrastructure and subsidies that actively harm natural systems—such as fossil fuel subsidies and environmentally damaging agricultural practices—exceed USD 500 billion in biodiversity-harmful subsidies alone, while funding for biodiversity conservation and Nature-based Solutions (NbS) averages approximately USD 124 ~ 143 billion, creating a substantial financing gap that impedes progress toward sustainable development goals[3]. Separately, broader fossil fuel subsidies, including implicit undercharging for environmental costs, reached a staggering USD 7 trillion in 2022, equivalent to 7.1% of global GDP, further entrenching nature-negative pathways[4].

Addressing this crisis demands a paradigm shift toward bold, systemic thinking that transcends incremental reforms. It requires rethinking urban and landscape design not merely as aesthetic or functional exercises but as critical interventions in planetary health. By integrating multidisciplinary insights from ecology, hydrology, and social sciences, we can forge pathways that mitigate emissions, enhance adaptive capacity, and restore ecological balance. This holistic approach is essential to reversing the current trajectory of degradation and fostering a resilient future for both human and non-human inhabitants of the planet.

2 Misplaced Adaptation: The Failure of Gray Infrastructure

2.1 Myopic Investments in Concrete

In the realm of climate adaptation, multilateral financial institutions, including the World Bank and the Asian Infrastructure Investment Bank (AIIB), have historically prioritized strategies that perpetuate environmental vulnerabilities rather than alleviating them. These institutions often endorse and fund so-called "gray" infrastructure solutions—such as elevating dams, erecting flood walls, channelizing rivers, and constructing subterranean deep tunnels—for flood management and urban resilience. Such approaches, rooted in 20th-century engineering paradigms, consume enormous quantities of concrete and steel, accounting for a disproportionate share of global adaptation budgets. Recent analyses indicate that NbS for adaptation accounted for only 5.8% ~ 13.5% of total public international climate finance flows to developing countries in 2018 (approximately USD 3.7 ~ 8.7 billion out of USD 64.3 billion total), implying that gray infrastructure dominates the remaining 86.5% ~ 94.2% of adaptation-related expenditures within this finance stream[5–6]. This imbalance—where gray solutions dominate funding streams—reflects a systemic bias toward short-term, technocratic fixes over long-term ecological integration.

The consequences of this investment myopia are evident in repeated infrastructural failures worldwide. Iconic cases include the catastrophic levee breaches in New Orleans during Hurricane Katrina in 2005, which resulted in over 1,800 fatalities and widespread urban inundation; the devastating Beijing floods of 2012, where intense rainfall overwhelmed drainage systems, claiming 79 lives and causing economic losses exceeding USD 10 billion; the collapse of dams in Derna, Libya, in 2023 amid Storm Daniel, leading to thousands of deaths and the displacement of tens of thousands[7–8]. These incidents are not anomalies attributable solely to natural variability but rather symptomatic of design philosophies that impose rigidity on inherently dynamic ecological systems, ignoring the complexities of hydrological cycles and climate variability.

2.2 Why Gray Infrastructure Fails

Climate change-caused floods are the major risks that gray infrastructure is invested to fight against. Flooding manifests across multiple scales, each demanding nuanced responses that gray solutions often overlook.

1) Local floods: These involve stormwater accumulation across global urban and rural landscapes, where impervious surfaces in cities like New York lead to recurrent street inundations during heavy rains by preventing natural infiltration, while in rural areas, soil compaction from agriculture and land use changes exacerbates rainstorm runoff and flash flooding in regions such as Asia and Africa under intensifying climate conditions.[9–10]

2) Regional floods: Riverine overflows, such as those along the Hudson or Yangtze Rivers, are amplified by upstream deforestation and channel straightening, reducing natural buffering capacities and increasing peak flows by up to 20% ~ 50% in affected basins.[11–12]

3) Global floods: Driven by sea-level rise, these events are increasingly linked to anthropogenic factors such as groundwater depletion, which not only adds water directly to the oceans but also accelerates subsidence and alters flood discharge patterns in vulnerable regions. Terrestrial water storage loss contributes substantially to mass-driven global mean sea-level rise, with groundwater depletion identified as the dominant component in non-glaciated drying regions. In major deltas such as the Mississippi, Yangtze, and Amazon, excessive groundwater withdrawal exacerbates subsidence, compounding coastal flooding through the combined effects of sinking land and rising seas, and amplifying coastal vulnerabilities.[13–15]

The structural limitations of gray infrastructure stem from obsolete design paradigms rooted in 19th-century Western industrial urbanism. Initially developed for temperate climates in cities like London and Paris, these systems—exemplified by Joseph Bazalgette's 1860s London sewer network—were engineered to manage moderate, low-intensity rainfall (20 ~ 50 mm per hour) through rapid drainage and underground conveyance, aiming primarily to control disease and support urban expansion[16–17]. However, this "Victorian-era" model, premised on stability and uniformity, failed to anticipate the hydrological complexity of tropical and monsoonal regions. Rooted in the 19th-century British engineering traditions, it emphasized linear drains and rapid conveyance—designed for temperate climates—rather than adaptive, place-based water management.

Through colonial diffusion and postcolonial imitation, gray infrastructure is imposed across Asia, Africa, and Latin America—contexts where seasonal rainfall can exceed 100 ~ 200 mm per hour, far beyond the original design thresholds. In these settings, rigid drainage systems routinely fail under climatic extremes, triggering urban floods and infrastructure collapse[16]. More critically, this transplantation has marginalized indigenous water management systems long adapted to local hydrological rhythms. Traditional infrastructure—such as India's stepwells and rainwater harvesting tanks, China's dike-pond mulberry systems, or Southeast Asia's subak terraces and khlong canal networks—integrates storage, infiltration, biodiversity, and agriculture into resilient, community-managed systems[18–19].

The legacy of gray infrastructure reflects more than just a technological mismatch—it embodies cultural displacement. In cities such as Mumbai, century-old colonial drainage networks regularly fail during the monsoon, unable to cope with intense rainfall events. Meanwhile, in Jakarta, the Dutch-era canal systems are strained by land subsidence driven by excess groundwater extraction, combined with stronger storms and rising sea levels. In both cities, these imported, rigid models illustrate the vulnerability of traditional infrastructure in ecologically dynamic urban settings. As climate variability intensifies, such failures underscore the urgent need to shift toward adaptive, nature-based approaches grounded in local hydrological realities and knowledge.[17]

Beyond tropical cities, gray infrastructure also exhibits significant shortcomings in temperate urban areas. For instance, urban drainage systems in cities like New York were engineered for relatively low-intensity rainfall events, typically accommodating no more than 45 mm of precipitation per hour based on historical data from the early to mid-20th century①. However, as climate change intensifies, urban storms frequently surpass these thresholds, leading to flash flooding and system overloads. The 2012 Beijing flood exemplifies this mismatch: a single event delivered up to 460 mm of rain in some areas, far exceeding the capacity of undersized pipes and channels[20]. Such events are emblematic of a broader global pattern, where gray infrastructure's rigidity—exacerbated by urbanization-induced impervious surfaces and soil compaction—amplifies erosion, downstream flooding, and pollution, particularly in monsoon regions where precipitation variability has increased by 10% ~ 20% due to global warming[16]. Recent analyses underscore that this model, while effective in its original mild-climate contexts, fails spectacularly in diverse settings, contributing to a 30% ~ 50% rise in flood risks in rapidly urbanizing Global South cities, underscoring the urgent need for hybrid or nature-based alternatives that reintegrate indigenous wisdom[21–22].

Moreover, concrete itself is a climate hazard, producing over 8% of global carbon emissions annually[23–24]. As urbanization accelerates in the Global South—projected to add approximately 2 billion urban residents by 2050—this reliance on carbon-intensive materials will exacerbate both greenhouse gas emissions and hydrological risks, perpetuating a vicious cycle of vulnerability[25].

To break this cycle, adaptation strategies must pivot toward flexible, nature-integrated systems that align with ecological processes rather than opposing them, especially given that NbS receive only a fraction of the funding allocated to gray alternatives, despite their potential to deliver up to 10 $GtCO_2e$ per year in mitigation—equivalent to around 30% of the reductions needed for 1.5°C pathways[26–27].

2.3 The Perils of Scale: Failures in Mega-Gray Infrastructure

Beyond localized urban systems, the shortcomings of gray infrastructure become even more pronounced at larger scales, where mega-projects such as massive dams, extensive levee networks, fortified sea walls, and vast regional aqueducts—often heralded as pinnacles of engineering for climate adaptation—reveal profound vulnerabilities. These colossal interventions, designed to control vast hydrological systems, embody a hubris of dominance over nature, yet they frequently amplify risks rather than mitigate them, exacerbating ecological disruption, social inequities, and economic burdens amid escalating climate extremes[28–29]. Rooted in mid-20th-century modernist ideals, these structures prioritize containment and redirection of water flows on a regional or transboundary scale, but they falter under the compounded pressures of intensified storms, prolonged droughts, seismic activity, and sea-level rise, leading to cascading failures that affect millions[30–31].

Consider the case of large dams, which dominate global water management with over 60,000 structures worldwide exceeding 15 m in height. While intended for flood control,

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① Data source: 2024 Stormwater Analysis Report by New York City Department of Environmental Protection.

hydropower, and irrigation, they often induce upstream sedimentation, downstream erosion, and altered ecosystems, rendering them maladaptive in a changing climate[32]. The 2023 collapse of Libya's Derna dams during Storm Daniel, triggered by extreme Mediterranean rainfall exceeding design capacities by 300%, resulted in over 11,000 deaths and USD 1.8 billion in damages, highlighting how aging mega-dams—built without accounting for amplified precipitation—fail catastrophically[33–36]. These examples illustrate a systemic issue: large dams trap sediments essential for delta replenishment, accelerating subsidence in coastal zones already stressed by sea-level rise, with global studies estimating that dam-induced sediment reduction has contributed to 20% ~ 30% of delta land loss since the 1950s[9,37].

Levee systems and sea walls, engineered for flood defense on expansive scales, suffer analogous fates. The U.S. Army Corps of Engineers' extensive Mississippi River levee network, spanning thousands of kilometers, has channeled flows to prevent overflows but inadvertently heightened flood peaks by constricting natural floodplains, culminating in breaches during the 2019 Midwest floods that inundated 14 million acres (56,656 km^2) and caused USD 12.5 billion in losses[33–34]. In Europe, the Netherlands' Delta Works—a vast array of sea walls, storm barriers, and dikes—while innovative, faces escalating maintenance costs projected at EUR 1.5 billion annually by 2050 due to accelerated sea-level rise, with recent modeling showing potential overtopping risks during compound events like storms and high tides[29–30]. Globally, sea walls in vulnerable megacities like Jakarta and Shanghai, often built to colonial specifications, subside faster than they protect, as groundwater extraction and weight compaction undermine foundations; Jakarta's sea wall project, National Capital Integrated Coastal Development, for instance, has been criticized for displacing communities while failing amid 2024 floods[28,31].

Regional aqueducts, designed for water transfer across vast distances, further exemplify scale-induced fragility. California's State Water Project aqueduct, a 700-mile (1,127-kilometer) network supplying 27 million people, has been plagued by seismic vulnerabilities and drought-induced shortages, with the 2021–2023 dry spell reducing deliveries by 60% and exposing cracks in aging concrete amid extreme heat waves that accelerate material degradation[35–36]. In India, the Interlinking of Rivers project—envisioning massive canals to redistribute monsoon waters—has stalled due to environmental impacts, including ecosystem fragmentation and flood exacerbation in donor basins, as evidenced by the 2023 Bihar floods, where incomplete canal works diverted flows unpredictably[9,37]. These mega-aqueducts not only consume immense energy and resources but also create dependencies that collapse under climate variability, with global assessments indicating that 40% of such systems are at high risk from multi-hazard events by 2050[28,31].

Ultimately, these larger-scale gray infrastructures perpetuate a cycle of maladaptation: their immense upfront costs—often trillions in public funds—yield diminishing returns as climate change outpaces design parameters, while displacing flexible, nature-based alternatives that could provide co-benefits like habitat restoration and carbon sequestration[29–30,32]. Transitioning to hybrid or sponge-like paradigms is imperative to avoid locked-in vulnerabilities on a planetary scale.

3 Beyond Concrete: The Sponge Planet Paradigm

In contrast to the rigid, emission-heavy gray infrastructure, the Sponge Planet paradigm offers a transformative, landscape-based approach centered on water-sensitive urban design. This concept, which has been developed and refined through decades of research and practice, evolves from the Sponge Cities initiative in China and emphasizes the integration of climate adaptation with ecological mitigation[38–40]. At its foundation, the Sponge Planet reimagines urban and rural landscapes as absorbent, adaptive systems that mimic natural hydrological cycles, thereby enhancing resilience against floods, droughts, and sea-level rise while sequestering carbon and bolstering biodiversity.

The paradigm is anchored in three core principles, each supported by hydrological and ecological science.

1) Retain water at the source: This involves capturing precipitation where it falls through decentralized features like permeable surfaces, rain gardens, and retention basins, preventing downstream runoff and promoting groundwater recharge. Studies demonstrate that such techniques, particularly bioretention systems, can reduce urban runoff volume by 85% ~ 90% annually in appropriate soils, with average reductions of up to 89% across measured storm events in systems without underdrains and effective management of runoff from 80% ~ 99% of storms depending on design.[41–43]

2) Slow down the flow: By increasing landscape roughness through terracing, meandering streams, and constructed wetlands, water velocity is moderated to facilitate infiltration, sedimentation, and pollutant filtration. This principle is grounded in geomorphological research demonstrating that natural river

sinuosity and restoration techniques can reduce flood peaks by up to 21% and increase lag times by 33% in small catchments, effectively dissipating flood energy through enhanced friction and channel dynamics.[44–46]

3) Embrace water: Rather than resisting inundation through barriers, designs accommodate periodic flooding and tidal fluctuations, transforming potential hazards into ecological assets. This adaptive stance aligns with contemporary resilience theory, which emphasizes that flexible, nature-based systems enhance urban adaptability and outperform rigid infrastructure in variable environments, as evidenced by studies showing improved flood risk management and biodiversity through integrated green solutions.[47–49]

This Sponge Planet model diametrically opposes conventional practices of rapid drainage and centralized control, which often exacerbate erosion and downstream flooding. Economic analyses suggest that reallocating investments toward hybrid green–gray infrastructure—such as wetlands and buffer zones—could deliver cost savings of up to 50% in capital expenditures for flood protection while yielding co-benefits in biodiversity and public health[50]. Implementing the Sponge Planet model requires interdisciplinary collaboration, incorporating landscape architecture with hydrology, urban planning, and community engagement to create multifunctional spaces that serve both human needs and ecosystem services. Through this lens, water becomes not a threat to be managed but a resource to be harnessed for planetary restoration, particularly as NbS offer cost-effective alternatives to gray infrastructure amid growing adaptation finance gaps[51].

4 Indigenous Wisdom and Monsoon Culture

The Sponge Planet paradigm is far from a novel invention; it is deeply rooted in millennia of indigenous knowledge and cultural practices that harmonize human settlements with natural water regimes. Historical examples abound: China's ancient terraced rice paddies in regions like Yunnan exemplify water retention through contour farming, which mitigates erosion and sustains agriculture in monsoon-prone areas[52]. Similarly, the Mayan chinampas—floating gardens in Mexico—demonstrated sophisticated wetland agriculture that retained water, filtered nutrients, and supported biodiversity in floodplains. In Europe, Venice's lagoon-based urbanism illustrates adaptation to tidal dynamics, using canals and marshes as infrastructure that accommodates rather than combats water flows[53].

These vernacular systems employed natural elements—slope gradients, soil profiles, and vegetation assemblages—as self-sustaining infrastructure, inherently adaptive to seasonal variations and climatic shifts. They embody a "monsoon culture" philosophy, where water is revered as a life-giving force rather than an adversary to be conquered, fostering resilience through coexistence. Modern scholarship on indigenous ecological knowledge reinforces this, highlighting how traditional practices often outperform contemporary engineering in sustainability metrics, such as energy efficiency and biodiversity support[54].

The contemporary challenge lies in modernizing these techniques: modularizing them for scalability, engineering them with advanced materials and modeling tools like GIS for precision, and integrating them into urban frameworks. This synthesis bridges ancient wisdom with cutting-edge science. By revitalizing these traditions, landscape architecture can evolve into a discipline that not only designs spaces but also stewards cultural and ecological heritage, ensuring that future developments honor the adaptive ingenuity of our ancestors while addressing 21st-century threats.

Drawing from peasantry wisdom, such as simple cut-and-fill methods to transform landscapes, modern applications revive these approaches for urban resilience. For instance, in Benjakitti Forest Park in Bangkok, Thailand, a modular landscape was created by preserving existing trees and using on-site soil for islanding and ponding, forming a resilient wetland system that retains stormwater and fosters biodiversity with minimal maintenance[38,55]. This low-cost technique, inspired by ancient farming, employs recycled materials and native seedlings to achieve scalability, turning a derelict tobacco factory into a flood-mitigating urban oasis during monsoons. The modular design, with standardized island diameters based on tree canopies, minimizes labor and uses one excavator for earthworks, integrating GIS for terrain modeling to optimize water flow and habitat diversity.

Similarly, reviving ancient pond-and-dike systems from China's Pearl River Delta integrates with GIS modeling for precision in projects like the Meishe River corridor in Haikou, where terraced wetlands filter pollutants and buffer floods, engineered with bio-swales and advanced hydrological simulations[56]. These upgrades modularize traditional forms—standardizing island diameters and wetland depths—for rapid deployment across cities, combining low-energy biological processes with modern tools to handle extreme weather. In Sanya Mangrove Park, ancient islanding techniques are engineered with interlocking finger designs and bio-swales, using GIS for tidal flow prediction, enhancing scalability while restoring mangroves for coastal protection[57].

Further, in Zhengzhou Yellow River Floodplain Park, indigenous terracing and ponding are modernized through a "three-tier" floodplain management model, using cut-and-fill for wetland restoration in lower floodplains and modular eco-farming in higher zones, supported by GIS for sediment flow simulation and ecosystem service optimization[58]. This approach scales ancient wisdom by engineering advanced materials like permeable geotextiles and real-time monitoring tools, boosting flood resilience and biodiversity in monsoon contexts. Extending to watershed scales, the Sponge Watershed Approach in Sihui River Basin upgrades traditional retention methods with GIS-based modeling for source-flow-sink strategies, enhancing flood resilience across urban–rural gradients[59].

Green infrastructure revives ancient peasant wisdom—cut-and-fill for landforming, framing for protection, irrigating with gravity, and harvesting ecosystem services—integrating with modern sciences for deep forms in urban nature[57]. In ecological restoration, modular approaches like low-maintenance wetlands in constructed landscapes demonstrate scalability, as in Sanya's Dong'an Wetland Park, where terracing and ponding improve water exchange and biodiversity[60].

These examples demonstrate how upgrading indigenous knowledge—through modularization for scalability and engineering with GIS and sustainable materials—creates deep forms in urban nature, blending peasant adaptability with modern techniques to address climate challenges effectively.

5 Demonstrating the Sponge Planet: Case Studies

Over the past two decades, more than 600 landscape projects have been implemented in over 200 cities, providing empirical validation for the Sponge Planet principles[39]. These initiatives, spanning diverse climatic and urban contexts, demonstrate how landscape architecture can operationalize water-centric resilience, yielding measurable outcomes in flood mitigation, ecological restoration, and socio-economic benefits. Below, expanded case studies illustrate each principle, incorporating detailed design elements, performance data, and broader implications.

5.1 Retain Water at the Source

5.1.1 Sanya Dong'an Wetland Park (Hainan, China)

Located in a flood-prone basin within tropical Hainan, the 67-hectare park was rapidly developed in one year on a site previously ravaged by seasonal urban flooding (Fig. 1). Employing sponge techniques such as terracing, islanding, and ponding, the design utilized on-site soil through cut-and-fill methods to create topographic variations and ecological zones. This enables the park to retain over 400 mm of stormwater in a single day—exceeding New York's storm sewer design capacity by more than threefold. The restored wetlands function as habitats for native species, flood infrastructure, and public cultural landscapes, while improving water quality through natural filtration. Economically, adjacent land values surged by over 400%, illustrating how water-retention systems catalyze regeneration. This project underscores the efficacy of decentralized retention in tropical monsoonal climates, reducing urban heat islands and enhancing biodiversity[38].

5.1.2 Benjakitti Forest Park (Bangkok, Thailand)

Transformed from a derelict 42.3-hectare tobacco factory during the COVID-19 pandemic, the park exemplifies low-impact brownfield redevelopment using army labor and minimal machinery (Fig. 2). The islanding strategy created a mosaic of constructed isles


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Fig. 1 Example of retaining water at the source: Sanya Dong'an Wetland Park.

Fig. 2 Example of retaining water at the source: Benjakitti Forest Park.

within retention ponds, capturing and cleansing stormwater while fostering wildlife habitats. Over 110 bird species have returned, highlighting biodiversity gains, with vegetated berms and wetlands serving as natural filters and flow moderators. Elevated boardwalks provide immersive public access, promoting social equity in dense urban settings. Hydrologically, the park retains up to 300 mm of rainfall, mitigating flash floods common in Bangkok's monsoon season. This case demonstrates the convergence of ecological restoration, climate resilience, and community well-being, with carbon sequestration estimates at 500 t annually through reforestation[55].

5.1.3 Nanchang Fish Tail Park (Jiangxi, China)

Spanning 51 hm^2 on a degraded former coal ash dump and fishery along the Ganhe River in the Yangtze River floodplain, Fish Tail Park reimagined a toxic brownfield as a multifunctional sponge infrastructure (Fig. 3). The design features fish-tail-shaped landforms that enhance hydrological contact zones, with terraced wetlands, micro-islands, and retention ponds filtering urban runoff and storing stormwater up to 1,000,000 m^3 annually[61]. Elevated boardwalks and a "floating forest" of native vegetation allow water levels to fluctuate seasonally, purifying polluted drainage from Class V (poor quality) to Class III (suitable for human exposure) before it reaches the adjacent Aixi Lake and Ganhe River. The park captures and treats urban stormwater, reducing nutrient loads by 60% and preventing downstream eutrophication. Once inaccessible and hazardous, it now supports over 200 species of plants and wildlife, including migratory birds, while serving as a public nature park that manages floods, remediates contaminated soils through phytoremediation, and revives ecological corridors. This brownfield regeneration project highlights the power of water-based urban remediation in industrial legacies, aligning with circular economy principles by repurposing on-site materials and achieving low-maintenance operations through natural processes[62].

5.2 Slow Down the Flow

5.2.1 Liupanshui Minghu Wetland Park (Guizhou, China)

In mountainous southwest China, this 90-hectare site, formerly channelized and ecologically barren, was restored through cascading wetland terraces, vegetated swales, and riparian buffers (Fig. 4). Rainwater is slowed throughout the landscape, facilitating infiltration and nutrient uptake, with peak flow reductions of 70% during storms. The "green sponge" integrates water detention with urban park functions, as well as outstanding hydrological and aesthetic performance. Biodiversity has thrived with native plantings supporting pollinators and aquatic life. This case proves that in topographically complex terrains, flow moderation enhances civic beauty and resilience, with long-term maintenance costs 30% lower than equivalent gray alternatives[63–64].

5.2.2 Meishe River Ecological Corridor (Hainan, China)

Once a hardened urban canal, the 23-kilometer long Meishe River was rewilded into an ecological corridor by removing concrete edges and restoring meanders, floodplains, and side wetlands in 2017 (Fig. 5). Native vegetation filters runoff,

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Fig. 3 Example of retaining water at the source: Nanchang Fish Tail Park.

Fig. 4 Example of slowing down the flow: Liupanshui Minghu Wetland Park.

Fig. 5 Example of slowing down the flow: Meishe River Ecological Corridor.

supporting aquatic biodiversity and reducing flood peaks by 50%. As a climate-resilient urban spine, it links neighborhoods with nature, absorbing and cleansing stormwater while providing recreational greenways. Water quality improvements include a 40% drop in suspended solids. This transformation illustrates scalable river restoration in tropical cities, fostering urban connectivity and adaptive capacity against increasing precipitation intensities[56].

5.2.3 Tianhe Smart City Daguan Wetland (Guangzhou, China)

The project applied Sponge City principles to transform a degraded site into a multifunctional urban ecological corridor (Fig. 6). The design used terraced topography and a multi-pond wetland system to retain, purify, and slowly release stormwater. This reduces flood risks, improves water quality, and replenishes groundwater. Native, low-maintenance plants adapted to alternating drought and flood conditions enhance ecological resilience and biodiversity. Covering 46.8 hm^2, the project mitigates urban inundation and pollution while providing recreational, educational, and cultural values for residents. It demonstrates a replicable, low-impact development model that integrates flood control with public space, offering a micro-scale approach to sponge urbanism and climate adaptation.

5.3 Embrace Water

5.3.1 Shangrao Xinjiang Ecological Corridor (Jiangxi, China)

This 2.4-kilometer long corridor along the Xinjiang River's monsoon floodplain was redesigned from a rigid bypass into a flood-adapted landscape with terracing, wetland mosaics, and elevated walkways. During heavy rains, floodwaters spread across ponds and channels; after the flood recedes, it reverts to a public park. Infrastructure remains accessible year-round, accommodating rather than resisting water, exemplifying living with water, and enhancing community resilience and cultural engagement in flood-prone regions (Fig. 7).

5.3.2 Sanya Mangrove Park (Hainan, China)

Restoring a 10-hectare degraded estuary, this project applied Tai Chi principles—softness over hardness—through tidal creeks, oyster reefs, and native mangroves that buffer wave energy and adapt to sea-level rise (Fig. 8). Floating paths protect sensitive areas while allowing public experience, with diverse bird species and fishes returning. Storm surge attenuation is obvious, nurturing marine biodiversity. As a prototype, it integrates coastal protection with education, demonstrating nature-based defenses' superiority in dynamic shorelines[38,65].

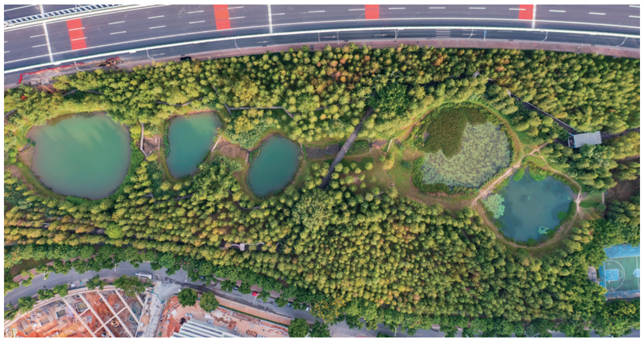

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Fig. 6 Example of slowing down the flow: Tianhe Smart City Daguan Wetland.

Fig. 7 Example of embracing water: Shangrao Xinjiang Ecological Corridor during the monsoon flood and after the flood.

Fig. 8 Example of embracing water (sea surge): Sanya Mangrove Park.

5.3.3 Haikou Jiangdong Coastal Park (Hainan, China)

Covering 370 hm^2 along a 3.72 km beach, Haikou Jiangdong Coastal Park in Hainan offers a transformative solution, replacing a concrete wall and desolate fish farm with verdant, resilient sponge infrastructure embracing water (Fig. 9). Serving as a buffer against tropical storms, meeting public recreational needs, and enhancing urban development and community value, it exemplifies nature-based climate adaptation, blending ecological restoration with urban resilience and redefining traditional engineering. As seas rise, the landscape adapts morphologically, protecting infrastructure while restoring ecosystems. Wave energy reduction is proven to be significant and survives the historical tropical storm Yagi, proving the synthesis of resilience and amenity in vulnerable coasts[66].

6 Conclusions: A Nature-Based Infrastructure for a Climate-Resilient Future Beyond Carbon and Concrete

To address the climate crisis, we must move beyond the illusion that carbon-heavy, concrete-dominated infrastructure can ensure long-term resilience. Gray solutions—engineered to resist nature—have fragmented ecosystems, intensified emissions, and often failed under extreme conditions. Yet global adaptation finance still overwhelmingly prioritizes these outdated approaches, leaving nature-based strategies sidelined despite their proven efficacy[6].

The Sponge Planet paradigm offers a transformative alternative. By restoring the Earth's hydrological capacity—its ability to absorb, store, and release water in rhythm with ecological processes—we shift from domination to coexistence. This landscape-based framework is rooted in three principles: retaining water at the source, slowing down the flow, and embracing water. These strategies, grounded in ecological science and cultural heritage, redefine infrastructure as living systems rather than static defenses.

When informed by hydrological intelligence and indigenous wisdom, landscape architecture becomes the "art of survival." It enables the creation of adaptive, regenerative systems that buffer climate extremes, restore degraded environments, and foster human-nature harmony. Water is not merely a hazard to manage—but a force to design with[40]. This is not only a design method, but a planetary ethic. Let us move from draining to retaining, from resistance to adaptation, from fragmentation to integration. Let us heal the Earth—by designing with its flow.


9 © Turenscape

Fig. 9 Example of embracing water (sea surge): Haikou Jiangdong Coastal Park.

Competing interests | The author declares that he has no competing interests.

REFERENCES

[1] Berkeley Earth. (2024). *Global temperature report for 2023*.

[2] Nicholls, R., & Shirzaei, M. (2024). Earth's sinking surface: China's major cities show considerable subsidence from human activities. *Science*, *384*(6693), 268–269.

[3] Deutz, A., Heal, G. M., Niu, R., Swansonc, E., Townshend, T., Li, Z., … & Tobin-de la Puente, J. (2020). *Financing nature: Closing the global biodiversity financing gap*. The Paulson Institute, The Nature Conservancy, and Cornell Atkinson Center for Sustainability.

[4] International Monetary Fund. (2023). *IMF fossil fuel subsidies data: 2023 update*.

[5] Climate Policy Initiative. (2019). *Global landscape of climate finance 2019*.

[6] Swann, S., Blandford, L., Cheng, S., Cook, J., Miller, A., & Barr, R. (2021). *Public international funding of nature-based solutions for adaptatio*n. World Resources Institute.

[7] The Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Cambridge University Press.

[8] United Nations Office for Disaster Risk Reduction (UNDRR). (2023). *2023 Global assessment report on disaster risk reduction*.

[9] Tellman, B., Sullivan, J. A., Kuhn, C., Kettner, A. J., Doyle, C. S., Brakenridge, G. R., … & Slayback, D. A. (2021). Satellite imaging reveals increased proportion of population exposed to floods. *Nature*, *596*, 80–86.

[10] Li, J., Zhou, W., & Tao, C. (2024). The impact of urbanization on surface runoff and flood prevention strategies: A case study of a traditional village. *Land*, *13*(9), 1528.

[11] Dadson, S. J., Hall, J. W., Murgatroyd, A., Acreman, M., Bates, P., Beven, K., … & Wilby, R. (2017). A restatement of the natural science evidence concerning catchment-based 'natural' flood management in the UK. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *473*(2199), 20160706.

[12] Lane, R. A., & Kay, A. L. (2021). Climate change impact on the magnitude and timing of hydrological extremes across Great Britain. *Frontiers in Water*, *3*, 684982.

[13] Chandanpurkar, H. A., Famiglietti, J. S., Gopalan, K., Wiese, D. N., Wada, Y., Kakinuma, K., … & Zhang, F. (2025). Unprecedented continental drying, shrinking freshwater availability, and increasing land contributions to sea level rise. *Science Advances*, *11*(30), eadx0298.

[14] Jasechko, S. Seybold, H., Perrone, D., Fan, Y., Shamsudduha, M., Taylor, R. G., … & Kirchner, J. W. (2024). Rapid groundwater decline and some cases of recovery in aquifers globally. *Nature*, *625*, 715–721.

[15] Seo, K.-W., Ryu, D., Eom, J., Jeon, T., Kim, J.-S., Youm, K., … & Wilson, C. R. (2023). Drift of earth's pole confirms groundwater depletion as a significant contributor to global sea level rise 1993–2010. *Geophysical Research Letters*, *50*(12), e2023GL103509.

[16] Gupta, K. (2020). Challenges in developing urban flood resilience in India. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *378*(2168), 20190211.

[17] Ohenhen, L. (2025, May 14). *Why are the world's cities sinking?*. Financial Times.

[18] Shah, T., Roy, A. D., Qureshi, A. S., & Wang, J. (2003). Sustaining Asia's groundwater boom: An overview of issues and evidence. *Natural Resources Forum*, *27*(2), 130–141.

[19] Varghese, A., & Shekhar, S. (2023). Integrated Urban Water Management in Chandigarh Smart City. *Fifth World Congress on Disaster Management: Volume V*. Routledge.

[20] Zhang, D., Lin, Y., Zhao, P., Yu, X., Wang, S., Kang, H., & Ding, Y. (2013). The Beijing extreme rainfall of 21 July 2012: "Right results" but for wrong reasons. *Geophysical Research Letters*, *40*(7), 1426–1431.

[21] Saco, P. M., McDonough, K. R., Rodriguez, J. F., Rivera-Zayas, J., & Sandi, S. G. (2021). The role of soils in the regulation of hazards and extreme events. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *376*(1834), 20200178.

[22] Mishra, A., Bruno, E., & Zilberman, D. (2021). Compound natural and human disasters: Managing drought and COVID-19 in California, South Africa, and Brazil. *Science of the Total Environment*, *754*, 142210.

[23] International Energy Agency (IEA). (2024). *Cement*.

[24] Global Cement and Concrete Association (GCCA). (2024). *Cement industry net zero progress report 2024/25*.

[25] UN-Habitat. (2022). *World cities report 2022: Envisaging the future of cities*. United Nations Human Settlements Programme.

[26] United Nations Environment Programme (UNEP). (2023). *State of finance for nature 2023*.

[27] Buma, B., Gordon, D. R., Kleisner, K. M., Bartuska, A., Bidlack, A., DeFries, R., … & Hamburg, S. P. (2024). Expert review of the science underlying nature-based climate solutions. *Nature Climate Change*, *14*, 402–406.

[28] Chang, S. E., McDaniels, T. L., Mikawoz, J., & Peterson, K. (2007). Infrastructure failure interdependencies in extreme events: Power outage consequences in the 1998 Ice Storm. *Natural Hazards*, *41*, 337–358.

[29] Jongman, B. (2018). Effective adaptation to rising flood risk. *Nature Communications*, *9*(1), 1986.

[30] Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., … & Kanae, S. (2013). Global flood risk under climate change. *Nature Climate Change*, *3*(9), 816–821.

[31] Kreibich, H., Van Loon, A. F., Schröter, K., Ward, P. J., Mazzoleni, M., Sairam, N., … & Di Baldassarre, G. (2022). The challenge of unprecedented floods and droughts in risk management. *Nature*, *608*(7921), 80–86.

[32] Bates, B. C., Kundzewicz, Z. W., Wu, S., & Palutikof, J. (Eds.) (2008). *Climate change and water*. Intergovernmental Panel on Climate Change.

[33] Willner, S. N., Otto, C., & Levermann, A. (2018). Global economic response to river floods. *Nature Climate Change*, *8*(7), 594–598.

[34] Dottori, F., Szewczyk, W., Ciscar, J.-C., Zhao, F., Alfieri, L., Hirabayashi, Y., … & Feyen, L. (2018). Increased human and economic losses from river flooding with anthropogenic warming. *Nature Climate Change*, *8*(9), 781–786.

[35] Alfieri, L., Dottori, F., Betts, R., Salamon, P., & Feyen, L. (2018). Multi-model projections of river flood risk in Europe under global warming.

Climate, *6*(1), 6.

[36] Aerts, J. C. J. H. (2020). Integrating agent-based approaches with flood risk models: A review and perspective. *Water Security*, *11*, 100076.

[37] Rentschler, J., & Salhab, M. (2020). *People in harm's way: Flood exposure and poverty in 189 countries*. World Bank Group.

[38] Yu, K. (2021). The Sponge City: Planning, Design and Political Design. In: S. Pelsmakers & N. Newman (Eds.), *Architecture and the Climate Emergency: Everything Needs to Change* (pp. 47–55). RIBA Publishing.

[39] Yu, K., Li, D., Yuan, H., Fu, W., Qiao, Q., & Wang, S. (2015). Sponge city: Theory and practice. *City Planning Review*, *39*(6), 26–36.

[40] Yu, K., Gies, E., & Wood, W. W. (2025). To solve climate change, we need to restore our sponge planet. *Nature Water*, *3*, 4–6.

[41] Merriman, L. S., & Hunt, W. F. (2014). Maintenance versus maturation: Constructed storm-water wetland's fifth-year water quality and hydrologic assessment. *Journal of Environmental Engineering*, *140*(10), 04014030.

[42] Spraakman, S., Martel, J.-L., & Drake, J. (2022). How much water can bioretention retain, and where does it go?. *Blue-Green Systems*, *4*(2), 89–107.

[43] Nazarpour, S., Gnecco, I., & Palla, A. (2023). Evaluating the effectiveness of bioretention cells for urban stormwater management: A systematic review. *Water*, *15*(5), 913.

[44] Environment Agency. (2025). *River and floodplain management*. UK Government.

[45] Wohl, E., Fryirs, K., Grabowski, R. C., Morrison, R. R., & Sear, D. (2024). Enhancing the natural absorbing capacity of rivers to restore their flood resilience. *BioScience*, *74*(11), 782–796.

[46] Naghavi, M., Mohammadi, M., & Mahtabi, G. (2024). Flow simulation in curved compound channels: Effect of changing sinuosity of the main channel and width of floodplain. *Physics of Fluids*, *36(*12), 125143.

[47] Kronenberg, J., Andersson, E., Barton, D. N., Borgstrom, S. T., Langemeyer, J., Bjorklund, T., … & Wolff, M. (2021). The thorny path toward greening: unintended consequences, trade-offs, and constraints in green and blue infrastructure planning, implementation, and management. *Ecology and Society*, *26*(2), 36.

[48] McPhearson, T., Kabisch, N., & Frantzeskaki, N. (2023). Towards Mainstreaming Nature-Based Solutions for Achieving Biodiverse, Resilient, and Inclusive Cities. *Nature-Based Solutions for Cities* (pp. 364–385). Edward Elgar Publishing.

[49] Raška, P., Bezak, N., Ferreira, C. S. S., Kalantari, Z., Banasik, K., Bertola, M., … & Hartmann, T. (2022). Identifying barriers for nature-based solutions in flood risk management: An interdisciplinary overview using expert community approach. *Journal of Environmental Management*, *310*, 114725.

[50] Browder, G., Ozment, S., Rehberger Bescos, I., Gartner, T., & Lange, G.-M. (2019). *Integrating green and gray: Creating next generation infrastructure*. World Resources Institute and The World Bank.

[51] United Nations Environment Programme. (2023). *Adaptation gap report 2023: Underfinanced. Underprepared. Inadequate investment and planning on climate adaptation leaves world exposed*.

[52] Hua, H., Wang, Y., Ding, Z., Liu, H., Zhou, S., & Liu, Y. (2022). Relationship, discourse and construction: The power process and environmental impact of the Honghe Hani Rice Terraces as a World Heritage Site. *International Journal of Environmental Research and Public Health*, *19*(24), 17100.

[53] Finotello, A., Tognin, D., Carniello, L., Ghinassi, M., Bertuzzo, E., & D'Alpaos, A. (2023). Hydrodynamic feedbacks of salt-marsh loss in the shallow microtidal back-barrier lagoon of Venice (Italy). *Water Resources Research*, *59*(3), e2022WR032881.

[54] Kobluk, H. M., Gladstone, K., Reid, M., Brown, K., Krumhansl, K. A., & Salomon, A. K. (2021). Indigenous knowledge of key ecological processes confers resilience to a small-scale kelp fishery. *People and Nature*, *3*(3), 723–739.

[55] Yu, K., & Wang, D. (2023). Modular approach creating low-maintenance sponge city: Benjakitti Forest Park in Bangkok, Thailand. *Landscape Architecture Frontiers*, *11*(1), 72–85.

[56] Yu, K. (2020). Turning grey into green—Meishe River Greenway. *Urban Solutions*, *6*(17), 68–73.

[57] Yu, K. (2017). Green infrastructure through the revival of ancient wisdom. *Bulletin of the American Academy of Arts & Sciences*, *70*(4), 35–39.

[58] Yu, K., & Gong, Y. (2021). Exploration on ecological restoration model for the improvement of ecosystem services of Yellow River floodplains—A case study of Zhengzhou Yellow River floodplain park planning and design. *Landscape Architecture Frontiers*, *9*(3), 86–97.

[59] Peng, X., Heng, X., Li, Q., Li, J., & Yu, K. (2022). From sponge cities to sponge watersheds: Enhancing flood resilience in the Sihui River Basin in Zhengzhou, China. *Water*, *14*(19), 3084.

[60] Bai, Z., Yu, W., Zhang, Y., Dong, T., & Lin, G. (2018). From an ignored grey place to a resilient urban wetland—Dong'an Wetland Park in Sanya, Hainan Province. *Landscape Architecture Frontiers*, *6*(3), 90–103.

[61] Landscape Performance Series. (2024). *Fish Tail Park*. Landscape Architecture Foundation.

[62] Langenheim, N., & Yu, K. (2023). The Mega-Eco-38 Garden City: Stories of rewilding and ecodystopia. *Architectural Design*, *93*(1), 38–45.

[63] Yu, K. (2014). Slow down: Minghu Wetland Park in Liupanshui, Guizhou. *Landscape Architecture Frontiers*, *2*(2), 130–137.

[64] Landscape Performance Series. (2015). *Liupanshui Minghu Wetland Park*. Landscape Architecture Foundation.

[65] American Society of Landscape Architects (ASLA). (2020). *Deep form of designed nature: Sanya Mangrove Park*.

[66] Yu, K. (2024). A breathing sea wall: Haikou Jiangdong Beach Park. *Landscape Architecture Frontiers*, *12*(1), 80–95.

[67] American Society of Landscape Architects (ASLA). (2024). *Benjakitti Forest Park: Transforming a brown field into an urban nature*.

[68] Benny, N. M. (2023). *Navigating climate-induced migration in Kerala: Challenges, responses, and adaptation strategies*. Social Policy Research Foundation.

[69] Wada, Y., van Beek, L. P. H., van Kempen, C. M., Reckman, J. W. T. M., Vasak, S., & Bierkens, M. F. P. (2010). Global depletion of groundwater resources. *Geophysical Research Letters*, *37*(20), L20402.

https://doi.org/10.15302/J-LAF-0-020052 收稿日期 | 2025-06-06 录用日期 | 2025-08-22 中图分类号 | TU985, TU986 文献标识码 | A

海绵地球：基于自然的气候适应基础设施

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摘要

随着气候变化影响的加剧及相关灾害的频繁发生，以减少碳排放为核心的气候减缓策略和依赖钢筋水泥等灰色基础设施的适应策略弊端日益显现。本文介绍了“海绵地球”的气候韧性范式——一种以景观为基础、遵循水文逻辑并基于自然的气候适应与生态修复框架。文章综合了数十年的研究成果与全球600余个实践案例，系统反思了灰色基础设施的局限性，指出其在历史、文化与物质层面与生态原则的背离。相较之下，“海绵地球”模式围绕三大核心策略展开——源头留住雨水、过程减缓水流、末端与水为友——从而将城乡环境重新构想为基于水的适应性生态系统，具备缓解洪水、干旱灾害及应对海平面上升和城市热岛效应等问题的能力，并能够促进生境的自我修复。通过来自中国、泰国及其他国家和地区的案例，文章展示了如何运用模块化设计、本土材料与基于GIS的精细化技术建构深层次的生态基础设施。最后，本文提出一个面向地球的设计框架，将科学知识、文化遗产与景观设计相结合，以恢复地球的再生能力，并在气候危机背景下提升地球和城乡环境的长期韧性。

关键词

海绵地球；气候韧性；基于自然的解决方案；水文设计；灰色基础设施；防洪适应；本土智慧

文章亮点

- 分析了灰色基础设施在气候风险应对中的局限性
- 介绍了“海绵地球”范式，开辟基于自然的韧性建设路径
- 展示了本土智慧与现代科学在可规模化水敏感设计中的融合
- 通过全球案例阐释“海绵地球”实践在生态、社会与经济层面的综合效益

基金项目

- 国家重点研发计划“城镇污水高效低碳资源化利用技术集成与示范项目”（编号：2016YFC0401108，2016YFC0401105）
- 国家自然科学基金项目“全球气候变化背景下中国城市水适应能力建设的景观途径”（编号：51078004）
- 国家自然科学基金面上项目“城市水适应性景观的水文调控机制及其效绩评估”（编号：51678002）
- 国家自然科学基金应急管理项目“安全韧性雄安新区构建的理论方法与策略研究”（编号：71741042）
- 国家科学技术部攻关课题“土地生态设计关键技术问题研究”（编号：2004BA516A18）
- 环境保护公益性行业科研专项“我国国土生态安全格局构建关键技术与保护战略研究”（编号：201209027）

编辑 王颖