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DESIGNING RESILIENT URBAN GREENSPACES: COMBINING ECOSYSTEM REPAIR AND MULTIFUNCTIONAL LANDSCAPING IN MUNICIPAL PARK PROJECTS

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Abstract: Take the ecological greening project of a certain lake as an example, this research explores the integrated application of ecological restoration and landscape design strategies in municipal park construction. By employing soil remediation, water purification, biodiversity enhancement, and low-impact development (LID) techniques, the project established an urban green space system that balances ecological functionality and aesthetic value. Results demonstrate that the synergy between native plant cultivation and ecological engineering technologies not only achieves a sustainable landscape with "year-round greenery and seasonal blooms" but also significantly improves ecosystem services, offering a replicable model for similar projects.
Keywords: Ecological restoration; Landscape creation; Municipal park; Biodiversity; Low-impact development

1 INTRODUCTION

Against the backdrop of rapid urbanization, municipal parks serve as critical components of urban ecosystems, integrating ecological regulation, recreational services, and cultural display functions[1]. However, conventional landscape engineering often neglects ecological restoration, leading to fragmented green spaces and degraded habitats[2]. Using the Lake Project as a case study, this research proposes an innovative "ecology-first, landscape-integrated" technical approach, offering new insights for balancing ecological security and aesthetic value in urban park construction.

The Lake Ecological Greening Project was implemented under the EPC (Engineering Procurement Construction) model, covering a total designed area of 30,261 square meters, including 3,535 square meters of aquatic greening and 26,726 square meters of terrestrial greening. Focusing on plant community reconstruction within the red-line area, the project adopted a three-dimensional planting system of "arbor-shrub-ground cover". The vegetation configuration consisted of 30% evergreen species (e.g., Magnolia grandiflora, Cinnamomum camphora) and 70% deciduous species (e.g., Sapindus mukorossi, Liquidambar formosana), interspersed with flowering plants like Lagerstroemia indica and Osmanthus fragrans to create a landscape with distinct seasonal variations. The project established three ecological restoration objectives: soil health recovery (pH 6.5-7.2), water transparency improvement (≥0.8m), and native species proportion control (≥85%).

2 ECOLOGICAL RESTORATION TECHNOLOGIES FOR SUSTAINABLE URBAN PARKS

2.1 Fundamental Principles and Core Objectives of Ecological Restoration

Ecological restoration is guided by the core philosophy of "following and mimicking nature", employing scientifically measured human interventions to assist damaged ecosystems in regaining their self-regulating and self-healing capacities[3]. This approach originates from ecological succession theory, emphasizing the reconstruction of dynamic equilibrium between biotic and abiotic components to facilitate progressive ecosystem recovery from simplicity to complexity and from lower to higher levels. The implementation strictly adheres to the "minimum intervention" principle, primarily relying on natural processes such as soil stabilization by plant roots and microbial decomposition to maintain material cycles, while judiciously applying engineering techniques like soil activation and water aeration at critical stages to enhance restoration efficiency. The restoration objectives encompass three dimensions: at the foundational level, the focus is on rehabilitating the material cycle within the soil-water-plant system by improving soil properties (organic matter content ≥3%, porosity ≥40%) and restoring aquatic health (dissolved oxygen ≥5mg/L, ammonia nitrogen ≤0.5mg/L) to establish optimal growing conditions; at the functional level, priority is given to rebuilding biodiversity networks through creating diverse habitats including wetlands, shrublands and deadwood piles, thereby reestablishing complete food chains comprising "pollinator insects-predatory birds-decomposer microbes" with a target arthropod abundance index (AAI) no less than 0.8; at the landscape level, emphasis is placed on harmonizing ecosystem services with human needs by employing resilient design features such as floodable zones and ecological buffers to keep anthropogenic impacts within the ecosystem's carrying capacity, ultimately achieving comprehensive benefits including ≥90% soil conservation and ≥6dB noise attenuation.

2.2 Categorization and Characterization of Ecosystem Restoration Methods

2.2.1 *Soil remediation technology*
To address the prevalent issues of compacted construction backfill and poor fertility in municipal park development, this project innovatively adopted an integrated remediation strategy combining "biological activation and physical improvement". The vermicomposting technique (stocking density of 300 earthworms/m^3) was introduced to significantly enhance soil permeability by leveraging the bioturbation effect of earthworms, which can excavate soil up to 10 times their body weight daily. Concurrently, earthworm castings increased soil nitrogen and phosphorus content to 0.15% and 0.08% respectively. Complementary organic amendments were implemented using a composite substrate of garden waste compost (C/N ratio 25:1) and humus soil, combined with mycorrhizal fungi inoculation. This intervention boosted the soil cation exchange capacity (CEC) from an initial 9.2 cmol/kg to 16.5 cmol/kg, substantially improving soil nutrient retention. Post-remediation results demonstrated optimized soil bulk density of 1.35 g/cm^3 and porosity of 42%, creating ideal physical conditions for root development. Six-month monitoring data revealed a 28% increase in soil microbial community Shannon diversity index and sustained organic matter content above 3.2%, with all parameters meeting the Grade II standards for parkland soil quality specified in the "Planting Soil for Greening" (CJ/T 340-2016) standard.

2.2.2 Water body ecological restoration technology
Based on the synergistic purification mechanism of "plant-microorganism-hydraulic regulation"[4], this project established a multi-level aquatic ecosystem restoration system. Within the 3,535m^2 aquatic greening area, a three-dimensional vegetation configuration was implemented, comprising submerged plants (Vallisneria and Potamogeton, 40%), floating-leaved plants (Nymphaea, 25%), and emergent plants (Phragmites and Typha, 35%), forming a plant filtration belt with daily treatment capacity of 800m^3. By optimizing hydraulic retention time to 24-36 hours, the system achieved removal rates of 65% for total nitrogen and 58% for total phosphorus. Twelve solar-powered aerators (2.2kW each) were installed and operated intermittently to maintain dissolved oxygen levels at 5.2-6.8mg/L, effectively promoting the proliferation of nitrifying bacteria communities. Post-implementation monitoring showed water transparency significantly improved from 0.3m to 1.2m, chlorophyll-a concentration decreased by 72%, with all water quality parameters meeting standards, while successfully establishing a complete aquatic food chain of "algae-cladocera -fish".

2.2.3 Biodiversity restoration techniques
A three-dimensional habitat network was engineered to systematically restore regional biodiversity, featuring three 15-20m-wide ecological corridors planted with nectar-producing species like Robinia pseudoacacia and Broussonetia papyrifera to interconnect eight green patches. Thirty-two modular insect hotels crafted from bamboo tubes, pine cones, and drilled timber provided targeted habitats for 35 beneficial insect species including leafcutter bees and ladybugs. Seasonally-staged avian forage systems incorporated 20% berry-producing plants such as Pyracantha (winter fruit) and Morus (spring fruit), attracting 12 resident bird species like Light-vented Bulbul and Common Blackbird. Post-construction monitoring via infrared cameras and transect surveys documented 36% growth in arthropod richness (58→79 species) and 32% elevation in avian Shannon diversity index (1.82→2.41), confirming enhanced ecosystem stability. The regular foraging activities of nationally protected Eurasian Kestrels (Falco tinnunculus) validated habitat rehabilitation effectiveness.

2.2.4 Ecological slope protection and slope defense technology
The project implemented groundbreaking ecological protection measures along 1.2km of lakeshore and five slopes with 1:2 gradients. Employing a synergistic mechanism of "biodegradable materials and living vegetation", coir-fiber ecological blankets with 12-18 month degradation cycles were installed, their three-dimensional mesh structure providing ideal growth substrates for herbaceous roots to eventually form self-sustaining protective layers. In critical erosion zones, innovative live willow stakes (8-10cm diameter at 1.5m intervals) were implanted, achieving over 85% sprouting rate to establish 2.3m^3 root networks per stake within six months. Climbing plants including Trachelospermum jasminoides and Euonymus fortunei (with 1.2m/year aerial root growth) were introduced simultaneously, forming multi-tiered protection systems with Cynodon dactylon turf. Monitoring results demonstrated dramatic improvements: annual slope erosion decreased sharply by 68% (550→176 tons/km^2), vegetation coverage reached 92% stabilization within nine months, and comprehensive ecological benefit indices reached 3.8 times that of traditional concrete revetments, establishing a new paradigm for waterfront ecological restoration.

2.3 Selection and Application of Ecological Restoration Technologies

This project established a sustainable ecological restoration system based on nature-based solutions. For soil remediation, garden waste compost combined with vermiremediation achieved 100% waste recycling through organic matter circulation, completely avoiding secondary pollution risks from chemical agents. The water purification system innovatively utilized topographic elevation differences to create terraced ecological filtration beds, where gravity-driven natural aeration synergized with submerged plants' nutrient removal functions, reducing system energy consumption by 40% and extending maintenance intervals to 2.3 times that of conventional constructed wetlands. The slope protection system pioneered bio-physical synergistic technology, with coir-based material's anti-scouring properties and native climbing plants' root networks forming spatiotemporal complementary protective layers, accelerating natural vegetation succession by 55% while ensuring slope stability. By systematically integrating regional ecological elements and natural process-driven mechanisms, the project achieved 22% reduction in life-cycle costs compared to conventional engineering approaches, with over 30% enhancement in ecosystem service values, successfully creating an urban ecological space paradigm of "minimal intervention - maximal benefits"[5].

3 LANDSCAPE CREATION TECHNIQUES AND DESIGN STRATEGIES

3.1 The Principles for Creating the Landscape of Municipal Parks

This project innovatively developed a three-dimensional synergistic landscape system integrating "ecological foundation, functional hybridity, and cultural continuity". With ecosystem stability as the core principle, leisure facilities and viewing nodes were precisely arranged within 50-meter service radius, achieving dynamic balance between visual permeability (over 60%) and spatial accessibility. Spatial superposition strategies were employed to organically combine the bioretention function of rain gardens with recreational features of children's play areas, while cultural sculpture installations were artfully embedded within ecological tree-lined walkways. Particular emphasis was placed on innovative interpretation of local culture, with traditional craftsmanship essence translated through contemporary design language into paving patterns and furniture details that carry historical memories. The outcome is a hybrid urban public space demonstrating 40% enhanced ecosystem service value and 92% public satisfaction rate, successfully transforming from conventional green space into an urban cultural living room.

3.2 Ecological Landscape Design Method

3.2.1 Application of the Low-Impact Development (LID) concept

The project developed a three-stage rainwater management system incorporating "source reduction-process regulation-end storage and purification", thoroughly integrating low-impact development principles into landscape design[6]. The innovative permeable pavement technology combines modified ceramic aggregates with polymer binders, achieving high permeability of 1 × 10-3cm/s and reducing peak runoff intensity by 42% through 35% pavement coverage. The tiered rain garden system features 15-30cm gradient storage depths, with 10-20mm volcanic rock filter media at the base and moisture-tolerant plant communities including Lythrum salicaria and Iris pseudacorus, delivering 85% annual runoff volume control. Ecological grass swales along road networks adopt trapezoidal cross-sections (1.2m top width × 0.4m depth) with 0.5%-2% slopes and gravel drainage layers to form efficient conveyance channels. Monitoring data demonstrates the LID system delays 24-hour rainfall peaks by 45 minutes and reduces runoff pollutant loads by 61%, exceeding all technical requirements for parkland projects in the Sponge City Construction Evaluation Standards.

3.2.2 Sustainable hydrological management

This project developed an innovative water management system based on the synergistic interaction of terrain, vegetation, and water networks. Through 3D drone mapping and SWMM modeling[7] ,the site was precisely delineated into five hydrologically connected catchment units, with a 1.5-meter elevation difference ingeniously utilized to create gravity-driven stormwater pathways. The ecological dry stream system features high-porosity eco-concrete substrate (25% porosity) and 2-4 meter variable-width channels, safely conveying $3m^3/s$ flood peaks during rainy seasons while transforming into immersive nature education spaces in dry periods. A smart monitoring network (50-meter well spacing) achieves 0.3m precision groundwater tracking, enabling a 30% water-saving intelligent irrigation system. Post-implementation evaluation demonstrates 78% stormwater utilization rate and 60% reduction in municipal drainage load, establishing a model for perfect integration of hydrological regulation and spatial functionality.

Table 1 Landscape Functional Zoning and Technical Specifications

Functional Zone	Area Proportion (%)	Area (m^2)	Primary Functions	Specialized Technologies/Facilities
Ecological Conservation Area	30	9,078	Biodiversity protection, Water and soil conservation	Ecological floating islands (15% coverage), Insect hotels (1 unit per $500m^2$), Near-natural forest restoration
Recreational Activity Area	45	13,617	Public recreation, Outdoor sports	Permeable pavement (1×10^{-6} cm/s permeability coefficient), Fog cooling system ($2,000m^2$ coverage), Smart irrigation system
Cultural Exhibition Area	25	7,565	Regional cultural display, Public education	Cultural ground reliefs (historical event themes), Night lighting system (3,000-4,000K color temperature), AR interactive installations

3.2.3 Native plant configuration

This project developed a three-dimensional vegetation system with a "tree (35%)-shrub (25%)-herb (40%)" structure based on the principle of "right plant for right site and community stability." The tree layer features 12 native species such as Cinnamomum camphora (crown width 6-8m) and Sapium sebiferum (autumn leaf color index 0.85), achieving an 80% canopy closure. The shrub layer incorporates flowering plants like Pittosporum tobira and Hibiscus syriacus (blooming from April to October), combined with fruiting species such as Pyracantha fortuneana and Nandina domestica, ensuring year-round visual interest. The herb layer employs innovative mixed-seeding techniques, integrating over 20 native wildflowers including Viola philippica (shade-tolerant) and Pennisetum alopecuroides (drought-resistant), forming five distinct plant communities: waterside wetland (Phragmites australis + Juncus effusus), woodland edge (Farfugium japonicum + Spiraea salicifolia), open woodland (Cynodon dactylon + Trifolium repens), rock garden (Sedum spp. + Sedum lineare), and pollinator corridor (Vitex negundo + Buddleja lindleyana). Ecological monitoring revealed a 40% increase in insect diversity index (H'), 75% natural regeneration rate, and 28% reduction in maintenance costs, successfully establishing a low-maintenance, high-biodiversity plant community.

3.3 Landscape Function Zoning and Feature Enhancement

The project established a tripartite functional zoning system integrating "ecological conservation, recreational activity, and cultural exhibition"[8], with scientifically designated 30% ecological conservation area, 45% recreational zone, and 25% cultural display sector. An 1.5km ecological boardwalk network seamlessly connects eight distinctive landscape features, including concealed birdwatching platforms and immersive rain gardens. The innovative fog-cooling microclimate system achieves notable 2-3°C temperature reduction, significantly enhancing outdoor thermal comfort during summer. Detailed technical specifications for each functional area are presented in Table 1.

3.4 The Relaxation Area is Integrated with the Cultural Landscape

This project innovatively reinterpreted regional textile culture by transforming decommissioned textile machinery components into landscape elements with both artistic and functional value. Through deconstruction and recombination techniques, gear systems were reinvented as kinetic sculptures while textile bobbins became ergonomic seating fixtures (45cm seat height with 5° reclining angle and lumbar-supporting curved backrests). The lighting system utilizes 3000-4000K adjustable LED sources with culturally-patterned perforated shades to project meaningful light patterns at night. The monitoring results show that after the renovation, the recognition rate of cultural elements in the space has increased, the average stay time of tourists has been extended, and the satisfaction level has improved. This has achieved an organic integration of historical memories and contemporary life.

4 CONCLUSION

This study demonstrates that integrated ecological restoration and landscape design can significantly enhance park green space carbon sequestration capacity to 1.2kg $CO_2/(m^2 \cdot yr)$ while achieving 30% maintenance cost reduction. Future research should focus on developing quantitative models linking vegetation community structure with ecosystem service functions, facilitating the paradigm shift of municipal parks from traditional landscape display to "ecological life communities", thereby providing innovative ecological solutions for urban sustainable development.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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