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Floodable Park Landscape Model as Adaptive Infrastructure: Integrating Blue-Green Technology and Community Education for Urban Flood Mitigation in Bandar Lampung, Indonesia

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ABSTRACT

Bandar Lampung City faces escalating flooding challenges driven by rapid urbanization and climate change, necessitating the adoption of nature-based solutions. This study proposes a floodable park landscape model that integrates blue-green infrastructure with community education programs, serving as an alternative to traditional structural mitigation. The research focused on Barunaria Field in the Panjang District, a site identified as a high-priority flood-prone area through previous GIS-based spatial analysis. The study utilized a modified LaGro landscape design framework across three stages: inventory and site selection, analysis and synthesis, and conceptual development. Primary data were gathered via field surveys, temporal environmental measurements of temperature, humidity, and noise, behavioral observations, and semi-structured interviews with residents, supplemented by documentation reviews. Analysis revealed several critical factors contributing to flooding, including low infiltration capacity from extensive impermeable surfaces, high runoff coefficients, and acidic soil conditions. Additionally, the site suffered from waste accumulation, noise pollution, and a lack of social or educational infrastructure. The resulting modular design integrates rain gardens, bioswales, permeable pavements, and infiltration wells with social and agricultural zones, including urban farming areas, amphitheaters, and pedestrian pathways. A distinguishing feature of this model is the incorporation of Lampung's Tapis batik motifs into functional landscape elements. It also establishes educational zones for disaster risk reduction and urban farming, functioning as a practical site for environmental education. The proposed model facilitates recreation and food production during dry periods while functioning as a retention system during the rainy season to reduce runoff. This culturally grounded, modular approach provides a framework for sustainable flood mitigation that supports environmental education and community resilience through ecological and social benefits.

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■ INTRODUCTION

Urban flooding has emerged as one of the most serious social and environmental issues facing the fast-growing cities of the Global South. Take Bandar Lampung in Indonesia, for instance. Based on recent data from 2024, 56% of the city's area has been exposed to worsening flood events caused by large-scale land-use conversion, dwindling infiltration zones, and severe rainfall associated with climate change (Rohman et al., 2024). The Regional Disaster Management Agency of Bandar Lampung City (2021) states that the frequency of flooding has increased dramatically in the last decade, with the most severe impacts concentrated in low-lying areas and along river basins under heavy pressure from urban development. Furthermore, large floods can carry debris from upstream, resulting in downstream hazards that compound existing ones (Aliyah et al., 2022).

Conventional structural solutions, such as embankments, river normalizations, and traditional drainage systems, are inadequate. They often shift problems downstream and are not flexible enough to respond to climate dynamics and ongoing urbanization (Sharma et al., 2018; Chan et al., 2018). What we need is a new paradigm: resilient, multifunctional nature-based solutions (NbS) integrated into communities' lives. A strategic alternative is proposed in the form of a "floodable park" (taman banjir) integrated with urban agriculture. These parks are designed as multifunctional spaces that collect and temporarily store rainwater runoff from impermeable surfaces and remain accessible to citizens during drier periods (SOS4Life, 2023). They are green infrastructure that reduces floods, providing environmental, social, and economic benefits (Martin et al., 2024). Research conducted in Mojokerto City indicated that planned green open spaces can reduce surface runoff by up to 50% through water retention and infiltration methods (Krishamurti et al., 2021). However, there are limitations to implementing similar concepts in Bandar Lampung, including limited land availability, low public awareness, and a lack of a holistic landscape model suited to local conditions (Ebissa & Desta, 2022).

Based on the previous research on spatial analysis using Geographic Information Systems (GIS) with weighted overlay methods integrating five physical parameters, namely landform, slope, soil type, elevation, and rainfall, Panjang District was recognized as a priority area for adaptive infrastructure development with a flood vulnerability percentage of 9.75% (Hutriani et al., 2025). This percentage was obtained from a weighted integration of five parameters: landform (20% weight), slope (20%), soil type (20%), elevation (10%), and rainfall (30%), using the linear equation for Flood Vulnerability. The total score ranges from 900 to 100 and is divided into five vulnerability classes using the Sturges formula (Hutriani et al., 2025). The study site was selected in Barunaria Field, located in the Panjang District, based on its low-lying topography, with an altitude ranging from 0-12.5 meters above sea level, making it highly vulnerable to inundation (Hutriani et al., 2025).

The potential of blue-green infrastructure (BGI) as an educational tool for disaster risk mitigation and urban agriculture is largely unexplored. Beyond passive information dissemination, effective community education for BGI implementation necessitates participatory approaches (Saha et al., 2024). In Guwahati, Assam, community education workshops using physical models and creative media proved an effective way to inform communities about BGI solutions. Community-led initiatives integrated feedback and local knowledge (Saha et al., 2024). Disaster and climate risk education needs to adopt comprehensive strategies that include school education, community outreach, governance, capacity development, and technological integration to link awareness to substantive action (Yildiz & Shaw, 2024). The KIDA (Knowledge, Interest, Desire, Action) framework highlights collaboration among schools, communities, and families, with support from educational boards and local governments (Yildiz & Shaw, 2024). Community empowerment through participatory education and technical support in urban drainage and rainwater management has been shown to improve awareness, basic technical understanding, and community commitment to maintaining the drainage system (Putra et al., 2026).

What is innovative about this research is the integration of blue-green infrastructure, community education, and local knowledge into a common framework for flood-resilient urban landscapes. A bibliometric analysis of Scopus-indexed publications from 2015 to 2025 was performed using VOSviewer (Figure 1), revealing that the research is primarily focused on technical topics and that blue-green infrastructure is strongly linked to urban flooding, stormwater management, urban planning, resilience, and climate change adaptation. However, environmental education, community involvement, stakeholder engagement, and public perception are peripheral and loosely connected to the central BGI cluster. The network knows nothing of the local. These findings show a clear gap in research on the integration of ecological engineering, educational functions, and socio-cultural values, which is the originality of our proposal: an adaptive learning landscape that simultaneously enhances flood resilience,

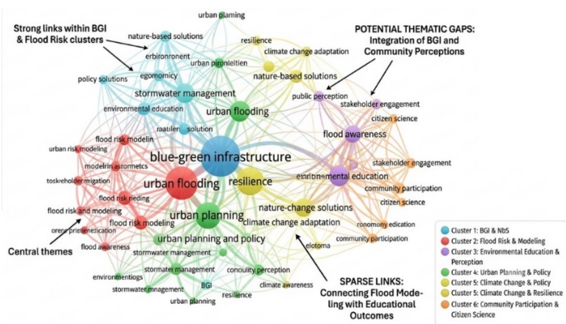

Figure 1. Vosviewer bibliometric analysis of scopus-indexed publications (2015–2025)

Figure 2. Research location map at barunaria field, panjang district, bandar lampung city

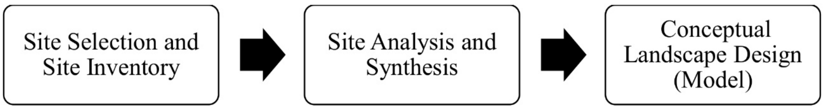

Figure 3. Modified lagro landscape design stages (adapted from lagro, 2013).

environmental awareness, and local cultural identity.

These gaps prompt us to formulate the following hypotheses:

H1: Components of blue-green infrastructure (rain gardens, bioswales, permeable pavements, and infiltration wells) are expected to reduce surface runoff by at least 40% from pre-design conditions, as determined by rational method runoff coefficient analysis.

H2: The proposed modular design will provide stormwater retention capacity to accommodate the peak rainfall event for the 2.24 hectare site for a 5-year return period (24-hour duration).

H3: Participatory design and visible BGI elements will lead to a significant increase in residents' understanding of nature-based flood mitigation methods, as measured by pre- and post-knowledge assessment instruments.

Hence, this research aims to develop a landscape model of a floodable park based on urban agriculture in Barunaria Field, Panjang District, as an adaptive and sustainable solution for flood mitigation, integrating technical innovation, educational function, and local cultural philosophy.

■ METHOD

Research Design and Location

The research applied a modified landscape design methodology, developed from LaGro (2013). The original technique consisted of the following seven stages: project initiation, site selection and programming, site inventory, site analysis, conceptual design, design development, and project implementation. Since the primary purpose was to produce a landscape model and site plan for a floodable park, rather than extensive engineering design documentation or supervision of physical construction (Kavousi et al., 2009), we focused on the conceptual design phase. This choice is in line with guidance from the American Society of Landscape Architects (ASLA) that conceptual design studies are appropriately concluded at the design development stage when the research goal is the generation of models rather than the validation of a built project (ASLA, 2023; Deming & Swaffield, 2011). Post-occupancy evaluation is an important tool but is not part of this stage of conceptual inquiry. Our design approach consisted of three steps: (1) site selection and inventory, (2) analysis and synthesis, and (3) conceptual design creation. The study activities were carried out at Barunaria Field, Panjang District, Bandar Lampung City (coordinates: 5.4291° S, 105.2620° E) from June to November 2025. The selected site area is 2.24 hectares (22,470 square meters), based on a GIS-based spatial study that identified the Panjang District as a priority area for adaptive infrastructure development, with a flood vulnerability of 9.75% (Hutriani et al., 2025). The site's low elevation, ranging from 0 to 12.5 m above sea level, makes it particularly vulnerable to flooding and inundation.

Participants and Sampling Strategy

Five key informants were interviewed using semi-structured interviews. Purposive sampling is a technique in which key informants are selected for their ability to provide rich, relevant information (Deming & Swaffield, 2011). It is commonly used in interpretive landscape research. This method

Table 1. Demographic characteristics of key informants

Informant Code	Age Group	Stakeholder Category	Residence Duration	Inclusion Criteria Met
K1	46–60 years	Government/Community Leader	>10 years	Adult resident, flood experience, site knowledge
K2	31–45 years	Community Leader (RT/RW)	>10 years	Adult resident, flood experience, community representation
K3	31–45 years	Farmer/Urban Agriculture Practitioner	6–10 years	Adult resident, flood experience, site utilization
K4	31–45 years	Street Vendor/Small Business Owner	>10 years	Adult resident, flood experience, site utilization
K5	46–60 years	Long-term Resident	>10 years	Adult resident, flood experience, historical site knowledge

uses stratified purposeful and snowball sampling, which are both valuable for accessing different stakeholders' perspectives and for identifying key individuals (Marshall & Rossman, 1999, cited in Deming & Swaffield, 2011). Inclusion criteria were: adult resident (age ≥ 18 years) with at least one year of residency and direct experience with flood events or frequent site use. The five informants were the Head of Panjang District (Lurah), a community leader (RT/RW head), a local farmer, a street vendor, and a long-term resident. While qualitative research guidelines generally recommend 12–15 participants for thematic adequacy (Guest et al., 2006), the key informant approach emphasizes the depth and diversity of viewpoints rather than statistical representation (Deming & Swaffield, 2011). It has been successfully applied in studies of the landscape architecture design process (Kavousi et al., 2009, 2010).

Instruments and Measurement Specifications

Environmental measurements were carried out at four identified sites on the site using calibrated instruments according to the site-specific ground-based climate measurement methods (VDI, 2023). Temperature and humidity were monitored using a KRISBOW Thermohygrometer (temperature accuracy ±1°C, humidity accuracy ±4% RH, temperature: -10 °C to 60 °C, humidity: 0–99 % RH, resolution 0.1. The noise level was measured using a KRISBOW Environment Meter 5-in-1 Pro (range: 30–130 dBA, resolution: 0.1 dBA). The equipment was selected for its reliability in environmental monitoring investigations and for its calibration certificates that meet international standards. Four measurement points were chosen based on stratified purposive sampling criteria that considered different land-use and activity zones on the site (Galalizadeh et al., 2025): A (major entrance close to Jalan Soekarno Hatta) is a region with considerable traffic and noise exposure. B (Central open field) is the major leisure area. Point C (eastern drainage channel) is a hydrological effect area, and Point D (western residential boundary) is the neighborhood interface. Microclimate parameters were measured in two sessions (September 15, 2025 and September 19, 2025) across two daily intervals (morning: 09:25–09:50 WIB; afternoon: 14:27–15:00 WIB) to record diurnal fluctuations. This temporal sampling design aligns with the approach proposed for mobile urban climate measuring devices, which conduct observations during peak periods to capture geographical and temporal variability (Galalizadeh et al., 2025).

Data Collection Procedures

Primary Data Collection consisted of: (1) Field surveys and environmental data. The physical site parameters such as terrain, land use patterns, existing infrastructure, and vegetation inventory were documented through direct field surveys. The environmental measurements were performed according to conventional protocols, and the sensors were set at 1.5 m above ground level to represent pedestrian exposure levels. For each measurement session, three successive readings at each point were taken, and the mean value was recorded for analysis (VDI, 2023). (2) User behavior observation. A defined protocol was employed for systematic observation of user activities and spatial use for one week in the morning, midday, and afternoon. This is intended to monitor temporal patterns of activity, user demographics, and behavioral interactions with the facility (Deming & Swaffield, 2011). (3) Semi-structured interviews. The interviews were conducted using a protocol that included: (a) flood experiences and risk perceptions, (b) site use patterns and user requirements, (c) preferences of recreational and educational facilities, and (d) awareness of flood mitigation methods (Kavousi et al., 2009). Interviews were conducted in Bahasa Indonesia and took roughly 30 minutes. The audio recordings were made with the consent of the participants. Secondary Data Collection: Documentation studies reviewed spatial data (landform, slope, soil type, elevation, and rainfall maps), regulatory documents: Regulation of the Minister of ATR/BPN Number 14 (Kemen ATR/BPN, 2022), and technical reports from BPBD Kota Bandar Lampung (2021).

Data Analysis Procedures

Quantitative Data Analysis

The microclimate conditions of each measurement location were described using quantitative descriptive statistics of environmental measurement data (temperature, humidity, and noise levels) such as mean, range, and standard deviation (Galalizadeh et al., 2025). The temperature data were averaged from 4 measurement stations during both the morning and afternoon sessions. The researchers also examined humidity readings to see how relative humidity differed across land use zones and over time. Noise level data were evaluated to identify locations of high exposure and to inform design recommendations for vegetation as a noise buffer.

Runoff Calculation (Hydrological Performance Evaluation)

The flood mitigation efficiency of the suggested design was obtained by assessing hydrological performance using the Rational Method ($Q = C \times I \times A$) for a 2.24 hectare watershed (Chow et al., 1988; Rossman, 2015). Land cover of the site was classified into surface types (e.g., impervious concrete/asphalt, compacted soil, vegetated areas, permeable pavement, grass blocks, rain gardens, bioswales, and infiltration wells). Runoff coefficients were assigned to each based on reference values from the GREENSHIP Rating Tools New Building (NB) Version 1.2. The weighted runoff coefficient for present and proposed conditions was estimated using an area-weighted averaging approach as follows: $C\ weighted = \Sigma\ Ai\ Ci/Ai\ total$. The rainfall intensities for Bandar Lampung are collected from BMKG data for a 5-year return period of 45 mm/hour (BMKG, 2024). The two situations were assessed for peak runoff rates and total runoff volumes over a 24-hour event. The capacity was then compared to the estimated runoff volumes to verify the design was suitable for stormwater management during extreme rain events.

Qualitative Data Analysis

The interview transcripts and observation notes were thematically analyzed using Braun and Clarke's (2006) six-phase framework: (1) familiarizing with the data by transcribing the data directly and reading the data repeatedly; (2) generating initial codes by inductive coding (Deming & Swaffield, 2011); (3) searching for themes by organizing the codes into patterns and hierarchies; (4) reviewing themes at two levels, the coded extracts and the whole data set; (5) defining and naming themes with precise articulations; and (6) producing the report with compelling extracts as evidence.

Synthesis was accomplished by merging quantitative and qualitative data through an analysis-synthesis matrix that systematically connected identified problems with context-sensitive, specific design solutions (LaGro, 2013) and enabled the shift from analysis to conceptual design creation. The synthesis process included interpretive practices, involving coding, organizing, interrogating, rearranging, and reflecting on the data to create insights related to the study objectives (Deming & Swaffield, 2011).

■ RESULTS AND DISCUSSION

Site Inventory Findings: Physical, Biological, and Socio-Cultural Conditions Contributing to Flood Vulnerability

The site inventory in Barunaria Field revealed a complex interrelation between physical, biological, and socio-cultural factors that together contribute to higher flood vulnerability and the difficulty in establishing a floodable park. The inventory stage of the updated LaGro (2013) landscape design framework identified critical site conditions demanding integrated design responses.

Physical conditions

a. Topography and hydrology

The site shows a specific lowland character with slopes of 0–2% that allow gravitational water flow and also conditions for long-term flooding in the central and lower parts of the basin. Previous GIS-based spatial analysis (Hutriani et al., 2025) determined the topographical features and elevations of the site ranging from 0 to 12.5 meters above sea level,

Figure 4. Inventory of physical attributes: topography, soil and hydrology.

highlighting the site's inherent hydrological vulnerability. Sediment and waste have built up in the existing drainage system around the site, reducing its ability to convey stormwater during heavy rain events. In particular, approximately 80% of the soil surface is covered by impermeable materials, which significantly decreases infiltration capacity and increases surface runoff generation. In the basin areas, inundation depths of 30–50 cm were measured in the field during the September 2025 assessment, confirming the site's vulnerability to flooding.

b. Microclimate

Environmental measurements at four crucial periods in the temporal microclimate were considerably different at the site. Temperatures of 31.5°C-37.7°C, with the highest at Point A (major entry near Jalan Soekarno Hatta) and the lowest at Point C (eastern drainage channel), indicate the influence of flora and aquatic surroundings in mitigating temperature. Relative humidity ranged from 55 to 78%, with the lower values corresponding to the afternoon readings that coincided with higher temperatures. The noise level measurements revealed a high level of acoustic pollution, with values reported up to 80.3 dBA at point A during peak traffic hours, which is far higher than the recommended limits set by the World Health Organization for community areas (55 dBA daytime). This calls for urgent interventions using noise-buffering plants.

c. Soil Conditions

The soil data from a secondary source: Bandar Lampung Spatial Plans (*Rencana Tata Ruang Wilayah*, RTRW), indicates that the kind

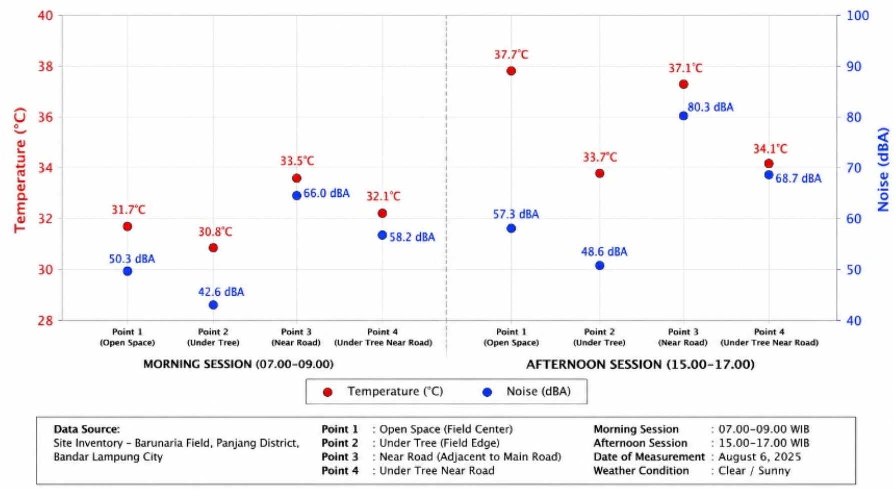

Figure 5. Scatter plot visualization of temperature and noise fluctuations at four measurement points across morning and afternoon sessions

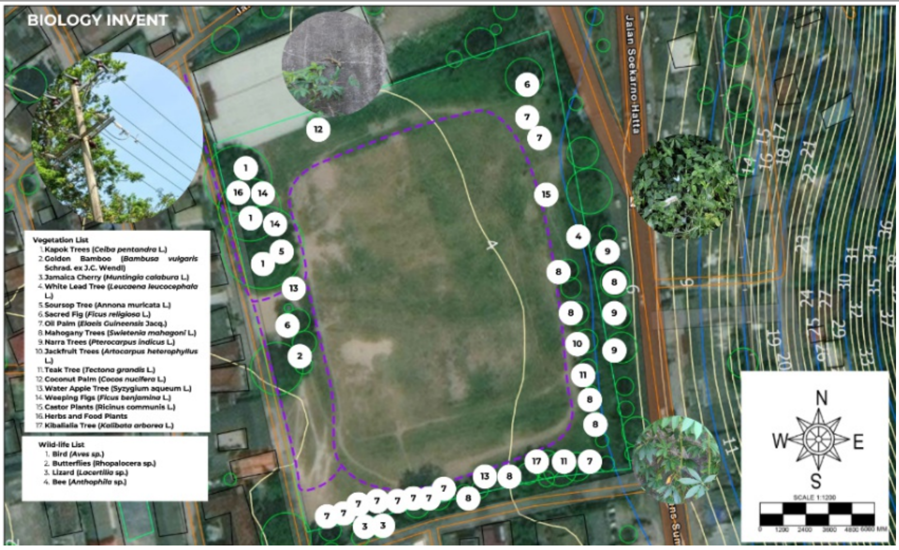

Figure 6. Inventory of biological attributes: Existing vegetation and wildlife

of soil on the site is Andosol. This type of soil has specific features such as a porous structure, loose consistency, an acid pH of 4.5–5.5, and high infiltration capability in an undisturbed state. However, the combination of acidity and compaction of soil due to heavy human activity has diminished the soil's natural infiltration capacity while keeping it prone to erosion. The low pH limits the types of vegetation that can be grown, either needing low pH-tolerant species or soil additives to establish effective urban agricultural zones.

Biological condition

The biological inventory recorded the presence of seventeen species of existing vegetation dominated by kapok (Ceiba pentandra L.), yellow bamboo (Bambusa vulgaris Schrad. ex J.C. Wendl), cherry (Muntingia calabura L.), petai cina (Leucaena leucocephala L.), and soursop (Annona muricata L.). Other species found include oil palm, mahogany, jack fruit, teak, coconut, and some medicinal plants. The existing vegetation provides some shade and habitat functions but is not strategically located to provide flood mitigation benefits. Wildlife observations showed the presence of birds, lizards, and butterflies, indicating the site's potential to support urban biodiversity if designed in the right way with diverse and stratified vegetation communities. The prevalence of self-help plants such as castor and medicinal species indicates community utilization patterns that could be optimized within the floodable park design.

Socio-cultural conditions

Five key informants were interviewed through semi-structured interviews to identify the primary socio-cultural variables impeding park development. The thematic analysis of the interview transcripts and observation notes revealed four primary themes:

Theme 1: Experiences of flooding and perceptions of risk. All informants had personal knowledge of flooding incidents, and the majority claimed that flooding had become more frequent in the last decade. In heavy rain, water entered homes, with depths of 30–100 cm in severe incidents, residents reported. For some, the flood danger was just another predictable seasonal problem, but others were concerned about the implications of climate change.

Theme 2: Strategies of site use. Observations found that the site was very active with community activities like morning exercise, children's play, informal meetings, and street selling. However, users pointed to the absence of organized amenities as a barrier and indicated requests for pedestrian routes, seating, and defined places for activities. The unregulated street sellers used advantageous sites. It provided economic benefits, but also presented managerial issues.

Theme 3: Facility Needs and Preferences. Informants asked for recreational facilities (playgrounds, jogging tracks, meeting spaces), educational infrastructure (community learning spaces), and economic prospects (organized vending areas). The strong interest in urban agriculture and the continuing self-help planting initiatives indicated that the community was ready for organized urban farming programs.

Theme 4: Perceived approaches to flood mitigation. Residents recognized flooding as an issue, but they knew little about nature-based solutions. Most respondents believed the government should bear the main duty in flood mitigation, and they were not aware of the support green-blue infrastructure may offer in reducing flooding. The finding points to the necessity of educational aspects in the design of the park.

Analysis-Synthesis: Design Interventions for Flood Mitigation and Community Education

Four main issues were identified by adopting LaGro's (2013) methodology of site analysis and by integrating inventory data. These issues were synthesized into design solutions that specifically address flood vulnerability while incorporating community education and local cultural values.

Hydrological problems and design interventions

Problem 1. Low infiltration capacity and flooding of the basin. The 80% impermeable surfaces, poor drainage systems, and low-lying geography meant stormwater was primed to pool quickly during rain events. The analysis-synthesis strategy for hydrological problems proposes converting basin regions into rain gardens and bioswales, replacing impervious materials with permeable pavement with biopores and infiltration wells. The combination of these treatments reduces runoff and increases infiltration capacity.

a. Hydrological performance calculation

The flood mitigation performance of the proposed design was evaluated using the Rational Method ($Q = C \times I \times A$), an established technique for predicting peak runoff from small urban catchments (Chow et al., 1988; Rossman, 2015). Runoff coefficients were assigned for each land cover type using known reference values picked carefully to be representative of both existing site conditions and projected design improvements. The weighted runoff coefficient for the existing condition is $C\_existing = 0.624$ and is based on 60% concrete/asphalt surfaces ($C = 0.95$), 20% compacted soil ($C = 0.17$), and 20% vegetated areas ($C = 0.10$). This is increased to reflect the present status of the site. The site is primarily covered with impermeable surfaces that generate a substantial amount of runoff during a rain event. The coefficient was applied to each intervention module according to its type of surface for the proposed design condition as follows: permeable pavement of gravel with $C = 0.65$ (20% of site area), grass blocks described as "solid ground/flat grass" with $C = 0.17$ (15%), rain gardens and bioswales described as "shrubs" with $C = 0.21$ (10%), infiltration wells assigned to $C = 0.10$ for its high permeability design (5%) and vegetated areas described as "dense trees" with $C = 0.10$ (50%). The weighted summation resulted in $C\_proposed = 0.232$, a 62.8% decrease from

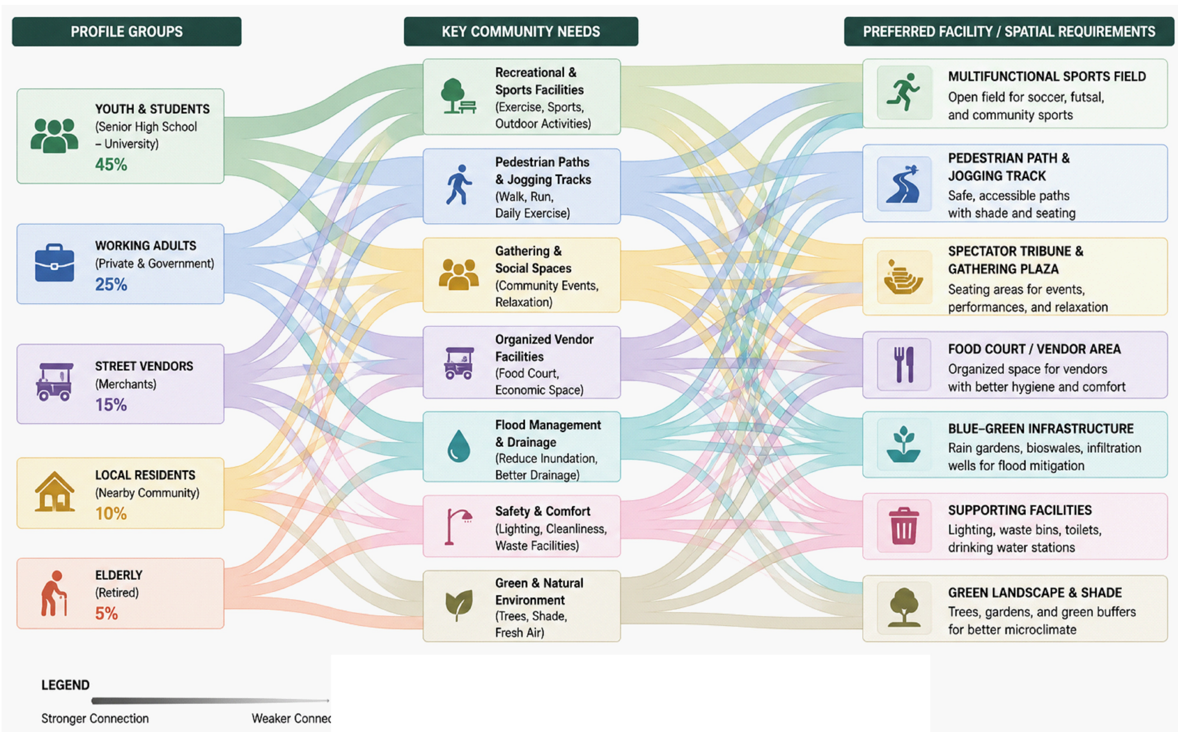

Figure 7. Sankey diagram mapping community needs and spatial requirements for Barunaria Field

Table 2. Existing condition - weighted runoff coefficient calculation based on land cover classification

Land Cover Type	Area (m^2)	Percen tage	Reference Surface Type *GREENSHIP Rating Tools New Building (NB) Version 1.2.*	Runoff Coefficient (C)	Weighted C
Existing Condition					
Concrete/Asphalt	13,482	60%	*Beton / Aspal*	0.95	0.570
Compacted Soil	4,494	20%	*Tanah padat/rerumputan (datar <2%)*	0.17	0.034
Vegetated Areas	4,494	20%	*Pepohonan rimbun*	0.10	0.020
Total Existing	22,470	100%			C_existing = 0.624

the current condition.

The peak runoff volume was computed based on 5-year return period rainfall intensity for Bandar Lampung, I = 45 mm/hour (24 hours duration) and site area A = 22,470 m^2.

Existing condition Qexisting=0.624 x (45/3600) x 22,470=175.2 L/sec

Proposed condition (Q_proposed) 0.232 x (45/3600) x 22470 = 65.1 L/sec

Total reduction: 175.2 - 65.1 = 110.1 L/s (62.8%)

Runoff volume for a 24-hour event:

Total rainfall = 45 mm x 22,470 m2 = 1,011 m^3

Existing runoff volume 1,011 x 0.624 = 631 cu. m.

Proposed runoff volume = 1,011 x 0.232 = 235 m^3

Reduction in runoff volume = 631 – 235 = 396 m^3 (62.8 %).

To analyze the design retention capacity, rain gardens with an area of 2,247 m^2 (10% of the site) were developed, with an average ponding depth of 0.30 m and soil storage depth of 0.60 m with porosity of 35%. The overall retention capacity is 1,146 m^3, of which 674 m^3 is due to ponding and 472 m^3 to soil storage. The capacity is 82% larger than the 5-year runoff volume (631 m^3), which indicates that the suggested design can sufficiently cope with the 5-year return period. The retention capacity (1,146 m^3) for the 10-year return period event (I = 62.5 mm/hour) is 32% higher than the projected runoff volume (870 m^3), indicating the efficiency of the floodable park for intense rainfall events (BMKG, 2024).

The calculations indicate that the proposed design of a floodable park, using permeable pavements, grass blocks, rain gardens, bioswales, infiltration wells, and vegetated areas, significantly reduces surface runoff and provides adequate retention capacity for stormwater management in Barunaria Field.

b. Material specifications for permeable infrastructure

The design used a locally produced permeable material from the waste of the coal mining sector in an effort to limit the usage of cement, with porosity of 11-15% and infiltration rate of 8-12 mm/sec (Krisanti & Triningsih, 2020). The values are higher than the normal rainfall intensities for Bandar Lampung and will provide enough capacity to manage stormwater. The running track is defined as rubber surfacing with infiltration wells underneath. Pedestrian zones use grass blocks for surface permeability. Drainage layers are built into the planter benches made of porous concrete to help transport water into the soil profile. These material requirements allow a quantitative estimate of hydrological performance.

Problem 2: High Runoff Coefficient and Poor Water Quality. The large amount of impermeable surfaces causes runoff coefficients in the range 0.7–0.8, much greater than what is suggested for sustainable urban drainage systems. Runoff transfers accumulated contaminants from the site and nearby areas and degrades the water quality of recipient water bodies. Bioretention systems are suggested for quantity regulation and pollutant removal (Jiang et al., 2017).

Microclimate problems and design interventions

Problem 3: Environmental Quality Degradation. High temperature (31-37°C) with low humidity in open areas and high noise levels near the major road (up to 80.3 dBA) reduce user comfort and site usability. The synthesis recommends planting flood-tolerant, locally native, high-canopy shade trees (including banyan and kapok trees), creating vegetation buffers with mahogany trees along the main road, and adding rain garden elements to increase humidity and provide evaporative

Table 3. Proposed design condition - weighted runoff coefficient calculation based on land cover classification

No	Land Cover Type	Area (m²)	Percentage (%)	Reference Surface Type *GREENSHIP Rating Tools New Building (NB) Version 1.2.*	Runoff Coefficient (C)	Weighted C (Area × C)
1	Permeable Pavement	4,494	20%	*Kerikil*	0.65	0.130
2	Grass Blocks	3,370	15%	*Tanah padat/rerumputan (datar <2%)*	0.17	0.026
3	Rain Gardens / Bioswales	2,247	10%	*Semak*	0.21	0.021
4	Infiltration Wells	1,124	5%	*Highly pervious structure* (assumed)	0.10	0.005
5	Vegetated Areas (trees & shrubs)	11,235	50%	*Pepohonan rimbun*	0.10	0.050
	Total	22,470	100%			C Proposed Design = 0.232

cooling effects (Kleerekoper et al., 2012). These measures improve the climatic conditions, but also add to the educational role of the park.

Soil Constraints and Vegetation Selection

Problem 4: Acidic Soil Conditions. The acidic Andosol soil (pH 4.5–5.5) limits vegetation establishment for urban agricultural zones. The summary advises selecting adaptive vegetation in Sumatra, validated by the Global Biodiversity Information Facility (GBIF) database, for riparian and flood-resistant plants. The species selected were *Syzygium polyanthum* (Indonesian bay leaf), *Archidendron pauciflorum* (jengkol), *Artocarpus heterophyllus* (jack fruit), *Nephelium lappaceum* (rambutan), *Durio zibethinus* (durian), and some tolerant bamboo species (*Bambusa vulgaris, Dendrocalamus asper*) to acidic conditions. For productive zones, local liming and organic fertilizer applications are recommended to boost soil fertility. This way, urban agricultural modules can be both productive and instructional, exhibiting communal soil improvement techniques.

Social and cultural constraints

Problem 5: Limited Community Understanding and Inadequate Social Infrastructure. Interviews (n=5) with key informants pointed to a critical gap between the perceived flood risk and the knowledge of nature-based mitigation approaches. Most interviewees considered flood management to be the duty of government. However, all had firsthand experience of floods and noted the need for recreational facilities, pedestrian pathways and gathering spaces; awareness of blue-green infrastructure alternatives was still limited. The site inventory also reported the presence of uncontrolled street vendors in key locations, the absence of permanent pedestrian pathways, insufficient drainage and lighting systems, and a total lack of waste management facilities or spectator tribunes for community activities. These factors jointly limit the physical development of the site and the social acceptability of novel flood mitigation strategies (Saha et al., 2024; Yildiz & Shaw, 2024).

Integrated design solutions in the synthesis handle these socio-cultural limits for community demands and educational functions. Organized food courts for street vendors provide economic opportunities and better management/hygiene of the place. The pedestrian walkway combined with a jogging track is designed using universal design principles based on accessibility guidelines issued by the Ministry of Public Works and Housing of Indonesia, with a ramp slope of 1:12 (maximum) and specifications of guiding blocks for persons with disabilities (Hutriani et al., 2024). The tribunes for the spectators and the play zones for the children improve user comfort and safety. Its modular design features instructional signage and QR codes explaining hydrological processes, reduction of

Figure 8. Analysis-synthesis matrix for physical and biological attributes

catastrophic risks, and urban farming procedures. This is not merely the broadcast of knowledge, but rather the construction of an interactive, concrete infrastructure that facilitates community understanding through direct observation and experiential learning. This has been effective in similar community education initiatives for BGI implementation (Saha et al., 2024; Putra et al., 2026).

Modular Design Components: Integrating Blue-Green Technology and Local Cultural Values

Based on the urban agriculture-based floodable park idea, six integrated modular landscape components are proposed to address the stated difficulties and optimize the park's multifunctional potential. Each module blends blue-green technology with community education and local cultural values. Based on the site area of 22,470 m2 and the Indonesian Regulation of the Minister of Agrarian and Spatial Planning No. 14 of 2022, the Barunaria Field is classified as a Sub-district Park Green Open Space "A" typology. This typology demands a service radius of 2,500 m and a minimum size of 15,000 m^2, with a minimum of 80% green cover and 20% non-green, ecologically friendly cover. The multiple functions of sub-district parks are: ecological (water catchment and microclimate control), water infiltration (retention/detention ponds, biopores, infiltration wells, bioswales, rain gardens), economic (nursery gardens and urban agriculture areas), socio-cultural (sports facilities, multifunctional plazas, playgrounds,

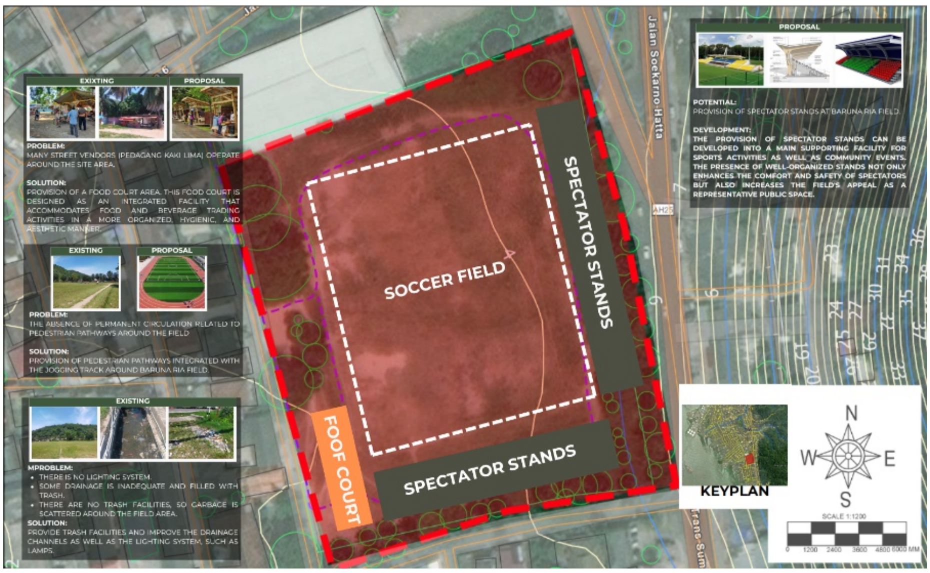

Figure 9. Analysis-synthesis matrix for socio-cultural attributes.

recreational facilities, gazebos, seating, parking), aesthetic (local wisdom reflecting regional identity), and disaster management (evacuation spaces, evacuation routes, fire hydrants).

Design transformation: Local wisdom as design framework

Local wisdom, in particular traditional textile motifs, has been recognized as a valuable resource for urban branding and placemaking (Soni et al., 2024). The design transformation offered is a new way to deliver the philosophy of Lampung's Tapis batik motif. Blue-green open space modules such as rain gardens are dispersed around the site, symbolizing the "bamboo shoot" notion (pucuk rebung) that stands for growth and fertility. The triangle pattern of the pucuk rebung motif is both attractive and utilitarian. The converging angles form natural flow channels to channel surface water to the rain garden collection points. The repeated geometric pattern allows mechanical loads to be distributed, reducing point-load stress across the permeable pavement surface and reducing stress on the porous infrastructure. The concept is also seen in the layout of various softscape and hardscape elements such as planter benches (seating with integrated planters), amphitheater seating sections, and plant nursery spaces.

The synergy between local knowledge and landscape design generates more meaningful and sustainable solutions (Chen et al., 2025). Local knowledge offers cultural relevance; technical design provides functional performance. This modular application of Tapis batik motifs can have a big social impact through community empowerment in park care and management. Different community organizations will administer each module; this will create a common ownership structure and ensure long-term sustainability. Wahyudi (2025) further emphasized that the ecological principles embedded in traditional structures such as Sasak Bale Tani can inspire culturally rooted design upgrades that harmonize environmental purpose and local identity. The modular application of Tapis batik motifs in this way can have a significant social impact by allowing people to take care of and administer the park. Different community organizations can oversee each module and create a common ownership system for a sustainable future. This is in accord with the discovery of Wahyudi (2025) that the ecological principles included in the traditional architecture, such as the Sasak Bale Tani, can provide insight for design improvements that are anchored in culture and balance the environmental function and local identity.

Pedestrian paths and jogging trails have dynamic curves that connect different modules of the facility, thus creating a constantly changing and stimulating spatial experience. The urban agriculture elements are integrated

Table 4. Summary of site analysis and descriptive synthesis

No.	Aspect/ Attribute	Analysis	Synthesis and Design Recommendations
1.	Physical - Hydrology	Potential inundation due to basins and low drainage capacity; high runoff and poor water quality; large open space potential for natural drainage systems.	Transform basin areas into rain gardens and bioswales; replace impermeable materials with permeable pavement; integrate infiltration wells, biopores, rain gardens, and bioswales.
2.	Physical - Climate	High temperature (31–37°C); high noise near main road; low humidity in open areas; varied wind circulation.	Plant high-canopy shade trees that are flood-tolerant and locally native; create vegetation buffers along the main road; add rain garden elements for humidity and cooling.
3.	Physical - Soil	Andosol soil: porous, loose, acidic pH (4.5–5.5), high infiltration, erosion-prone, low bases.	Select vegetation adaptive to flooding and acidic soil; local liming for productive zones; use organic fertilizer for fertility.
4.	Biological - Vegetation	Flood-prone site; existing community self-help plants (castor, medicinal plants).	Use water-tolerant mesophytic vegetation; optimize self-help garden zones as educational and productive community spaces.
5.	Socio-Cultural	High street vendor activity; no permanent pedestrian paths; inadequate drainage and lighting; no waste facilities or tribunes.	Provide an integrated food court; pedestrian paths & jogging track; new drainage and lighting; waste bins; multifunctional spectator tribunes for sports and public events.

as planter benches, amphitheater seating, and plant nursery zones with local premium products suitable for Andosol soil characteristics and flood resistance. The paving materials (porous paving, grass blocks) and furnishings (porous concrete) use permeable materials to reduce flood and inundation situations. The blue-green open spaces are connected to the plazas and pedestrian corridors through biopores, and infiltration wells are provided in the grassy areas to increase the infiltration capacity.

Modular Components as Blue-Green Technology and Educational Media

This paper proposes six cohesive modular landscape models for a floodable park based on urban agriculture to address flooding concerns and improve the utilization of urban green space. Each module is built as an integrated green-blue infrastructure system that is flexible, multifunctional, and educative.

Module 1 – Planter Bench: The planter bench combines seating with on-site stormwater infiltration and urban agriculture. The porous concrete seating area absorbs surface water and provides seating for users. The integrated planter may sustain food-producing and water-infiltration-boosting vegetation such as water spinach, tomatoes, and indigenous medicinal plants. The module incorporates both recreational utility and hydrological efficiency, offering a nature-based solution to address both environmental and community concerns. Educational aspects include signage describing infiltration processes, QR codes linking to video material, and labels for plant species identification. Productive plants offer an opportunity to educate about urban food security and urban agriculture.

Module 2 – Amphitheater Tribune Seating: The amphitheater tribune seating is made of permeable concrete and is directly connected to rain gardens and urban agricultural regions. The seating steps are also used as planters for food crops such as water spinach, turmeric, galangal, and tomatoes. It is an example of real-life productive urban agriculture. “This is a module that can be used for teaching, event space. Studies indicate that access to knowledge facilitates successful adoption of climate-smart agriculture in flood-prone areas (Billah et al., 2024).

Module 3 – Rain Garden: Rain Gardens are designed to soak up stormwater and include pathways for people to walk and rest. Vegetation is made up of hydrophilic, pollutant-absorbing plants such as yellow iris (*Iris pseudacorus*) and vetiver (*Chrysopogon zizanioides*). The module connects the amphitheater seats directly to urban agriculture zones, forming an integrated system of stormwater management and ecological benefit. Rain gardens are able to successfully retain inflow volumes, leading to a runoff decrease of 54–98% (Jiang et al., 2017) as evidenced in field tests conducted in bioretention. The rain garden is a live experiment, showing how water can soak into the earth and be organically cleaned. Educational signage describes stormwater management concepts.

Module 4 – Bioswale: The bioswale captures, removes, and treatments stormwater runoff prior to infiltration into soil or release to receiving waterways. It employs certain soil mixes and plants, such as yellow iris and vetiver, to minimize pollutants and the water flow rate. Field studies reported that bioswales can reduce runoff volume from 77.6% to 98.3% (Jiang et al., 2017) and are an important component of a stormwater management

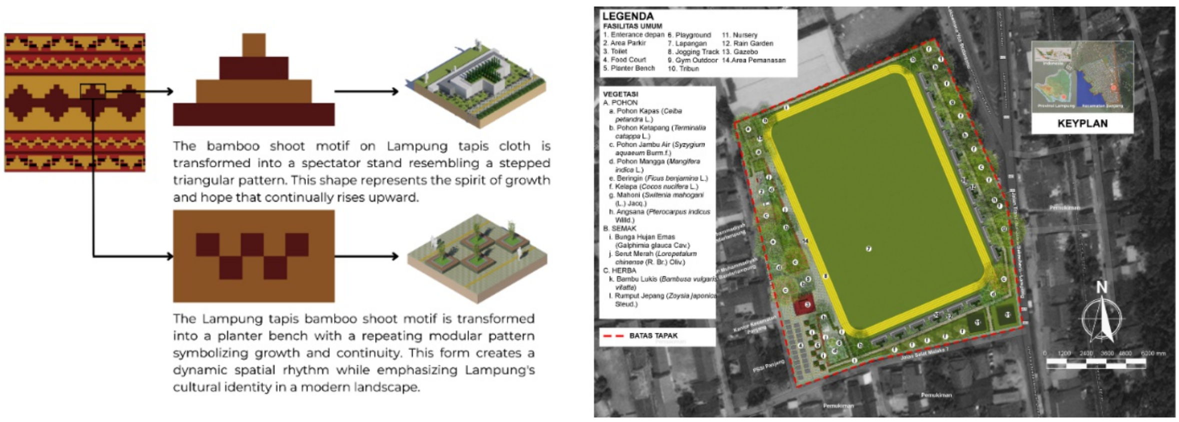

Figure 10. Design transformation concept: translating tapis batik lampung motifs into floodable park modules (no scale) (right) and site plan of the urban agriculture-based floodable park (case study: barunaria field, panjang district, bandar lampung city) (left).

system. Educational signs explain how plants absorb contaminants and how water is naturally purified. Bioswales are linear in form and create a place for tourists to view water moving and being filtered along the channel, an example of how to improve water quality.

Module 5 – Pedestrian Path: The pedestrian walkway is constructed using a grass block material which is substantially more permeable than conventional paving material. Biopore holes are also introduced below the passage to boost the infiltration capacity. The path is provided with guiding blocks so that individuals with disabilities can pass (Hutriani et al., 2024). This complies with the concepts contained in the Indonesian Ministry of Public Works and Housing accessibility standards. Ramp slope ratios shall not be greater than 1:12, and the specifications of the guiding block shall comply with universal design standards. It is designed to be inclusive and environmentally sustainable, building micro-habitats for soil organisms and protecting natural water cycles.

Module 6 - Running Track and Field: The running track and field is constructed on rubber surfacing with integrated infiltration well systems. This incorporation allows the facility to function as athletic infrastructure and a stormwater retention/absorption area. Infiltration wells are excellent for water retention and percolation of water into the soil, thereby reducing flooding. This concept blends recreational amenities with adaptive infrastructure for flood control.

Integration of Blue-Green Infrastructure with Community Education

This green-blue network composite provides an infrastructure for stormwater management and a platform for technology-based environmental education. The park is an outdoor school where children and community members can witness and learn about real-time stormwater infiltration, filtration, and retention, making hydrological processes visible and interactive. Community education and engagement are essential for BGI implementation (Saha et al., 2024). The notion of the Barunaria model was proposed by:

a. Methodology of participatory design. Semi-structured interviews provided findings to drive design choices, ensuring the park meets locally recognized requirements and preferences. A participatory method develops ownership, and the community may sustain and perpetuate it.
b. Good hydrological behavior. The park demonstrates the characteristics of the BGI and offers access to stormwater management techniques that are usually hidden in the typical drainage systems. This clarity helps people to comprehend the flood hazard and how to reduce it.
c. Urban farming as a form of integration. People are trained in sustainable food production, climate adaptation, and water resources management, using plants that generate food and demonstration plots. Research has indicated that education can support the uptake of climate-smart agriculture (Billah et al., 2024).
d. Improved Learning Technology. QR codes and digital materials are provided for different audiences to support blended education and learning outside the physical area.

The Model as Adaptive Infrastructure for Mitigation, Education, and Cultural Identity

The proposed floodable park model is superior to traditional flood mitigation and forms an integrated green-blue network in an efficient and pleasing water management system. It incorporates sponge city concepts for enhancing nature's role in urban water management (Li et al., 2020). The system uses an integrated strategy that promotes community education and stormwater management.

Educational and social implications

With visible, interactive BGI, the park becomes a resource for technology-enhanced environmental education. Rain gardens and bioswales in dry and wet seasons are not just a way to learn about the water cycle, infiltration, and sustainable urban drainage, but a way to see how they work. As'ari et al. (2026) stated that integrating technology with nature-based solutions creates more effective disaster education platforms for communities to understand and proactively address flood risks. The seasonal transformation of the park from a recreation and agricultural zone in the dry season to a flood retention system in the rainy season makes for a powerful educational story about climate adaptation and disaster risk reduction. As a monitoring site, BGI was used by Lam and Chu (2026) to show that teaching microclimate and stormwater management based on climate literacy significantly enhances students' understanding of microclimate dynamics and stormwater management and supports the use of living laboratories for formal geography and science curricula.

Integration of local cultural values

The use of Tapis Batik motifs in modular design has social effect potential to promote community empowerment in the care and

(A) Planter bench *(B) Amphitheater tribune seating*

(C) Rain garden *(D) Bioswale*

(E) Pedestrian path with biopores *(F) Running track and field with infiltration wells*

Figure 11. Integrated modular components of the urban agriculture-based floodable park: (a) planter bench, (b) amphitheater tribune seating, (c) rain garden, (d) bioswale, (e) pedestrian path with biopores, (f) running track and field with infiltration wells.

maintenance of parks. The modules can be utilized by varied community organizations to provide a model of shared ownership and ensure long-term sustainability. This strategy integrates ecological function with regional identity (Wahyudi, 2025) and enhances cultural resonance and operating efficiency (Chen et al., 2025). The blending of local cultural history, the inclusion of multicultural values in the technical infrastructure, and the translation of the Lampung tapis batik motifs into the functional landscape characteristics are presented.

Limitations and Future Research

This study has methodological limitations that must be acknowledged. The hydrological effectiveness (62.8% reduction of runoff, retention capacity 1,146 m^3) is calculated using the Rational Method, with runoff coefficients based on known reference values. The estimated values have to be checked in the field by continuous tracking in actual rainfall events. Only microclimate data for 2 days (September 15th and 19th, 2025) were recorded; therefore, only diurnal variation is recorded but not seasonal changes. Porous concrete: The specifications for porous concrete (porosity 19–23%, infiltration rate 0.17–0.42 cm/second) are theoretical assumptions from international literature (Matthew et al., 2024; Krisanti & Triningsih, 2020) and need to be validated with local materials according to SNI or ASTM standards. Water quality testing (BOD, COD, TSS), life-cycle cost analysis, and pedagogical impact

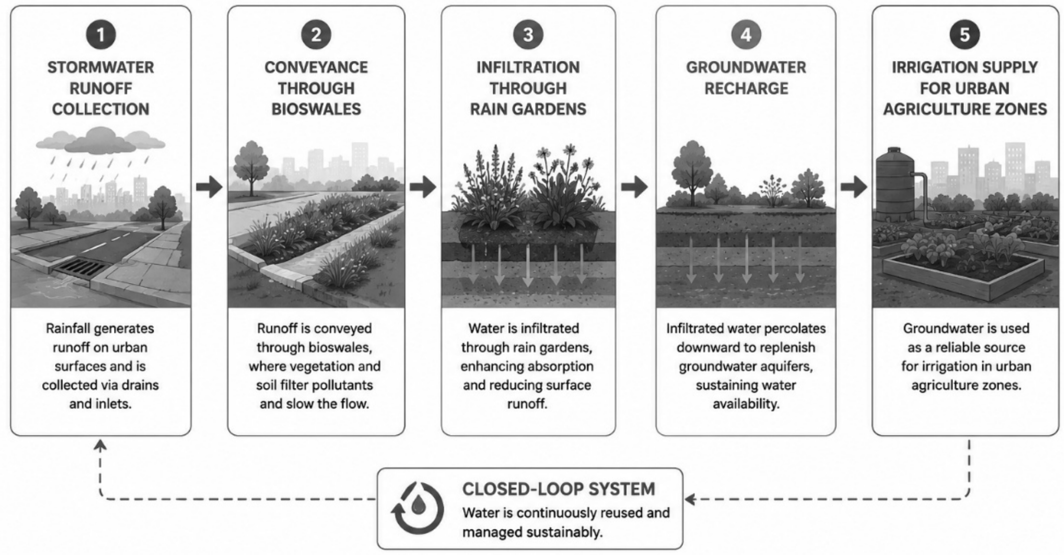

Figure 12. Technical flow diagram illustrating the closed-loop water cycle mechanism: stormwater runoff collection → conveyance through bioswales → infiltration through rain gardens → groundwater recharge → irrigation supply for urban agriculture zones.

assessments were not conducted in this study, as the model was not yet developed. The absence of such data reveals the theoretical nature of this landscape architecture research and suggests important directions for future research.

Future research should focus on (1) the implementation of a pilot project with detailed hydrological monitoring to validate the theoretical runoff reduction and retention capacity during extreme rainfall events; (2) the evaluation of locally-sourced porous materials for compressive strength and infiltration rate to determine the technical viability; (3) the development of participatory community management frameworks with clear operational budgets and maintenance responsibilities; (4) the design and implementation of pre-and post-educational assessments to measure changes in flood risk awareness, environmental knowledge, and the adoption of sustainable methods after the park's construction; and (5) the exploration of the applicability of the modular design framework to other flood-prone urban areas in Indonesia and the Global South, adapting the approach to local biophysical conditions, community needs, and cultural contexts. These priorities range from ecological engineering to community education and local cultural heritage. Future research can improve this conceptual model by validating, scaling, and making it sustainable for implementation.

■ CONCLUSION

In this study, the development of floodable park landscape models for Barunaria Field, Bandar Lampung, by integrating blue-green infrastructure, community education, and local cultural values as an adaptive strategy for urban flood mitigation was well achieved. The site inventory revealed that flood vulnerability at Barunaria Field is due to several interrelated factors: physical, lowland topography (0–12.5 m asl), 80% impermeable surfaces, poor drainage, and acidic Andosol soil (pH 4.5–5.5) with extreme microclimate conditions (temperatures up to 37.7°C, noise levels up to 80.3 dBA); biological, the existing vegetation is not strategically located for flood mitigation; and socio-cultural, limited community understanding of nature-based solutions, unregulated vendor activities, and inadequate social infrastructure collectively impede park development.

The modular design illustrates how blue-green infrastructure can be effectively incorporated with education and local knowledge through six interconnected modules: planter benches, amphitheater seating, rain gardens, bioswales, pedestrian paths, and running tracks, which integrate hydrological functions (infiltration, retention, and filtration) with educational elements. Adapting the Lampung Tapis batik motif 'bamboo shoot' to practical landscape features encourages cultural value. QR codes, signage, and demonstration plots make the park an interactive educational space that tackles the vital deficiency in community understanding.

The quantitative hydrological analysis by the Rational Method ($Q = C \times I \times A$) confirmed the efficiency of the design. The weighted runoff coefficient was reduced from $C\_existing = 0.624$ to $C\_proposed = 0.232$, a reduction of

62.8%. Peak runoff was reduced from 175.2 L/s to 65.1 L/s, a reduction of 110.1 L/s. For the 24-hour 5-year return period event, runoff volume decreased from 631 m^3 to 235 m^3, a decrease of 396 m^3. The integrated rain garden system has a total retention capacity of 1,146 cubic meters, composed of 674 cubic meters from ponding storage and 472 cubic meters from soil storage. This is 82% higher than the 5-year runoff volume of 631 cubic meters and 32% higher than the 10-year runoff volume of 870 cubic meters. The results show that the proposed design is capable of handling the 5-year return period event adequately and has large capacity to handle more severe scenarios. Structured social amenities and universal design features such as 1:12 ramp gradients and guiding blocks are also provided. This turns the site into a dynamic laboratory where communities can see stormwater management in real time, while learning about disaster risk reduction and urban agriculture.

The floodable park doubles as a stormwater retention area during the rainy seasons and a recreational and educational area during dry periods, telling a compelling story of climate adaptation. Hydrological calculations show that the proposed model can reduce surface runoff by more than 60% while maintaining stormwater volumes above the 5-year return period event. This culturally informed, modular framework offers a sustainable approach to flood mitigation that advocates for environmental education and community resilience in the rapidly expanding cities of the Global South. However, validation through field testing and material testing is necessary before implementation.

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