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Ecological Architecture for an Integrated Coffee Production and Tourism Center in Sinjai

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ABSTRACT

Coffee-producing regions often retain limited added value because cultivation, processing, education, product development, and tourism occur in separate locations. This study develops an ecological architecture framework for an integrated Coffee Production and Tourism Center in Sinjai Regency, South Sulawesi. The design-research method combined site observation, comparison of two location alternatives, climate and access analysis, user–activity mapping, spatial programming, precedent review, architectural synthesis, and qualitative evaluation. The result is a 2.5-ha campus comprising a visitor and education building, production building, greenhouse, cafe and restaurant, prayer facility, productive landscape, and connected open spaces. The documented net program totals 2,121 m²: the main visitor building accounts for 51.2%, while production, hospitality, and greenhouse functions represent 19.6%, 19.8%, and 9.4%, respectively. A coffee journey links nursery, cultivation, processing observation, workshops, tasting, and retail, while a separate service route protects hygiene and safety. Ecological strategies include climate-responsive orientation, natural ventilation and daylight, shading, contour-sensitive massing, local materials, rainwater management, wastewater separation, and coffee-residue utilization. The proposal demonstrates a spatial method for connecting agroindustry, visitor learning, community enterprise, and environmental systems. Its operational performance remains subject to simulation, engineering validation, stakeholder testing, and post-occupancy evaluation.

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1. Introduction

Coffee-producing regions can capture more value when cultivation, post-harvest processing, education, product development, hospitality, and tourism are connected rather than dispersed across unrelated locations. Coffee tourism is increasingly understood through consumer behavior, place consumption, and ethical consumption, which means that a destination must communicate not only taste but also origin, labor, landscape, and environmental responsibility [1]. In Indonesia, visits to coffee landscapes can improve familiarity with local brands and stimulate direct purchasing, while community-based tourism can create opportunities for guiding, food services, retail, and small enterprises [2,3]. These benefits are relevant to Sinjai Regency, South Sulawesi, where the design documentation identified coffee production, mountainous scenery, and proximity to established nature-based attractions as a foundation for a regional production-and-tourism facility.

The opportunity is accompanied by a spatial problem. Production buildings require hygienic process flows, loading access, storage, utilities, worker safety, and separation between clean and dirty activities. Visitor environments require orientation, interpretation, accessibility, comfort, memorable sequences, and safe observation points. Agritourism also requires landscape conservation, controlled carrying capacity, waste management, and operational coordination. When these priorities are designed independently, the production area becomes inaccessible, the tourist area becomes detached from agricultural labor, and ecological architecture is reduced to a visual language of natural materials. The central design question is therefore how architecture can make production legible without compromising operations and how environmental systems can become part of the learning experience.

Coffee-tourism research supports an experience-based response [4]. Authenticity contributes to memorable experiences, satisfaction, and revisit intention when visitors encounter credible objects, practices, and social interaction rather than generic thematic decoration [4]. Specialty-coffee experiences are also shaped by baristas, olfactory encounters, social settings, and active explanation [5]. Destination image, novelty seeking, and perceived value influence intention to visit coffee plantations [6], while layout, color, and interior design can attract attention and encourage return visits at coffee destinations [7]. These findings indicate that the visitor route, visual access, material atmosphere, smell, landscape views, and interaction with producers should operate as one experiencescape.

The economic effects of coffee tourism are neither automatic nor evenly distributed. Coffee farming and tourism can be financially complementary, and farmers may support destination development when it improves market access and product recognition [8]. Coffee can generate economic, educational, emotional, research, and experiential value in mountain community-based tourism

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[9]. However, weak zoning, limited infrastructure, absent standard operating procedures, unclear tourism products, and unmanaged hosting responsibilities can burden rural communities [10]. Unequal land relations and commercial priorities can also produce labor exploitation, spatial commodification, and uneven benefit distribution [11]. The proposed center must therefore function as social infrastructure for farmers, students, cooperatives, local enterprises, and visitors, rather than as an isolated tourist enclave.

Environmental risk is equally important. Coffee landscapes support biodiversity and cultural continuity, especially where agroforestry is retained, but tourism growth can increase traffic, land conversion, water consumption, waste, and pressure on slopes and forests [12,13]. Carrying-capacity studies show that visitor numbers, facility management, waste, and ecological sensitivity must be considered together [14]. Local multistrata planting and community conservation knowledge can simultaneously support slope stability, agriculture, and tourism [15]. For Sinjai, this means that the site plan should preserve productive landscape, minimize unnecessary cut and fill, maintain infiltration, and distribute visitors through controlled routes.

This study responds to the intersection through a Coffee Production and Tourism Center on an approximately 2.5-ha site in the Bonto Tengnga–Sinjai Borong corridor. The proposal includes a main visitor and education building, production building, greenhouse, cafe and restaurant, prayer facility, productive landscape, parking, and connected open spaces. The main building uses a coffee-flower transformation as an identity device, while the campus layout follows climatic observations, views, road noise, contour, and functional separation. The study asks: (1) how can production, education, tourism, and commercial functions form a coherent spatial sequence; and (2) how can ecological architecture guide site planning, building form, materials, water, energy, and waste systems? The aim is to develop a traceable design framework, quantify the programmed area, evaluate the relationship between visitor and production flows, and identify the technical verification required before construction. Its novelty lies in treating production flow, visitor learning, and climate water waste cycles as one spatial system rather than as independent programmatic layers.

2. Methods

This study uses an architectural design-research approach in which problem definition, site evidence, spatial programming, iterative synthesis, and critical evaluation form a traceable chain. The evidence base comprises site observations documented during the design study, two-site comparison notes, room schedules, zoning and circulation diagrams, plans, visualizations, material concepts, and utility proposals. These documents were interpreted alongside a focused review of recent studies on coffee tourism, ecological architecture, community governance, and resource management. No new environmental measurements or stakeholder surveys were conducted for this article. Accordingly, observed conditions and calculated program areas are reported as evidence, whereas environmental and socio-economic effects are treated as propositions requiring verification.

The process comprised seven stages. The seven-stage design-research process, including the evidence, analytical variables, and corresponding design outputs, is summarized in Table 1. First, the design problem was formulated from the regional limitations documented in the design brief: dependence on primary coffee products, limited processing and training facilities, weak market exposure, underdeveloped coffee tourism, and the absence of an integrated educational destination. Second, two site alternatives were compared according to access, relationship to coffee landscapes, visual quality, utility availability, environmental character, and development capacity. The selected parcel, approximately 25,000 m², offered road access and service feasibility while retaining views and a landscape setting suitable for agritourism. Because the archived comparison did not contain numerical scores, the selection is reported as a qualitative documentary judgment, not as a quantitatively optimized decision.

Third, the selected site was analyzed for wind, solar exposure, access, noise, views, vegetation, and contour. The documented observations identified airflow from the southeast and west, strong midday-to-afternoon solar exposure, road-related noise at the front edge, and mountain and distant sea views. These findings were used qualitatively to orient masses, place buffers, determine public and service entrances, and define shaded outdoor circulation. The absence of a calibrated weather file, topographic survey, or computational simulation means that these responses remain design hypotheses.

Table 1. Design-research stages and traceable outputs

Stage	Evidence and analytical variables	Design output
Problem definition	Regional coffee value-chain limitations; literature on tourism and ecological design	Integrated brief and research questions
Site selection	Two alternatives; access, utilities, landscape relation, development capacity	Selection of the 2.5-ha Bonto Tengnga–Sinjai Borong site
Site analysis	Wind, sun, road noise, views, vegetation, and contour	Distributed massing, buffers, orientation, and shaded routes
User and activity mapping	Visitors, farmers, workers, staff, students, service users; privacy and hygiene	Graduated zoning and separate visitor/service movement
Spatial programming	Room schedules, capacity, process order, and adjacency	2,121 m² documented net program
Ecological synthesis	Passive comfort, water, waste, materials, and landscape continuity	Integrated ecological architecture framework
Evaluation	Functional, environmental, experiential, and contextual criteria	Strengths, trade-offs, and verification requirements

Note. Environmental and operational outcomes are design hypotheses pending detailed simulation and measurement.

Fourth, users and activities were mapped. User groups included visitors, farmers, production workers, managers, hospitality and operational staff, technicians, students, training participants, worshippers, and general users. Production activities comprised delivery, weighing, sorting, washing and pulping, fermentation, initial drying, roasting, grinding, packaging, quality control, storage, and dispatch.

Visitor activities comprised orientation, gallery learning, nursery observation, landscape walking, processing observation, workshops, sensory experience, tasting, dining, retail, and recreation. Supporting activities included management, staff services, maintenance, prayer, sanitation, security, and utilities.

Fifth, the documented room schedules were recalculated. Net areas were available for four primary groups: the main visitor building, production building, cafe and restaurant, and greenhouse. Spaces without stated areas, including some toilets, were excluded, as were walls, structure, major circulation, parking, and external infrastructure. The calculated total is consequently a net programmed area rather than gross floor area or site coverage. Sixth, adjacency, privacy, hygiene, and operational safety were translated into public, semi-public, semi-private, private, and service zones. A visitor "coffee journey" and a separate production-service route were then connected through controlled visual access.

Table 2. Qualitative evaluation matrix and verification needs

Criterion	Design evidence	Current interpretation	Required verification
Problem definition	Regional coffee value-chain limitations; literature on tourism and ecological design	The layout reduces likely route conflicts and makes production visible without unrestricted public access	Throughput, loading geometry, hygiene zoning, fire safety, and emergency egress
Environmental responsiveness	Orientation, shading, protected openings, contour-sensitive massing, and separated water and residue systems	The strategy provides a plausible passive-first response but does not establish measured performance.	Weather file, topographic survey, thermal, airflow, and daylight simulation, water balance, and life-cycle assessment
Experiential legibility	Sequential journey from nursery and cultivation to processing, workshops, tasting, and retail	The sequence makes the value chain readable and connects sensory experience to production.	Tour-group tests, seasonal operating scenarios, wayfinding, accessibility, and visitor-learning evaluation
Contextual value	Farmer-oriented workshops, local-enterprise spaces, productive landscape, and interpretation of Sinjai coffee	The program can support local participation, but spatial provision alone cannot guarantee equitable benefit.	Stakeholder agreements, governance model, local procurement targets, and benefit-distribution indicators

Note. Interpretations are analytical judgments derived from the available design documents; they are not measured building-performance results.

Seventh, the proposal was evaluated against four criteria: functional integration, environmental responsiveness, experiential legibility, and contextual value. Functional integration assessed conflicts among visitor, production, service, and staff flows. Environmental responsiveness assessed orientation, shade, ventilation, daylight, contour adaptation, water, waste, and materials. Experiential legibility assessed whether the coffee value chain could be understood through movement and views. Contextual value assessed local identity, farmer access, enterprise support, and landscape continuity. The evaluation was qualitative because the available data did not support artificial performance scores. The qualitative evaluation criteria, current interpretations, and technical verification requirements are summarized in Table 2.

3. Findings and Discussion

3.1 Site organization and spatial program

The selected site creates a useful intermediate condition: it is accessible enough for visitors, deliveries, workers, and utility connections but remains related to coffee cultivation and mountain scenery. Public arrival and parking are placed toward the road edge, where buildings and vegetation can buffer traffic noise. Quieter learning and landscape functions extend deeper into the site. The production building retains an independent service connection so that agricultural delivery and product dispatch do not cross the principal visitor entrance. Buildings are distributed as a campus rather than consolidated into a large block, reducing perceived scale and creating a sequence of outdoor rooms.

Figure 1. Proposed masterplan showing the main visitor building, production, greenhouse, hospitality, prayer facility, parking, pedestrian routes, and productive landscape. Source: author's design, 2026.

Plan key: A, bus entrance; B, motorcycle entrance and exit; C, car entrance and exit; D, bus exit; E–G, car, motorcycle, and bus parking; H, drop-off; I, accessible parking; J, service and staff parking; K, coffee plantation; L, main building; M, cafe and restaurant; N, prayer facility; O, greenhouse; P, production building; Q, waste-management area; R, coffee-drying area; S, amphitheater; T, bicycle track; U, glamping area.

The masterplan in Figure 1 organizes the main visitor building as an orientation landmark, with the greenhouse, production building, cafe and restaurant, prayer facility, landscape paths, and coffee-growing areas forming a connected educational circuit. The distributed low-rise masses allow views and airflow between buildings, but they also increase the length of covered paths, utility lines, roofs, and external walls. The environmental value of dispersed massing therefore depends on durable detailing, continuous weather protection, accessible gradients, and efficient service distribution.

The documented net program totals 2,121 m². The distribution of the documented net program among the four principal functional groups is summarized in Table 3. The main visitor building contains 1,085 m² (51.2%), the cafe and restaurant 420 m² (19.8%), the production building 416 m² (19.6%), and the greenhouse 200 m² (9.4%). The distribution confirms that the proposal is primarily an education-and-

experience institution supported by production, rather than a processing plant with a small visitor annex. The ratio is appropriate only if galleries, workshops, discussion rooms, and product-development spaces are routinely accessible to farmers, students, cooperatives, and micro-enterprises. Otherwise, visitor-oriented activities could dominate the institution without strengthening the local coffee value chain.

Table 3. Documented net program distribution

Functional group	Net area (m²)	Share (%)	Primary role
Main visitor building	1,085	51.2	Orientation, galleries, workshops, product experience, management, and retail
Cafe and restaurant	420	19.8	Tasting, dining, social activity, and commercial support
Production building	416	19.6	Receiving, processing, roasting, grinding, packing, and storage
Greenhouse	200	9.4	Nursery, cultivation education, seedling storage, and solar drying
Total documented program	2,121	100.0	Net scheduled functions before grossing allowances

Note. Areas were recalculated from the source room schedules. The total excludes unstated toilet areas, major circulation, walls, structure, parking, and most external infrastructure.

The greenhouse acts as a hinge between productive landscape and industrial transformation. It accommodates nursery education, seedling storage, and solar drying, allowing the visitor sequence to begin with plant life rather than packaged coffee. This reinforces authenticity because cultivation, seasonal variation, and ecological dependency become visible. The room schedule accommodates approximately 20 learners in the nursery-education area, while galleries and discussion rooms generally serve groups of 15–30. These capacities support guided tours, but peak-day operation should test school groups, weekend visitors, buses, delivery windows, prayer periods, and emergency evacuation. Timed tours and alternative short and long routes can reduce congestion. Experience-based training is particularly relevant because structured coffee-tourism learning can strengthen entrepreneurial competency among prospective coffee entrepreneurs [16].

The main visitor building develops a vertical sequence. The first floor introduces coffee history, varieties, products, and discussion. The second floor supports workshops and participatory product development. The third floor contains experience-oriented spaces associated with coffee-derived products. This progression can broaden value addition, but specialized spa, salon, and treatment functions should be retained only where product safety, demand, staffing, and local enterprise participation are demonstrated. Flexible rooms would allow the institution to adapt to training, exhibitions, sensory evaluation, culinary workshops, and business incubation without committing excessive area to unverified uses.

3.2 Coffee journey, zoning, and institutional operation

The circulation strategy is the proposal's central integrative device. Visitors move from arrival and orientation to history and varieties, nursery and cultivation, controlled processing observation, workshops and sensory learning, and finally tasting, retail, and landscape relaxation. Materials move from farm delivery to receiving, wet and dry processing, roasting, grinding, packaging, storage, and dispatch. The two routes remain physically separated but intersect visually through glazing, protected viewing points, interpretive windows, or elevated walkways. This arrangement avoids two opposite failures: unsafe public access to production and a tourist route that hides agricultural labor. The relationship between the visitor-learning route and the production-service route is illustrated in Figure 2.

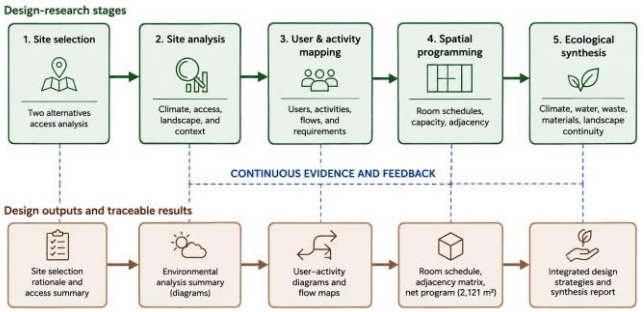

Figure 2. Parallel visitor-learning and production-service sequences with controlled visual connections. Source: author's analysis, 2026.

The sequence is consistent with research that identifies origin narratives, producer interaction, sensory engagement, and reflection as mechanisms of value co-creation in specialty-coffee tourism [17]. It also supports the multiple values economic, educational, emotional, research, and experiential found in community-based coffee tourism [9]. The route should therefore explain not only the technical process but also farm ecology, labor, quality control, price formation, waste, water, and local culture. Gallery content should be developed with growers and processors as knowledge holders, not solely by tourism operators.

Zoning provides graduated access. Arrival, galleries, retail, dining, outdoor seating, and landscape areas form the public layer. Workshops, discussion rooms, demonstration areas, and selected greenhouse spaces are semi-public and can be supervised or scheduled. Production preparation, staff support, and nursery storage are semi-private. Roasting, grinding, packaging, finished-product storage, utilities, and service yards are private. This hierarchy permits parts of the campus to operate independently, reducing staffing and conditioning requirements outside full tour hours.

Governance is inseparable from this spatial model. Participatory management in agricultural tourism assigns complementary roles to government, private operators, farmer groups, and communities [18]. Social-innovation research also shows that local networks and intermediary organizations are needed to sustain cooperation and create spaces for experimentation. Long-term knowledge transfer and cooperative governance can enable locally controlled training centers, brands, and tourism routes [19]. In Sinjai, workshop schedules, equipment access, procurement, retail allocation, guide training, and revenue distribution should be formalized before operation. The architecture can enable participation, but it cannot substitute for transparent institutional arrangements.

The spatial narrative also supports destination development. Coffee-tourism value chains benefit from thematic routes, professional service, digital communication, and coordinated promotion, whereas fragmented stakeholders limit shared value [20]. Forest-coffee initiatives in Indonesia similarly show that community engagement and destination identity can strengthen marketing. The Sinjai center can become a gateway to surrounding plantations and nature destinations rather than concentrating all activity within its boundary. Such a networked model distributes visitor spending and reduces pressure on a single site.

The interpretive program should also be specific to Sinjai. Generic coffee graphics or imported specialty-coffee language would weaken the relationship between the center and its productive territory. Exhibitions should identify local growing conditions, farming calendars, varieties, processing choices, family enterprises, and the social history of coffee in the regency. Farmers and processors should participate as narrators, demonstrators, and curators. This approach is consistent with Indonesian coffee-education initiatives that connect youth participation, local economic development, and learning facilities [21]. It also responds to research showing that coffee-agritourism development depends on economic, environmental, and supporting conditions rather than attraction design alone [22].

The architectural language can reinforce this specificity without turning culture into surface ornament. The coffee-flower transformation, views toward cultivation, tactile materials, open work areas, aroma, and shaded landscape movement form a coherent identity when they explain the value chain. The center should avoid staging agricultural work solely for photographs. Observation windows should reveal genuine activities at scheduled times, while interpretive media should explain periods when fermentation, drying, or roasting are not operating. Seasonal programming harvest demonstrations, cupping, pruning education, seedling distribution, product fairs, and farmer-led talks can keep the visitor experience credible throughout the year. The proposed exterior architectural expression of the principal campus facilities is presented in Figure 3.

Figure 3. Exterior design visualizations: (A) visitor and education building; (B) greenhouse; (C) cafe and restaurant; and (D) prayer facility. Source: author's design, 2026.

Commercial functions should be positioned as the conclusion of learning rather than the beginning of the route. The cafe can translate processing and sensory information into tasting choices; retail can show farm origin, processing method, producer identity, and price components; workshops can connect by-products to verified products. This sequence encourages informed purchasing instead of passive consumption. It also creates multiple levels of participation: casual visitors may use the landscape and cafe, guided groups may follow the full journey, and farmers or students may attend dedicated training independently of tourist operations.

Representative interior environments supporting visitor learning, hospitality, cultivation education, and worship are shown in Figure 4.

Figure 4. Interior design visualizations: (A) visitor gallery; (B) cafe and restaurant; (C) greenhouse learning space; and (D) prayer room. Source: author's design, 2026.

The prayer facility strengthens contextual completeness and should be linked to both public and staff routes. Water-efficient ablution, shade, natural airflow, and a quiet landscape edge can connect religious practice with responsible resource use. Its placement should avoid forcing workers or visitors to cross service yards, while its capacity should be tested against peak occupancy. In this way, social infrastructure is integrated with the campus rather than treated as an isolated accessory.

3.3 Climate, landscape, materials, water, and waste

The ecological framework combines passive climatic design, landscape continuity, material differentiation, water management, and coffee-waste handling. The site observations support orientation and openings that respond to southeast and western airflow, while deep overhangs, shaded corridors, vegetation, and facade protection address strong solar exposure and heavy rain. High roofs, voids, large protected openings, and semi-open transition spaces promote cross-ventilation and daylight in public areas. Mechanical cooling remains appropriate for spaces where humidity, process control, security, or occupancy make passive operation insufficient.

The integration of climate-responsive design, landscape continuity, material selection, water management, and coffee-residue handling is summarized in Figure 5.

A recent tropical-design study identifies cross-ventilation, shading, local materials, and renewable systems as key components of climate-responsive architecture [23]. The comparison is useful, but the reported performance of another building type should not be transferred directly to the Sinjai proposal. Building depth, orientation, internal heat gains, occupancy, roof construction, and local microclimate must be simulated. The current design should

therefore claim climatic responsiveness, not verified energy savings.

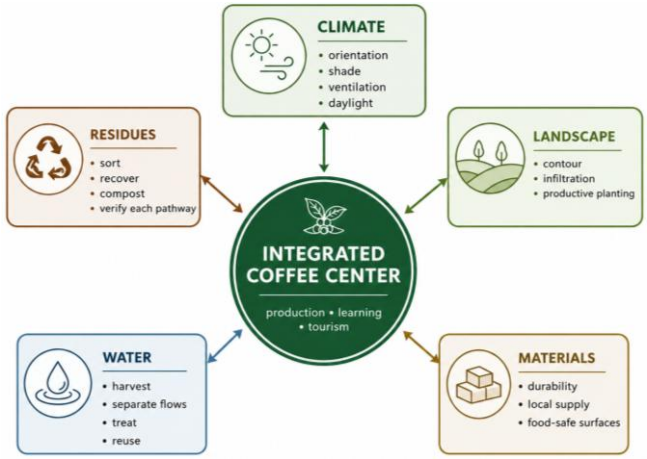

Figure 5. Ecological architecture framework linking climate, landscape, materials, water, and coffee-residue management. Source: author's analysis, 2026.

Distributed massing improves access to light and air, but increases exposure to wind-driven rain, insects, dust, and maintenance. Covered pedestrian routes must be continuous, non-slip, sufficiently wide, and designed with resting points. Accessibility across contours and the three-story visitor building requires ramps or lifts, tactile guidance, handrails, safe gradients, and sheltered transfer points. A stair-only concept would not meet the needs of older visitors, children, or people with mobility limitations. Inclusive circulation should be resolved together with the experiential route rather than added after form development.

The coffee-flower geometry gives the main building a recognizable identity and creates multiple perimeter exposures for daylight, ventilation, and views. Symbolic form is convincing only where it improves orientation and environmental performance. Radial geometry can create difficult roof valleys, structural junctions, residual spaces, and confusing sectors. Material, landscape, program, and sight lines should differentiate the "petals," while roof drainage must be tested for high rainfall. Pasiori et al. [24] similarly argue that nature-derived form and local materials can strengthen landscape integration. In Sinjai, this precedent supports the landscape relationship but does not justify form without functional and technical resolution.

Material selection is deliberately differentiated. Bamboo and timber provide renewable-material potential, warmth, and tactile identity in protected public and semi-open areas. Local stone can provide durable ground-contact and landscape surfaces. Reinforced concrete remains appropriate where soil conditions, lateral stability, hygiene, fire resistance, or process loads require it. Production and kitchen spaces need washable, non-absorbent, food-safe finishes rather than indiscriminate use of porous "natural" materials. A comparable ecological-architecture study coordinates climate, green space, alternative energy, and material strategy rather than treating them as separate decorative features [25].

"Local" and "natural" are not automatic measures of sustainability. Responsible sourcing, treatment chemicals, structural grading, moisture protection, biological durability, replacement cycles, and maintenance access must be specified. Bamboo and timber should be protected from direct wetting, separated from soil, ventilated, inspectable, and replaceable by component. The proposed foundation system also remains unresolved: the design documentation discusses both bore piles and foot-plate foundations. A geotechnical investigation, slope-stability assessment, and structural design are required before selecting either system.

Water is a central design opportunity because the design documentation describes substantial rainfall and proposes rainwater harvesting, open drainage, infiltration, biopores, and planted retention areas. Rainwater can support irrigation, cleaning, and other non-potable uses after appropriate treatment. However, rainwater, domestic greywater, blackwater, kitchen wastewater, and coffee-process wastewater must be separated at source. Wet coffee processing can produce high organic loads and should not enter a domestic septic or greywater system. A quantified water balance should establish demand, catchment area, tank volume, treatment capacity, seasonal overflow, erosion control, and reuse.

Coffee residues also require differentiated handling. Pulp, husk, parchment, spent grounds, food waste, and landscape trimmings have different moisture, contamination, and reuse characteristics. Possible pathways include compost, soil amendment, fuel, craft products, or experimental materials, but each requires operating protocols and quality control. System-level assessment of a coffee-growing agritourism setting indicates that sewage recycling can improve ecological-economic performance when treatment is optimized rather than appended as a symbolic feature. Coffee-processing energy recovery can also reduce impacts, but process-specific design and life-cycle assessment are required. The masterplan should reserve accessible service space for treatment, sorting, composting trials, maintenance, and future recovery technologies.

3.4 Community value, management, and verification

The proposal's social and environmental value depends on operation after construction. Coffee tourism can increase local product awareness and purchasing, but producers may struggle with capacity, price volatility, and market coordination [3]. Farmer income can improve where tourism, sustainable practice, and recognized cultural landscapes reinforce one another [26]. Conversely, workforce precarity, skill gaps, and fragmented institutions can undermine emerging coffee destinations [27]. The center should therefore measure farmer participation, local procurement, training attendance, enterprise sales, employment quality, and revenue distribution rather than equating visitor numbers with community benefit.

Educational coffee tourism in Indonesia offers opportunities in organic products, zero-waste innovation, branding, and derivative products, but faces climate, technology, intermediary, and market constraints [28]. This supports the proposed combination of production, workshop, gallery, retail, and landscape functions. It also reinforces the need for flexible spaces and partnerships with universities, farmer groups, local government, and enterprises. Competitiveness depends on coffee quality,

cultural meaning, geography, and institutional support, not architecture [29].

Facility management must be planned from the beginning. Agritourism routes can receive positive visitor evaluations while toilets, gazebos, paths, and other facilities deteriorate because maintenance resources are insufficient [30]. The Sinjai campus has extensive roofs, landscape, external circulation, drainage, and natural materials; these elements require clear ownership, inspection cycles, replaceable components, and realistic budgets. Carrying capacity should also be monitored. Visitor limits, timed tours, waste collection, habitat protection, and seasonal closure of sensitive areas may be needed to prevent the productive landscape from becoming merely scenic infrastructure [14].

The project remains a pre-construction hypothesis. Its principal strengths are the parallel visitor and production sequences, the greenhouse as a link between landscape and processing, the quantified program, and the integration of climate, water, materials, and waste into the educational narrative. Its unresolved issues include accurate topography, geotechnical conditions, production throughput, food safety, fire strategy, universal access, thermal and daylight performance, water balance, wastewater characterization, embodied carbon, costs, and governance.

Future development should combine technical and participatory verification. Environmental studies should include hourly climate analysis, shading, computational airflow, daylight autonomy, thermal comfort, energy modeling, water balance, and life cycle comparison. Operational studies should test loading, production capacity, tour group size, kitchen and processing hygiene, staffing, maintenance, and emergency movement. Stakeholder workshops should involve farmers, cooperatives, processors, tourism operators, educators, local government, people with disabilities, and nearby residents. If constructed, post-occupancy evaluation should monitor temperature, humidity, air speed, energy, water, wastewater quality, waste diversion, production throughput, route conflicts, visitor learning, satisfaction, farmer participation, and local enterprise outcomes. Multidimensional monitoring is necessary because ecological, economic, social, energy, legal, and institutional performance can develop unevenly [31].

4. Conclusion

The study develops a design framework for an integrated Coffee Production and Tourism Center on a 2.5-ha site in Sinjai Regency. The framework responds to fragmented production, limited training infrastructure, weak product diversification, and underdeveloped coffee tourism by organizing cultivation, processing, education, hospitality, retail, and landscape as a coherent coffee journey. A separate production-service route protects hygiene and operational safety, while controlled visual connections allow agricultural and industrial work to become educational content.

The documented net program totals 2,121 m². The main visitor building represents 51.2%, the cafe and restaurant 19.8%, the production building 19.6%, and the greenhouse 9.4%. This distribution creates a strong educational emphasis but requires governance that guarantees access for farmers, students, cooperatives, and local enterprises. The ecological strategy combines climate-responsive orientation, shade, natural ventilation and daylight, contour-sensitive massing, differentiated local materials, rainwater management, wastewater separation, productive landscape, and coffee-residue handling.

The proposal's main contribution is methodological: production flow, visitor experience, climatic response, resource cycles, and community value are developed together rather than appended as independent themes. The design does not yet demonstrate measured environmental or socio-economic performance. Geotechnical investigation, process engineering, simulation, accessibility and fire review, water and waste design, stakeholder testing, and post-occupancy evaluation are required before benefits can be verified. Subject to this validation, the framework offers a transferable basis for coffee-producing regions seeking value addition while retaining a direct relationship with landscape, climate, and local community.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this manuscript, the authors used OpenAI ChatGPT to assist with language editing, grammatical refinement, organizational consistency, and editorial review. The authors subsequently reviewed and revised all AI-assisted content and take full responsibility for the accuracy, integrity, and final content of the manuscript.

CRediT authorship contribution statement

Fitri Aulia: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing – original draft. **Andi Yusri**: Supervision, Validation, Writing – review & editing. **Citra Amalia Amal**: Supervision, Validation, Writing – review & editing. **Sahabuddin Latif**: Supervision, Validation, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

Data availability

The data supporting the findings of this study consist of architectural design documents, site observations, room schedules, spatial-program calculations, diagrams, plans, and design visualizations generated and compiled during the study. These materials are available from the corresponding author upon reasonable request.

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