Universities as living laboratories for circular economy: curriculum-integrated agroforestry as environmental management in higher education

International Journal of Sustainability in Higher Education

Received 21 January 2026
Revised 5 April 2026
13 July 2026
Accepted 24 July 2026

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Abstract

Purpose – This article aims to examine how curriculum-integrated circular economy (CE) practices can function as an environmental management mechanism within higher education institutions (HEIs). It argues that the academic curriculum, when tightly coupled with operational infrastructure, can serve as a form of institutional "soft governance" that orchestrates circular resource flows across teaching, research and community engagement.

Design/methodology/approach – A qualitative, single embedded case study methodology is used, conceptualised through a living laboratory (LL) framework. The case is the "Passionfruit Commercialization Project" initiative at an Australian branch campus university in Sarawak, Malaysia. Two embedded units of analysis are examined: (1) a faculty-led agroforestry trial plot functioning as an upstream environmental production system, and (2) a formally integrated final-year Business Consulting Project unit involving 30 undergraduate business students organised into six teams. The complete analytical corpus comprised eight technical and operational records, 24 student assessment artefacts contained within six team portfolios and one consolidated practitioner field-note and reflexive-memo record. Deductive thematic analysis aligned the evidence against three theoretical pillars: environmental management in HEIs, living laboratories and CE principles.

Findings – Four principal findings emerge. Firstly, the academic curriculum functioned as environmental management infrastructure, with semester deadlines imposing production discipline on the agroforestry system. Secondly, CE principles were operationalised through a dual-layered approach comprising precision agriculture at the upstream level and entrepreneurial waste valorisation at the downstream level. Thirdly, the HEI acted as an environmental orchestrator, bridging internal academic silos and external stakeholder

International Journal of Sustainability in Higher Education
Emerald Publishing Limited
1467-6370
DOI 10.1108/IJSHE-01-2026-0144

networks. Fourthly, the university extended environmental governance beyond the physical campus by assuming stewardship of a productive rural landscape characterised by biological, agronomic and market uncertainty. Together, these findings illustrate a model of “pedagogical symbiosis” in which the farm needed the students to address its waste and commercialisation challenges, while the students needed the farm’s material resources and operational data to complete authentic assessment tasks.

Research limitations/implications – The single-site case study in a specific tropical agro-ecological context limits direct generalisability. The study did not formally track the continuation of student-developed products or enterprises after the teaching semester; therefore, enterprise persistence is not claimed as an outcome. Future comparative research across disciplinary contexts and regions is recommended, together with six- and twelve-month follow-up studies examining venture continuation, partnership durability and sustained use of secondary biomass streams.

Practical implications – The model is low-cost and replicable: it requires land, inter-faculty administrative coordination and an existing curriculum unit, rather than expensive smart infrastructure. University leaders should view operational assets as pedagogical resources. Policymakers in emerging economies should commission HEIs as managers of productive landscapes, expanding green campus metrics to include “community circularity.”

Social implications – By embedding CE experimentation in curriculum and community partnerships, universities can expand their social role as facilitators of sustainable development and contributors to local innovation ecosystems. The model fosters student agency, sustainability literacy and entrepreneurial capability, while generating socio-economic value for surrounding communities through market testing, value-adding and collaborative production. In emerging economy contexts, such living laboratories can strengthen rural livelihoods, support low-carbon agri-food transitions and widen public participation in environmental problem-solving. The study illustrates how HEIs can act as socially engaged environmental managers rather than purely educational institutions.

Originality/value – The article makes three original contributions: it reframes curriculum as environmental management infrastructure; it extends the LL concept from urban-technocratic settings to rural agroforestry production; and it demonstrates empirically how CE education and campus environmental management can be integrated through student entrepreneurship in an emerging economy context.

Keywords Circular economy, Living laboratory, Higher education institutions, Agroforestry, Entrepreneurship education, Environmental management, Sustainability governance, Sarawak

Paper type Case report

1. Introduction

Higher education institutions (HEIs) increasingly occupy a critical role in global sustainability transitions. Universities manage energy, land, buildings, water, transportation systems and food services, making them comparable to small cities in terms of their environmental footprint (Suster *et al.*, 2025). At the same time, HEIs function as centres of knowledge production, curriculum development and professional training. This dual positioning, as both environmental operators and educational institutions, presents a distinctive opportunity: universities can act not merely as advocates for sustainability, but as operational actors capable of implementing and testing circular innovations in real contexts.

Over the past two decades, “green campus” initiatives have emerged as the dominant mode of institutional environmental management. These typically focus on energy efficiency, carbon reduction, waste management and sustainable procurement (Hebala *et al.*, 2025). Despite their tangible gains, a growing literature notes that many campus sustainability strategies remain technocratic and siloed, operating primarily through estate departments with limited integration into teaching, research or community engagement (Norales, 2025; Ma and You, 2026). This fragmentation constrains the transformative potential of sustainability within HEIs, reducing it to a series of discrete operational fixes rather than systemic institutional change.

Against this backdrop, this article advances the argument that curriculum-integrated circular economy (CE) practices can operate as a concrete mechanism of environmental management in higher education. We conceptualise curriculum not merely as a vehicle for content delivery, but as a form of institutional infrastructure, what this study terms "environmental management infrastructure", capable of structuring how environmental interventions are designed, implemented and evaluated.

1.1 Research aims and contribution

The article pursues two main aims. Firstly, it examines how curriculum-integrated CE practices can function as an environmental management mechanism within HEIs. Secondly, it demonstrates empirically how such practices can be realised through a living laboratory (LL) approach extending beyond the physical campus into surrounding agro-ecological contexts.

Methodologically, a single embedded case study design is adopted, conceptualised through a living-laboratory framework (Serrate-González *et al.*, 2025). The case comprises two embedded components:

(1) a faculty-led agroforestry research plot functioning as an environmental production system; and

(2) a formally integrated entrepreneurship unit through which students undertook downstream value creation and market experimentation.

This initiative is interpreted as a LL for circular resource management in which students, academic staff, industry partners and local communities co-produce environmental and socio-economic outcomes.

The article advances three key conceptual contributions. Firstly, it reframes curriculum as an environmental management infrastructure capable of orchestrating circular practices across teaching, research and engagement. Secondly, it bridges the emerging literatures on campus living laboratories, CE in higher education and participatory sustainability governance. Thirdly, it offers a practice-based model illustrating how HEIs, particularly within emerging economy contexts, can leverage LL approaches to align environmental management with their broader educational mission.

The remainder of the article is structured as follows. Section 2 reviews the relevant literature. Section 3 details the methodology and case context. Section 4 describes the LL in practice. Section 5 presents the findings. Sections 6 and 7 offer discussion and implications, followed by a conclusion in Section 8.

2. Literature review

This review synthesises four interrelated bodies of scholarship: environmental management in HEIs, universities as living laboratories, CE in higher education and curriculum-community integration. It moves from identifying limitations in each strand to articulating the gap that this study addresses.

2.1 Environmental management in higher education institutions

Universities are significant environmental actors whose ecological footprints are comparable to those of small cities. As owners of extensive physical assets, buildings, laboratories and land, HEIs manage complex flows of energy, water and materials (Jia *et al.*, 2026). Historically, environmental management in HEIs has concentrated on operational efficiency through top-down, technocratic interventions led by estates or facilities departments (Hebala *et al.*, 2025). While these strategies have reduced direct environmental impacts, they suffer from weak integration with the university's academic mission.

Research consistently finds that when environmental management is isolated from teaching and research, it fails to influence institutional culture or student behaviour (Alexander *et al.*, 2022). Governance of these initiatives is frequently siloed, treating environmental targets as compliance metrics rather than opportunities for educational innovation (Ma and You, 2026). Recent scholarship accordingly calls for "whole-institution approaches" in which environmental management is not only a facilities function but a pedagogical tool that actively engages students and staff in co-creating sustainability outcomes (Costa *et al.*, 2025; Brinkhurst *et al.*, 2011).

What is conspicuously absent from this literature is an operational model that demonstrates how the academic curriculum itself can serve as an environmental management mechanism, not just a medium for sustainability awareness.

2.2 Universities as living laboratories

The LL concept has emerged as a promising response to the limitations of siloed green campus initiatives. A campus living lab is a user-centred, open-innovation ecosystem in which students, staff and external partners co-create solutions in real-life contexts (Serrate-González *et al.*, 2025; Evans *et al.*, 2015). Unlike traditional research pilots, LLs are embedded in daily university operations, turning the campus itself into a testbed for sustainability transitions.

Empirical studies highlight several advantages. LLs provide authentic experiential learning environments in which students develop problem-solving skills by engaging with complex, unstructured challenges (Lee and Li, 2025). They also foster transdisciplinary collaboration, breaking down departmental silos by bringing together students from engineering, social sciences and business (Trevisan *et al.*, 2026). However, existing studies are heavily skewed towards urban and technological interventions, smart building systems, renewable energy grids, while research on LLs focused on agro-ecological systems or rural environmental management remains sparse (Blakong *et al.*, 2025). This is a significant gap for HEIs situated in agricultural regions, where pressing sustainability challenges concern land use, food security and rural economic development rather than urban infrastructure.

Furthermore, recent work cautions that LLs often remain confined to specific technical domains and face challenges of institutionalisation, scaling and long-term governance (Trevisan *et al.*, 2026). Unlike studies that conceptualise the LL as a site of observation or monitoring (e.g. energy use dashboards), this study positions the LL as a site of active intervention and biological production, a distinction with significant implications for environmental management theory.

2.3 Circular economy in higher education

The CE offers a transformative framework for HEIs, shifting focus from linear "take-make-waste" models to regenerative systems in which resources are kept in use. In the higher education context, CE is typically approached through two distinct avenues: as a subject of theoretical instruction, and as an operational goal for campus waste management (Craveiro *et al.*, 2025).

Operational implementations of CE on campuses often focus on closed-loop recycling, composting organic waste or sustainable procurement (Leal Filho *et al.*, 2025). CE education, meanwhile, focuses on teaching circular design principles and business models (Kruja *et al.*, 2025). A critical disconnect remains, however: students rarely get the opportunity to practise circularity by managing actual material flows. While they may learn about circular business models in class, they lack access to real-world production systems, farms, manufacturing units, where they can test those models by converting waste into viable products (Trevisan *et al.*, 2026).

This gap is particularly acute in entrepreneurship education. While entrepreneurial intentions are widely studied (Ben and Ali, 2025), there are few documented examples of curriculum-integrated projects in which students act as downstream value creators for a university's own environmental production, thereby closing the loop between campus operations and commercialisation. The present study directly addresses this gap.

2.4 Curriculum, community engagement and circular value creation

The integration of community engagement with environmental management constitutes the fourth strand of this review. Service learning and community-engaged scholarship have long been staples of higher education, typically taking the form of student volunteering or consultancy for local non-governmental organisations (NGOs) (Sotelino-Losada *et al.*, 2025). These initiatives are celebrated for their social impact and civic outcomes (Norales, 2025).

However, traditional service learning often treats the community as a passive recipient of aid rather than an active partner in a circular value chain. Recent studies call for more reciprocal models in which universities and communities co-produce value (Djedidi, 2026). In an environmental management context, this means moving beyond one-off interventions to establishing permanent, productive systems, such as community agroforestry or waste-to-wealth enterprises, that generate sustained ecological and economic benefits (Xu and Guo, 2025).

2.5 Synthesis: the research gap

Despite the rich individual literatures on green campuses, living laboratories and CE education, there is a lack of integrated research connecting these domains. Specifically, existing studies rarely examine how curriculum-integrated entrepreneurship projects can act as institutional mechanisms for environmental management by creating downstream value from university-managed production systems. Most LLs remain focused on infrastructure rather than enterprise; most entrepreneurship projects remain theoretical rather than grounded in the physical reality of environmental resources. This study addresses that gap by analysing a faculty-led agroforestry initiative that simultaneously functions as an environmental management site, a CE LL and a real-world platform for student entrepreneurship.

3. Methodology

3.1 Case context: the "passionfruit commercialization project"

The study is situated within an Australian branch campus university operating in Sarawak, Malaysia, a state whose economy is deeply rooted in agriculture and whose government has prioritised agro-entrepreneurship as a regional development strategy. The specific case is the "Passionfruit Commercialization Project" (hereafter, the Project), a university-led agricultural research initiative established in response to a state directive to catalyse food security and agro-entrepreneurship.

The Project comprises two formally connected components. The first is a faculty-managed agroforestry trial plot located in Matang, Sarawak, approximately 20 km from the main campus. The plot cultivates *Passiflora edulis* (passion fruit) across a high-density trellis system supporting 400 vines, using precision irrigation and Internet of Things (IoT) monitoring to manage nutrient delivery and environmental variables. The second component is the Business Consulting Project (BCP), a capstone unit in the university's undergraduate business curriculum. The iteration analysed in this study involved exactly 30 final-year students organised into six teams of five. Within the unit, the agroforestry plot was positioned as the "client", and the student teams functioned as external consultants tasked with developing commercialisation strategies for the farm's outputs.

This dual-component structure, farm as production system, BCP as valorisation mechanism, constitutes the empirical basis for examining how curriculum and environmental management can be integrated within an LL framework.

3.2 Research design

This study adopts a qualitative, single embedded case study design (Yin, 2018). Case study methodology is particularly appropriate for examining contemporary phenomena within their real-life context, especially when the boundaries between the phenomenon (curriculum-integrated CE) and the context (the university and its surrounding community) are not clearly delineated.

The design is characterised as an instrumental single case study (Stake, 1995). The case is instrumental because the primary interest lies not in the specific agricultural site itself but in the broader theoretical issue of how HEIs can operationalise living laboratories for CE transitions. An embedded design (Type 2) is used, allowing analysis of multiple units within a single case:

> Unit 1: Upstream (Production): The faculty-led agroforestry trial plot, which functions as the environmental management site responsible for resource inputs, land stewardship and biomass production.
>
> Unit 2: Downstream (Valorisation): The BCP entrepreneurship unit, which functions as the value-creation mechanism responsible for product development, market testing and circular business modelling.

This embedded structure captures the dynamic interplay between operational environmental management and pedagogical innovation, providing a holistic view of the university as a circular system. As illustrated in Figure 1, the two units are linked by bidirectional flows: agricultural resources flow upstream to downstream, while market feedback from student analyses flows back to inform farm operational planning.

3.3 Data sources and triangulation

Data collection followed a triangulation strategy (Yin, 2018) to strengthen construct validity and analytical credibility. The study examined the complete available corpus generated during the 2024–2025 growing cycle and the 2024 delivery of the BCP unit; no purposive or convenience subsampling was undertaken. The final corpus comprised 33 items: one comprehensive technical project report and seven associated operational records; six complete student team portfolios containing 24 assessed artefacts; and one consolidated chronological practitioner field-note and reflexive-memo record. Materials were included when they were generated directly through the Project and contained evidence relevant to either the upstream production unit or the downstream valorisation unit:

(1) *Technical and operational records:* Eight items were analysed: one comprehensive technical project report and seven associated records covering CAPEX, fertigation schedules, agricultural inputs, pest and disease incidents, harvest volumes, fruit grading and biomass availability and IoT environmental monitoring. These records

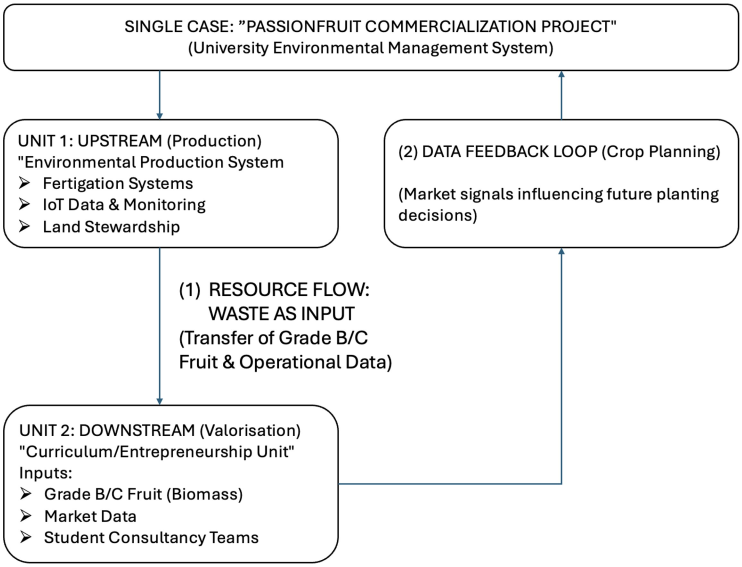

Figure 1. Embedded case study design showing the resource flow from the upstream agroforestry production system to the downstream curriculum-based valorisation unit and the market-data feedback loop informing subsequent crop planning

Source(s): Authors' own elaboration

documented the 2024–2025 growing cycle and provided the principal evidence for resource efficiency, biological constraints and the identification of Grade B/C material streams.

(2) *Student assessment outputs:* The full set of six team portfolios was included, representing all 30 students in the studied cohort. Each portfolio contained four assessed components: a situation analysis report, a business model canvas, a product prototype or service blueprint and a final commercialisation pitch deck. This yielded 24 student assessment artefacts. These materials captured how environmental constraints, biomass quality and supply uncertainty were translated into product, market and commercialisation logic.

(3) *Practitioner field notes and reflexive memos:* The practitioner-researcher maintained one consolidated chronological record covering client briefings, coordination between the Research Office and teaching faculty, site and stakeholder discussions and interpretive reflections. The complete record was included to illuminate governance barriers, enabling conditions and decisions that were not fully visible in the formal project documentation or student submissions. Table 1 summarises the composition, period of coverage and analytical use of the complete data corpus.

To mitigate potential observational bias inherent in a practitioner-researcher role, analytical conclusions were triangulated across all three data sources before being accepted as findings. No single claim rests on field notes alone; each is corroborated by either technical documentation or student outputs. Reflexive memos were maintained throughout the

Table 1. Composition and analytical coverage of the complete data corpus

Data source	Number analysed	Period	Contents and analytical use
Technical and operational records	Eight items	2024–2025 growing cycle	One comprehensive report plus Seven records covering CAPEX, fertigation, inputs, pest/disease incidents, harvest, fruit grading/biomass and IoT monitoring; used to analyse resource efficiency, production constraints and waste-stream formation
Student team portfolios	6 portfolios; 24 artefacts	2024 BCP delivery	Complete submissions from 30 students in Six teams: situation analyses, business model canvases, prototypes/service blueprints and pitch decks; used to examine waste valorisation, market logic and circular business-model development
Practitioner field-note and reflexive-memo record	1 consolidated chronological record	Project and BCP implementation period	Briefings, coordination activities, stakeholder discussions and reflexive notes; used to analyse governance, orchestration and the practitioner-researcher position
Total analytical corpus	33 items	2024–2025	Complete available corpus; no subset was selected for analysis

Source(s): Authors' compilation

analysis process to monitor the influence of the author's institutional position on interpretive decisions.

3.4 Data analysis

Data analysis was conducted using a deductive thematic analysis approach (Braun and Clarke, 2006). The coding process was structured around the study's three theoretical pillars:

(1) Environmental Management Functions: Technical reports were coded for evidence of resource efficiency, land stewardship, pest management and circular resource flows at the production level.

(2) CE Principles: Student outputs were coded against CE criteria, specifically targeting instances in which upstream "waste" (Grade B and Grade C fruit) was re-valued by the downstream entrepreneurship unit.

(3) Living Laboratory Characteristics: Governance documents and field notes were coded for mechanisms of co-creation, transdisciplinary engagement and stakeholder orchestration.

The analysis proceeded in two stages. In the first cycle, the materials were coded deductively against the three theoretical pillars. In the second cycle, related codes were compared across the two embedded units and consolidated into four higher-order themes. Codes concerning assessment deadlines, harvest categorisation and standardised data handover formed the theme "curriculum as environmental management infrastructure". Codes relating to fertigation efficiency, Grade B/C biomass and product transformation formed "dual-layered CE operationalisation". Cross-faculty coordination, SME participation and external evaluation formed "the HEI as environmental orchestrator," while off-campus land stewardship, biological uncertainty and community demonstration formed "governing productive landscapes”. Only patterns supported by at least two independent data types were elevated to final themes. The coding was conducted by the practitioner-researcher; reflexive memos and source triangulation were used to mitigate positional bias, while future multi-coder research would strengthen inter-coder reliability. Table 2 summarises the progression from the deductive first-cycle codes to the four higher-order analytical themes and identifies the principal supporting data sources.

3.5 The business consulting project: curriculum and assessment structure

Given that the BCP unit is central to the study’s argument, functioning as the mechanism through which the curriculum acts as environmental management infrastructure, greater transparency about its academic structure is warranted.

The BCP is a 15-credit capstone unit offered in the final semester of the Bachelor of Business programme. The studied iteration comprised 30 final-year students organised into six teams of five, and all six teams were included in the analysis. Students worked on a real client brief over the teaching semester. The agroforestry plot served as the client, with the farm manager, a member of the research faculty, providing harvest data, fruit-quality grading information, waste-stream estimates and logistical constraints at the semester outset.

Learning outcomes for the unit include:

- conducting a market analysis for an identified product opportunity;
- developing a financially viable business model canvas;
- constructing a go-to-market strategy; and
- reflecting on the CE dimensions of the proposed enterprise.

Assessment is divided into four components: a situation analysis report (20%), a business model canvas submission (20%), a product prototype or service blueprint (30%) and a final commercialisation pitch to an industry panel (30%). The inclusion of an industry panel, comprising representatives from the local business associations, local food and sustainability

Table 2. Development of deductive codes into higher-order analytical themes

Theoretical domain	Illustrative first-cycle codes	Higher-order theme	Principal supporting sources
Environmental management functions	Harvest standardisation; semester deadlines; yield categorisation; production planning	Curriculum as environmental management infrastructure	Technical records; student outputs; field notes
Circular economy principles	Water/nutrient efficiency; grade B/C fruit; secondary processing; biomass recovery	Dual-layered CE operationalisation	Technical records; prototypes; business models
Living laboratory characteristics	Cross-faculty coordination; client handover; SME participation; external evaluation	HEI as environmental orchestrator	Field notes; student outputs; showcase records
Environmental governance and place	Off-campus stewardship; pest pressure; crop uncertainty; community demonstration	Governing productive landscapes	Technical records; field notes

Source(s): Authors’ compilation

sectors, ensures that evaluation integrates external professional judgement alongside academic criteria.

Importantly, the rubric balances process learning with commercial rigour. Teams are not penalised for harvest variability or crop failure; rather, their ability to adapt their business model to real-world constraints, fluctuating yields, grading uncertainty, supply chain disruption, is assessed under the "strategic resilience" criterion. This operationalises the concept of "Authentic Entrepreneurship Pedagogy", in which uncertainty and material constraints are treated as learning mechanisms rather than obstacles.

4. Case description: the living laboratory in practice

This section presents a descriptive account of the Project, conceptualised as an active LL. It details the physical infrastructure of the agroforestry plot, the integration of the BCP unit, the application of CE principles and the community-market interface.

4.1 Upstream: the agroforestry trial plot as production system

The core infrastructure of the LL is a faculty-managed agroforestry research trial plot located in Matang, Sarawak, approximately 20 km from the university's main campus. Established in response to a state directive to catalyse food security and agro-entrepreneurship, the plot serves as a pilot for a larger agricultural initiative in the Gedong district. The site focuses on the cultivation of *Passiflora edulis* (passion fruit), selected for its high market value and suitability to the local tropical climate (Nor *et al.*, 2022).

The plot is designed as a controlled production system rather than a conventional open field. It uses a high-density trellis system supporting 400 vines, constructed from galvanised iron to withstand tropical weathering. To overcome the environmental constraints of the region, specifically poor peatland soil quality and high pest prevalence, the vines are planted in polybags using coco peat as a sterile growing medium rather than directly in the ground.

Resource inputs are managed through an automated fertigation system that delivers a precise mixture of water and nutrients (including NPK Blue Special and Calcium Nitrate) directly to the root zone via a timer-controlled drip network. This system constitutes the technological layer of the LL, enabling rigorous monitoring of resource efficiency. An IoT smart agriculture system continuously logs environmental variables including temperature, humidity and soil moisture. Together, these interventions transform the plot from a simple farm into a data-rich environment suitable for academic analysis and student engagement. Unlike traditional campus greening initiatives that are often passive or ornamental, this site represents an active production system managed by the university.

The site faces significant environmental management challenges typical of the humid tropics. Persistent threats include fruit flies (*Bactrocera* spp.), fungal diseases (*Phytophthora*) and physical damage from snails. Managing these biological constraints requires constant intervention, providing an authentic "problem context" for students to engage with the complexities of agricultural production.

4.2 Downstream: the business consulting project as valorisation mechanism

Bridging the physical farm and the classroom is the BCP unit, whose structure was described in Section 3.5. In this model, the agroforestry plot acts as the client and final-year undergraduate students serve as consultants. Unlike traditional case studies that rely on hypothetical scenarios, students engage with live data from actual harvest cycles. They analyse supply and demand dynamics, evaluate logistics of distribution and develop commercialisation strategies for the crop, all under conditions of genuine supply-chain uncertainty.

The formal link between the BCP unit and the trial plot is established at the semester outset through a structured briefing session in which the farm manager presents harvest data, grading statistics and current waste streams to student teams. This briefing constitutes the “client handover” in the consulting framing and directly connects academic assessment to operational environmental management. As illustrated in Figure 2, this integration means the curriculum intercepts the farm’s Grade B and Grade C waste stream before it reaches disposal.

4.3 Circular economy logic: from waste to value

The LL operates on a CE logic that seeks to maximise resource efficiency and eliminate waste across both upstream and downstream levels. At the production level, the fertigation system reduces water and fertiliser runoff compared to conventional broadcasting methods, reflecting the CE principle of resource efficiency. The most distinct application of circularity, however, occurs at the post-harvest, downstream level.

A major challenge identified in the technical report is fruit quality variability. While Grade A fruit can be sold directly to the fresh market, the farm produces a significant volume of Grade B and Grade C fruit, undersized or cosmetically blemished but nutritionally sound, that would typically be discarded as waste. Student projects were explicitly tasked with “designing out” this waste by converting it into value-added products.

Through this curriculum-driven mechanism, student teams developed multiple innovation pathways. Food processing innovations included passion fruit jams, syrups and dried fruit snacks. Some groups extended this circular logic to the cultural context, partnering with a local brewer to produce *tuak* (a traditional Bornean rice wine) infused with passion

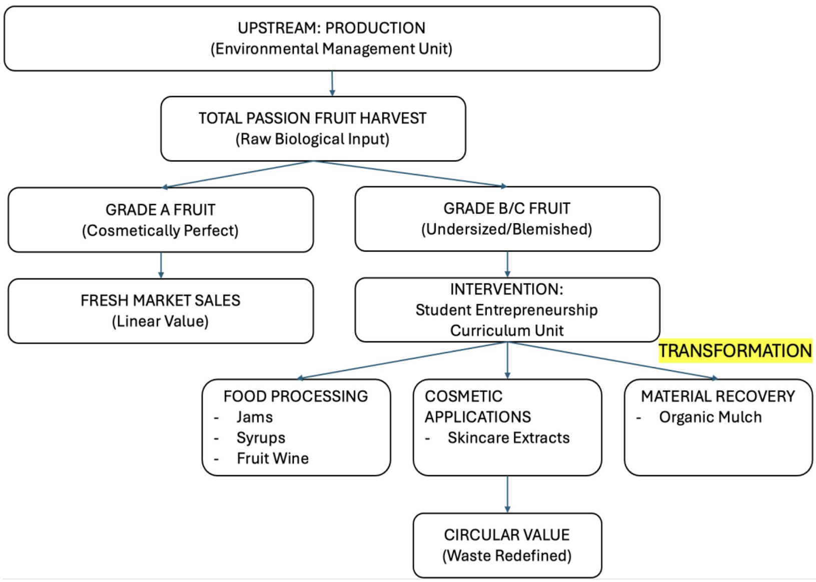

Figure 2. Material flow analysis showing how Grade B and Grade C passion fruit is diverted from disposal and transformed into food-processing, cosmetic and material-recovery pathways through the Business Consulting Project

Source(s): Authors’ own elaboration

fruit (Swinburne University of Technology Sarawak, 2024). Cosmetic applications involved extracting bioactive compounds from fruit skins for skincare prototypes. In addition, students developed material recovery proposals for using dried vines and husks as organic mulch for the next planting cycle, extending circular logic to the agricultural infrastructure itself.

4.4 Community and market interface

The final dimension of the LL is its interface with the broader community and market. A formal "commercialisation showcase" was conducted at semester end, in which student teams pitched their circular products to an industry panel comprising representatives from the Sarawak E-Commerce Association and leaders from local food and sustainability sectors (Swinburne University of Technology Sarawak, 2024). This event served two functions: firstly, it provided an external market validation loop for student-developed CE products; secondly, it demonstrated the university's role as an innovation broker to the local business community.

By sourcing raw materials exclusively from the university's trial plot and partnering with local SMEs, including Beez Gelato and Bad Cat Borneo, for processing, the students built a micro-supply chain that connected the university's environmental management system to local economic actors. This proved that the farm's outputs could support not just ecological goals but also local economic development, fulfilling the Project's original mandate of catalysing agro-entrepreneurship in the region.

5. Findings

5.1 Curriculum as environmental management infrastructure

The first major finding is that the academic curriculum functioned effectively as institutional infrastructure for environmental management. In conventional campus sustainability models, operations management is distinct from the academic calendar. In this case, however, the BCP unit provided the temporal and structural framework necessary to manage the agricultural outputs of the LL.

The rigid timelines of the academic semester imposed a "production discipline" on the agroforestry project. The requirement for students to deliver commercialisation strategies by semester end compelled the project team to standardise harvest data and categorise yields rigorously (Grade A versus Grade B/C). Rather than treating harvest variability as an operational failure, the curriculum transformed it into a pedagogical asset, a case study in supply chain resilience. This represents a direct inversion of the conventional relationship: instead of the campus sustainability office defining what counts as "waste", the academic assessment criteria did.

Students operated not as passive observers but as active operational actors. Their coursework required calculating break-even points for different processing methods, converting fresh fruit to puree versus dried skins, for instance. This data was not hypothetical; it directly informed the university's decision-making regarding the trial plot's future direction. Student analysis of demand for processed skincare ingredients, for example, suggested that future planting cycles could prioritise biomass volume over cosmetic fruit perfection. The curriculum thereby provided a feedback mechanism that is routinely absent in technocratic "green campus" initiatives (Hebala *et al.*, 2025), where user behaviour rarely influences infrastructure planning.

5.2 Operationalising circular economy principles through entrepreneurship

The second finding is that the LL successfully operationalised CE principles through a dual-layered approach: technological efficiency at the upstream level and entrepreneurial waste valorisation at the downstream level.

At the upstream (production) level, CE logic was embedded in the precision agriculture infrastructure. The timer-controlled fertigation system reduced nutrient leaching and water wastage relative to conventional broadcast irrigation, directly applying the CE principle of designing out waste from the production process. The IoT monitoring layer generated temperature, humidity and soil-moisture records that were supplied alongside harvest and grading information. These data helped teams treat supply as variable rather than fixed and encouraged business models centred on processed, shelf-stable outputs instead of relying exclusively on immediate fresh-fruit sales.

The most significant CE finding, however, lies in the closing of the loop for biological nutrients at the downstream level. A persistent challenge in the trial plot was the generation of cosmetically imperfect Grade B/C fruit due to pest pressures from *Bactrocera* spp. In a linear model, this biomass would be disposed of. The student projects re-categorised it as raw input for secondary value chains. Analysis of student outputs reveals multiple innovation pathways: food processing (jams, syrups, dried snacks), cultural-heritage products (*tuak* infusions), cosmetic extracts and organic agricultural mulch. Entrepreneurship education thus acted as the catalyst for circularity: without the market-driven motivation provided by the BCP assessment, the environmental management response would likely have been simple composting or disposal. The curriculum converted a waste management problem into a product development opportunity.

5.3 The HEI as environmental orchestrator

The third finding redefines the role of the HEI from a simple educational provider to an environmental orchestrator. The data indicate that the university functioned as the central node in a network of diverse stakeholders, absorbing risks associated with sustainability transitions while distributing benefits across the network.

As illustrated in Figure 3, the orchestration occurred across two dimensions. Internally, the Project forced collaboration between the Research Office, managing agronomic risks such as crop failure and pest control, and the Teaching Faculty, managing academic risks related to assessment validity and pedagogical quality. These are departments that typically operate independently (Ma and You, 2026). The BCP briefing process, the semester-aligned data handover and the shared commercialisation showcase created structural interdependencies that dissolved the conventional academic silo.

Externally, the university connected the Research Faculty with local SMEs, such as Beez Gelato and Bad Cat Borneo, who provided processing capacity in exchange for a steady, de-risked supply of raw passion fruit material. The network also extended to the rural community: farmers in Gedong used the trial plot as a demonstration model for assessing the viability of adopting the crop in their own operations. This supports the concept of the university as an "innovation broker" (Serrate-González *et al.*, 2025) capable of de-risking circular business models for the local economy.

5.4 Beyond the physical campus: governing productive landscapes

The fourth finding challenges the traditional boundaries of "green campus" management. Most campus sustainability literature focuses on urban footprints, energy in buildings, recycling systems (Jia *et al.*, 2026). This case demonstrates that effective environmental management can, and perhaps should, extend into the surrounding landscape.

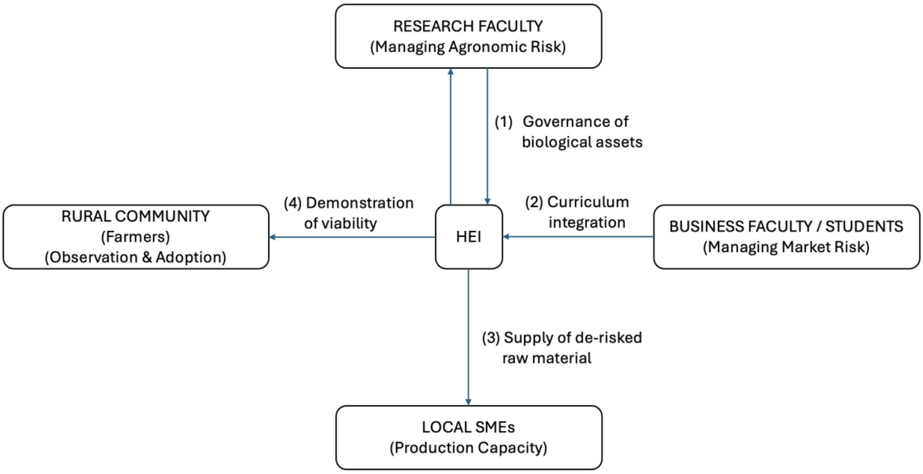

Figure 3. Stakeholder orchestration map showing the university's internal coordination role between research and teaching functions and its external brokerage role connecting local SMEs and rural communities

Source(s): Authors' own elaboration

The Project is located off-campus, in a rural district targeted for development. By managing this land, the university extended its environmental governance to address issues of land use change, biodiversity (via pest management protocols) and rural economic development. The environmental challenges encountered, real pest infestations, soil degradation, harvest unpredictability, provided a level of complexity that a campus garden could not replicate. Consequently, the student-generated solutions, such as resilient supply chain designs that account for crop loss, were more robust and transferable to the local economy than hypothetical case study outputs typically are.

6. Discussion

This study set out to examine how curriculum-integrated CE practices can function as a mechanism for environmental management in higher education. The findings from the Passionfruit Commercialisation Project suggest that when the curriculum is tightly coupled with operational infrastructure, it transforms the university from a passive observer of sustainability into an active producer of circular value. This section discusses implications in relation to the evolving literature on living laboratories and environmental governance.

6.1 Reframing universities as living laboratories for active production

The campus LL literature has predominantly focused on the "campus as a small city" metaphor, emphasising urban infrastructure such as smart grids, energy efficiency systems and waste separation (Evans *et al.*, 2015; Blakong *et al.*, 2025). While valuable, this urban-centric framing often relegates environmental management to a technocratic maintenance function. Our findings challenge this limitation by reframing the LL as an active production system.

In the Gedong case, the university did not merely "manage" a site, it acted as a primary producer, managing biological risks, resource inputs and harvest outputs. This aligns with calls for a reconstruction of agro-pastoral relations in HEIs (Xu and Guo, 2025), but extends the application into the LL context. Theoretically, this shifts the definition of a living lab from a site of observation (monitoring energy use) to a site of intervention (managing trophic flows). For HEIs to act as true living laboratories, they must assume operational responsibility for productive landscapes, not just manage their built estate.

This finding resonates with the concept of the "co-creative university" (Evans *et al.*, 2015), in which the institution co-designs solutions with society rather than just for it. Our case extends this concept: the co-creation is not merely social but material, involving the physical transformation of Grade B fruit into marketable goods by student-community partnerships.

6.2 Curriculum as soft governance for circular economy

A central contribution of this study is the identification of curriculum as a soft governance mechanism for environmental management. Traditional environmental governance in HEIs relies on "hard" mechanisms: policy documents, ISO 14001 certifications and estate regulations (Leal Filho *et al.*, 2025; Hoover and Harder, 2015). While necessary, these often fail to engage the core academic community, producing the "silo effect" widely critiqued in the literature (Ma and You, 2026).

The findings demonstrate that the curriculum can act as a bridge across these silos. By embedding the waste problem of the farm into the assessment criteria of the BCP unit, the university created a governance interdependency: the farm needed the students to solve its waste issue, and the students needed the farm's data to complete their assessments. This dynamic creates what CE theorists term "industrial symbiosis" (Chertow, 2000), translated here into "pedagogical symbiosis". The most effective environmental policies in HEIs may not be those written in administrative handbooks, but those embedded in the learning outcomes of students.

This challenges the prevailing orientation in CE education literature, which largely focuses on teaching about the CE (Kruja *et al.*, 2025). We argue that HEIs should move towards operationalising CE through curriculum. When students valorise real waste streams, the curriculum becomes a tool for managing material flows. Future environmental management strategies in HEIs should therefore look beyond the Estates Department and consider how the course catalogue can be leveraged to drive sustainability outcomes.

6.3 Implications for sustainability transitions in emerging economies

This study offers significant implications for the scalability and replicability of sustainability transitions, particularly in the Global South. Most "green campus" models are imported from the Global North, assuming high-tech infrastructure and urban settings (Jia *et al.*, 2026). For many universities in developing regions, the pressing sustainability challenges are not only carbon emissions but food security, rural poverty and agricultural resilience (Norales, 2025).

The Project demonstrates that environmental management in these contexts can be effectively linked to regional economic development. By acting as an anchor institution (Goddard *et al.*, 2014), the university used its environmental management capabilities to de-risk a new crop for local farmers. The student-led commercialisation did not just serve the university; it proved market viability of the crop to the surrounding community, generating a public good that is rarely captured in conventional campus sustainability metrics.

This also has implications for how green-campus success is measured. Established benchmarking frameworks already recognise multiple institutional dimensions. UI GreenMetric assesses setting and infrastructure, energy and climate change, waste, water, transportation and education and research, while the Sustainability Tracking, Assessment and Rating System (STARS) encompasses academics, engagement, operations and planning and administration (UI GreenMetric, 2025; Association for the Advancement of Sustainability in Higher Education, 2025). Nevertheless, the principal unit of measurement in both frameworks remains the institution and its directly reported activities. The present findings suggest a complementary "community circularity" dimension that would assess how university-managed resources, curricula and external partnerships contribute to circular production systems beyond the formal campus boundary.

Regarding scalability, this model's barrier to entry is deliberately low. It does not require multimillion-dollar smart building investments. It requires land, inter-faculty administrative coordination and an existing curriculum unit with authentic learning outcomes. This makes it a replicable model for HEIs in the Global South that wish to move beyond performative sustainability towards becoming engines of regional circular transition. That said, scalability claims should be qualified: institutional context, particularly the flexibility of curriculum governance, the availability of suitable land and the agricultural policy environment, will shape the feasibility of replication in specific settings.

7. Implications

7.1 Implications for university leaders

For university administrators and strategic planners, specifically vice-chancellors, deans, heads of sustainability offices and programme directors, the primary implication is the need to move beyond "estates-led" sustainability models. This study demonstrates that treating environmental management as solely a facilities function misses the transformative potential of the university's academic core.

University leaders should view operational infrastructure, farms, laboratories, energy systems, not merely as assets to be maintained, but as pedagogical resources. To achieve this, leadership must actively dismantle the administrative silos that separate Academic Affairs from Campus Operations (Brinkhurst *et al.*, 2011; Ma and You, 2026). Cross-functional governance structures should be incentivised, enabling facility managers and academic staff to co-design campus interventions. For example, rather than outsourcing waste management, leaders can mandate that campus waste streams be made available as data and material inputs for relevant curriculum units. This requires a cultural shift from risk-averse operational management to the experimentation ethos of the LL (Evans *et al.*, 2015).

7.2 Implications for policymakers

For policymakers, particularly in emerging economies, this study highlights the underutilised potential of HEIs as anchor institutions for regional development (Goddard *et al.*, 2014). The Project illustrates that universities can effectively de-risk environmental innovations for the private sector by absorbing the initial capital expenditure and technical risks of new agricultural systems, providing a proof-of-concept that SMEs and farmers can adopt.

Funding mechanisms for higher education should be reimagined to support this innovation brokerage role. Policy frameworks should move beyond funding discrete research projects or teaching facilities, towards supporting "demonstrator ecosystems" in which research, teaching and commercialisation overlap (Serrate-González *et al.*, 2025). In contexts where agricultural resilience is critical (Xu and Guo, 2025), governments should explicitly commission regional universities to manage productive landscapes, aligning university funding with national development goals.

7.3 Implications for sustainability educators

For educators, the implications centre on a shift from "awareness" to "agency". Education for Sustainable Development has often prioritised theoretical knowledge about sustainability challenges (Costa *et al.*, 2025). This study demonstrates that deep learning occurs when students are positioned as active agents in a value chain, grappling with real material constraints rather than hypothetical scenarios.

Curriculum design should move towards competency-based models that require students to navigate material realities (Trevisan *et al.*, 2026). Entrepreneurship education, in particular, should be decoupled from purely hypothetical business planning and re-rooted in the physical constraints of the CE (Kruja *et al.*, 2025). The concept of "agency" as used here is distinct from awareness or knowledge acquisition: it refers to students' capacity to make decisions that materially affect real supply chains, production systems and community stakeholders. Educators should integrate live environmental data, harvest yields, waste volumes, energy metrics, into assessment tasks, enhancing both student employability and the resilience to navigate the uncertainties of the green transition (Ben and Ali, 2025).

7.4 Replicability conditions

The model is transferable only when several minimum organisational and operational conditions are in place. Table 3 converts the case evidence into a practical checklist that university leaders and educators can use when adapting the approach to farms, food systems, laboratories, energy assets or other identifiable material streams.

8. Conclusion

This study has explored the transformative potential of reframing the university curriculum as a concrete mechanism for environmental management. By analysing the Passionfruit

Table 3. Replicability checklist for a curriculum-integrated circular living laboratory

Requirement	Minimum arrangement
Productive environmental asset	A farm, garden, laboratory, food system, energy system or other identifiable material stream capable of generating operational data and material inputs
Credit-bearing curriculum mechanism	An existing unit with authentic assessment, explicit learning outcomes and sufficient flexibility to work with live operational uncertainty
Operational-academic agreement	Named representatives responsible for data sharing, site access, safety, timelines, ownership and decision-making
Structured client handover	A briefing containing material-flow, harvest or operational data, quality constraints, current waste streams and commercial expectations
Student project structure	Defined team responsibilities for analysis, prototype development, business modelling and commercialisation planning
External validation	Participation by SMEs, community stakeholders, technical specialists or industry panellists able to evaluate feasibility
Risk and governance arrangements	Procedures for safety, ethics, intellectual property, product testing, data governance and reputational risk
Feedback and continuity mechanisms	A process for returning student findings to operational managers, coupled with post-semester ownership, incubation or longitudinal tracking arrangements

Source(s): Authors' compilation

Commercialisation Project, the research challenges the prevailing technocratic view of campus sustainability, which typically treats operational efficiency and academic instruction as separate domains. Instead, the case demonstrates that when the university functions as an active producer, in this instance, through an agroforestry research plot, the curriculum can serve as the critical infrastructure that bridges environmental production and circular value creation.

The study advances three primary contributions to the literature on environmental management in HEIs. Firstly, it expands the definition of the university LL beyond the urban-centric, observation-focused models that dominate existing scholarship, illustrating that HEIs can effectively govern productive landscapes and act as sites of active biological production. Secondly, it establishes the role of curriculum as environmental management infrastructure, demonstrating that the academic requirements of a capstone unit can function as a form of soft governance, providing the discipline and structure necessary to manage a trial plot's biological outputs. Thirdly, it demonstrates the operationalisation of CE logic through curriculum-integrated entrepreneurship, showing that student creativity can "design out waste" from the university's own supply chain.

The primary limitation of this study is its reliance on a single embedded case situated within a specific tropical agro-ecological and institutional context. Although the complete available project corpus was analysed, the evidence remains bounded by one production site, one 30-student cohort and one curriculum iteration. The findings may therefore reflect institutional flexibilities in curriculum governance, land access and stakeholder relationships that do not exist universally. The practitioner-researcher role provided privileged access to operational evidence but also introduced potential interpretive bias, which was mitigated through reflexive memoing, source triangulation and the requirement that each final theme be supported by at least two independent data types.

Future research should test the model through comparative, multi-site studies across disciplinary and geographical contexts. The present study did not establish a formal post-semester tracking system and therefore does not claim that the student-developed products or enterprise concepts persisted after completion of the BCP unit. Subsequent research should incorporate six- and twelve-month follow-up points to assess venture continuation, revenue generation, partnership durability, operational adoption of student recommendations and continued use of secondary biomass streams. Ultimately, this study posits that the sustainable university of the future is not merely an institution that reduces its footprint, but one that actively cultivates circular value with and for its community.

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