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The Triple F Agroecology Model (TFAM): An Integrated Systems Architecture for University-Led Agroecological Innovation

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Abstract

Agricultural and food systems face interlinked challenges and pressures from climate change, biodiversity loss, land degradation, food insecurity, and constrained rural livelihood opportunities. Although agroecology, living laboratories, experiential learning, circular bioeconomy, and enterprise incubation each offer important pathways for sustainability, they are often implemented as distinct interventions, limiting their combined capacity to support systemic food-systems transformation. This paper introduces the Triple F Agroecology Model (TFAM), a systems architecture for operationalising the Food-Feed-Forest philosophy through integrated ecological production, learning, enterprise and community knowledge co-creation pathways. The Model was developed through an integrative conceptual synthesis encompassing agroecology, food-systems transformation, experiential learning, living laboratories, university co-creation, and circular bioeconomy scholarship. Its application is illustrated through the proposed Triple F Green Enterprise Incubation and Living Laboratory Programme in Uganda. The model comprises four interacting domains- Normative, Biophysical, Socio-economic, and Innovation and Learning - supported by system inputs and an enabling institutional context. Resource and information flows, feedback loops, and co-creation connect these components to ecological, socio-economic, educational, and institutional outcomes. TFAM therefore provides a coherent conceptual basis for designing university-led agroecological innovation ecosystems and a framework for future empirical evaluation across diverse socio-ecological contexts.

Keywords: agroecology, sustainable food systems, living laboratories, experiential learning, green enterprise incubation, circular bioeconomy

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Introduction

Agricultural and food systems must meet rising food and livelihood needs while responding to climate change, biodiversity loss, land degradation, and persistent food insecurity. These challenges are mutually reinforcing: ecological decline constrains productivity, weak livelihood opportunities can intensify pressure on natural resources, and fragmented institutions often limit the translation of scientific knowledge into locally relevant innovation. Sustainable food-systems transformation therefore requires approaches that connect ecological integrity, knowledge generation, economic opportunity, and social participation rather than treating them as separate objectives (Gliessman, 2020; Stone *et al.*, 2026)

Agroecology provides a strong foundation for such integration because it applies ecological and social principles to the redesign of agricultural and food systems, with particular emphasis on diversity, synergies, recycling, resilience, fairness, and co-creation of knowledge (Rastorgueva *et al.*, 2026). Complementary approaches broaden this systems perspective. Living laboratories create real-world spaces for experimentation and stakeholder participation (Gamache *et al.*, 2020) Experiential learning connects practical engagement with reflection and competence development (Carvalho, 2025) Circular bioeconomy thinking promotes the productive use and recirculation of biological resources and by-products(Stegmann et al., 2020); and university co-creation frameworks emphasize the role of higher-education institutions in producing societal value through collaboration with external actors(Morris *et al.*, 2021). Despite these complementarities, the approaches are frequently developed and applied as distinct strands of practice. Existing frameworks may explain agroecological principles, participatory experimentation, experiential learning, enterprise development, or sustainability-oriented university engagement, but they seldom show how these domains can be organised as one adaptive innovation ecosystem (Rastorgueva *et al.*, 2026). This creates a conceptual and operational gap for universities and agroecology demonstration centres seeking to align teaching, research, ecological restoration, entrepreneurship, and community engagement. TFAM addresses this gap by providing a systems architecture that makes the relationships among these functions explicit and links them to intended transformational outcomes. The paper therefore develops TFAM and illustrates its operational logic through the proposed programme in Uganda.

Methodology

The study employed a conceptual framework-development approach. TFAM was constructed through an integrative synthesis of conceptual and review literature on agroecology, sustainable food systems, experiential learning, living laboratories, sustainability-oriented university co-creation, and circular bioeconomy. Sources were purposively selected for their articulation of principles, components, enabling conditions, actor relationships, or feedback processes relevant to framework construction. These concepts were organised around the Food-Feed-Forest philosophy. The authors assessed internal coherence by tracing logical connections among inputs, the four system domains, system flows, enabling conditions, and intended outcomes. Practical logic is illustrated through the proposed Triple F Green Enterprise Incubation and Living Laboratory Programme at the Triple F Agroecology Demonstration and Research Centre in Uganda, involving students, researchers, farmers, and communities. The illustration demonstrates operational logic rather than empirical effectiveness; consequently, impact claims are propositions for future testing.

Results and Discussion

TFAM translates the Food-Feed-Forest philosophy into an integrated agroecological innovation ecosystem. Food represents diversified crop and horticultural production; Feed emphasises sustainable livestock feeding and circular crop-livestock linkages; and Forest encompasses agroforestry, biodiversity, and landscape restoration. The architecture extends these biophysical relationships by connecting them with guiding values, learning, enterprise development, institutional collaboration, and community participation. The central proposition is that sustainable transformation becomes more likely when ecological, educational, economic, and institutional processes reinforce one another through deliberate feedback and co-creation rather than operating as parallel projects.

The Triple F Agroecology Model

Figure 1 presents TFAM as four interacting domains - Normative, Biophysical, Socio-economic, and Innovation and Learning - supported by system inputs and an enabling context. The model also distinguishes three connecting mechanisms: resource and information flows, learning and feedback loops, and co-creation and participation. These mechanisms are essential because the value of the model lies not in the presence of individual components, many of which are established in the literature, but in how they are organised to

function as a coherent adaptive system. This emphasis on interconnections, feedback, and adaptation is consistent with systems-thinking principles (Meadows, 2008).

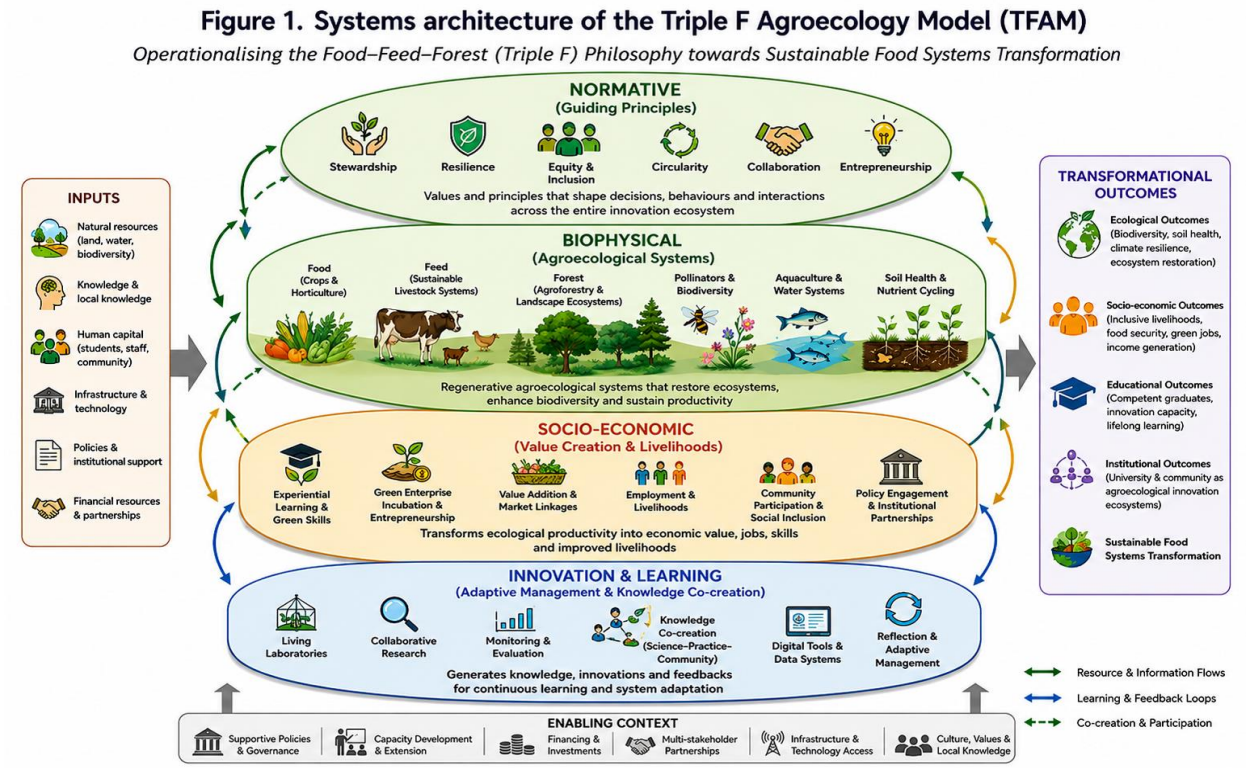

Figure 1: Systems architecture of the Triple F Agroecology Model (TFAM), operationalising the Food-Feed-Forest philosophy towards sustainable food systems transformation. Source: Authors' conceptualisation.

Components of the systems architecture

The Normative domain provides guiding principles for decisions and relationships across the ecosystem: stewardship, resilience, equity and inclusion, circularity, collaboration, and entrepreneurship. It gives the architecture a values base and ensures that technological or commercial innovation is assessed against ecological integrity and social responsibility. The Biophysical domain translates these principles into regenerative agroecological systems by linking crops and horticulture, sustainable livestock systems, forests and agroforestry, pollinators and biodiversity, aquaculture and water systems, and soil health and nutrient-cycling processes. This reflects agroecology's emphasis on diversity, synergies, recycling, and resilience (Barrios *et al.*, 2020). TFAM extends this logic by embedding biophysical processes within educational, enterprise, and institutional feedback mechanisms.

The Socio-economic domain converts ecological productivity and knowledge into educational and livelihood value through experiential learning, green skills, enterprise incubation, value addition, market linkages, employment, community participation, and policy engagement. Enterprise development is therefore embedded within ecological production rather than added as a separate commercial activity, creating opportunities for circular and bio-based ventures consistent with circular bioeconomy principles (Stegmann et al., 2020). Here, experiential learning creates human-capital value, while system-wide adaptive learning is embedded in the Innovation and Learning domain.

Innovation, feedback and transformational outcomes

The Innovation and Learning domain functions as TFAM's adaptive engine. Living laboratories, collaborative research, monitoring and evaluation, knowledge co-creation, digital tools, and reflective adaptive management allow actors to test practices, learn from outcomes, and modify subsequent action. This extends the participatory, iterative logic of living labs (Lianu *et al.*, 2023; Stone *et al.*, 2026) by embedding experiential learning in the management and adaptation of real agroecological systems and enterprises. The model is further conditioned by natural resources, local and scientific knowledge, human capital, infrastructure, policy support, finance, partnerships, governance, and institutional culture. Making these conditions explicit prevents innovation outcomes from being attributed solely to technical practices.

Through resource and information flows, feedback loops, and co-creation, TFAM links the four domains to ecological outcomes such as biodiversity, soil health, climate resilience, and restoration; socio-economic

outcomes such as food security, green jobs, income, and inclusive livelihoods; educational outcomes such as graduate competence, innovation capacity, and lifelong learning; and institutional outcomes in which universities and communities operate as connected agroecological innovation ecosystems. Its scientific contribution is therefore integrative: agroecology, living laboratories, experiential learning, enterprise incubation, circular bioeconomy, and university co-creation are not claimed as new individually. The novelty lies in specifying how these domains can be combined within one systems architecture and how their interactions can be traced from inputs and enabling conditions to learning processes and outcomes. Consistent with ecosystem-as-structure thinking (Adner, 2017), TFAM complements university co-creation through an agroecology-specific design logic linking teaching, research, enterprise development, ecological restoration, and community engagement (Trencher *et al.*, 2014).

Conclusion and Outlook

The Triple F Agroecology Model provides a coherent architecture for operationalising the Food-Feed-Forest philosophy within university-led agroecological innovation ecosystems. By integrating guiding values, regenerative biophysical systems, socio-economic value creation, and innovation and learning, TFAM clarifies how ecological restoration, education, research, entrepreneurship, and community participation can function as mutually reinforcing processes. The proposed Triple F Green Enterprise Incubation and Living Laboratory Programme illustrates how the architecture could be translated into practice. Because TFAM remains a conceptual model, future research should operationalise indicators for its domains, enabling conditions, flows, and outcomes; test causal and feedback relationships; and compare performance across contrasting agroecological and institutional settings. Such empirical work will determine the model's effectiveness, scalability, and transferability as a framework for sustainable food-systems transformation.

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