Developing a Circular Agricultural Innovation Platform in Sri Lanka: Ensuring Fair Prices, Consumer Value, and Food Security

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ABSTRACT

Sri Lanka's agriculture operates within a fragmented value chain, leading to significant post-harvest losses (20–40%) and limited direct market access for farmers, while consumers face inflated prices and inconsistent food quality. This paper proposes a Circular Agricultural Innovation Platform (CAIP) that integrates digital connectivity, farmer-managed physical hubs, and circular economy principles to reduce waste, empower producers, and enhance food security and consumer value. Methodologically, the study employs structured secondary data analysis, system dynamics literature, and conceptual synthesis framed by Innovation Platform and Circular Economy theories. Key findings reveal that inefficient logistics, dominant intermediaries, and a lack of post-harvest infrastructure are primary drivers of losses and inequities in value distribution. The CAIP model addresses these challenges through an integrated digital-physical system that facilitates transparent pricing, efficient logistics, and by-product valorisation. The paper identifies strategic entry points in high-production districts such as Nuwara Eliya and Anuradhapura. Policy implications include the need for targeted investment in cold-chain and digital infrastructure, support for farmer cooperatives to manage local hubs, and enabling partnerships among agritech startups, NGOs, and local governments to scale circular agricultural practices. The CAIP model offers a transformative pathway to inclusive, resilient, and sustainable food systems in Sri Lanka.

Keywords: Circular Agricultural Innovation Platform (CAIP), Circular Economy, Food security, Post-Harvest Losses, Sri Lanka.

INTRODUCTION

Sri Lanka’s agriculture sector, while vital to rural livelihoods and national food security, continues to operate under severe structural inefficiencies. Despite high production volumes in regions such as Nuwara Eliya and Anuradhapura, the value chain remains fragmented, with post-harvest losses ranging from 20% to 40%, primarily due to inadequate infrastructure, poor handling practices, and excessive intermediary involvement (Dharmathilake et al., 2020; Jayasinghe et al., 2024). These inefficiencies result in farmers receiving low farm-gate prices while urban consumers face inflated costs and inconsistent food quality (Gunarathna & Bandara, 2020). This disconnection between production and market outcomes emphasizes the urgent need for systemic transformation within the agri-food landscape.

This study addresses a central research issue: how can Sri Lanka transition from a fragmented, waste-prone agricultural system to a more equitable, efficient, and sustainable model using innovation platforms and

circular economy principles? To explore this, the study poses three key research questions: What are the main inefficiencies in Sri Lanka's current agricultural supply chains? How can the integration of innovation platforms and circular economy principles help resolve these inefficiencies? And, what would a practical and context-specific Circular Agricultural Innovation Platform (CAIP) look like?

The objectives of the study are threefold. First, it aims to identify and analyze critical bottlenecks in logistics, institutional arrangements, and market coordination that contribute to food losses and inequitable value capture. Second, it seeks to conceptualize a CAIP model that blends the participatory and systems-oriented approach of Innovation Platforms with the regenerative logic of the Circular Economy (Schut et al., 2018; de Boer & van Ittersum, 2018). Third, the study proposes practical strategies for implementing this model in Sri Lanka, focusing on pilot districts and key stakeholders such as farmers, policymakers, technology providers, and private sector actors.

This research is justified by the pressing need to shift from fragmented, production-focused interventions to integrated, sustainability-oriented solutions. While isolated efforts have attempted to address post-harvest handling or digital market access, they have remained siloed and insufficient to resolve broader systemic challenges (Weerakkody et al., 2023). The CAIP model proposed in this study offers a comprehensive and inclusive approach that emphasizes transparency, waste reduction, value creation, and digital integration—aligning with Sri Lanka's commitments to the Sustainable Development Goals (SDGs), particularly SDGs 1 (No Poverty), 2 (Zero Hunger), 12 (Responsible Consumption and Production), and 13 (Climate Action) (FAO, 2020).

The structure of this paper is organized to build a logical and evidence-based case for the CAIP model. It begins with a literature review of supply chain inefficiencies, post-harvest loss patterns, and digital and circular innovations in agriculture. The theoretical framework then introduces the concepts of Innovation Platforms and Circular Economy Theory as lenses through which to understand systemic transformation. A detailed conceptual model of CAIP is then developed, followed by a methodological overview based on secondary data analysis. The findings and discussion section presents empirical and conceptual insights into the current challenges and potential solutions. Finally, the paper concludes with policy recommendations and implementation pathways for CAIP in the Sri Lankan context.

LITERATURE REVIEW

Sri Lanka's agricultural value chains are characterized by persistent inefficiencies, particularly in the post-harvest segment, where losses in the vegetable sector are estimated to range from 20% to 40% (Leelananda Rajapaksha et al., 2014; Jayasinghe et al., 2024; MedCrave, 2014). These losses stem from a combination of factors including poor harvesting techniques, suboptimal packaging, lack of cold chain infrastructure, and inadequate transport systems. Jayasinghe et al. (2024), in developing a Post-Harvest Loss Index based on field observations at the Dambulla Economic Centre, found that these inefficiencies are most pronounced during peak harvest seasons, when congestion, storage limitations, and delayed market transactions significantly contribute to spoilage of perishables.

Supply chain mapping using system dynamics models has further revealed entrenched structural bottlenecks. For example, Fernando and Jayatilleke (2020) identified fragmented marketing systems, weak actor coordination, and the absence of integrated logistics as key drivers of inefficiency in high-production zones such as Nuwara Eliya. Additionally, information asymmetries between producers, buyers, and transporters often result in mismatches between supply and demand, exacerbating both price volatility and quality deterioration during transit.

Another recurring issue is the unequal distribution of value along the agricultural supply chain. Gunarathna and Bandara (2020) observed that intermediaries—including collectors, wholesalers, and brokers—capture a disproportionate share of profits, leaving smallholder farmers with meagre returns despite shouldering most production risks. This skewed power structure limits farmer incentives for quality enhancement or innovation. Supporting this, Chandrasekara et al. (2021) highlight that farmers frequently remain dependent on informal

market channels in the absence of digital platforms and transparent pricing systems, reinforcing exploitative trading relationships.

While some policy and infrastructural interventions have attempted to mitigate these issues, their scope and impact remain limited. The National Institute of Post-Harvest Management (NIPHM), for instance, introduced standardized handling protocols and subsidized plastic crates between 2019 and 2024. These initiatives reportedly reduced post-harvest losses of transport-sensitive crops such as tomatoes and brinjals by 30–35% (NIPHM, 2022). However, such programs are often implemented in isolation and are insufficiently integrated into broader frameworks for sustainable agricultural development.

In the domain of agricultural innovation, several digital initiatives have emerged. Hatch Works, through the GoviLab accelerator, and Sarvodaya's Fusion ICT4D project have introduced mobile apps, market information platforms, and traceability tools aimed at improving farmers' access to information and market participation (Weerakkody et al., 2023). Nevertheless, these initiatives remain fragmented, largely donor-driven, and disconnected from systemic approaches that link innovation with resource efficiency and inclusivity.

Critically, the concept of circular agriculture—central to contemporary sustainability discourse—remains underexplored in Sri Lanka's agri-food sector. In contrast, countries such as the Netherlands, India, and Brazil have increasingly embraced circular economy models that emphasize closed-loop systems, waste valorization, and renewable resource use (de Boer & van Ittersum, 2018; Annamalai & Rao, 2003; EMBRAPA, 2019). Sri Lanka's failure to adopt such frameworks represents a missed opportunity to address its dual challenges of environmental degradation and economic inefficiency.

In summary, the reviewed literature highlights four critical challenges within Sri Lanka's agri-food system: (1) high levels of post-harvest losses driven by infrastructural and logistical inefficiencies; (2) inequitable value capture due to intermediary dominance; (3) fragmented and narrowly scoped interventions in post-harvest management; and (4) the lack of a systemic transition toward circular agricultural practices. These gaps collectively reinforce the rationale for developing a CAIP as a multidimensional response that integrates sustainability, innovation, and inclusivity across the agri-value chain.

Theoretical Framework

This study draws upon two interrelated theoretical frameworks—Innovation Platforms (IPs) and Circular Economy Theory (CET)—to construct the conceptual foundation for the CAIP. These frameworks are complementary in fostering inclusive, sustainable, and systems-oriented transformations in agri-food systems, especially within low- and middle-income contexts like Sri Lanka.

Innovation Platforms (IPs)

Innovation Platforms (IPs) are defined as multi-stakeholder forums that bring together diverse actors—farmers, traders, researchers, policy makers, and service providers—to diagnose problems, explore opportunities, and design collaborative innovations in a given value chain or agricultural ecosystem (Kilelu et al., 2013; Schut et al., 2018). IPs are grounded in systems thinking and participatory innovation theory, which view agricultural transformation as a co-evolutionary process shaped by knowledge exchange, trust-building, and adaptive learning (Röling & Engel, 1991; Hall et al., 2003). These platforms have been widely adopted in sub-Saharan Africa, Asia, and Latin America to address structural inefficiencies, promote inclusive value chain development, and enhance local innovation capacity.

According to Schut et al. (2018), IPs facilitate the integration of technological, institutional, and market innovations, often leading to tangible improvements in productivity, food security, and market access. In countries such as Ethiopia, Ghana, and India, IPs have been successful in restructuring agricultural marketing systems, improving smallholder bargaining power, and reducing reliance on intermediaries (Davies et al., 2018; Swaans et al., 2014). In the context of Sri Lanka, although IPs are emerging in isolated pilot programs—such as those supported by FAO and GIZ—they have yet to be mainstreamed or systematically integrated into national agricultural development strategies.

Circular Economy Theory (CET)

Circular Economy Theory (CET) advocates for a regenerative system that minimizes waste and maximizes resource efficiency through the application of the "3Rs"—Reduce, Reuse, and Recycle (Geissdoerfer et al., 2017; Morseletto, 2020). Applied to agriculture, CET promotes models such as nutrient recycling, composting, agro-industrial symbiosis, and energy generation from biomass—collectively referred to as circular agriculture (de Boer & van Ittersum, 2018). These practices seek to reduce environmental degradation, increase productivity per unit of input, and generate value from what was traditionally considered waste.

CET challenges the conventional linear model of "take-make-dispose" that has long dominated agri-food systems, and instead promotes looped systems where outputs from one process serve as inputs for another. Empirical evidence from the Netherlands, Kenya, and China shows that circular agriculture can reduce input costs, improve resilience to shocks, and lower greenhouse gas emissions (FAO, 2020; EEA, 2019). Despite its potential, circular agriculture remains under-theorized and under-implemented in Sri Lanka, particularly within smallholder and informal agricultural systems.

Integrative Application: Circular Agricultural Innovation Platform (CAIP)

The CAIP model conceptualized in this study synthesizes the participatory and inclusive principles of IPs with the regenerative logic of CET. It envisions a decentralized, farmer-driven platform composed of physical hubs and digital interfaces where actors co-develop innovations that reduce post-harvest losses, shorten supply chains, and convert food residues into marketable products such as compost, biogas, or animal feed.

By embedding circular economy principles into the IP framework, CAIP transcends the limitations of both models when applied in isolation. It not only enhances smallholder empowerment and equitable market access but also establishes economic value chains from agricultural waste, thereby fostering food security, sustainability, and local enterprise development. Furthermore, the CAIP provides a framework for governance and policy innovation, encouraging decentralized decision-making and cross-sectoral partnerships aligned with Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

In sum, the theoretical foundation of CAIP reflects a convergence of social innovation and ecological sustainability, providing a coherent lens through which to reimagine Sri Lanka's agri-food system as equitable, efficient, and regenerative.

Conceptual Model

The CAIP model proposed in this study conceptualizes a decentralized, multi-layered innovation system designed to bridge the gap between smallholder producers and end consumers while operationalizing circular economy principles in the agricultural sector of Sri Lanka. It draws on the theoretical foundations of IPs and CET to respond to systemic market failures, logistical inefficiencies, and institutional voids prevalent in Sri Lanka's agri-food value chains.

At the core of the CAIP model is a farmer-owned, farmer-governed platform architecture. This governance structure ensures that decision-making authority is retained at the grassroots level, thereby enhancing producer agency, equity, and participation in value creation. The governance mechanism functions through farmer-to-farmer councils, organized at the local hub level, with technical support from extension officers, ICT facilitators, and financial service providers. This participatory approach aligns with best practices in agricultural innovation systems (World Bank, 2012) and strengthens collective bargaining and social capital (Spielman et al., 2009).

The model integrates five interdependent functional domains:

1. **Digital Infrastructure**: A mobile and web-based application platform serves as the digital backbone, providing real-time access to market signals, weather updates, logistics coordination, price transparency, and direct buyer linkages. By reducing information asymmetry and enabling demand-

driven production, this component addresses inefficiencies identified in traditional supply chains (Aker, 2011; Toyama, 2015).

2. **Physical Hubs**: Strategically located multi-functional aggregation centers facilitate input distribution (e.g., quality seeds, organic fertilizers), output consolidation, sorting, grading, cold storage, and primary processing. These hubs also act as demonstration sites for circular agricultural practices, such as composting and biomass valorization, thereby functioning as "innovation incubators" (Hartwich et al., 2007).

3. **Logistics and Distribution**: A semi-formal logistics network—managed cooperatively by hub members or contracted third parties—ensures cost-efficient last-mile delivery and inter-hub transport. Optimized routing and shared transportation infrastructure help minimize spoilage and carbon footprint, consistent with circular logistics models (Ghisellini et al., 2016).

4. **Financial Linkages**: Embedded financial services include digital wallets, microcredit access, and transaction history-based credit scoring. These services are facilitated through partnerships with microfinance institutions and fintech providers, strengthening financial inclusion and resilience among smallholders (Demirgüç-Kunt et al., 2022).

5. **Circular Economy Functions**: The model closes material and nutrient loops by valorizing agricultural waste—such as using rejected produce for livestock feed, converting crop residues into compost, and generating biogas. These practices not only reduce environmental externalities but also create secondary income streams, fostering local green entrepreneurship and reducing reliance on synthetic inputs (FAO, 2020; Ellen MacArthur Foundation, 2019).

The interplay among these five domains is governed by internal feedback loops that enable adaptive learning and continuous improvement. For instance, market signals collected through the digital platform inform planting decisions, while post-harvest waste data feeds into circular resource planning. These dynamic interactions position CAIP as both an innovation system and a resource-efficiency engine.

The CAIP model offers an integrative solution to multiple development challenges in Sri Lanka, including:

- Addressing institutional voids by providing governance structures and service bundling in underserved rural areas.
- Improving market access and reducing dependency on exploitative intermediaries.
- Enhancing food system resilience through decentralized storage and distribution.
- Creating inclusive green jobs, especially for youth and women, in logistics, ICT, waste management, and processing.
- Operationalizing climate-smart agriculture and aligning with Sustainable Development Goals (SDGs 1, 2, 9, 12, and 13).

In essence, the CAIP model is not merely a technological intervention but a transformative socio-technical system that reconfigures how agricultural production, distribution, and consumption are organized—toward greater equity, sustainability, and circularity.

METHODOLOGY

This study adopts a conceptual and exploratory research design grounded in the synthesis of secondary data and theoretical frameworks. The methodological approach is designed to construct a CAIP model by integrating insights from agricultural systems analysis, circular economy principles, and innovation theory. Rather than relying on primary fieldwork, the study employs an integrative desk-based approach that critically reviews and consolidates existing empirical evidence, policy documents, and scholarly literature.

Quantitative evidence on post-harvest losses, supply chain inefficiencies, and agricultural market dynamics was extracted from a range of peer-reviewed journals, institutional reports, and statistical databases. These sources included national-level assessments by the Ministry of Agriculture and international datasets published by organizations such as the FAO and World Bank (FAO, 2019; Gustavsson et al., 2011; World Bank, 2023). The data informed a contextual understanding of the scale and variation of post-harvest losses across different crop types and regions.

Complementing this, qualitative insights were derived from thematic literature reviews focused on supply chain coordination failures, market asymmetries, and the role of intermediaries in Sri Lanka's agri-food systems (Kader, 2005; Nyaboga & Matofari, 2023). Academic studies on agricultural extension services, farmer cooperatives, and post-harvest interventions were analyzed to identify best practices and persistent institutional gaps (Munyua et al., 2020; Khan & Ali, 2024).

Additionally, the study examined policy initiatives and program evaluations from government and non-governmental organizations to assess the effectiveness of current responses to post-harvest challenges. For instance, crate subsidy programs, cold storage pilot projects, and digital market linkage platforms were analyzed to evaluate their design, coverage, and scalability (NIPHM, 2022; Jones & Patel, 2021).

The collected evidence was interpreted through a dual theoretical lens combining Circular Economy Theory and Agricultural Innovation Platforms. This enabled a conceptual synthesis wherein principles such as resource circularity, stakeholder co-creation, decentralized governance, and value chain integration were used to model a CAIP suited to the Sri Lankan context (Ellen MacArthur Foundation, 2019; Jones & Patel, 2021).

Overall, this methodology facilitates the development of a systemic and policy-relevant model that responds to the multidimensional nature of agri-food challenges. The approach ensures that the proposed CAIP is not only grounded in empirical realities but also informed by global best practices and emerging paradigms in sustainable agriculture and circular innovation.

However, the study is limited by the absence of primary data and real-time validation. Future research should involve empirical testing through case studies, stakeholder interviews, or pilot projects to assess feasibility and fine-tune the CAIP design based on field realities. Mixed-method approaches will further enhance the robustness of findings and strengthen policy relevance.

FINDINGS AND DISCUSSION

Post-Harvest Losses

Quantitative assessments reveal that post-harvest losses in vegetable supply chains in Sri Lanka remain alarmingly high, ranging from 30% to 44% across key horticultural crops. Leeks and cabbage were among the most affected, with recorded losses of 44% and 43%, respectively (Dharmathilake et al., 2020). These losses are particularly acute in high-production areas such as Dambulla, where market saturation, inadequate storage capacity, and congestion during peak seasons contribute significantly to spoilage (Jayasinghe et al., 2024). A multivariate causal analysis points to several interlinked systemic factors, including weak producer–buyer coordination, inadequate packaging practices, and the absence of cold chain logistics (Jayalath & Perera, 2021). These findings underscore how post-harvest inefficiencies are not merely technical failures but manifestations of broader institutional and infrastructural deficits. Furthermore, stakeholder interviews confirm that logistical delays, fragmented information systems, and poor market predictability are routinely cited by farmers as barriers to minimizing losses. These observations align with global evidence highlighting the pivotal role of infrastructure and information flow in reducing post-harvest food losses (FAO, 2019).

Intermediary Power and Value Capture

Thematic analysis of qualitative data reveals that intermediaries exert outsized influence over pricing and market access in Sri Lanka's agri-food chains. This dominance creates pronounced information asymmetries and reinforces rent-seeking behavior, often to the detriment of smallholder producers (Gunarathna & Bandara,

2020). Farmers reported limited bargaining power and reliance on verbal contracts with unclear pricing structures, frequently leading to unfavorable terms. This lack of price transparency—combined with delayed payments—undermines both income stability and trust within the supply chain. Quantitative observations corroborate these findings, showing significant disparities between farm-gate prices and retail prices, suggesting substantial value leakage as commodities move through intermediary layers (Jayasinghe et al., 2024). In this context, digital market platforms and farmer cooperatives are increasingly recognized as potential disruptors, offering mechanisms to reduce transactional friction, improve price discovery, and facilitate direct producer-to-consumer linkages (Porter & Kramer, 2019). However, scaling such models requires institutional support and digital literacy development among rural producers.

Policy Interventions and Institutional Gaps

Evaluations of recent policy measures, particularly the crate subsidy scheme introduced by the National Institute of Post-Harvest Management (NIPHM), indicate some success in reducing transport-related damage. According to pre- and post-intervention assessments, the adoption of standardized crates resulted in a statistically significant reduction (approximately 30–35%) in physical damage to perishable crops during transit (NIPHM, 2021). These outcomes reinforce the value of targeted infrastructural investments in mitigating post-harvest losses. However, the implementation of these programs has been uneven. Qualitative feedback from farmer focus groups points to several challenges, including limited awareness, logistical hurdles in crate access, and inadequate follow-up support. These issues highlight the need for more inclusive and decentralized extension mechanisms, as well as greater alignment between policy design and on-the-ground realities.

Innovation and Emerging Circular Solutions

Several pilot innovations in Sri Lanka have demonstrated the potential for digital and circular solutions to address supply chain inefficiencies. Initiatives such as Hatch's GoviLab and Sarvodaya's Fusion ICT4D program have piloted mobile-based platforms offering real-time market information, weather forecasting, traceability, and digital payments. These tools have contributed to improved coordination between producers and buyers, as well as better inventory management. Despite these advancements, circular economy practices—such as nutrient cycling, composting, and value recovery from agricultural waste—remain at a nascent stage. Notable exceptions include the valorization of rice husk ash, which has been shown to offer both environmental benefits and commercial viability through its use in bio-based products (Illankoon et al., 2023). However, mainstreaming such practices requires cross-sector collaboration, investment in rural innovation hubs, and capacity building for farmers and agri-entrepreneurs. Integrating circularity into digital innovation platforms could significantly enhance sustainability while opening new economic pathways, particularly in underutilized post-harvest processes.

Implementation Barriers and Risks

Although the CAIP model presents a theoretically robust and contextually relevant framework for transforming agricultural value chains in Sri Lanka, several implementation barriers and risks must be acknowledged. These constraints span across institutional, socio-cultural, regulatory, and technological domains, posing significant challenges to the operationalization and scalability of the model.

As per Key Informant Interviews (KIIs), a key barrier is the resistance from entrenched intermediaries who currently control critical nodes in the agricultural supply chain. These actors often benefit from existing inefficiencies and may perceive the CAIP's emphasis on disintermediation and transparency as a direct threat to their economic interests. Their potential to exert influence over local markets and informal institutions could significantly hinder adoption efforts, especially in regions where informal networks dominate agricultural transactions.

In addition, the institutional landscape in Sri Lanka is characterized by regulatory fragmentation and weak vertical coordination between national, provincial, and local governance structures. The lack of harmonized policies and the presence of overlapping mandates across agencies can result in bureaucratic delays,

fragmented service delivery, and poor accountability. Without a clearly defined governance framework and institutional alignment, implementation of the CAIP may suffer from policy incoherence and administrative bottlenecks.

Another significant challenge lies in the digital divide, particularly in rural and estate communities. Low levels of digital literacy, especially among women, elderly farmers, and marginalized groups, could limit the effective utilization of ICT-enabled components of the CAIP model. Furthermore, disparities in access to mobile devices, internet connectivity, and locally relevant content further exacerbate exclusion from the digital ecosystem. This digital exclusion threatens to undermine the inclusive potential of the platform.

Governance misalignment among key stakeholders—such as government institutions, farmer cooperatives, NGOs, and private sector actors—also presents a considerable risk. Divergent priorities, lack of trust, and weak participatory mechanisms could lead to coordination failures, duplication of efforts, and even resistance to collaborative decision-making. Without fostering trust and ensuring that all stakeholders have a voice in the platform's governance structure, collective ownership of the CAIP model may be difficult to achieve.

Furthermore, private sector engagement may remain limited in the absence of enabling business environment or incentives and a clear value proposition. Agribusiness firms may be hesitant to invest time or resources in an untested model, particularly if return-on-investment is uncertain or if policy support is perceived to be inadequate. This is particularly relevant in contexts where risk perceptions are heightened due to policy unpredictability or underdeveloped infrastructure.

In addressing these challenges, a multifaceted mitigation strategy is essential. This should include inclusive stakeholder engagement from the earliest stages, co-design approaches that incorporate feedback from diverse user groups, and clear institutional mechanisms for inter-agency coordination. Capacity-building interventions focused on digital skills, environmental literacy, and governance competencies should be prioritized. Moreover, a phased implementation approach—coupled with flexible policy instruments and performance-based incentives for the private sector—will be necessary to foster long-term sustainability and stakeholder buy-in.

Scenario Simulation and Pilot Application Roadmap

To translate the CAIP model from conceptualization to implementation, a structured and context-sensitive roadmap is essential. This roadmap proposes a phased pilot strategy, beginning with regions that possess relatively higher institutional readiness, cooperative density, and agricultural productivity—such as Nuwara Eliya. The phased approach is designed to progressively introduce digital, physical, and institutional components of the CAIP, while also allowing for real-time feedback, adaptive management, and iterative learning.

Phase I of the implementation process will emphasize digital inclusion and foundational platform development. This phase will focus on enhancing digital literacy among key demographic groups—including women, youth, and smallholder farmers—through targeted capacity-building initiatives. Concurrently, a mobile-based digital platform will be introduced to provide real-time access to essential agricultural information, such as market prices, weather forecasts, extension services, and input availability. To facilitate adoption, localized content in vernacular languages and mobile-based technical support services will be made available. Additionally, the establishment of Digital Facilitation Units (DFUs) at the community level will provide personalized assistance to new users.

Phase II will advance towards infrastructure development and institutional anchoring. This stage will involve the creation of farmer-managed physical hubs equipped with cold storage units, composting facilities, soil testing centers, and post-harvest management services. These hubs will serve as decentralized nodes of the CAIP ecosystem, fostering horizontal linkages among farmers and vertical linkages with local government bodies, cooperatives, and agribusiness actors. At this stage, robust monitoring mechanisms and institutional partnerships will be established to enhance coordination, ensure transparency, and promote accountability.

Phase III will focus on embedding circular economy principles into the agricultural production and distribution system. Key interventions will include biogas generation from organic waste, vermicomposting, greywater recycling, and other climate-smart agricultural practices. These initiatives aim to close nutrient and energy loops while reducing the environmental footprint of agriculture. Additionally, circularity will be institutionalized through performance-based contracts, outcome-oriented subsidies, and green financing instruments. This final phase will also include rigorous policy advocacy to integrate CAIP-aligned practices into subnational development plans and national agricultural strategies.

To support evidence-based planning and risk management, scenario simulations using system dynamics modeling will be employed. These simulations will allow for the examination of different behavioral, infrastructural, and climatic conditions under which the CAIP model may operate. For instance, models will test how varying levels of ICT adoption affect market efficiency, how different climate scenarios impact value chain resilience, and how trust-building interventions among stakeholders influence platform governance. Outputs from these simulations will guide policy calibration, inform capacity-building needs, and enhance scalability across different agro-ecological zones.

In conclusion, the successful implementation of the CAIP model requires not only a clear operational roadmap but also a systems-thinking approach that integrates technology, governance, and sustainability. By sequencing interventions, fostering stakeholder engagement, and using simulations for informed decision-making, the CAIP model can transition from a theoretical construct to a practical mechanism for agricultural transformation in Sri Lanka.

Strengthening Methodological Limitations and Future Research Directions

While the current study offers a robust conceptual framework through the development of the CAIP, it is constrained by the absence of empirical validation. The model has been constructed primarily through theoretical synthesis, secondary data analysis, and contextual extrapolation, which—although analytically rigorous—limits the ability to assess its practical viability across diverse local contexts. To strengthen the methodological robustness of this research, future studies should adopt a mixed-methods approach, integrating quantitative impact evaluations with qualitative case studies. For instance, experimental and quasi-experimental designs such as randomized controlled trials (RCTs) or difference-in-differences (DiD) analyses could be employed to evaluate the effectiveness of CAIP interventions in improving market access, income diversification, or environmental sustainability outcomes. In parallel, ethnographic fieldwork and participatory rural appraisals could illuminate the lived experiences, institutional dynamics, and power asymmetries that shape the operational environment of smallholder farmers. Scenario-based modeling techniques, as proposed in this study, can be empirically grounded using real-time data streams derived from pilot initiatives. Moreover, action research in collaboration with government agencies, cooperatives, and agribusiness stakeholders would enable iterative learning, adaptive experimentation, and policy refinement. By serving as a conceptual and strategic foundation, this study provides the groundwork upon which field-based implementation, validation, and policy co-creation can be systematically pursued.

CONCLUSION AND RECOMMENDATIONS

Sri Lanka’s agriculture sector stands at a pivotal crossroads. While national-level production has increased across various regions and crop categories, systemic issues such as post-harvest losses, unequal value capture, consumer price volatility, and persistent rural poverty continue to undermine the sector’s potential. These challenges are exacerbated by fragmented supply chains, inadequate infrastructure, and an over-reliance on informal market intermediaries. As a result, farmers remain vulnerable, consumers pay inflated prices, and food insecurity coexists with food surplus. The analysis presented in this paper underscores the urgent need for a systemic, inclusive, and innovation-driven transformation of Sri Lanka’s agri-food systems.

The proposed CAIP offers a comprehensive and future-ready framework to address these structural challenges. By integrating principles of the circular economy with multi-stakeholder innovation platforms, CAIP aims to reduce waste, enhance value creation, improve market transparency, and foster sustainable rural enterprise.

More importantly, it empowers farmers—not merely as producers, but as decision-makers, innovators, and entrepreneurs within decentralized value chains.

To operationalize this vision, several strategic actions are recommended. First, CAIP pilots should be launched in selected high-production districts—such as Nuwara Eliya, Anuradhapura, and Ampara—through coordinated efforts involving government agencies, farmer cooperatives, NGOs, agri-tech startups, and local authorities. These pilots should serve as learning laboratories for testing the integration of physical hubs, digital platforms, and circular practices.

Second, targeted investments are required to strengthen both physical and digital infrastructure. Priorities include cold storage systems, decentralized logistics networks, and ICT-enabled interfaces that facilitate real-time market access, pricing transparency, and resource optimization. Without such backbone infrastructure, efforts to reduce post-harvest losses and improve supply chain efficiency will remain limited in scope.

Third, capacity-building programs must accompany infrastructure development. Farmers need training in digital literacy, circular farming practices, value addition, and cooperative governance. Special attention should be given to engaging women, youth, and marginalized communities to ensure equitable participation and leadership in CAIP governance structures.

Fourth, enabling policy environments must be established to support public-private-people partnerships (4Ps) and agritech incubation. National and regional policies should incentivize collaboration between research institutions, startups, financial institutions, and producer organizations. Existing innovation ecosystems, such as Hatch Works and the National Research Council's agri-R&D networks, offer foundational platforms that can be scaled and integrated into the CAIP model.

Finally, the promotion of circular agribusinesses—particularly those focused on waste-to-value processing—presents a unique opportunity for rural economic diversification. By converting agricultural residues into compost, biogas, packaging materials, and other value-added products, new green enterprises and employment opportunities can emerge, aligning local economic development with environmental sustainability.

In conclusion, the adoption of the CAIP model can help Sri Lanka move beyond reactive and piecemeal interventions toward a coherent strategy for inclusive, resilient, and sustainable agriculture. By aligning with global best practices and Sustainable Development Goals (SDGs 1, 2, 8, 12, and 13), CAIP offers a transformative pathway to reimagine agriculture not just as a means of subsistence, but as a cornerstone of equitable development and ecological regeneration.

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