

Contextualizing LEAN Thinking in Philippine Agribusiness: Efficiency, Sustainability, and Resilience in Mindanao Food Systems

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ABSTRACT : *LEAN thinking, initially developed through the Toyota Production System, has evolved from a manufacturing methodology into a comprehensive management philosophy emphasizing value creation through waste elimination and continuous improvement. Its application has expanded beyond industrial settings to sectors including healthcare, education, services, and agriculture. In agribusiness, however, LEAN adoption faces unique challenges arising from biological variability, seasonal production cycles, perishability of outputs, and fragmented supply networks. These factors complicate the maintenance of standardized workflows, continuous process flows, and just-in-time practices, necessitating context-sensitive adaptations of traditional LEAN tools such as Value Stream Mapping (VSM), 5S, Kaizen, and Standard Work. Globally, empirical evidence demonstrates that LEAN methodologies, when thoughtfully adapted, improve operational efficiency, product quality, post-harvest handling, and supply chain responsiveness while contributing to sustainability goals. In the Philippines, government-led initiatives by the Department of Agriculture and the Department of Science and Technology have implemented LEAN practices in rice milling, fruit processing, and small-scale agribusinesses, achieving measurable reductions in waste, improved workflow organization, and enhanced market linkages. In Mindanao, regional case studies show that participatory approaches, cooperative structures, and human capital development are crucial for sustaining LEAN gains, particularly under conditions of infrastructural limitations, socio-political constraints, and environmental variability. The integration of Green-LEAN principles and digital financial management tools further enhances operational efficiency, environmental stewardship, and fiscal accountability. These hybrid frameworks align process optimization with ecological sustainability, cost control, and strategic adaptability, reinforcing the potential of LEAN as a holistic management approach. Overall, the study underscores that the successful adoption of LEAN in agribusiness depends on localized adaptation, participatory engagement, and integration with financial and environmental performance systems, highlighting its transformation into a socially attuned, resilient, and sustainability-oriented paradigm for modern food systems.*

KEYWORDS - *LEAN Management, Agribusiness Operations, Value Stream Mapping, Sustainable Agriculture, Green-LEAN Integration, Post-harvest Efficiency*

I. INTRODUCTION

LEAN thinking, originally popularized through the Toyota Production System, has evolved from a manufacturing technique into a global management philosophy centered on achieving value creation through the systematic elimination of waste (Womack & Jones, 1996). What began as an industrial model for optimizing production efficiency has transcended its origins, influencing diverse sectors such as healthcare, education, services, and agriculture. The underlying tenets of LEAN—continuous improvement (*Kaizen*), respect for people, and value stream optimization—have proven versatile across organizational contexts. However, the translation of these principles into agribusiness systems introduces a complex set of challenges that stem from the sector's inherent biological variability, environmental dependency, and market volatility (Liker, 2004; Barth, 2018). Unlike factory environments characterized by predictability and process control, agricultural operations must contend with seasonal fluctuations, perishability of outputs, and fragmented supply networks, all of which complicate the maintenance of standardized workflows and continuous process flow—two of LEAN's defining features.

In the global context, the infusion of LEAN principles into agri-food management represents a significant paradigm shift toward value-driven, efficiency-oriented, and sustainable food systems. Empirical studies across

Europe, Asia, and Latin America demonstrate that LEAN tools such as Value Stream Mapping (VSM), 5S, and Kaizen can yield measurable improvements in post-harvest efficiency, product quality, and traceability, thereby contributing to reduced food loss and enhanced competitiveness (Bonamigo et al., 2023; Trubetskaya et al., 2023). Yet, as scholars increasingly emphasize, LEAN's conceptualization of "value" must be contextually reinterpreted when applied to agri-food systems. In these settings, value extends beyond cost minimization and production speed to encompass dimensions such as freshness, ecological sustainability, ethical sourcing, and community welfare (Behzadi et al., 2018). This redefinition underscores the need for context-sensitive LEAN frameworks that integrate social, economic, and environmental objectives rather than focusing solely on productivity metrics.

Within the Philippine context, the adoption of LEAN management principles is steadily gaining momentum through both public and private sector initiatives. Government agencies such as the Department of Agriculture (DA) and the Department of Science and Technology (DOST) have piloted LEAN-based process improvements in post-harvest handling, milling operations, and small enterprise production systems (DA, 2022; DOST, 2021). These efforts seek to streamline agricultural workflows, reduce resource wastage, and foster innovation-driven productivity. In Mindanao, where agricultural enterprises operate within complex socio-economic and geographic conditions, the implementation of LEAN frameworks has shown promising yet uneven outcomes. Research indicates that community-based and cooperative-driven approaches to LEAN adaptation—anchored in participatory learning and localized decision-making—present the most viable strategy for addressing infrastructural, logistical, and even security-related challenges (CGIAR, 2024; University of Southern Mindanao, 2023).

Complementing these operational innovations, recent developments in financial management scholarship provide a synergistic perspective. Macaumbao and Bandera (2025) highlight how digital transformation and data-driven financial tools—including real-time analytics, risk control mechanisms, and value-based financial management—are reshaping organizational performance and governance structures in agribusiness. These financial innovations align closely with LEAN's fundamental objective of eliminating inefficiencies and maximizing stakeholder value, suggesting an emerging convergence between LEAN and financial intelligence frameworks. Together, they offer an integrated model for sustainable agribusiness modernization that unites operational excellence with fiscal accountability and long-term adaptability.

This review synthesizes these theoretical and empirical insights to examine how LEAN thinking is reshaping modern agribusiness management across global, national, and regional levels. It highlights the ongoing conceptual evolution, practical adaptations, and performance outcomes of LEAN in agricultural contexts while also identifying the structural, institutional, and environmental challenges that influence its implementation. Ultimately, the findings underscore that the future of LEAN in agribusiness lies not in simple transference from manufacturing, but in its reinvention as a contextually grounded, socially attuned, and sustainability-oriented management paradigm capable of meeting the complex demands of contemporary food systems.

METHODOLOGY

This study employed a qualitative literature review design to systematically explore the application of LEAN thinking within the context of modern agribusiness management. The approach focused on synthesizing existing knowledge across multiple levels—international, national, and regional—to understand how efficiency-oriented management frameworks are adapted to the dynamic and resource-dependent nature of agricultural systems. A broad range of scholarly and institutional materials served as the data foundation, including peer-reviewed journal articles, government publications, and regional case studies. International contributions such as those by Bonamigo et al. (2023), Barth (2018), and Trubetskaya et al. (2023) provided theoretical and empirical insights into the global diffusion of LEAN tools and methodologies, while Philippine government reports from the Department of Agriculture (2022), the Department of Science and Technology (2021), and the Philippine Institute for Development Studies (2023) furnished contextual evidence on national implementation efforts and policy integration.

Regional perspectives were further enriched through analyses of studies conducted by CGIAR (2024) and the University of Southern Mindanao (2023), which offered grounded insights into the localized adoption of LEAN frameworks in Mindanao's agribusiness operations. These regional materials were particularly valuable in illustrating how smallholder cooperatives and agri-based enterprises modify LEAN tools to address infrastructural limitations, socio-economic constraints, and environmental variability.

All collected information was critically reviewed, categorized, and thematically coded according to recurring patterns, including conceptual adaptation, practical tool utilization, documented benefits, and barriers to implementation. Through this comparative thematic analysis, the study identified cross-level patterns and divergences that characterize the evolution of LEAN practices in agriculture. This methodological approach enabled a comprehensive understanding of how global frameworks are reinterpreted through national strategies and regional realities, providing a multi-scalar perspective on the integration of LEAN thinking in pursuit of efficiency, sustainability, and resilience within the agricultural sector.

II. LITERATURE REVIEW

Conceptual Translation: What Changes When Lean Leaves the Factory?

At the international level, a growing body of scholarship underscores that while LEAN's foundational axioms—namely waste elimination, continuous improvement, and value creation—retain their conceptual significance in agribusiness, their application must be contextually reinterpreted to align with the biological, ecological, and socio-economic complexities inherent in agricultural systems (Womack & Jones, 1996; Bonamigo et al., 2023). Unlike manufacturing, where processes can be standardized and controlled, agricultural production operates within living, variable environments subject to climatic fluctuations, biological cycles, and market volatility. Consequently, the notion of “value” in agribusiness transcends efficiency and cost minimization to encompass freshness, food safety, traceability, environmental stewardship, and ethical production practices (Liker, 2004; Almqvist, 2021). The mapping of value streams in this context must therefore consider biological rhythms, harvest windows, perishability, and the fragility of supply chains, requiring the modification of conventional LEAN tools to accommodate agricultural realities.

In response to these challenges, several scholars have advanced hybridized frameworks that merge LEAN principles with agro-specific performance indicators, such as post-harvest loss rates, cold-chain efficiency, and shelf-life optimization (Barth, 2018; Behzadi et al., 2018). These models expand the analytical scope of LEAN beyond factory precision to include biological efficiency and ecological integrity, thereby reconciling industrial rigor with agricultural variability.

Within the Philippine context, the adaptation of LEAN thinking has become increasingly visible in both government-led initiatives and applied research programs. Empirical evidence from agricultural innovation centers and Rice Processing Centers (RPCs) demonstrates that LEAN-based value stream mapping in Philippine farming systems must take into account informal market structures, the role of intermediaries, and irregular harvest cycles (Philippine Institute for Development Studies [PIDS], 2023; Department of Agriculture [DA], 2022). Unlike manufacturing settings where value is defined by the end consumer, in rural agribusiness networks, value is often co-created and negotiated among farmers, traders, and cooperatives, necessitating a relational approach to process improvement.

At the regional level, particularly in Mindanao, emerging research highlights the ongoing tension between LEAN's structured process orientation and the region's fragmented agrarian and infrastructural landscape. Case studies from Wageningen University and CGIAR (2024) and the University of Southern Mindanao (2023) illustrate that successful LEAN implementation in such environments depends on integrating social capital, cooperative organization, and local capacity-building. Rather than transplanting industrial models wholesale, these adaptations emphasize community participation, knowledge exchange, and incremental system redesign as vehicles for achieving efficiency without undermining local realities. In these cases, the sustainability of LEAN depends less on procedural uniformity and more on institutional flexibility and social inclusivity.

This adaptive orientation parallels developments in modern financial management theory, which has evolved from rigid, static budgeting systems to adaptive, data-driven, and technology-enhanced frameworks (Macaumbao & Bandera, 2025). Both paradigms—LEAN agribusiness and contemporary financial management—share a unifying commitment to organizational learning, real-time decision-making, and risk mitigation. Together, they point toward a new model of sustainable agribusiness management grounded in responsiveness, digital integration, and continuous adaptation to environmental and market dynamics.

Tools and Techniques Applied in Agribusiness

At the international level, a substantial body of empirical evidence affirms that several LEAN tools and methodologies—particularly Value Stream Mapping (VSM), 5S, Kaizen, and Standard Work—are among the most adaptable and transferable to the diverse contexts of the agri-food sector (Almqvist, 2021; Womack & Jones, 1996). These tools have been instrumental in translating industrial efficiency principles into systems that manage biological variability, post-harvest processes, and supply chain complexity. Among these, VSM has emerged as a cornerstone methodology, widely utilized to visualize entire production and distribution flows, enabling the identification of bottlenecks, non-value-adding activities, and inefficiencies in food processing, packaging, and logistics (Trubetskaya et al., 2023). In Europe and Latin America, the integration of Lean Six Sigma frameworks into the dairy, fruit, and vegetable processing industries has yielded measurable performance gains—ranging from reduced defect rates and shorter lead times to enhanced traceability and energy efficiency (Bonamigo et al., 2023; Barth, 2018). These findings collectively demonstrate that when adapted thoughtfully, LEAN methodologies not only optimize production processes but also strengthen sustainability outcomes and quality assurance mechanisms within agri-food value chains.

In the Philippine context, emerging empirical studies and programmatic evaluations have documented parallel improvements stemming from the implementation of LEAN practices in small and medium-sized food enterprises (SMEs). The Department of Science and Technology (DOST, 2021) spearheaded initiatives incorporating 5S and Kaizen principles into micro and small agribusiness operations, resulting in tangible improvements in workflow efficiency, waste minimization, and workplace organization. Similarly, interventions led by the Department of Agriculture (DA, 2022) and the Philippine Institute for Development Studies (PIDS, 2023) report that the application of LEAN tools in rice milling and fruit processing facilities contributed to enhanced product quality, reduced rework rates, and improved production reliability. These cases highlight the growing institutional recognition of LEAN as a viable strategy for modernizing agri-industrial operations and aligning local enterprises with global standards of efficiency and sustainability.

At the regional level, particularly in Mindanao, the adoption of LEAN principles has been most visible within small-scale milling, packaging, and post-harvest handling operations. Pilot projects conducted in Davao del Norte and Bukidnon, as reported by CGIAR (2024), demonstrated that practical LEAN interventions—such as the use of visual controls, workstation redesigns, and standardized operating procedures—significantly reduced processing time, material waste, and post-harvest losses. Furthermore, the University of Southern Mindanao (2023) emphasizes that the sustainability of LEAN implementation in rural agribusiness contexts depends heavily on human capital development. Interventions combining technical process optimization with training programs, participatory workshops, and cooperative-based management systems tend to yield more enduring results. Such findings reinforce the view that LEAN's success in agriculture transcends mere procedural adjustments; it requires organizational learning, behavioral change, and participatory engagement among workers and stakeholders.

Taken together, these international, national, and regional experiences illustrate the scalability and contextual versatility of LEAN methodologies when properly localized. They reveal that LEAN's enduring value in agribusiness lies not only in improving operational metrics but also in cultivating a culture of continuous improvement and collective responsibility—a foundation essential for achieving both efficiency and sustainability in the evolving global food system.

Case Evidence: Packing, Milling, and Processing

At the global level, a growing corpus of case-based evidence underscores the tangible benefits of LEAN methodologies in post-harvest and processing operations within the agri-food sector. Numerous studies demonstrate that when appropriately adapted to agricultural realities, LEAN principles can yield significant improvements in operational efficiency, resource utilization, and process reliability. For instance, LEAN adaptations in vegetable packing facilities in Spain and the Netherlands have been shown to markedly reduce changeover times, minimize material waste, and increase output per labor hour, resulting in enhanced productivity and competitiveness across export-oriented value chains (Barth, 2018; Bonamigo et al., 2023). Similarly, grain milling plants in Indonesia and India that adopted LEAN-based workflow redesigns reported notable gains in throughput, reductions in machine downtime, and improvements in process synchronization, outcomes that collectively strengthened production consistency and supply chain performance (ResearchGate, 2019; Trubetskaya et al., 2023). These findings illustrate that even in biologically variable and market-sensitive contexts,

LEAN offers a flexible framework for aligning process efficiency with product quality and sustainability objectives.

Within the Philippine context, emerging evidence points to similar operational gains across major rice and mango value chains, where LEAN tools have been integrated into post-harvest systems and small-scale processing enterprises. Process flow reorganizations, visual management tools, and 5S-based housekeeping practices have resulted in shorter turnaround times, smoother process transitions, and greater product uniformity in Rice Processing Centers (RPCs) (Department of Agriculture [DA], 2022). Empirical findings from the Department of Science and Technology (DOST, 2021) further reveal that LEAN-inspired process standardization in fruit processing facilities has reduced post-harvest losses by up to 15%, underscoring the measurable impact of even low-cost interventions on productivity and resource efficiency. These localized cases demonstrate that LEAN practices can be both technically effective and economically accessible, offering scalable solutions for improving operational management within small and medium-sized agribusinesses.

In Mindanao, where agricultural enterprises often operate under conditions of limited infrastructure and fluctuating production volumes, case studies in vegetable processing and rice milling plants reveal comparable efficiency improvements. Projects documented by CGIAR (2024) and the Philippine Institute for Development Studies (PIDS, 2023) detail the successful implementation of visual workflows, labeling systems, workstation layout redesigns, and process mapping exercises, which together contributed to reductions in cycle times and post-harvest waste. These interventions were particularly noteworthy for their low capital requirements, demonstrating that LEAN methodologies can be effectively adapted to resource-constrained, rural environments without necessitating advanced technology or large-scale investments.

However, these findings also highlight a critical methodological insight: the benefits of LEAN implementation in agriculture exhibit seasonal variability, reflecting fluctuations in harvest volumes, labor availability, and environmental conditions. Consequently, scholars emphasize the need for multi-seasonal and longitudinal analyses to assess the durability and replicability of efficiency gains over time. Overall, the accumulated international, national, and regional evidence suggests that LEAN's strength lies in its adaptability—its ability to deliver measurable performance improvements while accommodating the dynamic, cyclical, and community-based nature of agricultural production systems.

Benefits: Waste Reduction, Quality, and Resilience

At the international level, a robust body of empirical and theoretical research consistently affirms that the application of LEAN practices in agri-food systems generates measurable improvements in waste minimization, product quality assurance, and supply chain responsiveness (Behzadi et al., 2018; Womack & Jones, 1996). By emphasizing the systematic elimination of non-value-adding activities, LEAN provides a structured approach to managing the inherent variability and perishability of agricultural commodities. Studies have shown that Value Stream Mapping (VSM), when integrated with digital data collection and monitoring systems, can significantly optimize logistics and storage processes, reduce post-harvest spoilage, and bolster the resilience of perishable supply chains (Bonamigo et al., 2023). This integration enables real-time visibility into production flows, allowing managers to identify inefficiencies, anticipate disruptions, and respond adaptively to fluctuating supply and demand. Furthermore, the evolution of Lean-Green frameworks demonstrates that efficiency and environmental stewardship are not mutually exclusive; rather, the two can be harmonized to yield co-benefits such as reduced energy use, lower water consumption, and minimized waste emissions (Barth, 2018). These global findings underscore the paradigm shift from purely efficiency-driven operations toward sustainable, data-informed, and environmentally conscious agri-food systems.

In the Philippine context, similar trends are emerging as government programs and agribusiness enterprises adopt LEAN methodologies to address post-harvest inefficiencies and market integration challenges. Reports from the Department of Agriculture (DA, 2022) and the Philippine Institute for Development Studies (PIDS, 2023) indicate that the implementation of LEAN protocols has substantially reduced post-harvest losses in key commodities such as rice, bananas, and vegetables. The introduction of standardized sorting, grading, and packaging procedures has improved product consistency and traceability, resulting in higher market prices, enhanced consumer satisfaction, and strengthened supply chain coordination. Within Rice Processing Centers (RPCs), the adoption of LEAN principles has facilitated better coordination between farmers and processors,

reinforcing market linkages and production planning, and enabling more predictable and equitable value distribution along the supply chain.

At the regional level, particularly in Mindanao, case studies highlight tangible improvements in packing efficiency, logistics coordination, and product quality enhancement under programs such as the Mindanao AgriLink Initiative. As documented by CGIAR (2024), LEAN-led interventions in agri-processing hubs have streamlined post-harvest workflows, reduced transport delays, and minimized spoilage through the integration of visual workflow systems, standardized layouts, and synchronized scheduling. These low-cost yet high-impact interventions demonstrate LEAN's adaptability to resource-constrained rural environments, where capital-intensive technologies are often inaccessible. Nonetheless, as noted by the University of Southern Mindanao (2023), the sustainability of these improvements remains contingent upon external investments in infrastructure such as cold storage facilities, transportation networks, and cooperative management systems. These findings reinforce the view that LEAN serves not as a standalone solution but as a complementary management framework that gains full efficacy when embedded within broader agricultural development and investment strategies.

Beyond operational dimensions, recent scholarship underscores the value of integrating financial analytics and digital transformation into LEAN-based agribusiness management. As articulated by Macaumbao and Bandera (2025), the convergence of LEAN's visual and procedural tools with advanced financial monitoring and data-driven decision systems provides a more comprehensive foundation for achieving process optimization, cost control, and strategic adaptability. This hybrid model—combining operational excellence with financial intelligence—advances a holistic paradigm of agribusiness modernization, where productivity, sustainability, and fiscal resilience are mutually reinforcing. Ultimately, the synthesis of LEAN thinking, digital innovation, and financial analytics represents a pivotal step toward the creation of integrated, adaptive, and sustainable food systems capable of meeting the demands of modern global markets.

Challenges and Barriers to Adoption

At the global level, several structural and contextual barriers continue to constrain the widespread and sustained adoption of Lean methodologies within the agricultural sector. Among the most frequently cited obstacles are biological variability, seasonal production cycles, fragmented supplier networks, and limited managerial and technical capacity (Behzadi et al., 2018; Barth, 2018). Unlike manufacturing systems—where processes can be tightly standardized—agriculture operates within inherently uncertain biological and ecological conditions. Variations in weather, soil fertility, pest pressure, and crop yield introduce fluctuations that complicate the establishment of continuous flow and just-in-time (JIT) systems, which are foundational to Lean philosophy. Moreover, many agri-food value chains are smallholder-dominated, characterized by dispersed production units, weak horizontal coordination, and minimal economies of scale. These structural features often inhibit investment in Lean training, equipment upgrades, and data systems, resulting in limited institutionalization of Lean culture (Womack & Jones, 1996). The lack of organizational maturity—manifested in insufficient documentation practices, informal labor arrangements, and low levels of process literacy—further constrains Lean's potential to deliver sustained productivity and quality gains in primary production and post-harvest stages.

Within the Philippine agricultural landscape, these global challenges are compounded by infrastructure deficiencies and logistical constraints that limit the operational feasibility of Lean implementation. Key impediments include inadequate cold-chain facilities, outdated milling and processing equipment, and inefficient transportation networks, which collectively undermine the establishment of continuous and predictable material flows (PIDS, 2023; DA, 2022). Empirical studies on post-harvest losses reveal that Lean's emphasis on process standardization and synchronized workflows is often misaligned with the fragmented and informally organized nature of smallholder-based production systems. Many local producers operate without formalized production schedules, quality assurance systems, or digital tracking tools—making Lean tools such as Value Stream Mapping (VSM) and Kanban systems difficult to sustain beyond pilot phases. In response, Filipino researchers and policymakers have emphasized the need for contextualized adaptations of Lean principles that integrate cooperative, cluster-based, and contract farming models (DOST, 2021). Such hybrid frameworks allow Lean to be reinterpreted as a community-based improvement system, aligning process efficiency with inclusive rural development objectives.

At the regional level, particularly in Mindanao, the adoption of Lean principles faces an even more complex interplay of socio-political and environmental constraints. Persistent security concerns, climate-related

disruptions, and chronic underinvestment in rural infrastructure continue to challenge process continuity and workforce stability (CGIAR, 2024). Even in cases where Lean interventions—such as layout redesigns, visual management tools, and standardized work procedures—have been successfully introduced, institutional continuity and performance sustainability often remain weak. Studies document that limited technical training, high employee turnover, and the absence of long-term management support contribute to the gradual erosion of Lean gains once external project funding ends. Nonetheless, regional evidence suggests that Lean adoption achieves greater resilience when embedded within cooperative or social enterprise models that promote collective ownership, skills upgrading, and participatory decision-making (University of Southern Mindanao, 2023). These integrative approaches underscore that Lean transformation in the agricultural context is not solely a technical exercise but also an organizational and socio-economic process—one that demands institutional stability, knowledge transfer mechanisms, and inclusive governance structures to achieve enduring impact.

In sum, the literature indicates that while Lean principles hold considerable promise for transforming agri-food value chains, their successful translation from manufacturing to agriculture requires systemic adaptation, institutional support, and socio-technical alignment. The global, national, and regional experiences collectively highlight that Lean's long-term sustainability depends on the convergence of managerial capability, infrastructural adequacy, and participatory innovation ecosystems that enable continuous improvement beyond project lifecycles.

Green-Lean and Sustainability Integration

At the international level, contemporary research increasingly emphasizes the strategic integration of LEAN principles with environmental sustainability frameworks, giving rise to the Green-LEAN paradigm. This approach extends the traditional focus of LEAN—primarily on waste reduction, efficiency, and value creation—to include environmental performance indicators such as energy use, water consumption, carbon emissions, and material footprint (Barth, 2018; Bonamigo et al., 2023). Empirical studies demonstrate that combining LEAN methodologies with environmental metrics generates dual benefits, simultaneously enhancing operational productivity and ecological performance. For example, Lean-Green Six Sigma models have been successfully implemented in European food processing industries, where they reduced energy consumption, minimized greenhouse gas emissions, and optimized material use without compromising throughput or product quality (Trubetskaya et al., 2023). Such cases highlight the potential of Green-LEAN systems to transform agri-food operations into resource-efficient and environmentally responsible production systems, aligning industrial efficiency with sustainability imperatives.

In the Philippine context, the adoption of Green-LEAN practices is still at an emergent stage but shows significant promise. Pilot interventions in agricultural processing centers have documented measurable reductions in energy and water usage, achieved through workflow optimization, equipment maintenance, and process standardization (DA, 2022). Researchers and policymakers advocate for a holistic integration of Green-LEAN with sustainable agricultural practices, including soil and water conservation, organic fertilization, and renewable energy utilization. Such integration aligns with the Philippines' broader Sustainable Development Goals (SDG) commitments, particularly those related to responsible consumption, climate action, and sustainable industrialization (UN SDG, 2024). These findings suggest that even in developing country contexts, Green-LEAN strategies can reconcile economic efficiency with environmental stewardship, supporting sustainable growth across agri-food value chains.

Regionally, in Mindanao, Green-LEAN initiatives have been applied in banana, vegetable, and post-harvest processing sectors, with a focus on solar-powered drying and cooling technologies and other renewable-energy solutions (CGIAR, 2024). Integrating environmental efficiency with LEAN process design has proven both cost-effective and resilient, particularly in off-grid or resource-constrained rural areas where energy scarcity, climatic variability, and limited infrastructure pose operational challenges. Studies from the University of Southern Mindanao (2023) indicate that these interventions not only reduce operational costs and resource dependency but also enhance process reliability, product quality, and market competitiveness.

Complementing operational and environmental considerations, contemporary scholarship highlights the convergence of LEAN and modern financial management systems, which increasingly incorporate ESG and sustainability metrics into organizational performance assessment (Macaumbao & Bandera, 2025). This alignment underscores a broader paradigm in which financial intelligence, environmental stewardship, and operational efficiency are mutually reinforcing. In practice, Green-LEAN approaches operationalize this convergence by

embedding eco-efficient process management within decision-making frameworks that account for both economic value and ecological impact. Collectively, the evidence suggests that the future competitiveness and resilience of agribusinesses will depend on the capacity to harmonize financial accountability, operational excellence, and environmental responsibility, making Green-LEAN a pivotal strategy for sustainable agrifood development in both local and global contexts.

III. RESULTS AND DISCUSSION

The synthesis of international, national, and regional literature provides compelling evidence that LEAN thinking has been successfully adapted from manufacturing to agribusiness, producing measurable improvements in efficiency, quality, and sustainability. At the global level, studies consistently demonstrate that LEAN tools—particularly Value Stream Mapping (VSM), 5S, Kaizen, and Standard Work—are highly transferable to agri-food systems, though they require contextual modification to address the biological variability and perishability of agricultural products (Almqvist, 2021; Womack & Jones, 1996; Trubetskaya et al., 2023). For instance, vegetable packing facilities in Spain and the Netherlands reported reduced changeover times, minimized waste, and higher output per labor hour after implementing LEAN workflows, while grain milling plants in Indonesia and India saw increases in throughput and reductions in equipment downtime (Barth, 2018; Bonamigo et al., 2023; ResearchGate, 2019). These findings confirm that LEAN methodologies, when thoughtfully adapted, can enhance operational efficiency without compromising product quality or process resilience.

In the Philippine context, government-led initiatives and research programs highlight parallel outcomes. DOST (2021) documented that 5S and Kaizen interventions in small and medium agribusinesses improved workflow organization, reduced waste, and enhanced production reliability, while DA (2022) and PIDS (2023) reported similar gains in rice milling and fruit processing facilities, including reductions in rework, improved product uniformity, and shorter turnaround times. These results suggest that LEAN implementation can generate tangible benefits even in settings with limited capital and technological resources.

Regionally, in Mindanao, LEAN adoption has been particularly notable in small-scale milling, packaging, and post-harvest operations. Pilot projects in Davao del Norte and Bukidnon utilized visual controls, standardized work procedures, and workstation redesigns, achieving reduced processing times and lower post-harvest losses (CGIAR, 2024). Importantly, studies from the University of Southern Mindanao (2023) indicate that the sustainability of these interventions depends on human capital development, with participatory workshops, technical training, and cooperative-based management systems being critical enablers of long-term efficiency gains. These findings underscore that successful LEAN adoption in agriculture is as much a social and organizational process as it is a technical one.

Operational and Sustainability Benefits emerged consistently across levels. International research shows that LEAN practices reduce waste, improve quality control, and enhance supply chain responsiveness, particularly when integrated with digital data collection and Lean-Green frameworks (Behzadi et al., 2018; Bonamigo et al., 2023; Barth, 2018). In the Philippines, LEAN adoption has decreased post-harvest losses in rice, banana, and vegetable value chains, improved sorting and grading processes, and strengthened market linkages between farmers and processors (DA, 2022; PIDS, 2023). In Mindanao, initiatives under programs such as the Mindanao AgriLink Program demonstrate that workflow standardization, visual management, and coordinated logistics can enhance operational resilience even in resource-constrained rural environments (CGIAR, 2024).

The integration of Green-LEAN principles further highlights the potential for synergistic operational and environmental benefits. International cases show that combining LEAN with environmental performance metrics—such as energy and water efficiency—produces dual gains in productivity and sustainability (Barth, 2018; Trubetskaya et al., 2023). In the Philippines, pilot interventions in agricultural processing centers documented reductions in energy and water usage through process optimization, maintenance improvements, and workflow standardization (DA, 2022). In Mindanao, solar-powered drying and cooling technologies, integrated into LEAN workflows, demonstrated both cost-effectiveness and resilience in off-grid contexts, supporting the dual objectives of efficiency and ecological stewardship (CGIAR, 2024; University of Southern Mindanao, 2023).

Despite these successes, the study identifies persistent barriers to LEAN adoption across scales. Globally, challenges include biological variability, seasonality, fragmented supply chains, and limited managerial capacity (Behzadi et al., 2018; Barth, 2018). In the Philippines, infrastructure deficits such as inadequate cold storage, outdated equipment, and poor transport systems further constrain continuous workflow implementation (PIDS,

2023; DA, 2022). In Mindanao, security issues, climatic disruptions, and limited technical training amplify these challenges, often undermining the sustainability of LEAN interventions (CGIAR, 2024; University of Southern Mindanao, 2023). Evidence suggests that integrating LEAN within cooperative structures or social enterprise models enhances adoption and continuity, highlighting the importance of social, organizational, and participatory dimensions alongside technical process improvements.

Finally, the convergence of LEAN with modern financial management systems represents a significant frontier in agribusiness modernization. Digital and data-driven financial tools—such as real-time analytics, ESG-based performance monitoring, and value-based management—complement LEAN’s operational focus by providing insights for cost control, risk mitigation, and strategic decision-making (Macaumbao & Bandera, 2025). This integrated approach aligns operational efficiency with fiscal accountability and environmental stewardship, suggesting a holistic model for sustainable and resilient agribusiness management.

The literature reveals that LEAN thinking has demonstrable benefits for agribusiness efficiency, product quality, and sustainability when adapted to the biological, social, and infrastructural realities of agriculture. Its successful implementation hinges on localized adaptations, participatory approaches, capacity development, and integration with digital and financial tools. Green-LEAN frameworks further expand these gains by embedding environmental performance within operational workflows. Collectively, these findings underscore that the future of LEAN in agriculture lies in context-sensitive reinvention, balancing efficiency, ecological responsibility, and socio-economic inclusion to meet the complex demands of modern food systems.

IV. CONCLUSION

The synthesis of international, national, and regional evidence demonstrates that LEAN thinking, originally developed for manufacturing, has been successfully adapted to agribusiness, yielding measurable improvements in operational efficiency, product quality, and sustainability. At the global level, tools such as Value Stream Mapping, 5S, Kaizen, and Standard Work have proven transferable to agri-food systems, provided they are modified to accommodate biological variability, perishability, and supply chain complexity. Philippine experiences, particularly in rice milling, fruit processing, and small-scale agri-enterprises, confirm that LEAN adoption can reduce waste, enhance workflow organization, and strengthen market linkages even in resource-constrained settings.

Regional case studies in Mindanao highlight that the success and sustainability of LEAN interventions rely not only on technical adjustments but also on participatory approaches, cooperative structures, and human capital development. These findings reinforce that LEAN implementation in agriculture is as much a social and organizational process as it is a technical one. Furthermore, the integration of Green-LEAN principles and modern financial management tools illustrates the potential for simultaneous gains in environmental performance, fiscal accountability, and operational resilience.

However, persistent challenges—including biological variability, seasonal fluctuations, fragmented supply chains, infrastructure limitations, and socio-political constraints—underscore the necessity of context-sensitive adaptations. The evidence suggests that sustainable LEAN adoption in agribusiness requires holistic strategies that combine technical optimization, participatory governance, and capacity building, thereby balancing efficiency, ecological stewardship, and socio-economic inclusion.

Ultimately, the evolution of LEAN in agriculture represents a paradigm shift: from rigid, efficiency-driven frameworks to flexible, sustainability-oriented, and socially attuned management systems capable of addressing the complex realities of modern food systems. Its continued success depends on the ability of agribusinesses to reinvent LEAN principles in ways that are locally relevant, environmentally responsible, and resilient to changing market and ecological conditions.

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