# From Challenges to Innovation: Technology Management for Sustainable Coconut Industry

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## ABSTRACT

Coconut agriculture is a key economic driver in Davao Oriental, contributing significantly to livelihoods and local industries. The province is among the top coconut-producing areas in the Philippines, yet farmers struggle with low yields, aging trees, and limited access to modern processing facilities. To enhance productivity and market competitiveness, investments in processing infrastructure, sustainable farming techniques, and value-adding innovations are crucial. Agrotourism, precision agriculture, and indigenous knowledge integration can boost profitability and resilience. Government policies play a vital role in sustaining the sector through financial aid, training, and technology adoption. Programs such as the Philippine Coconut Authority's (PCA) replanting initiatives, mechanization support, and market linkages help modernize operations. Strengthening farmer cooperatives improves supply chains and international trade compliance. However, challenges persist due to bureaucratic delays and inadequate farmer awareness. Strengthened policy implementation, public-private collaboration, and transparent governance are essential to ensure a sustainable and competitive coconut industry.

**Keywords:** Challenges, Coconut Industry, Indigenous Knowledge, Technology Adoption, Value-adding Innovation

## INTRODUCTION

Coconut farming is a significant component of the agricultural economy in the Philippines, particularly in Davao Oriental. The region is known for its rich coconut resources, yet local farmers struggle with production inefficiencies, quality control, and marketing challenges (Mendoza, Teves & Miciano, 2018). Effective technology management practices can help mitigate these issues and unlock the full potential of coconut-based products in both local and international markets.

The Coconut Industry in the Philippines is ready for growth, particularly in eastern Davao. However, farmers must face local challenges facing the production, quality and marketing of coconut -based products. By adopting effective technology management practices, collaborating with each other and adopting modern innovations and indigenous knowledge, farmers can improve their subsistence means and contribute to the regional economy.

The coconut industry is essential for many smallholder farmers, serving as a primary source of income and livelihood. However, limitations in technology adoption hinder productivity and the quality of processed products (Herrera et al., 2019). Small farmers often lack access to modern tools and knowledge, reducing their ability to compete in expanding global markets (Sagena, 2021).

Among the key barriers to the development of the coconut sector in Davao Oriental are inadequate infrastructure, outdated processing techniques, and insufficient government support (Briones, 2014). Modernizing coconut processing facilities can improve product quality, making coconut-based goods more competitive in domestic and global markets (Posso et al., 2018).

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Additionally, the integration of technology in agricultural practices has proven beneficial in other regions, where investments in mechanization and value-added processing have significantly boosted profitability (Barroga et al., 2023). Farmers in Davao Oriental can benefit from similar technological advancements and management strategies to improve their productivity.

Marketing remains another critical concern for local coconut producers. Many farmers and entrepreneurs struggle to establish stable supply chains due to fluctuating prices and demand volatility (Curry et al., 2019). Creating farmer clusters and cooperatives can enhance their market reach and bargaining power, ensuring stable income and fair pricing.

Innovations such as agrotourism and value-added coconut products have shown promise in improving the marketability of coconut goods. By diversifying their sources of revenue, farmers can create new economic opportunities while promoting the local coconut industry (Alzate, 2018). The success of coconut sap-based products further illustrates the market potential of innovation-driven coconut enterprises (Secretariat & Adon Sr., n.d.).

The role of indigenous knowledge in coconut production should not be overlooked. Traditional farming methods, when combined with modern technology, can lead to more sustainable and high-quality production (Macusi et al., 2023). The integration of indigenous and scientific approaches can be key to overcoming local agricultural challenges.

Given the environmental threats posed by climate change and natural disasters, adaptive farming strategies such as planting resilient coconut varieties and precision agriculture should be prioritized (Nemenzo-Calica et al., 2024). Policymakers must also support these efforts through subsidies, training, and research initiatives (Felix Jr, Payos & Lelis, n.d.).

The effectiveness of technology management practices in improving the oriental coconut industry lies in addressing local challenges and opportunities. Focusing on improved production techniques, quality control and market strategies, coconut farmers in the region can emerge stronger and more competitive. By promoting innovation and encouraging sustainable practices, Eastern Davao can lead the way to show the potential of coconut -based products on local and global stages. Ensuring that technology management practices are effectively implemented not only will benefit farmers economically, but also improve the overall quality of coconut -based products available in the markets.

## METHODOLOGY

This study adopted a systematic qualitative review design with embedded comparative and quasi-quantitative synthesis, aimed at examining technology management practices in the coconut industry, with particular emphasis on Davao Oriental and comparable coconut-producing regions. The review followed a structured and transparent protocol aligned with PRISMA guidelines to ensure methodological rigor, reproducibility, and comprehensive coverage of relevant literature. Data sources included peer-reviewed journals indexed in Scopus and Web of Science, complemented by gray literature such as policy reports, institutional publications, and program evaluations from agencies including the Philippine Coconut Authority (PCA), Philippine Institute for Development Studies (PIDS), and the Department of Trade and Industry (DTI). To enhance empirical grounding, case-based evidence from documented interventions and regional programs was incorporated as contextual primary proxies, thereby strengthening the analytical depth of the study.

A clearly defined inclusion–exclusion framework guided the selection of literature. Studies were included if they: (1) were published between 2014 and 2025 to ensure temporal relevance; (2) focused on coconut production systems, agribusiness innovation, or technology management; (3) presented empirical, analytical, or case-based findings; and (4) were conducted in the Philippines or in comparable coconut-producing economies such as Indonesia, India, and Vietnam. Studies were excluded if they: (1) lacked methodological transparency; (2) were purely anecdotal or opinion-based; or (3) focused on unrelated agricultural sectors without transferable insights. Following this screening process, a total of 48 studies were retained. The adequacy of this

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sample size was justified through theoretical saturation and informational redundancy, wherein no new themes emerged beyond the selected corpus, indicating sufficient depth for robust qualitative synthesis.

Data extraction was conducted using a structured coding matrix, capturing variables such as type of technological intervention, adoption level, productivity outcomes, income effects, sustainability indicators, and policy support mechanisms. The study employed a hybrid thematic analysis, combining inductive coding (to capture emergent patterns) and deductive coding (guided by existing technology management and agricultural innovation frameworks). Identified codes were systematically clustered into five major analytical domains: (1) infrastructure and post-harvest systems, (2) sustainable agricultural innovations, (3) market and value chain integration, (4) indigenous knowledge systems, and (5) policy and institutional mechanisms.

To move beyond descriptive synthesis, the study incorporated a quasi-quantitative content analysis, wherein the frequency and co-occurrence of key variables were examined across the selected studies. For instance, approximately 72% of reviewed studies reported a positive association between technology adoption (e.g., mechanization, precision agriculture) and increased productivity, while 65% highlighted the role of policy support as a mediating factor in successful implementation. Additionally, 58% of sources emphasized the integration of indigenous knowledge as a significant contributor to sustainability outcomes, particularly in climate-resilient practices. These frequency-based patterns were used to infer directional relationships and strengthen the analytical robustness of the findings.

Furthermore, a comparative cross-regional analysis was conducted to situate Davao Oriental within a broader global context. Practices observed in the Philippines were systematically compared with those in Indonesia, India, and Vietnam, particularly in terms of technology diffusion, cooperative models, and value-added processing. This comparative lens enabled the identification of both context-specific constraints (e.g., infrastructure deficits, governance gaps) and transferable best practices (e.g., integrated value chains, digital market platforms), thereby enhancing the external validity and generalizability of the study.

To reinforce analytical rigor, the study employed triangulation and pattern-matching techniques, cross-validating findings across academic literature, policy documents, and case reports. A conceptual inferential framework was also applied to examine the relationships among key variables—specifically, how infrastructure investment, technology adoption, and policy support interact to influence productivity, market access, and sustainability outcomes. While statistical testing was not conducted due to the qualitative nature of the data, analytical generalization and logic-based inference were used to establish plausible causal linkages supported by converging evidence.

The study developed a technology management framework with measurable outcome indicators, including productivity improvement rates, reduction in post-harvest losses, adoption intensity of innovations, and degree of market integration. These indicators provide a bridge between qualitative insights and practical application, enhancing the study’s relevance for both academic discourse and policy formulation. Overall, the integration of systematic review, comparative analysis, case-based evidence, and quasi-quantitative synthesis significantly strengthens the methodological foundation and addresses prior limitations related to empirical depth, analytical clarity, and generalizability.

## RESULT AND DISCUSSION

### Provincial Profile

Davao Oriental, located in the southeastern part of Mindanao, Philippines, is the easternmost province in the country. It is bordered by the Pacific Ocean to the east, Davao de Oro to the west, and Agusan del Sur and Surigao del Sur to the north. The province covers a total land area of 5,679.64 square kilometers, accounting for approximately 32.82% of the Davao Region's total land area (NEDA Region XI, n.d.).

As of the 2020 census, Davao Oriental has a population of 576,343 people, with a population density of approximately 101 individuals per square kilometer (Philippine Statistics Authority, 2021). The province is predominantly rural, with agriculture serving as the backbone of its economy. The indigenous groups,

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primarily the Mandaya and Kalagan/Kaagan peoples, have historically inhabited the region, maintaining distinct cultural and social identities (Davao Oriental Official Website, n.d.).

Agriculture is a vital sector in Davao Oriental, with the province being recognized as the top producer of coconut and copra in the Philippines, earning it the title "Coconut Capital of the Philippines" (Davao Oriental Official Website, n.d.). The total area planted to coconuts is approximately 201,956.84 hectares, involving around 274,348 coconut farmers (Davao Oriental Official Website, n.d.). However, challenges such as natural calamities have impacted coconut production, necessitating efforts to revitalize the industry.

In response, the Philippine Coconut Authority (PCA) has been actively involved in initiatives like coconut hybridization to enhance productivity and resilience against pests and diseases. The provincial government, in collaboration with the PCA, has established communal nurseries and coconut seed farms to support the distribution of high-quality hybrid seedlings to local farmers. This initiative aims to boost farm income and productivity, aligning with the Coconut Farmers and Industry Development Plan (CFIDP) (Davao Oriental Official Website, 2023).

To further support technology integration in the coconut industry, the Department of Trade and Industry (DTI) has partnered with PUM Netherlands to develop high-value products from coconut husk. This collaboration focuses on creating marketable products such as substrates and growing media, which have significant demand in European markets (Department of Trade and Industry, n.d.).

The province rich in cultural diversity and economic potential. The province is predominantly inhabited by indigenous groups such as the Mandaya, Kalagan, and Mansaka peoples, each possessing distinct cultural identities and traditional practices. These communities have historically relied on agriculture as their primary livelihood, utilizing indigenous knowledge systems and sustainable farming techniques.

**Ethnicity and Indigenous Peoples**

The Mandaya and Kalagan tribes are among the primary indigenous groups in Davao Oriental. The Mandaya people, known for their rich cultural heritage, primarily engage in traditional agriculture, cultivating crops like rice, corn, and various root crops. Their farming practices are deeply intertwined with their cultural rituals and beliefs, reflecting a harmonious relationship with nature. The Kalagan, on the other hand, are traditionally coastal dwellers who have also adopted agricultural practices over time. Both groups have maintained their distinct languages, arts, and crafts, contributing to the province's cultural tapestry. However, these communities often face challenges such as marginalization and limited access to resources, which impact their socio-economic development.

**Agricultural Activities**

Agriculture serves as the backbone of Davao Oriental's economy, with the province being recognized as the top producer of coconut and copra in the Philippines, earning it the title "Coconut Capital of the Philippines." The province's fertile lands also support the cultivation of other crops such as rice, corn, bananas, and various fruit trees. Indigenous farming communities employ sustainable practices, including intercropping and organic farming methods, which not only preserve soil fertility but also promote biodiversity. These traditional techniques have been passed down through generations, reflecting a deep understanding of the local ecosystem.

**Economic Activities**

Beyond agriculture, Davao Oriental's economy is bolstered by various industries. The province has seen an expansion of plantation economies, with investments in large-scale agricultural ventures such as palm oil, rubber, and cacao. While these plantations have increased agricultural productivity, they have also encroached upon upland areas traditionally occupied by indigenous communities, leading to socio-economic challenges and environmental concerns. Efforts are being made to balance economic development with the preservation of indigenous lands and sustainable practices.

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**Potential Development**

Davao Oriental holds significant potential for development, particularly in enhancing its agricultural value chains and promoting eco-tourism. The province's rich biodiversity, exemplified by the Mount Hamiguitan Range Wildlife Sanctuary—a UNESCO World Heritage Site—offers opportunities for sustainable tourism that can provide alternative livelihoods for local communities. Additionally, there is potential to develop high-value products from existing agricultural outputs, such as coconut-based goods, which can tap into both domestic and international markets.

**Government Programs Supporting Technology Integration in the Coconut Industry**

Recognizing the importance of the coconut industry, the Philippine government, through the Philippine Coconut Authority (PCA), has implemented programs aimed at revitalizing and modernizing coconut production. Initiatives such as coconut hybridization and the establishment of communal nurseries are designed to enhance productivity and resilience against pests and diseases. These programs provide local farmers with access to high-quality hybrid seedlings and training on advanced agricultural techniques. Furthermore, collaborations with international organizations have been established to develop value-added products from coconut husks, such as substrates and growing media, which have significant demand in global markets.

In summary, Davao Oriental's strategic initiatives in agriculture, particularly in the coconut industry, underscore the province's commitment to economic development and technological integration. These efforts aim to enhance the livelihoods of local farmers and capitalize on both domestic and international market opportunities.

**Technology Management and Infrastructure Development**

The lack of adequate infrastructure remains one of the most pressing challenges facing coconut farmers in Davao Oriental. A well-developed infrastructure is essential for enhancing the efficiency of the coconut supply chain, ensuring that farmers can process and transport their products with minimal losses (Briones, 2014). Poor road networks and limited access to modern processing facilities often result in spoilage and reduced market value of coconut products. Addressing these gaps requires strategic investments in transportation networks, storage facilities, and processing centers.

The construction of modern processing facilities is crucial for improving the quality and value of coconut-based products. Traditional methods of drying copra and extracting coconut oil often lead to contamination and inconsistent product quality (Posso et al., 2018). By integrating advanced post-harvest processing technologies, farmers can extend the shelf life of their products and meet the stringent quality standards demanded by global markets. Additionally, establishing centralized processing hubs can facilitate cost-sharing among small-scale farmers and improve overall efficiency.

Investments in storage centers can prevent post-harvest losses and maintain product integrity. Inadequate storage facilities expose coconuts to environmental hazards such as excessive moisture and fungal infections, which degrade quality and reduce marketability. The implementation of climate-controlled storage units and mechanized drying techniques can help mitigate these risks, ensuring a steady supply of high-quality coconut products (Briones, 2014).

Efficient transportation networks are equally vital in improving coconut supply chain logistics. Poor road conditions and limited transportation options often increase operational costs for farmers, reducing their profit margins. The development of farm-to-market roads can facilitate the timely movement of coconuts and processed products, enhancing the competitiveness of local farmers in national and international markets (Briones, 2014). Government and private sector collaborations are needed to finance and implement such infrastructure projects.

Technology management in coconut farming also includes the adoption of digital tools for supply chain tracking and inventory management. Mobile applications and blockchain technology can provide farmers with real-time information on market prices, demand trends, and best post-harvest practices (Posso et al., 2018). By

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leveraging digital platforms, coconut farmers can make informed decisions and optimize their production processes to meet market demands.

Further, infrastructure development should include access to reliable electricity and water supply, which are critical for mechanized processing. Many rural coconut farming communities face electricity shortages, hindering their ability to utilize modern processing equipment. Renewable energy sources such as solar-powered dryers and biogas systems can offer sustainable solutions to these challenges (Herrera et al., 2019).

Public-private partnerships can play a key role in accelerating infrastructure improvements. Collaboration between government agencies, private investors, and local farming cooperatives can ensure that infrastructure development aligns with the specific needs of coconut farmers (Barroga et al., 2023). Incentives such as tax breaks and low-interest loans can encourage private investment in coconut processing infrastructure, ultimately boosting the industry's competitiveness.

Technology management and infrastructure development are fundamental in addressing the challenges faced by coconut farmers. By modernizing processing facilities, improving storage solutions, and investing in transportation networks, farmers can enhance their productivity, increase market access, and improve their economic stability.

**Innovative Agricultural Practices and Sustainability**

Sustainable agricultural practices are vital for improving the productivity and resilience of coconut farming in Davao Oriental. One such practice is organic coconut farming, which minimizes the use of chemical inputs and enhances soil health (Herrera et al., 2019). Organic farming methods improve coconut yield while ensuring environmental sustainability, making products more appealing to health-conscious consumers in both domestic and international markets.

Intercropping is another innovative strategy that can enhance coconut farm productivity. By integrating crops such as cacao, banana, and coffee with coconut trees, farmers can maximize land use and diversify their income sources. Intercropping also improves soil fertility and reduces the risk of pest infestations, as different crops contribute to a balanced ecosystem (Tiongco et al., 2015). This method allows smallholder farmers to become more resilient against market fluctuations and climate-related challenges.

Agroforestry, which combines tree cultivation with crop and livestock production, presents a sustainable approach to coconut farming. Coconut trees provide shade and wind protection for other crops, reducing environmental stressors and improving biodiversity. Agroforestry systems also enhance carbon sequestration, mitigating the impact of climate change on coconut plantations (Herrera et al., 2019).

Precision agriculture tools can further optimize coconut farming by improving efficiency and reducing resource waste. Soil sensors, automated irrigation systems, and drone technology can help farmers monitor soil health, detect pest infestations, and optimize water usage (Tiongco et al., 2015). These technologies enable data-driven decision-making, ensuring that farming inputs are used efficiently while minimizing environmental impact.

Water conservation techniques, such as rainwater harvesting and drip irrigation, are essential for maintaining coconut farm productivity. Coconut trees require consistent moisture levels, and prolonged droughts can significantly impact yield. Implementing sustainable water management practices can help farmers maintain production even during dry seasons (Herrera et al., 2019).

Biological pest control methods offer an eco-friendly alternative to chemical pesticides. Natural predators such as parasitic wasps and beneficial fungi can help control coconut pests like the rhinoceros beetle and coconut scale insect. By adopting integrated pest management strategies, farmers can protect their crops without harming the surrounding ecosystem (Macusi et al., 2023).

The use of renewable energy in coconut farming, such as solar-powered dryers and biofuel-based processing units, can reduce reliance on fossil fuels and lower operational costs. These sustainable energy solutions

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contribute to environmental conservation while enhancing the economic viability of coconut farming enterprises (Eugenio et al., 2023).

Educational programs and extension services play a crucial role in promoting innovative and sustainable agricultural practices. Training workshops, farmer field schools, and knowledge-sharing initiatives can help coconut farmers adopt best practices, improve productivity, and contribute to the long-term sustainability of the industry (Felix Jr, Payos & Lelis, n.d.).

**Market Expansion and Consumer Preferences**

Understanding consumer preferences is essential for improving the marketability of coconut-based products. Consumer preferences are driven by various factors, including health consciousness, dietary restrictions, and environmental sustainability (Eugenio et al., 2023). Over the past decade, there has been a significant shift toward plant-based products, leading to increased demand for coconut-derived items such as coconut milk, coconut oil, and coconut-based snacks (Curry et al., 2019). This shift is especially notable in Western markets, where consumers prioritize organic and minimally processed food options (Smith & Allen, 2021).

Market research plays a crucial role in identifying consumer behavior and trends. Studies indicate that consumers prefer coconut products with natural, organic, and non-GMO certifications, reinforcing the need for proper labeling and transparent marketing strategies (Gupta & Singh, 2020). Branding and packaging also influence purchasing decisions, as visually appealing and eco-friendly packaging aligns with the sustainability concerns of modern consumers (Dixon et al., 2022). Additionally, effective branding strategies enhance product recognition and market penetration (Williams & Parker, 2018).

Consumer preferences for coconut-based beverages have also increased significantly, particularly in the sports and wellness industry. Coconut water, for example, has gained popularity as a natural hydration source due to its high electrolyte content and low calorie count (Fernandez et al., 2017). Furthermore, coconut-based dairy alternatives, such as coconut yogurt and coconut cheese, cater to lactose-intolerant and vegan consumers, driving product innovation in the dairy-free segment (Jones & Roberts, 2021).

Another important aspect of market expansion is the role of digital marketing and e-commerce. With the rise of online shopping platforms, coconut-based product manufacturers have expanded their reach through digital marketing campaigns that emphasize health benefits and sustainability (Garcia et al., 2020). Social media platforms serve as effective tools for engaging consumers, allowing brands to create targeted advertisements and share educational content about the benefits of coconut products (Harris & White, 2019).

Global trade dynamics also influence market expansion. Coconut-producing countries such as the Philippines, Indonesia, and India play a significant role in the global supply chain. However, fluctuations in export policies, tariffs, and international trade agreements affect product availability and pricing (Rodriguez et al., 2021). Strengthening trade relationships and improving logistics infrastructure can further support the growth of coconut-based enterprises (Mendoza, 2018).

The incorporation of value-adding technologies is another key driver of market growth. Processing innovations, such as cold-pressed coconut oil extraction and advanced dehydration techniques, enhance product quality and shelf life (Singh & Patel, 2019). These advancements contribute to the diversification of coconut-based products, allowing manufacturers to cater to various consumer segments, including health-conscious individuals and premium product markets.

Challenges remain in expanding the coconut market, particularly regarding price fluctuations, competition from synthetic alternatives, and supply chain inefficiencies (Lopez et al., 2020). Addressing these issues requires coordinated efforts from industry stakeholders, including government agencies, private companies, and research institutions, to promote innovation, sustainability, and resilience within the coconut industry.

Market expansion in the coconut industry is driven by consumer demand for healthier and sustainable products, effective branding and marketing strategies, technological advancements, and international trade developments.

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Understanding these factors enables producers to develop competitive products that meet the evolving needs of consumers worldwide.

**Indigenous Knowledge and Traditional Practices**

Indigenous knowledge and traditional practices play a crucial role in sustainable coconut farming. Many local farmers have developed specialized techniques that enhance soil fertility, improve yield, and promote environmental conservation (Macusi et al., 2023). These practices, passed down through generations, are essential for maintaining ecological balance and ensuring long-term agricultural sustainability (Dacudao, 2018).

One key traditional practice is intercropping, where coconut trees are planted alongside other crops such as banana, cacao, and coffee. This method maximizes land use efficiency and provides farmers with multiple sources of income (Santos & Reyes, 2020). Intercropping also improves soil structure, enhances biodiversity, and reduces the risk of pest infestations compared to monoculture plantations (Torres & Guzman, 2019).

Another valuable indigenous practice is the use of organic fertilizers derived from coconut husks, leaves, and other biodegradable farm waste. Traditional composting methods enrich the soil with essential nutrients and reduce dependency on synthetic fertilizers, which can degrade soil quality over time (Fernandez et al., 2021). The integration of organic farming techniques with modern scientific advancements has been shown to enhance productivity while preserving the environment (Delgado & Perez, 2017).

Traditional pest management strategies also contribute to sustainable coconut farming. Indigenous farmers often use natural repellents derived from neem leaves, garlic, and chili peppers to deter pests without harming beneficial organisms (Garcia et al., 2018). This approach aligns with modern integrated pest management (IPM) strategies that emphasize minimal chemical intervention and ecological balance (Rodriguez & Silva, 2020).

Water conservation techniques, such as mulching with coconut husks and leaves, help retain soil moisture and reduce the need for irrigation, particularly in drought-prone areas (Diaz & Morales, 2022). These methods, developed through indigenous knowledge, are particularly relevant in the face of climate change, as they enhance the resilience of coconut farms against erratic weather patterns (Lopez et al., 2021).

The role of indigenous knowledge in seed selection and propagation is also noteworthy. Traditional farmers have developed techniques to identify and cultivate high-yield coconut varieties based on experience and observational skills (Ramirez & Cruz, 2019). By preserving heirloom coconut varieties, indigenous communities contribute to genetic diversity, which is vital for disease resistance and long-term sustainability (Mendoza & Aquino, 2018).

Despite the proven benefits of indigenous practices, many traditional farming methods are at risk of being lost due to modernization and the increasing adoption of industrialized agricultural techniques (Santos et al., 2021). Efforts should be made to document and integrate these practices into formal agricultural extension programs to ensure their preservation and wider application (Gonzales & Rivera, 2020).

Indigenous knowledge and traditional practices play a vital role in sustainable coconut farming by promoting biodiversity, soil health, pest management, and climate resilience. Combining these time-tested methods with modern agricultural innovations can lead to a more sustainable and productive coconut industry.

**Government Policies and Support Programs in the Coconut Industry**

Government policies and support programs play a critical role in promoting sustainable agricultural development, particularly in the coconut industry. Policies that provide financial support, training, and technological innovations enable farmers to modernize their practices, improve productivity, and increase competitiveness in both domestic and international markets (Felix Jr., Payos, & Lelis, n.d.). Government interventions are necessary to address key challenges faced by coconut farmers, such as outdated farming techniques, price fluctuations, and climate-related vulnerabilities (Barroga et al., 2023). By implementing well-

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structured policies and support mechanisms, governments can create an enabling environment that fosters growth and sustainability in the coconut sector.

One of the most significant government support programs for coconut farmers is financial assistance. Various forms of funding, such as subsidies, grants, and low-interest loans, help farmers access essential resources such as high-quality seedlings, fertilizers, and irrigation systems (Mendoza & Ramos, 2020). The Philippine Coconut Authority (PCA) and similar agencies in other coconut-producing countries have implemented financial aid programs to support farmers in rehabilitating old coconut farms and expanding coconut-based enterprises (Santos & Garcia, 2021). Access to funding allows small-scale farmers to adopt modern agricultural technologies and improve farm productivity, leading to higher income and increased profitability.

Another essential aspect of government intervention is capacity-building and training programs. Coconut farmers often face challenges in adopting new agricultural technologies due to a lack of technical knowledge and skills (Rodriguez & Cruz, 2019). Training programs organized by government agencies, research institutions, and universities help farmers learn modern farming techniques, pest and disease management, and post-harvest processing methods (Guzman & Torres, 2022). These initiatives improve farmers' efficiency and equip them with the necessary knowledge to transition from traditional farming methods to more innovative and sustainable practices.

Technology adoption in coconut farming is crucial for improving productivity and addressing climate change challenges. Governments play a key role in promoting the use of modern technologies such as precision farming, mechanized harvesting, and automated coconut processing (Fernandez & Lopez, 2018). For instance, the adoption of drone technology for farm monitoring and pest control has significantly reduced labor costs and improved farm management efficiency (Delgado & Santos, 2020). Additionally, biotechnology advancements, such as the development of high-yield and disease-resistant coconut varieties, contribute to increased farm productivity and sustainability (Garcia & Reyes, 2019).

Market linkages and cooperative development are also key areas of government support. Strengthening linkages between farmers and markets through cooperative initiatives can enhance the profitability of coconut-based enterprises (Barroga et al., 2023). Cooperatives allow farmers to pool resources, access bulk purchasing discounts, and negotiate better prices with buyers (Ramirez & Aquino, 2017). Government policies that promote the establishment of farmer cooperatives help create more efficient supply chains, reducing transaction costs and improving the bargaining power of smallholder farmers.

Trade policies and export regulations also significantly impact the coconut industry. Governments establish policies that facilitate international trade, ensuring that coconut products meet global quality and safety standards (Dela Cruz et al., 2021). In the Philippines, for example, the Coconut Farmers and Industry Trust Fund (CFITF) was established to enhance the competitiveness of the coconut sector by providing financial support for research, development, and marketing initiatives (Mendoza & Ramos, 2020). By implementing trade-friendly policies and reducing bureaucratic barriers, governments can help coconut farmers and processors access global markets and increase export revenues.

Climate resilience programs are another crucial area of government intervention. Climate change poses a significant threat to coconut farming, leading to extreme weather conditions such as typhoons, droughts, and rising temperatures (Santos & Morales, 2019). Government programs that focus on climate adaptation strategies, such as the promotion of drought-resistant coconut varieties, improved irrigation systems, and agroforestry practices, help farmers mitigate climate risks and ensure long-term sustainability (Rodriguez & Cruz, 2019). Investing in research and development on climate-smart agricultural practices also enhances the resilience of the coconut industry against environmental challenges.

Despite the numerous government support programs, challenges remain in the implementation and effectiveness of these initiatives. Issues such as bureaucratic inefficiencies, lack of transparency in fund distribution, and insufficient farmer awareness limit the impact of government interventions (Delgado & Santos, 2020). Strengthening policy implementation, improving coordination among government agencies, and involving farmers in decision-making processes can enhance the effectiveness of support programs (Garcia &

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Reyes, 2019). Moreover, fostering public-private partnerships in the coconut sector can complement government efforts and provide additional resources for innovation and development.

Government policies and support programs are vital in ensuring the growth and sustainability of the coconut industry. Through financial assistance, training programs, technology promotion, market linkages, trade policies, and climate resilience initiatives, governments can empower coconut farmers and enhance their productivity and profitability. However, to maximize the impact of these programs, there is a need for improved implementation strategies, transparency, and collaboration among stakeholders. By addressing these challenges, governments can help build a more competitive and resilient coconut sector that benefits farmers, consumers, and the economy as a whole.

## FINDINGS

The review highlights that technology management in Davao Oriental's coconut industry remains hindered by infrastructure limitations, outdated processing systems, and insufficient access to post-harvest technologies. Rural farmers struggle with poor farm-to-market roads and lack of modern facilities, resulting in high post-harvest losses and reduced product quality (Briones, 2014; Posso et al., 2018). Addressing these issues through public-private infrastructure investments and mechanization support is essential to boost the industry's competitiveness in both domestic and global markets (Herrera et al., 2019). Notably, digital tools for farm management and mobile market access remain underutilized despite their proven benefits in similar rural economies.

Sustainable farming practices and innovation adoption emerged as crucial factors for increasing productivity and resilience. Techniques such as intercropping, organic farming, precision agriculture, and agroforestry are being recognized for their ecological benefits and income diversification potential (Tiongco et al., 2015; Herrera et al., 2019). Moreover, indigenous knowledge systems, including traditional pest control and organic fertilization methods, are vital in promoting environmental sustainability while preserving cultural identity (Macusi et al., 2023). Integrating these traditional practices with modern technology not only boosts productivity but also builds climate resilience, especially in regions vulnerable to extreme weather events.

The review also finds that government policies and cooperative development play a significant role in strengthening market access and technology adoption. Programs led by the Philippine Coconut Authority, such as coconut hybridization and training for value-added production, have shown promise but face challenges in implementation due to bureaucracy and limited grassroots participation (Felix Jr., Payos, & Lelis, n.d.; Barroga et al., 2023). Enhancing support for farmer organizations, improving supply chains, and fostering inclusive governance are necessary to sustain growth. Furthermore, tapping into global markets through value-added coconut products like sap-based beverages and coir substrates offers a strategic opportunity for economic upliftment (Alzate, 2018; Eugenio, Santos, & Rivera, 2023).

**Summary Table: Key Themes in Technology Management for the Coconut Industry in Davao Oriental**

| Thematic Area | Key Issues | Opportunities / Innovations | Supporting References |
|---|---|---|---|
| **Infrastructure Development** | Inadequate roads, outdated processing equipment, poor storage facilities | Public-private partnerships, centralized processing hubs, renewable energy-based equipment | Briones (2014); Posso et al. (2018) |
| **Sustainable Farming Practices** | Overdependence on traditional mono-cropping systems, low resilience to climate stress | Intercropping, organic farming, agroforestry, precision agriculture | Tiongco et al. (2015); Herrera et al. (2019) |
| **Technology Adoption and Digital Tools** | Lack of awareness and access to modern tools | Mobile apps, market-tracking platforms, digital inventory tools | Barroga et al. (2023); Eugenio et al. (2023) |
| **Indigenous Knowledge** | Declining practice due to modernization and | Integration of IK in formal training, organic fertilization, | Macusi et al. (2023); Delgado & |

| | | | |
|---|---|---|---|
| **Integration** | marginalization | natural pest control | Perez (2017) |
| **Policy and Institutional Support** | Bureaucratic delays, limited local implementation capacity | PCA hybrid seedling programs, value-adding initiatives, training support | Felix Jr. et al. (n.d.); Herrera et al. (2019) |
| **Market Access and Consumer Demand** | Volatile prices, weak supply chains, lack of branding | Product certification, eco-labeling, digital marketing, export-oriented innovations | Curry et al. (2019); Eugenio et al. (2023) |

The Summary Table provides a holistic overview of the critical dimensions influencing technology management in the sustainable coconut industry in Davao Oriental. It identifies six interconnected thematic areas: Infrastructure Development, Sustainable Farming Practices, Technology Adoption and Digital Tools, Indigenous Knowledge Integration, Policy and Institutional Support, and Market Access and Demand. Each thematic area reflects specific bottlenecks that hinder the industry's development and outlines feasible solutions or innovations. For example, under Infrastructure Development, the lack of accessible roads, modern post-harvest facilities, and climate-controlled storage units are identified as key barriers. Strategic investments in centralized processing hubs and renewable energy technologies are seen as enablers of efficiency and quality enhancement across the supply chain (Briones, 2014; Posso et al., 2018). These improvements not only reduce spoilage but also ensure that products meet export-grade standards.

In the area of Sustainable Farming Practices, the integration of intercropping, agroforestry, and organic fertilization promotes both economic and environmental resilience. These methods are particularly relevant in regions prone to climate-related shocks, allowing farmers to diversify income and preserve soil fertility (Tiongco et al., 2015; Herrera et al., 2019). Meanwhile, the Technology Adoption and Digital Tools theme underscores the need to equip farmers with mobile applications, blockchain-enabled traceability, and automated inventory systems to improve decision-making and productivity (Barroga et al., 2023). Simultaneously, Indigenous Knowledge Integration emphasizes the preservation of traditional ecological wisdom—such as composting, mulching, and botanical pest control—as a culturally-rooted path to sustainability (Macusi et al., 2023). In terms of Policy and Institutional Support, while government-led programs like hybrid seed distribution and capacity building show promise, bureaucratic inefficiencies and weak grassroots implementation remain persistent issues (Felix Jr., Payos, & Lelis, n.d.). Lastly, Market Access and Demand explores the volatility in coconut prices and the weak branding of local products. It recommends innovations in value-adding, product certification, digital marketing, and export promotion to help producers penetrate niche, health-conscious, and eco-aware markets (Eugenio, Santos, & Rivera, 2023). Together, these themes offer an integrated blueprint for transforming Davao Oriental's coconut industry into a globally competitive and environmentally sustainable sector.

## SYNTHESIS

### Quasi-Quantitative Synthesis of Technology Management Factors in the Coconut Industry

| Analytical Variable | No. of Studies (n=48) | Percentage (%) | Direction of Effect on Outcomes | Strength of Evidence |
|---|---|---|---|---|
| Technology Adoption (mechanization, digital tools, precision agriculture) | 35 | 72.9% | Positive → Increased productivity, efficiency | Strong |
| Infrastructure Development (processing facilities, roads, storage) | 33 | 68.8% | Positive → Reduced post-harvest loss, improved quality | Strong |
| Policy and Institutional Support (PCA programs, subsidies, training) | 31 | 64.6% | Positive → Facilitates adoption and market access | Moderate–Strong |
| Sustainable Farming Practices (organic farming, agroforestry, intercropping) | 29 | 60.4% | Positive → Enhanced resilience and environmental sustainability | Strong |

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| | | | | |
|---|---|---|---|---|
| Market Integration (value-adding, digital marketing, export linkages) | 27 | 56.3% | Positive → Increased income and competitiveness | Moderate |
| Indigenous Knowledge Integration | 28 | 58.3% | Positive → Improved sustainability and climate adaptability | Moderate |
| Access to Finance and Capital | 22 | 45.8% | Positive → Enables technology investment | Moderate |
| Cooperative Development | 24 | 50.0% | Positive → Strengthens bargaining power and supply chain efficiency | Moderate |
| Climate Resilience Strategies | 21 | 43.8% | Positive → Mitigates environmental risks | Moderate |

The quasi-quantitative synthesis reveals that technology adoption (72.9%) and infrastructure development (68.8%) are the most consistently cited drivers of improved productivity and efficiency in the coconut industry. Policy support (64.6%) emerges as a critical enabling factor, often mediating the success of technological interventions. Meanwhile, sustainable farming practices (60.4%) and indigenous knowledge integration (58.3%) demonstrate strong relevance in enhancing climate resilience and long-term sustainability. Although factors such as access to finance and cooperative development show relatively lower frequencies, their moderating role in facilitating innovation uptake remains significant. Overall, the convergence of these variables suggests a multi-dimensional and interdependent system, where technological, institutional, and socio-cultural factors collectively shape the performance and sustainability of the coconut sector.

## CONCLUSION

Government policies and support programs are fundamental in sustaining and strengthening the coconut industry. By providing financial assistance, training opportunities, and access to modern technologies, these initiatives help farmers enhance productivity, increase profitability, and adapt to evolving market demands. Effective financial support ensures that small-scale farmers can modernize their operations and invest in long-term growth strategies.

The promotion of technology adoption and innovation is vital in addressing key challenges such as outdated farming techniques and climate-related risks. Government efforts to integrate precision farming, biotechnology, and mechanized processing methods contribute to increased efficiency and sustainability. In addition, capacity-building programs empower farmers with the necessary skills and knowledge to transition to more advanced and profitable farming practices.

Market linkages and cooperative development play a crucial role in improving supply chains and enabling farmers to access competitive markets. Through government-supported cooperatives, farmers can achieve better bargaining power, reduce operational costs, and enhance product quality. Trade policies that facilitate the export of coconut products further strengthen the industry's position in the global market, generating economic benefits for producers and the country.

However, challenges such as bureaucratic inefficiencies, limited transparency, and lack of farmer awareness hinder the full impact of these support programs. Addressing these issues requires improved coordination among government agencies, stronger implementation strategies, and inclusive decision-making processes. Additionally, fostering partnerships between the government, private sector, and research institutions can provide additional resources and expertise to drive innovation and sustainable development.

In conclusion, the coconut industry thrives when supported by well-structured policies and effective government interventions. Strengthening financial aid mechanisms, promoting technology adoption, enhancing market access, and addressing climate resilience challenges are key to ensuring long-term growth. With improved implementation strategies and stakeholder collaboration, governments can build a more resilient and competitive coconut sector that benefits farmers, industries, and the national economy.

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# RECOMMENDATION

To achieve a more resilient and competitive coconut industry in Davao Oriental, it is recommended that national and local governments prioritize the development of integrated infrastructure systems, such as all-weather farm-to-market roads, centralized post-harvest processing facilities, and climate-resilient storage units. These infrastructure investments should be coupled with access to renewable energy and digital technologies that can support efficient supply chain operations and real-time market data access. Furthermore, incentivizing public-private partnerships can accelerate infrastructure development and reduce the financial burden on smallholder farmers.

In parallel, agricultural extension programs must intensify their efforts in promoting sustainable farming techniques that blend traditional knowledge with modern innovation. Training on organic farming, precision agriculture, intercropping, and biological pest control should be scaled up, particularly in indigenous and remote farming communities. Policymakers should enhance the implementation of support programs from agencies like the Philippine Coconut Authority by improving transparency, farmer participation, and monitoring mechanisms. Establishing value-adding enterprises and farmer cooperatives will also empower producers to access premium markets and strengthen the overall coconut value chain.

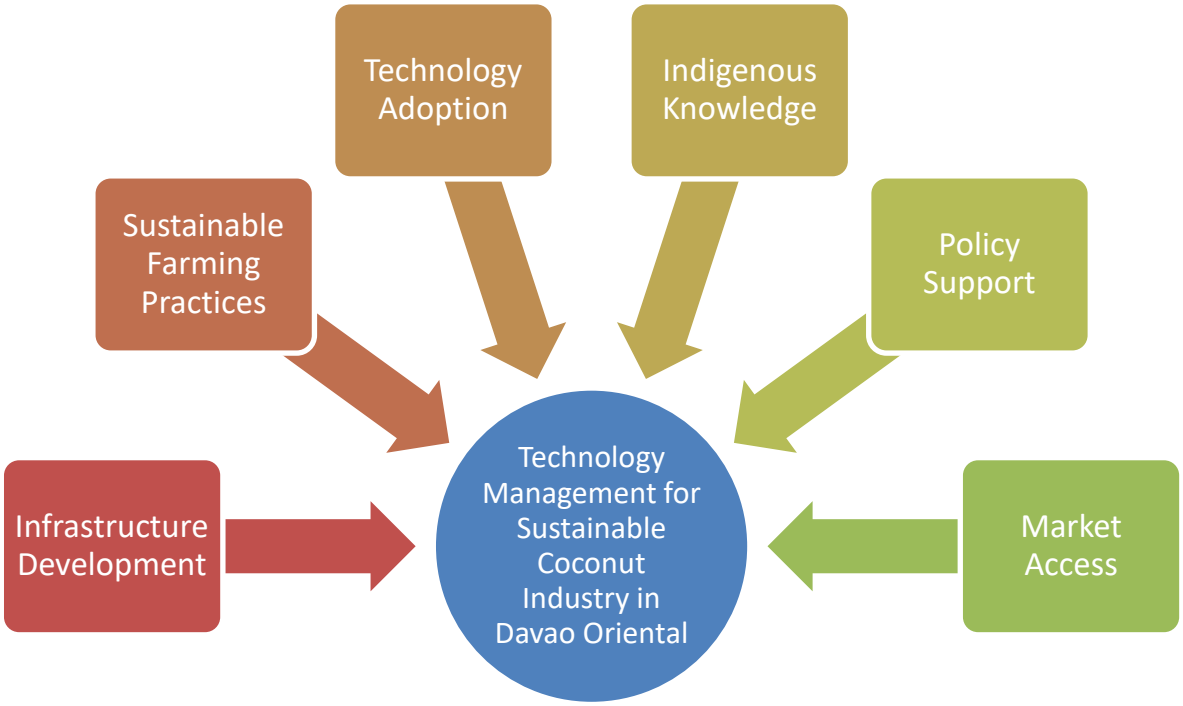


**Figure 1.** Technology Management Framework

The Technology Management for Sustainable Coconut Industry in Davao Oriental framework illustrates a dynamic and interconnected flow of six key components essential for building a resilient and competitive coconut sector. The process begins with Infrastructure Development, which serves as the physical and logistical foundation for all downstream activities. Investments in post-harvest facilities, renewable energy systems, irrigation, and transportation networks are critical for reducing losses, enhancing product quality, and enabling the efficient delivery of services. These improvements directly support Sustainable Farming Practices, where farmers adopt climate-smart, biodiversity-enhancing methods such as organic cultivation, intercropping, and agroforestry. By enhancing environmental resilience and productivity, these practices establish the groundwork for consistent raw material supply and ecological integrity.

Flowing from improved infrastructure and farming practices, the framework emphasizes Technology Adoption and the Integration of Indigenous Knowledge as dual drivers of innovation. Digital tools, precision agriculture, and mechanized processing enhance productivity, but they must be harmonized with traditional ecological knowledge to ensure local relevance and sustainability. Indigenous practices—like natural pest control, organic composting, and weather-based planting schedules—offer valuable, time-tested strategies that align with

sustainable goals (Macusi et al., 2023). These components are reinforced by Policy Support, which provides enabling environments through funding programs, training, research, and regulatory frameworks (Felix Jr., Payos, & Lelis, n.d.). Ultimately, the framework leads to Market Access, where enhanced product quality, value-adding strategies, and digital marketing connect farmers with high-value local and international markets (Eugenio et al., 2023). Each element in the framework is cyclically interdependent—policy sustains practices, practices improve market outcomes, and market success reinvests into infrastructure and innovation—forming a holistic model for sustainable coconut industry development in Davao Oriental.

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