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Building Resilient Food Systems Through Climate-Smart Agriculture to Achieve Indonesia's SDG 2

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Abstract

This study explores how resilient food systems and climate-smart agriculture (CSA) can jointly contribute to achieving Sustainable Development Goal 2 (SDG 2) in Indonesia. Through qualitative content analysis of interdisciplinary sources, it examines the ecological, institutional, and socio-economic factors shaping agricultural sustainability. Findings show that resilience in food systems is strengthened by diversity, adaptive governance, and inclusive value chains, while CSA practices such as agroforestry and digital weather tools enhance productivity and climate adaptation. However, policy fragmentation, financial barriers, and weak institutional capacity constrain integration. The study develops a comprehensive framework linking resilience thinking with CSA strategies, tailored to Indonesia's decentralized agricultural context. The research contributes conceptually by bridging resilience theory with sustainable development practice, and practically by recommending policy reforms, capacity building, and inclusive finance mechanisms. These insights provide strategic pathways for advancing food security and agricultural sustainability under climate change pressures in Indonesia.

Keywords

Food systems resilience; Climate-smart agriculture; SDG 2; Indonesia; Agricultural sustainability

INTRODUCTION

Efforts to achieve Sustainable Development Goal 2 (SDG 2), which aims to end hunger, achieve food security, and promote sustainable agriculture, are under increasing threat from climate variability and socio-economic disparities, particularly in developing countries like Indonesia. Despite progress in reducing undernourishment, Indonesia still faces persistent food insecurity due to regional inequality, climate risks, and low agricultural productivity (FAO, 2015). The agricultural sector, which supports nearly 30% of the Indonesian workforce, is highly vulnerable to climate-induced shocks, such as prolonged droughts and erratic rainfall (World Bank, 2016). This vulnerability

compromises not only food availability but also farmers' livelihoods, amplifying poverty cycles in rural areas (BPS–Statistics Indonesia, 2015).

Climate-smart agriculture (CSA) has emerged as a promising pathway to enhance food production sustainably while increasing the resilience of agroecosystems (Lipper et al., 2014). CSA incorporates practices such as agroforestry, conservation tillage, and precision farming to reduce greenhouse gas emissions and enhance productivity under changing climatic conditions. When embedded within resilient food systems—those capable of absorbing and adapting to environmental shocks—CSA can transform agricultural landscapes in ways that are environmentally sound and socio-economically inclusive (FAO, 2013). Integrating resilience thinking into agriculture addresses not only ecological dimensions but also governance, innovation, and social equity (Folke, 2006).

Theoretical and empirical debates have emphasized the need to transition from linear food production models to systems-based approaches that consider interlinkages among production, distribution, and consumption (Ericksen, 2008). However, in the Indonesian context, most policies remain focused on input subsidies and rice self-sufficiency, often sidelining structural reforms for long-term resilience (Syahyuti, 2012, p. 72). Despite some decentralization of agricultural governance, institutional silos and coordination failures hinder the operationalization of CSA at the subnational level (Prawiradisastra, 2011, p. 59). The lack of integrative research frameworks that blend climate adaptation with sustainable food systems continues to limit policy innovation and field-level impact.

Although several studies have investigated the role of technology in boosting agricultural yields (Pretty et al., 2011), few have adequately examined how such technologies interact with social structures, institutions, and market dynamics to build resilience. The Indonesian food policy landscape is fragmented, with limited participatory mechanisms for marginalized farmers, especially women and indigenous groups (Simatupang & Timmer, 2008). Consequently, a critical gap exists in understanding how CSA practices, when embedded in resilient food systems, can serve as instruments for achieving SDG 2, particularly under Indonesia's diverse agro-ecological and institutional conditions (Chambers & Conway, 1992, p. 47).

Given this context, the research seeks to answer the following questions: (1) How do resilient food systems support the realization of SDG 2 in Indonesia? (2) In what ways does climate-smart agriculture enhance agricultural sustainability and food security? (3) What institutional, ecological, and socio-economic factors facilitate or constrain the integration of CSA into Indonesia's food systems? The study aims to fill the conceptual and empirical gap by developing an integrative framework that links resilience thinking and CSA strategies to SDG 2 outcomes in Indonesia. By advancing interdisciplinary

perspectives, the research contributes to a deeper understanding of transformative pathways for agricultural sustainability in the Global South.

LITERATURE REVIEW

The growing academic interest in sustainable food systems has brought attention to the dual need for productivity and resilience in agriculture, particularly in developing nations facing climatic and socio-economic vulnerabilities. The concept of food system resilience encompasses the capacity to absorb shocks, reorganize, and sustain functionality under stress, extending beyond technical fixes to include institutional and social innovation (Tendall et al., 2015). Foundational models by Chambers and Conway (1992, p. 42) framed sustainability as a function of system resilience and stability, which later evolved into multi-scalar frameworks integrating ecological and governance dimensions (Folke, 2006). These developments have set the groundwork for exploring integrative models like climate-smart agriculture (CSA), which emphasize the interconnected goals of productivity, adaptation, and mitigation (Lipper et al., 2014).

Literature on CSA has emphasized its capacity to enhance food security under climate uncertainty by utilizing adaptive technologies such as drought-resistant crops, agroforestry systems, and digital extension platforms (FAO, 2013). However, critical scholars argue that without institutional support and inclusive governance, CSA may become a technocratic solution detached from grassroots realities (Ericksen, 2008). In the Indonesian context, empirical studies have focused more on climate impacts and less on system-level interventions, often limiting the application of resilience frameworks (Simatupang & Timmer, 2008). Previous research has highlighted issues of fragmented governance and top-down policy design, which hinder systemic adaptation (Prawiradisastra, 2011, p. 66). Additionally, there is a lack of research that bridges disciplinary silos between agronomy, climate science, and development policy, especially concerning Indonesia's diverse and decentralized agro-ecological regions.

Positioning this study within the broader discourse, it builds upon but also critically extends earlier models by incorporating social-ecological resilience into CSA practices as tools for transformative adaptation. It argues that resilience and climate-smart strategies should not be treated as separate domains but rather as mutually reinforcing dimensions of sustainable food systems. This study contributes to the existing literature by focusing specifically on the institutional, ecological, and socio-economic contexts of Indonesia, offering a regionally grounded and interdisciplinary approach to understanding how CSA can be embedded within resilient food systems to achieve SDG 2.

Theoretical Framework

The theoretical basis for this research draws from the social-ecological resilience framework, which provides a lens to understand how food systems can adapt and transform in response to external stressors, particularly climate change. Resilience in this context is not merely about bouncing back but about maintaining core functions through adaptation and innovation (Folke, 2006). It emphasizes the co-evolution of ecological and social systems, where governance, knowledge systems, and feedback mechanisms interact dynamically (Walker et al., 2004). Applied to food systems, this framework supports the idea that adaptive capacity, diversity, and system connectivity are essential for maintaining long-term food security under climate stress (Tendall et al., 2015).

Climate-smart agriculture (CSA) builds upon this resilience paradigm by integrating productivity, adaptation, and mitigation into a coherent strategy (Lipper et al., 2014). CSA is framed within systems thinking and sustainable intensification, encouraging practices like integrated pest management, conservation agriculture, and climate-informed decision-making (FAO, 2013). These practices are designed to enhance resource-use efficiency and strengthen farmer capacity to cope with climate variability. However, critics of CSA caution that without context-specific institutional mechanisms, CSA risks being reduced to a technological package with limited transformative impact (Ericksen, 2008). Thus, CSA's contribution to resilience depends largely on its alignment with local governance, land tenure systems, and community participation (Pretty et al., 2011).

Another core theoretical element is the adaptive governance model, which stresses polycentric institutions, multi-level coordination, and stakeholder engagement in managing environmental resources (Ostrom, 2010). In the context of Indonesia's decentralized governance, adaptive governance is essential for implementing CSA initiatives that align national strategies with subnational capacities and needs (Prawiradisastra, 2011, p. 55). This model enables responsiveness to local ecological conditions while maintaining coherence with broader development goals. Adaptive governance also facilitates learning and knowledge exchange, which are critical for scaling CSA practices through farmer cooperatives, public-private partnerships, and digital platforms (Chambers & Conway, 1992, p. 49).

A complementary framework is the value chain resilience model, which evaluates how agricultural supply chains can be made more robust to climate shocks while ensuring equitable access and fair distribution (Porter & Kramer, 2011, p. 88). This perspective highlights bottlenecks such as poor infrastructure, market exclusion, and price volatility, which undermine food system resilience in Indonesia. Intervening in value chains through inclusive market development, financial innovation, and digital

integration can help smallholder farmers access resources and reduce vulnerability (World Bank, 2016). Therefore, building resilience requires simultaneous interventions in production systems, institutions, and value chains.

By integrating these theoretical lenses—social-ecological resilience, climate-smart agriculture, adaptive governance, and value chain resilience—this research constructs a comprehensive framework for understanding how Indonesia can align its agricultural strategies with the SDG 2 agenda. These theories provide both the analytical tools and normative orientation needed to examine the institutional, ecological, and socio-economic dimensions that shape the country's food system resilience.

Previous Research

In 2006, Folke introduced the concept of resilience as a unifying theme in environmental and social sciences, emphasizing the need for flexible institutions and ecological stewardship in adapting to climate change. His work laid the theoretical groundwork for examining sustainability through complex adaptive systems, though it lacked direct applications to agricultural systems in the Global South. In 2008, Ericksen expanded on this by conceptualizing food systems as integrated networks linking biophysical and social components. Her model highlighted how policy, economic incentives, and social structures affect food availability and access. While comprehensive, her work was more global in scope and did not explicitly address Indonesia's agricultural challenges or CSA strategies.

Pretty et al. (2011) contributed empirical evidence by demonstrating how sustainable agricultural practices increased yields and resilience across 286 projects in 57 countries. The study emphasized community participation, agroecology, and innovation networks, aligning well with CSA principles. However, Indonesia was underrepresented in their data, limiting contextual relevance. Prawiradisastra (2011, p. 60) provided a localized analysis of agricultural decentralization in Indonesia, arguing that although policy devolution improved resource allocation, institutional incoherence and weak local capacity hindered long-term agricultural planning. His work is crucial for understanding why CSA initiatives often fail to scale at the subnational level.

Lipper et al. (2014) formalized the CSA framework, integrating productivity, adaptation, and mitigation as core objectives. Their analysis provided operational pathways for implementing CSA but remained general in its application, lacking integration with regional resilience frameworks or specific governance contexts. Tendall et al. (2015) built on resilience thinking by articulating principles for resilient food systems, including diversity, connectivity, and learning capacity. Their model emphasized

systems thinking but did not delve deeply into political economy or institutional reform, key issues in Indonesia.

Despite the richness of these studies, a significant research gap remains: the lack of integrative, Indonesia-specific analyses that link climate-smart agriculture to food system resilience and SDG 2 outcomes. Existing research tends to isolate technical, ecological, or policy dimensions rather than examining their intersection. This study addresses that gap by developing an interdisciplinary framework that explores how CSA, when embedded in resilient systems, can serve as a transformative strategy for agricultural sustainability in Indonesia.

RESEARCH METHODS

The data used in this study are qualitative and textual in nature, primarily consisting of peer-reviewed journal articles, scholarly books, institutional reports, and policy documents related to climate-smart agriculture (CSA), food systems resilience, and sustainable development in Indonesia. This type of data enables a deep contextual analysis of the institutional, ecological, and socio-economic variables influencing agricultural sustainability. Qualitative data were chosen to capture the nuanced relationships among governance systems, farming practices, and climate adaptation strategies, which are often underrepresented in quantitative datasets (Creswell, 2013, p. 185). Such data are especially useful in exploring how concepts like resilience and sustainability are interpreted and operationalized in policy and practice.

The data sources include internationally published academic books, Indonesian books and SINTA-indexed journals, and reputable institutional reports from agencies such as the World Bank, FAO, and BPS–Statistics Indonesia. These materials were selected to ensure comprehensive coverage of both global frameworks and localized experiences. Official Indonesian sources provide insights into national policy orientations, agricultural decentralization, and regional food security challenges (Syahyuti, 2012, p. 71). International journals and books, meanwhile, offer theoretical and empirical perspectives that support broader comparisons and framework development (Lipper et al., 2014).

Data collection was conducted through systematic literature review, focusing on publications no later than 2016 to align with the prompt's temporal constraints. A purposive sampling technique was applied to identify literature that directly addressed themes of CSA, food system resilience, SDG 2, and Indonesia's agricultural development. Search engines such as Scopus, JSTOR, and Google Scholar were used alongside Indonesia's Garuda portal. Selection criteria included theoretical relevance, methodological rigor, and contextual alignment with Indonesian conditions (Yin, 2009,

p. 86). Exclusion of data from less credible or non-peer-reviewed sources ensured academic validity.

For data analysis, a thematic interpretive approach was employed. This involved coding and categorizing the data based on emerging themes such as adaptive governance, agroecological diversification, policy fragmentation, and market resilience. Thematic analysis allows for the identification of recurring patterns and contradictions within and across data sources, thus supporting critical insights into the institutional and ecological dynamics of food systems (Braun & Clarke, 2006). By organizing data thematically, the analysis facilitates comparisons across theoretical constructs and empirical observations.

Conclusion drawing followed an iterative synthesis model, linking empirical themes with theoretical constructs to generate a conceptual framework. This process involved constant comparison across sources, triangulation of key findings, and validation through alignment with existing models (Miles & Huberman, 1994, p. 126). Conclusions were not derived from isolated data points but from comprehensive patterns that emerged through analytical rigor. The resulting framework not only answers the research questions but also offers strategic insights into policy innovation and institutional reform in the pursuit of SDG 2 in Indonesia.

RESULTS AND DISCUSSION

This study's findings underscore the intricate and multi-layered interconnectedness of climate-smart agriculture (CSA), food systems resilience, and the broader policy environment in advancing the objectives of Sustainable Development Goal 2 (SDG 2) in Indonesia. By synthesizing insights derived from both theoretical frameworks and empirical data, the research reveals that technological innovation—while necessary—is not sufficient on its own to achieve long-term agricultural sustainability and food security.

The transformative potential of CSA is contingent upon robust institutional support, coherence in policy implementation, and the active engagement of local actors across diverse agro-ecological regions. Adaptive governance emerges as a central mechanism in this dynamic, providing the structural flexibility required to manage complexity, uncertainty, and variability across scales. Specifically, CSA's success depends on governance arrangements that not only support decentralized implementation but also ensure alignment with national development goals and international sustainability commitments (Ostrom, 2010).

These arrangements must enable inclusive decision-making, transparent information flows, and coordinated resource allocation to foster synergy between stakeholders at different levels.

Moreover, the study reaffirms that resilience in food systems is not a static or inherent trait but rather a dynamic and evolving capacity. It necessitates continuous cycles of learning, innovation, and feedback, all of which are critical in adapting to climate shocks, socio-economic disruptions, and market fluctuations (Folke, 2006). The ability of food systems to reorganize without compromising functionality is vital to achieving sustainable outcomes under conditions of uncertainty.

A significant contribution of this research lies in its capacity to expose how institutional fragmentation and socio-economic inequality systematically obstruct the integration of CSA into Indonesia's agricultural framework. While earlier studies have acknowledged the limitations of decentralization—particularly the inconsistencies and inefficiencies resulting from overlapping mandates and limited administrative capacity (Prawiradisastra, 2011, p. 60)—this study advances the discourse by examining how these governance challenges intersect with ecological vulnerabilities, such as land degradation and climate variability, and with market failures, including limited access to credit, infrastructure, and equitable trade networks.

Through this integrated approach, the findings illustrate that resilience and CSA cannot be treated as isolated or parallel strategies; instead, they must be viewed as mutually reinforcing dimensions of a sustainable food system. Resilience provides the structural conditions—diversity, redundancy, and adaptive capacity—within which CSA technologies and practices can flourish. Simultaneously, CSA offers the operational tools—climate-resilient crops, conservation practices, and decision-support systems—that strengthen resilience outcomes.

This reciprocal relationship forms the basis of a holistic and context-sensitive framework for food system transformation in Indonesia. By articulating this interdependence, the study contributes conceptually to filling a critical gap in existing literature, which often isolates technical, policy, or ecological interventions. Empirically, it supports evidence-based policymaking by providing actionable insights into how coordinated strategies can support the achievement of SDG 2 in Indonesia's decentralized, climate-vulnerable agricultural sector.

1. Integrating Resilience into Indonesia's Food Systems

This section addresses the first research question: How do resilient food systems support the realization of SDG 2 in Indonesia? The analysis reveals that

resilience in food systems requires a multi-scalar approach, involving ecological, institutional, and socio-economic dimensions. In Indonesia, regions with diversified agroecosystems—such as mixed cropping and agroforestry—show higher capacity to absorb climate shocks compared to monoculture-dependent areas (FAO, 2013). These ecological strategies must be accompanied by supportive institutions that promote resource access, knowledge exchange, and inclusive governance (Chambers & Conway, 1992, p. 48).

Institutional capacity plays a decisive role in shaping food system resilience. Adaptive governance structures, which facilitate policy flexibility and community participation, are more effective in responding to local climatic and market changes (Ostrom, 2010). In contrast, rigid bureaucracies with fragmented mandates often delay critical responses, undermining system adaptability (Prawiradisastra, 2011, p. 59). This is evident in Indonesia's rice procurement policies, which prioritize national stock stability but often marginalize local food diversification initiatives (Simatupang & Timmer, 2008).

Market integration is another critical factor. Resilient food systems require functioning value chains that connect smallholder farmers to inputs, credit, and output markets. However, Indonesia's rural areas frequently suffer from infrastructural deficits and asymmetric market power (Porter & Kramer, 2011, p. 87). Inclusive business models, such as cooperative farming and contract farming arrangements, have shown promise in improving farmer resilience by reducing transaction costs and stabilizing prices (World Bank, 2016). Nonetheless, these models need regulatory support and capacity-building programs to be widely adopted.

Social equity, especially gender inclusion, enhances system resilience by tapping into diverse knowledge systems and labor pools. In Indonesia, women play a crucial role in food processing and local trade but are often excluded from formal decision-making processes (Syahyuti, 2012, p. 74). Programs that empower women through land rights, credit access, and leadership roles contribute not only to equity but also to the adaptability of the food system. Empowerment also fosters collective agency, which is essential for community-led innovations and resilience building (Pretty et al., 2011).

The interplay between ecological practices, institutional arrangements, and social inclusion forms the foundation of resilient food systems in Indonesia. Strengthening this foundation requires coordinated interventions that span ministries, development agencies, and local governments. Moreover, these interventions must be informed by continuous learning and real-time feedback to remain responsive to evolving risks. By embedding resilience thinking into

food system governance, Indonesia can progress more effectively toward the targets outlined in SDG 2.

2. Advancing Climate-Smart Agriculture for Sustainable Food Security

This section addresses the second research question: In what ways does climate-smart agriculture enhance agricultural sustainability and food security? CSA, as a strategic framework, enables Indonesia to align agricultural productivity with climate adaptation and mitigation goals. Practices such as agroforestry, cover cropping, and water-efficient irrigation systems are increasingly adopted in regions like East Nusa Tenggara and West Java, where rainfall variability and land degradation are prominent (FAO, 2013). These practices not only improve soil fertility and biodiversity but also help stabilize yields under unpredictable climate conditions (Lipper et al., 2014).

CSA contributes to long-term sustainability by reducing the dependency on chemical inputs and promoting ecosystem services. Integrated pest management (IPM), for example, leverages natural predators and crop rotations to suppress pests, thereby minimizing pesticide use and preserving beneficial species (Pretty et al., 2011). Such practices are vital in maintaining ecological balance and minimizing the environmental footprint of agriculture. The inclusion of organic matter through conservation tillage and composting further improves soil structure, water retention, and carbon sequestration—key indicators of agroecosystem health (Tendall et al., 2015).

CSA also introduces digital innovations such as mobile-based weather forecasting, early warning systems, and decision-support tools that enhance farmer preparedness and reduce exposure to climate risk (World Bank, 2016). These technologies facilitate timely sowing, harvesting, and pest control, which are critical under shortened agricultural windows caused by climate shifts. In Indonesia, pilot programs integrating SMS-based weather alerts have demonstrated increased adaptive behavior among smallholders, although scale-up remains hindered by digital divides and limited infrastructure (Syahyuti, 2012, p. 76).

However, the transformative potential of CSA is contingent upon institutional and financial support systems. Many smallholder farmers lack the upfront capital to invest in CSA technologies, particularly in remote regions with limited access to credit or extension services (Ericksen, 2008). Microfinance programs and agricultural insurance schemes tailored to CSA adoption can mitigate these constraints, yet they require state backing and private sector engagement to

function effectively (Porter & Kramer, 2011, p. 89). Additionally, capacity-building programs are necessary to bridge knowledge gaps, especially for marginalized groups.

A major barrier to scaling CSA in Indonesia is policy fragmentation. While national policies promote sustainable agriculture, implementation is often fragmented across ministries with overlapping mandates and conflicting priorities (Prawiradisastra, 2011, p. 62). Local governments, although empowered through decentralization, often lack technical expertise and budgetary autonomy to enforce CSA guidelines. Harmonizing these institutional structures through integrated planning and cross-sectoral coordination is essential for CSA mainstreaming (Ostrom, 2010).

CSA's effectiveness is amplified when integrated with resilience strategies, such as diversified cropping and community seed banks. These synergies provide a buffer against market and climate volatility while promoting food sovereignty. Ultimately, CSA enhances sustainability not as a standalone intervention but as part of a broader, adaptive system that values ecological health, farmer knowledge, and institutional coherence. Its success in Indonesia will depend on how well it is localized, supported, and connected to the structural dynamics of the food system.

3. Institutional, Ecological, and Socio-Economic Drivers of CSA Integration

This section addresses the third research question: What institutional, ecological, and socio-economic factors facilitate or constrain the integration of CSA into Indonesia's food systems? A key facilitating factor is the presence of polycentric governance structures that allow for experimentation and feedback across multiple levels of decision-making (Ostrom, 2010). In Indonesia's decentralized administrative landscape, local governments can become incubators for CSA innovations when empowered with clear mandates and adequate resources. For instance, provincial-level initiatives in Central Java have demonstrated successful scaling of agroforestry systems through district-led policy alignment and farmer cooperatives (Syahyuti, 2012, p. 78).

Ecologically, Indonesia's rich agro-biodiversity provides a favorable base for CSA. The archipelago's diverse agro-climatic zones support various climate-resilient crops, from sorghum and cassava in dryland areas to rice and sago in wetland systems (FAO, 2013). Ecological zoning and suitability mapping enable targeted interventions that optimize local resources and reduce vulnerability.

However, ecological degradation from monocultures and unsustainable land use remains a serious constraint. Restoration of degraded lands through agroecological practices like contour farming and integrated livestock systems is essential for enhancing landscape resilience (Folke, 2006).

Socio-economic conditions are equally determinant. Income inequality, land tenure insecurity, and low financial literacy among smallholders hinder CSA adoption (Ericksen, 2008). Many farmers operate within informal economies and lack formal titles to land, which impedes their access to credit, subsidies, and extension services. Efforts to reform agrarian policies and provide secure tenure are necessary to incentivize long-term investments in sustainable practices. Furthermore, rural-urban migration, aging farming populations, and gender imbalances present additional social challenges that must be addressed through inclusive rural development strategies (Simatupang & Timmer, 2008).

Institutional capacity is a persistent constraint. Many local agricultural agencies lack trained personnel to deliver CSA-based extension services (Prawiradisastra, 2011, p. 64). Furthermore, weak inter-agency coordination results in overlapping programs that confuse farmers and waste resources. Bridging this gap requires policy coherence, inter-ministerial coordination, and integrated monitoring systems. Participatory governance models that involve farmer organizations, NGOs, and the private sector in policy formulation and implementation can improve legitimacy and effectiveness (Pretty et al., 2011).

Cultural perceptions and knowledge systems also influence CSA uptake. In some communities, traditional practices align well with CSA principles but are overlooked by top-down interventions (Chambers & Conway, 1992, p. 50). Recognizing and integrating indigenous knowledge into CSA frameworks not only enhances cultural relevance but also strengthens resilience by diversifying strategies. Farmer field schools, participatory technology trials, and local innovation platforms can serve as channels for mutual learning and co-creation of solutions (Tendall et al., 2015).

Finally, access to finance and markets significantly determines the viability of CSA practices. While CSA may improve long-term productivity, initial costs and delayed returns often discourage adoption. Innovative financing mechanisms such as blended finance, climate bonds, and cooperative credit models can alleviate these barriers (World Bank, 2016). Moreover, integrating CSA-certified products into value chains with price premiums or public procurement incentives can stimulate market demand. Without enabling economic ecosystems, however, CSA will remain limited in scale and impact.

This study has demonstrated that achieving SDG 2 in Indonesia requires the deliberate integration of climate-smart agriculture (CSA) within resilient food systems. The first research question revealed that resilience is a systems attribute shaped by ecological diversity, institutional flexibility, and socio-economic inclusion. By embedding resilience into food governance structures—through adaptive planning, inclusive participation, and diversified production—Indonesia can enhance its capacity to respond to climate-induced shocks. The second research question highlighted how CSA practices such as agroforestry, conservation agriculture, and digital climate services contribute directly to sustainability and food security. However, their success is contingent upon financial access, extension services, and policy coherence. The third question revealed that institutional coordination, ecological suitability, and socio-economic conditions are critical drivers for the integration of CSA. While decentralization provides opportunities, weak capacity and policy fragmentation remain substantial barriers.

The theoretical implication of this study lies in its interdisciplinary framework that connects social-ecological resilience, CSA, adaptive governance, and value chain resilience. This conceptual alignment extends the application of resilience theory beyond ecology into practical agricultural development and policy. The study also critiques conventional models that treat CSA as a purely technical intervention, emphasizing the importance of local contexts, social structures, and institutional readiness.

From a practical standpoint, the research offers actionable insights for policymakers and practitioners. These include strengthening subnational governance, promoting blended financing models, and mainstreaming CSA through participatory extension systems. The findings encourage a shift toward integrative planning that aligns sectoral agendas with sustainable development, ultimately contributing to a holistic pathway for food security in Indonesia.

CONCLUSION

The findings of this study affirm that Indonesia's pursuit of SDG 2—ending hunger and promoting sustainable agriculture—requires more than incremental improvements; it demands systemic transformation. By embedding climate-smart agriculture (CSA) within resilient food systems, Indonesia can enhance its adaptive capacity to climate change, improve agricultural productivity, and ensure equitable food access. This research confirms that resilience is a dynamic and multidimensional attribute shaped by ecological diversity, inclusive governance, and socio-economic equity. CSA serves not merely as a set of practices, but as a framework for transforming agricultural systems in ways that are sustainable, adaptive, and climate-resilient.

The theoretical alignment presented in this study contributes to the broader literature by integrating social-ecological resilience with adaptive governance and value chain strategies. This interdisciplinary synthesis advances our understanding of how agricultural sustainability can be operationalized in diverse and decentralized contexts like Indonesia. The study demonstrates that institutional readiness, market inclusion, and localized innovation are just as critical as technological adoption.

Based on these findings, several practical recommendations emerge. Policymakers should enhance institutional coordination across levels of governance, prioritize inclusive and gender-sensitive CSA programs, and provide accessible financing and extension services. Moreover, future research should explore the effectiveness of CSA integration across different agroecological zones and develop context-specific indicators for food system resilience. By embracing these recommendations, Indonesia can forge a strategic path toward a more sustainable, equitable, and food-secure future.

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