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Food security in ASEAN: progress, challenges and future

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This article examines the progress, challenges and future of food security in the Association of Southeast Asian Nations (ASEAN) region. The COVID-19 pandemic has exposed the fragility of ASEAN food systems, exacerbating existing challenges and vulnerabilities. With a focus on addressing the pressing issue of ensuring sufficient, affordable, and nutritious food for its growing population, the article explores the multifaceted challenges of food security faced by ASEAN. It emphasizes the need for an integrated approach to address the impact of climate change, investment in rural infrastructure and agricultural research, and the promotion of sustainable and inclusive agriculture for ASEAN's long-term food security. It also underscores the importance of collaboration with international partners and organizations to leverage expertise and resources. Overall, this article calls to action policymakers, stakeholders and external partners to collectively work toward achieving food security and sustainable development in the region.

KEYWORDS

ASEAN, agriculture, food security, climate change adaptation, sustainable development, research and development, technology, regional cooperation

1. Introduction

The Association of Southeast Asian Nations (ASEAN) comprises 10 member countries: Brunei, Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. ASEAN's combined population reached approximately 661 million in 2020, making it one of the most populous regions globally (ASEAN, 2021a). The region's population is projected to continue growing, increasing pressure on food systems to ensure sufficient and nutritious food for all. It is expected to reach 723 million people by 2030 (World Economic Forum, 2020). Rapid population growth, increasing disposable income, urbanization, and changing dietary patterns are transforming the food consumption landscape in ASEAN countries. It is widely acknowledged that "Southeast Asia's rising incomes, growing population, and increasing urbanization have contributed to growth in livestock production and meat consumption, particularly poultry and pork" (USDA Economic Research Service, 2019). This trend and population growth present significant challenges for food security in the region.

Agriculture is pivotal in ASEAN economies, contributing significantly to GDP and employment rates. In 2020, agriculture constituted approximately 11% of the ASEAN region's GDP, with some countries, like Cambodia and Myanmar, relying on it for over 20% of their national GDP. Additionally, agriculture remains a major source of employment in 2019 countries such as Laos, Myanmar, and Vietnam, where it accounted for more than 35% of total employment (Deloitte, 2022). Traditionally centered around rice production, the sector has witnessed shifts in production activities, with rice's share of agricultural production value declining and palm oil gaining prominence, driven by its higher value and dietary shifts. Southeast Asia's agricultural landscape has also faced challenges posed by climate change, resulting in significant production losses of about USD 21 billion due to extreme weather events between 2008 and 2018 (Asian Development Bank, 2021). The COVID-19 pandemic further

disrupted the sector, causing a 3.1% reduction in agricultural production and a 1.4% decrease in GDP in 2020 (Asian Development Bank, 2021).

Indeed, the COVID-19 pandemic has shed light on the fragility of global food systems, exacerbating existing challenges and vulnerabilities in achieving food security. In the context of ASEAN, the pandemic has highlighted the need for resilient and sustainable food systems to ensure the availability, accessibility, and affordability of safe and nutritious food for the people. The disruptions in supply chains, trade restrictions, and socioeconomic impacts have underscored the importance of addressing the multifaceted challenges facing ASEAN's food security, including climate change, limited resources, inadequate infrastructure, and vulnerability to external shocks. As ASEAN countries navigate the post-COVID-19 pandemic, there is an urgent call to strengthen regional cooperation, invest in innovative solutions, and promote sustainable agriculture to build resilient and safe food systems that can withstand future shocks and support the well-being of ASEAN's growing population.

Food security is a fundamental concern for ASEAN due to the region's high dependence on agriculture and its significant role in supporting livelihoods, protecting social stability, and driving economic growth. Achieving food security entails ensuring that all individuals have access to safe, nutritious, and affordable food that meets their dietary needs and preferences (Food and Agriculture Organization, 1996). The interconnectedness of food security with various sustainable development goals underscores the urgency of addressing food security challenges in ASEAN. In recent years, the COVID-19 pandemic has further highlighted the importance of food security and exposed vulnerabilities in food systems. It has "globally jeopardized food security, with heightened threats for the most vulnerable, including smallholder farmers as well as rural, indigenous populations" (Ghosh-Jerath et al., 2022). Disruptions in global supply chains, trade restrictions, and movement restrictions have impacted the availability and affordability of food, particularly for vulnerable populations. Enhancing food security has become a critical agenda for ASEAN to mitigate the impacts of future crises and build resilience. ASEAN has prioritized "food security in its integration agenda as the association strives to build resilience against possible crises" (Economic Research Institute of ASEAN and East Asia, 2022).

This article examines the challenges, achievements, and future perspectives of food security in ASEAN. It explores the multifaceted challenges ASEAN countries face in ensuring food security, identifies key opportunities for enhancing it, and discusses the future outlook. Additionally, it presents policy options and highlights the importance of collaboration with international partners and organizations to collectively work toward achieving food security and sustainable development in ASEAN.

2. Literature review

2.1. Progress of ASEAN food security cooperation

ASEAN's efforts to enhance food security in the region have been quite substantial, with various initiatives and arrangements in place. These endeavors aim to tackle the challenges arising from climate change, population growth, and disruptions in food supply chains.

One significant initiative is the ASEAN Food Security Reserve (AFSR), established in October 1979. The AFSR includes the ASEAN Emergency Rice Reserve (AERR), which aims to mitigate the impact of natural disasters on food security. Its purpose is to alleviate poverty and eradicate malnourishment in the region while ensuring normal trade in the global market is not distorted (Asian Development Bank Institute, 2018). Member countries commit to earmarking specific quantities of rice to be made available in emergency situations. The release of rice from the reserve follows procedural guidelines, including notifying other members and engaging in bilateral negotiations for prices, terms, and conditions (Asian Development Bank Institute, 2018). However, the AFSR has not been utilized since its establishment (Trethewie, 2013), and the Enhanced Dispute Settlement Mechanism (EDSM) remains untested. In past instances of food shortage, such as Indonesia's experience in 1997–1998, alternative solutions were pursued, such as obtaining loans from international financial institutions (Yoshimatsu, 2014).

The ASEAN Plus Three Emergency Rice Reserve (APTERR), established in October 2012, focuses on regional cooperation among ASEAN member states, China, Japan, and South Korea to enhance food security. APTERR comprises earmarked rice and physical rice stocks, including emergency reserves, stockpiled reserves of cash and rice, and other reserve forms like future contracts or donations (Trethewie, 2013). It operates through a three-tier system, facilitating commercial contracts, emergency grants and loans, and donated rice in times of acute emergencies (ASEAN Plus Three Emergency Rice Reserve, 2023). The APTERR Agreement imposes legally binding obligations on parties, ensuring their commitment to specific actions (Asian Development Bank Institute, 2018). However, dispute resolution within ASEAN member states relies on friendly negotiations, with a preference for political, diplomatic, or relations-based means rather than legal methods (Kraichitti, 2015). APTERR, like the AFSR, emphasizes national interests and laws in its implementation, allowing parties to suspend or withdraw from the agreement for reasons of national interest, subject to specified procedures.

APTERR has witnessed significant utilization, particularly in Tier 3 releases, with various countries contributing rice to assist beneficiaries in times of crisis (Trethewie, 2013). However, the dispute resolution mechanisms of both AFSR and APTERR have remained untested, primarily due to the limited utilization of reserves and the historical preference for resolving disputes through non-legal means (Kraichitti, 2015).

The ASEAN Food Security Information System (AFSIS) serves as a platform for sharing accurate and timely information related to food security in the ASEAN region. Its database contains information on five major food crops: rice, maize, soybean, sugarcane and cassava. It provides comprehensive data and analysis on various aspects of food security, including production, consumption, trade, and market trends (ASEAN Food Security Information System, 2023). The information includes planted and harvested area, production, yield, crop calendar, wholesale price, the labor force in agriculture, trade, GDP, food balance sheet, land use, cost of production, etc. In addition, the AFSIS project has published the ASEAN Agricultural Commodity Outlook (ACO) and the Early Warning Information (EWI) reports as the food security information of the project.

The ASEAN Food Safety Policy (AFSP) was adopted in 2015 by the ministerial bodies responsible for health, trade, and agriculture.

Its primary objective is to facilitate the free flow of food and enhance consumer health protection within ASEAN while ensuring food safety and supporting food security. This policy serves as the foundation for coordination and a common purpose among the relevant ASEAN sectoral ministerial bodies and their subsidiary bodies as they work toward establishing an integrated market for food. The agreed principles of the AFSP provide guidance and support the development of a sustainable and robust food safety regulatory framework within the region (ASEAN, 2016). Accordingly, the ASEAN Food Safety Regulatory Framework (AFSRF) serves as a comprehensive and unified approach to ensure food safety throughout the region. It establishes a cohesive legal framework that bridges gaps and promotes the implementation of food safety measures across the entire food chain. By building upon existing commitments, the AFSRF provides a structured framework and necessary tools to facilitate the seamless flow of safe food within ASEAN. Its primary goal is to enhance consumer protection and foster a harmonized approach to food safety regulations among ASEAN member states (ASEAN, 2016).

2.2. Challenges to ASEAN food security

Rice and maize take the spotlight as the primary cereals produced, consumed, and traded in ASEAN, as indicated in Table 1. In 2020, rice and maize constituted a staggering 99% of all cereal production within ASEAN, leaving just 1% encompassing soybean, wheat, barley, sorghum, millet, canary seed, and rye (Food and Agriculture Organization, 2021b). ASEAN's surplus production is primarily limited to rice among its staple foods, as reflected in Table 1. Although it remains the most important staple food, there has been a rising demand for maize, soybean and others like wheat. ASEAN's current production levels are insufficient to meet this increased demand, with maize and soybean becoming especially crucial as animal feeds due to the surging livestock demand (Teng, 2022) bolstered by rising income, urbanization and tourism. To fulfill the requirements, significant imports from outside ASEAN are being sought. According to the ASEAN Secretariat's estimate, in 2020 alone, ASEAN imported agricultural commodities valued at US$61 billion from external sources (Teng, 2022). For example, in 2021, Indonesia imported a substantial $3.5 billion worth of wheat, a vital component in the production of staple foods like noodles, bread, baked goods, and animal feed (Teng, 2022).

In addition to demographic shifts, evolving consumer preferences, COVID-19-induced supply chain disruptions, and the Russia-Ukraine conflict, a paramount concern for food security in ASEAN is the influence of climate change on agricultural production. Southeast Asia is widely recognized as one of the world's most susceptible regions to the impacts of climate change. The region is highly vulnerable to the adverse effects of climate change, including increased temperatures, changing rainfall patterns, and extreme weather events such as droughts and floods (USAID, 2023). These climate-related challenges directly affect agricultural productivity, leading to yield losses, crop failures, and livestock deaths (Lacetera, 2019). Smallholder farmers, who constitute a significant portion of the agricultural workforce in ASEAN, are particularly vulnerable to these climate risks due to limited access to resources and adaptive capacities. Agriculture is imperative for the 80% of impoverished smallholder farmers who live in rural areas and mainly work in agriculture as it helps reduce starvation, raise income, and improve food security (Gassner et al., 2019). With climate change intensifying, smallholder farmers face the urgent need to adapt their farming practices. However, the success of adaptation strategies relies on farmers having a sufficient understanding of climate change and its implications (Nor Diana et al., 2022).

ASEAN countries face constraints in terms of limited agricultural resources and land degradation, which pose significant challenges to food production and sustainability. The availability of arable land is decreasing due to urbanization, industrialization, and land-use changes. Increasingly, the "pressures on land and water resources have built to the point where productivity of key agricultural systems is compromised and livelihoods are threatened" (Food and Agriculture Organization, 2020a). Besides, farming systems are becoming polarized, with large commercial holdings now dominating agricultural land use, while "fragmentation of smallholder concentrates subsistence farming on lands susceptible to degradation and water scarcity" (Food and Agriculture Organization, 2020a). For example, the sizes of sugarcane farms in the Philippines are largely fragmented due to land distribution under the government's agrarian reform program, leading to diminished productivity among small farms (Business Council for Sustainable Development Singapore, 2016).

Furthermore, soil erosion, deforestation, and unsustainable farming practices contribute to land degradation, reducing soil fertility and productivity. In Southeast Asia, especially Indonesia, the shift from subsistence to intensive farming driven by rapid population growth has expedited human-induced soil degradation (Yagi, 2015). Altered land management practices, particularly erosion, have worsened soil fertility decline. In terms of net primary productivity loss, Indonesia is the most severely affected, followed by China, Myanmar and India (Bai et al., 2008). This degradation limits the capacity to produce food and threatens the long-term sustainability of agricultural systems in ASEAN. ASEAN has acknowledged in its plans and programs that the "impacts of agriculture are large and growing, where they are already undermining food production through land degradation, water scarcity, and adverse impacts of climate change" (ASEAN, 2023).

Inadequate infrastructure and logistics and uptake of digitalization in agriculture present obstacles to efficient and effective food supply

TABLE 1 Major cereal production and trade in ASEAN, 2021–2022 unit measure: million tons.

Item	Rice		Maize		Soybean	
	2021	2022	2021	2022	2021	2022
Domestic Supply (beginning stock and production)	150.43	163.97	68.76	60.34	10.89	9.41
Import	4.46	4.60	19.75	15.89	9.66	8.37
Export	14.97	17.42	2.04	2.39	0.03	0.04
Trade Balance	10.51	12.82	−17.71	−13.50	−9.63	−0.833

Source: AFSIS Secretariat: http://www.aptfsis.org/.

chains in ASEAN, especially in the post-COVID-19 pandemic era. Weak transportation networks, insufficient storage facilities, and inadequate post-harvest management systems contribute to high post-harvest losses and food wastage. The Food and Agriculture Organization (2021) has highlighted the existing gaps in food systems that lead to food loss and waste, such as "unreliable infrastructure for storage and transportation, and access to electricity." Examining the farm-to-retailer food supply chain of ASEAN countries, it becomes evident that food loss occurs at harvest or shortly after that, primarily attributed to inefficiencies. The concealed expenses associated with these losses frequently equal or even surpass the net profits of retailers, including those considered top performers in the region. For example, a 40 per cent reduction in these losses within Southeast Asia would yield a food output equivalent to 1.8 million hectares of land. This quantity represents approximately 22 per cent of Malaysia's total agricultural land (World Economic Forum, 2023).

The Food and Agriculture Organization (2021) has stated that following the COVID-19 pandemic, the region faces challenges in terms of "logistics for local producer-to-consumer markets and scaling-up of networks for recovery and redistribution of safe and nutritious food for human consumption." Food losses and waste from all food systems lead to an increase in greenhouse gasses (Food and Agriculture Organization, 2021a). These inefficiencies result in increased costs, reduced market access, and limited availability of nutritious food, particularly in remote and rural areas. Improving infrastructure and logistics is crucial for enhancing the resilience of food systems and ensuring the timely and efficient delivery of food from farms to consumers.

The COVID-19 pandemic has accelerated the digitalization of agri-food supply chains, which has brought about significant changes, offering new opportunities. ASEAN will have to leverage these technologies to safeguard and boost its food security. Disruptive digital technologies are revolutionizing agriculture and food systems, enabling governments to enhance the efficiency and effectiveness of existing policies and programs, as well as design better ones (Montesclaros, 2023). The application of new digital technologies can play a crucial role in improving food security. First, smart farming driven by digitalized, aggregated, and analyzed data and information can lead to more efficient and sustainable farming practices (Ahmed et al., 2019). Second, real-time information availability for farms and fisheries allows for better decision-making and resource management. Third, digital marketplaces facilitate the procurement of farming inputs and the sale of agricultural products, streamlining the supply chain. Finally, the implementation of digital ID systems for food and agricultural products ensures traceability and enhances transparency throughout the supply chain (Teng, 2019).

ASEAN's food security is susceptible to external shocks and price volatility in global markets. The region heavily relies on imports for critical commodities such as maize, soybeans and wheat. Disruptions in global supply chains, trade restrictions, and market fluctuations can significantly impact the availability and affordability of food. Moreover, the volatility of food prices can disproportionately affect vulnerable populations, exacerbating issues of accessibility and affordability. The Economic Research Institute of ASEAN and East Asia (ERIA) and the ASEAN Secretariat public forum, ASEAN on Point, held in January 2021 on ensuring food security in post-pandemic ASEAN highlighted the high dependency of some ASEAN countries to food and agricultural imports, which makes them 'vulnerable to international trade disruption' (Economic Research Institute of ASEAN and East Asia, 2022). During the COVID-19 pandemic, disruptions in global supply chains and trade restrictions affected the availability and affordability of food. The global health crisis led to difficulties in importing essential food commodities. The closure of borders and transportation restrictions resulted in food availability disruptions, causing price fluctuations and scarcity in certain areas. In this regard, ASEAN is working toward streamlining and expediting border clearance processes for perishable agricultural products. This initiative involves transitioning from traditional paper-based customs documents to digital ones, including adopting the ASEAN customs declaration document, e-phytosanitary certificate, and e-animal health certificate, all facilitated by the ASEAN Single Window system. ASEAN is also exploring the possibility of extending this digital document exchange arrangement to its dialog partners in the near future (ASEAN, 2022).

Ensuring the inclusion of the rural community is a crucial aspect of addressing food security in ASEAN, as they are often the most vulnerable to food insecurity. Many of the poor are in the agriculture, forestry and fishery sectors, and it is estimated that 70 per cent of the poor in Southeast Asia live in rural areas (ASEAN, 2012). Therefore, their participation in food security initiatives and programs will be critical. Organizing farmers through cooperatives will assist them in mitigating high fuel costs and minimize food waste as they often depend on intermediaries to transport their crops to retail markets, despite the considerable expenses associated with this practice where prices offered by middlemen to farmers can surpass the actual cost of cultivation (Economic Research Institute of ASEAN and East Asia, 2022). Besides, farmers now have increasing access to digital platforms offered by the private sector, which could empower them to market their crops more effectively. Governments would play a crucial role in supporting farmers by fostering an enabling environment, including improving digital literacy, ensuring equitable internet access, and implementing farmer-centric regulatory frameworks (Economic Research Institute of ASEAN and East Asia, 2022). Thus, the "whole of government" plus "whole of society" approach (Montesclaros and Teng, 2018; Caballero-Anthony et al., 2020) will allow the vulnerable rural community in ASEAN to participate in the food security initiatives and have a sense of ownership. The partnerships between the government agencies dealing with food and agriculture, external trade, environment and climate, human resources and logistics and transport, combined with farmer groups, civil society organizations and the private sector, will provide an enabling and empowering environment for the vulnerable segment of the rural population from whom food insecurity is a real challenge.

3. Methodology

This article employed a content analysis methodology to investigate food security in the ASEAN region. Every attempt was made to gather information and data related to the COVID-19 and post-pandemic periods, with limitations since such data was not readily available. The primary data sources included ASEAN reports, documents, research articles, studies and opinion editorials related to food security, sustainable agriculture, and the impact of climate change on agriculture and food security. Using a systematic approach, the research identified recurring themes, emerging patterns, and critical insights related to achievements, challenges, and potential directions for enhancing food

security in ASEAN's future. A comprehensive search strategy was employed to gather relevant documents and sources using online academic databases such as Google Scholar, ResearchGate, Academia.edu, and official ASEAN websites. Key search terms were predefined and categorized for systematic analysis, including agriculture policy and governance, sustainable agriculture and diversification, digital transformation, climate change adaptation, food safety and quality assurance, and regional trade cooperation. The search covered the period from March to September 2023.

Data collection involved a two-step process. Initially, relevant literature was gathered through a rigorous literature review. Subsequently, selected documents were subjected to content analysis using the predefined categories. The research was employed to identify recurring themes and patterns in the gathered literature. The findings from the literature analysis were then synthesized and interpreted to provide a comprehensive understanding of the state of food security in ASEAN. In this regard, the research reviewed and extracted relevant data points from the identified sources to ensure the credibility and reliability of the study. This systematic examination enabled the drawing of insightful conclusions and generated evidence-based insights that shed light on the region's current state of food security. The analysis focused on key aspects such as promoting sustainable agricultural practices, embracing environmentally friendly approaches, and investing in infrastructure development, with a tailored and climate-smart perspective considering the local context.

4. Analysis

4.1. Future of ASEAN food security

In order to enhance food security and effectively respond to future challenges, ASEAN countries must prioritize identifying opportunities and strategic approaches that can fortify their agricultural systems, boost productivity, and ensure a sufficient supply of safe and nutritious food for their population. To address the pressing issue of food security in the ASEAN region, it is imperative to implement a comprehensive range of policy directives. These directives address the complex challenges associated with agricultural production, resource management, trade, and resilience. By embracing these policy measures, ASEAN countries can pave the way for a more secure and sustainable food future.

4.2. Promoting sustainable agricultural practices and climate change adaptation

A significant prospect for enhancing food security in ASEAN lies in promoting sustainable agricultural practices and climate change adaptation. These practices, which encompass reducing reliance on chemical inputs, implementing composting techniques, diversifying crops, practicing efficient water management, and rehabilitating degraded soils, are not only crucial for addressing climate change but also for ensuring long-term resilience in the face of evolving agricultural challenges (Oxfam, 2015).

ASEAN countries can unlock several benefits by embracing environmentally friendly approaches such as organic farming, agroecology, and precision agriculture. For instance, organic farming promotes the use of natural fertilizers and pest control methods, minimizing the negative impacts of chemicals on soil health and water quality (Food and Agriculture Organization, 2023). Conversely, agroecology emphasizes integrating ecological principles into agricultural systems, fostering biodiversity, nutrient cycling, and natural pest control (Food and Agriculture Organization, 2023). Precision agriculture leverages advanced technologies and data analytics to optimize resource allocation, enabling farmers to make informed decisions regarding irrigation, fertilization, and crop protection (Food and Agriculture Organization, 2023). These sustainable approaches improve soil health, conserve resources, reduce environmental degradation, and increase agricultural productivity. By enhancing soil fertility, reducing soil erosion, and improving water-use efficiency, sustainable practices help optimize crop yields and ensure a stable supply of nutritious food (Çakmakçı et al., 2023) for the growing population in ASEAN. Moreover, these innovative approaches address both global concerns and local dynamics, emphasizing the importance of locally adapted solutions, active participation, and the utilization of local knowledge (Food and Agriculture Organization, 2019). By involving farmers, communities, and other stakeholders in decision-making, ASEAN countries can tailor agricultural practices to suit their specific contexts, enhance social inclusion, and foster sustainable development (Food and Agriculture Organization, 2019).

Despite the immense potential of agroecological approaches, they have been underinvested by the public and private sectors compared to conventional farming methods (Food and Agriculture Organization, 2019). This limits the widespread adoption and scaling-up of sustainable practices in the ASEAN region. To fully realize the benefits of these approaches, it is crucial to allocate adequate resources, provide financial incentives, and develop supportive policies that promote the transition toward sustainable agriculture (Food and Agriculture Organization, 2019). By rectifying the current imbalance in investment and prioritizing the promotion of sustainable agricultural practices, ASEAN countries can lay a strong foundation for ensuring long-term food security and building resilient food systems.

ASEAN countries should further prioritize climate change adaptation and agricultural mitigation strategies to address food security. While the region is already doing significant work on climate change adaptation and disaster risk reduction, more needs to be done in areas such as "climate change risk and vulnerability assessments, capacity building, and institutions including laws and policies" (ASEAN, 2021b). Additionally, enhancing early warning systems and providing farmers with access to climate information and insurance schemes can help them make informed decisions and mitigate the impacts of climate change on their livelihoods. The role of the private sector in climate adaptation will be critical for the provision of "risk insurance, innovative financial instruments, weather and climate data services, resilience infrastructure, energy and transportation" (ASEAN, 2021b). With regard to risk insurance, there could be two schemes in ASEAN where the private sector can provide assistance. The first is a regional insurance facility designed to provide coverage for catastrophic losses experienced by countries within the region. The second scheme involves enhancing risk insurance in specific vulnerable sectors, such as agriculture, home, and infrastructure insurance (ASEAN, 2021b).

Sustainable land and resource management practices must be promoted for better use of arable land. This includes implementing land-use planning, reforestation and afforestation programs, and promoting sustainable land and water management techniques. Investing in soil conservation measures, such as terracing and contour plowing, can help reduce soil erosion and improve soil health (Deng et al., 2021). Additionally, promoting sustainable intensification practices, such as agroecology and precision farming, can maximize productivity while minimizing the environmental impact. FAO suggests that agroecology is a practical way for 'ecological and social concepts and principles to the design and management of a sustainable and fair food system' that can contribute to several Sustainable Development Goals (SDGs) (Nelles and Ferrand, 2020).

The prioritization of infrastructure development should be considered. This includes improving road networks, upgrading storage and processing facilities, enhancing cold chain systems for perishable goods, access to electricity and greater acceptance of digitalization. Enhancing trade logistics and infrastructure and digitalization within ASEAN will facilitate the movement of food and materials more efficiently and affordably across the region. This is crucial for "expanding intra-ASEAN food trade and reducing the length of supply chains" (Teng et al., 2021). Strengthening market information systems and promoting innovative solutions such as e-commerce and mobile technologies can help improve market access for farmers and reduce post-harvest losses.

On the other hand, promoting resilient crop varieties, adopting climate-smart agricultural practices such as agroforestry and conservation agriculture, and investing in irrigation systems and water management technologies will be necessary. In the context of irrigation systems, Southeast Asia features diverse systems that reflect the region's varied topography, climate, and agricultural practices. Traditional irrigation methods, such as "rice terraces and canal systems," have been employed for centuries to support staple crop cultivation (Barker and Molle, 2004) and cash crops. These traditional surface water irrigation systems supported by rivers and streams are supplemented by groundwater irrigation systems using wells and boreholes. Recently, with the mushrooming of private farms, the region has been adopting modern irrigation technologies such as drip and pressurized water irrigation systems to address contemporary challenges of climate change, water scarcity and depletion of groundwater. Additionally, the region has witnessed the development of community-based irrigation management systems that empower local communities to collectively manage and allocate water resources (Kajisa, 2021). However, there are still issues to address, such as water scarcity, pollution, and conflicts over water allocation that impact the efficiency of such systems.

At the same time, efforts should be made to facilitate the adoption of high-yielding crops among small-scale and resource-poor farmers (Food and Agriculture Organization, 2015) in ASEAN, which would include pineapples, bananas, mango, sugarcane, coffee, cashew nuts and cassava. Engaging the smallholder farmers who do not have adequate access to technology, inputs, and services is key to producing high-quality cash crops demanded by consumers. It underscores the need for ASEAN to emphasize "inclusive agri-business" approaches more vigorously, ensuring sustained growth in the agriculture sector (Business Council for Sustainable Development Singapore, 2016). This can be achieved through a combination of strategies, including providing training, technical assistance, and credit, as well as creating policies that incentivize the adoption and uptake of biotech crops (Business Council for Sustainable Development Singapore, 2016). Collaboration between governments, research institutions, and farmers' organizations is essential for promoting knowledge sharing and capacity building. In addition, investments, including private sector investment in infrastructure, research and development, processing, distribution systems, post-harvest facilities, safe supply chain and grain marketing, are necessary to ensure farmers' access to markets and facilitate efficient trade. By improving logistical systems, including storage facilities and transportation networks, post-harvest losses can be minimized, and the quality of agricultural products can be maintained. This, in turn, enhances economic opportunities for farmers and contributes to food security.

4.3. Investing in research and development

Allocating resources to agricultural research and development (R&D) plays a vital role in identifying and disseminating best practices in sustainable agriculture (Desker et al., 2013). By investing in agricultural R&D, ASEAN countries can improve crop varieties, develop resilient farming systems, and enhance productivity. This can be achieved through various means, such as improved seeds and inputs, enhanced post-harvest and processing technologies, and upgraded infrastructure. These investments tend to yield higher levels of agricultural productivity and reduce losses in food production and distribution.

Establishing research centers, promoting public-private partnerships, and sustaining investments in agricultural R&D through collaborative efforts are essential for driving innovation and agricultural development (Skerritt, 2016). By prioritizing research projects that address local environmental challenges and directly impact the income-generating capabilities of resource-poor farmers, the need for expanding agricultural land can be minimized, thereby mitigating environmental impact. Additionally, technological breakthroughs in crop varieties, agricultural inputs, and mechanization can assist farmers in scaling up their agricultural production and productivity with government support.

Biotechnology, including genetically-engineered crop varieties, has played a role in addressing hunger and malnutrition (ISAAA, 2019). While biotechnology has provided a leap in productivity and gained acceptance in many countries, the cultivation of genetically-engineered crops continues to be a subject of controversy, with both risks and benefits involved (Ghimire et al., 2023). However, through the use of scientific evidence and increased public awareness, there is potential for smallholder farmers in ASEAN to reap the benefits of this technology. Enhanced collaboration among governments, the private sector, international organizations, and research institutes can facilitate the adoption of biotechnology among farmers while ensuring careful consideration of its potential impacts. Another critical aspect of enhancing agricultural R&D is the allocation of sufficient resources. Advocating for policies that promote sustained investments in agricultural R&D is crucial for achieving sustainable agriculture in ASEAN (Business Council for Sustainable Development Singapore, 2016). Both government and private sector organizations should prioritize allocating resources to agricultural research, as it has consistently demonstrated high returns on investment (Diemuth et al., 2022).

4.4. Leveraging regional and international cooperation

Regional cooperation and integration, facilitated by initiatives like the ASEAN Integrated Food Security Framework (AIFS), AFSR, APTERR and ASEAN Food Security Information System (AFSIS), offer significant opportunities for enhancing food security. By strengthening these mechanisms and exploring new avenues for collaboration, including knowledge and technology sharing, policy harmonization, and trade facilitation, ASEAN can effectively address food security challenges and ensure improved food availability and a stable food supply for its member states (ASEAN, 2020).

Several policy options are proposed to maintain and strengthen the momentum of rice reserves. First, there is a need to increase cooperation and financial support for APTERR to bridge the gap between demand and available reserves (Montesclaros, 2015). Second, efforts should be made to expedite negotiation, coordination, and response for Tier 3 releases, ensuring timely assistance in emergency situations (Trethewie, 2013). Third, the consensus requirement for APTERR Council decisions in disputes should be eliminated to facilitate more efficient resolution processes (Phan, 2013). Finally, establishing an enforcement and compliance mechanism for APTERR Council decisions is crucial to ensure their effectiveness, and this can be achieved by expanding the terms of reference to address enforcement aspects (Asian Development Bank Institute, 2018).

On the other hand, AFSIS has significantly enhanced food security in the region. One of its key successes lies in providing a platform for sharing accurate and timely information on food security. AFSIS offers comprehensive data and analysis on various aspects such as production, consumption, trade, and market trends. This has enabled policymakers and stakeholders to make informed decisions and formulate effective strategies to address food security challenges in ASEAN (ASEAN Food Security Information System, 2023). However, like any system, AFSIS also faces certain limitations and challenges. Food security in the ASEAN and ASEAN Plus Three regions relies on a range of data and information beyond basic food supply and demand. Previous episodes of food price spikes, the effects of climate change, and bioenergy development highlight the importance of a broader scope of data and information. Expanding the scope of food security information to include factors such as food market prices, long-term forecasts, vulnerability assessment, mapping of food insecurity, and connections with climate change and bioenergy impacts enables policymakers and managers to closely monitor food security situations and identify necessary interventions. This comprehensive approach is needed to prevent highly volatile food prices, crises, and insecurity (Montol, 2011). In addition, integrating nutritional data into AFSIS becomes crucial to enhance the tracking of nutrition and ensure sustained food security. This would address the food and nutritional requirements of populations, particularly those residing in remote rural and vulnerable areas, ultimately leading to improved livelihoods for farmers in the ASEAN region. In the ASEAN Integrated Food Security (AIFS) Framework and Strategic Plan Of Action On Food Security in the ASEAN Region (SPA-FS) 2021–2025, ASEAN has included a module on nutrition for development under the AFSIS (ASEAN, 2021c).

ASEAN is making efforts to boost its food security and food systems further to mitigate any future crisis. In this regard, Indonesia's efforts to enhance regional food security cooperation are reflected in the draft ASEAN declaration (Antara, 2023), which is expected to be adopted soon. This declaration emphasizes the importance of immediate regional actions to accelerate and strengthen the region's food systems. It calls for substantial commitments from ASEAN countries to effectively respond to the potential risks of a regional food crisis. The declaration also underlines the need for cooperation and synergy among various industries, including food, economy, transportation, and finance, to address common challenges and reinforce food security.

In addition to collaboration with ASEAN Plus Three countries, engaging with other dialog and development partners is crucial for ASEAN to strengthen food security and climate change collaboration. Sharing expertise, knowledge, best practices, and technology can assist ASEAN in mitigating the risks of food insecurity and promoting sustainable agriculture in the region. Leveraging the resources and expertise of multiple partners enhances ASEAN's capacity to address food security challenges effectively.

4.5. Embracing digital agriculture and technological innovation

Digital agriculture and technological innovation offer significant potential for enhancing food security in ASEAN. The adoption of digital technologies, such as precision agriculture, remote sensing, and data analytics, can enable farmers to optimize resource utilization, manage crop diseases, and mitigate climate risks (Teng et al., 2021). In fact, diseases affecting crops have been one of the reasons behind the production and economic losses in agriculture, which further threaten food security. To fully leverage these opportunities and address the challenges, ASEAN countries should prioritize the promotion of digital agriculture tools, provide technical training, and establish appropriate policies and regulations to foster innovation and enable farmers to benefit from digital transformation. By harnessing digital technologies, ASEAN can improve supply chain management, enhance market integration, ensure the resilience and responsiveness of its food systems (Teng et al., 2021) and monitor and control pests and diseases.

ASEAN's digital infrastructure and connectivity play a crucial role in facilitating the adoption of digital agriculture. Governments should focus on improving access to information, financial services, and markets for small-scale farmers by leveraging the region's growing digital infrastructure. Encouraging the adoption of digital tools, providing technical training, and developing supportive policies and regulations are essential steps in driving innovation and enabling farmers to harness the benefits of digital agriculture (Teng et al., 2021). Besides, digital technologies play a crucial role in supporting trade for agriculture and food products. They enable private sector suppliers to connect with new markets, facilitate government monitoring and compliance with standards, and streamline border procedures, particularly for perishable products (OECD, 2019). By leveraging digital tools and platforms, the agriculture and food sectors can enhance efficiency, improve market access, and ensure the smooth flow of goods across borders, ultimately contributing to enhanced trade and food security (Economic Research Institute of ASEAN and East Asia, 2021).

Moreover, digital technologies have significant relevance at various points in the agricultural supply chain, including post-harvest, storage, processing, marketing, and distribution (Teng et al., 2021). By

promoting the adoption of digital tools such as precision farming technologies, remote sensing, and data analytics, ASEAN countries can optimize resource utilization, monitor crop health, and improve efficiency in various stages of the supply chain. Investments in digital infrastructure, internet connectivity, and training programs are crucial to ensure equitable access to these digital technologies among farmers (Teng et al., 2021).

Additionally, digital platforms and mobile applications have the potential to revolutionize the agricultural sector by providing smallholder farmers and women entrepreneurs in agriculture with access to vital information, markets, and financial services (OECD, 2021). Real-time market prices, weather forecasts, and best practices shared through digital platforms empower farmers to make informed decisions and optimize their production. Mobile banking and digital payment systems can enhance financial inclusion and provide farmers with access to credit, enabling them to invest in their farms and improve productivity (OECD, 2021).

4.6. Promoting healthy and sustainable dietary patterns

Promoting healthy and sustainable diets is crucial to address the challenges associated with changing dietary patterns. The region's economic growth and urbanization have led to a shift in dietary preferences toward processed foods, sugar, and unhealthy fats, resulting in an increase in non-communicable diseases (NCDs) such as obesity and diabetes. NCDs are the primary cause of death in ASEAN, resulting in around 8.5 million fatalities, which accounts for approximately 62% of all deaths. Alarmingly, nearly half of these deaths occur among individuals below the age of 70 (World Health Organization, 2019). However, by encouraging the consumption of locally available nutritious foods, such as fruits, vegetables, whole grains, and traditional crops, ASEAN countries can improve diets and enhance food security (Food and Agriculture Organization, 2020b).

Besides, promoting the consumption of indigenous crops improves nutrition, supports local farmers, and preserves cultural heritage. ASEAN countries are rich in diverse agricultural produce, and by promoting the consumption of these indigenous crops, they can tap into their nutritional benefits while fostering agricultural diversity. Traditional food consumption and production practices play a crucial role in "enhancing nutritional security by countering detrimental dietary shifts, offering essential nutrients, and strengthening agricultural resilience" (Deaconu et al., 2021). Furthermore, diversifying agricultural production to include a wider range of nutritious crops can provide a sustainable source of affordable and healthy food. This approach helps reduce dependency on a limited set of staple crops and enhances dietary diversity, which is essential for meeting nutritional requirements. Promoting diverse food systems and incorporating a variety of foods into diets not only enhances human health but also brings numerous other advantages, such as preserving healthy ecosystems. Existing evidence underscores the significance of biodiversity in promoting human well-being, and promoting a food-based approach that embraces dietary diversity offers a range of social, cultural, economic, and environmental benefits (Dwivedi et al., 2017).

Educational campaigns and nutritional labeling are vital in raising awareness and promoting healthier food choices. Collaborations between governments, civil society, and the private sector can support initiatives that improve food literacy, encourage responsible food marketing, and provide nutritional education to communities. Food literacy interventions are commonly employed worldwide to enhance the food security and health of individuals with low socioeconomic status (West et al., 2020). By empowering individuals with knowledge and information, ASEAN countries can foster a culture of healthy eating and contribute to improved food security in the region. Diet can depend on an individual's food choices, but also the availability and affordability of healthy foods and sociocultural factors. Therefore, promoting a healthy food environment requires involvement across multiple sectors and stakeholders, including government, the public and the private sector (World Health Organization, 2023).

4.7. Consolidating local and regional food systems

In response to the vulnerabilities exposed by the COVID-19 pandemic and global supply chain disruptions, there is a growing recognition of the need to strengthen local and regional food systems. Relying heavily on international trade for food leaves the region susceptible to disruptions, emphasizing the importance of building resilience through local and regional food systems. The interconnection between the resilience of food systems, including household resilience to food security, is critical for ASEAN governments in planning their interventions. The traditional definition of food security, as outlined by the World Food Summit in 1996 and Food and Agriculture Organization (2006), encompasses four key dimensions: food availability, food accessibility, food utilization, and stability. This definition highlights the critical aspects of food security, emphasizing the importance of stability in access to, availability of, and quality of food. Furthermore, it suggests that stability is closely linked to resilience in ensuring long-term food security (Béné, 2020).

To strengthen local food systems, ASEAN countries can focus on promoting domestic production, reducing post-harvest losses, and improving storage and distribution infrastructure. By investing in cold chain infrastructure due to the region's tropical climate, such as refrigerated storage and transportation facilities, and modernizing food storage facilities, ASEAN countries can ensure that perishable goods are preserved and transported efficiently. There is an even more pressing need for the cold chain due to the expansion in demand for perishable products, such as processed, livestock, and aquatic products, that has arisen from the population increases and economic growth in the region (Economic Research Institute of ASEAN and East Asia, 2019).

Furthermore, fostering regional trade and cooperation within ASEAN and the broader Asia Pacific is essential for enhancing food security. Advocating for trade policies that promote the free and unrestricted import and export of agricultural goods is vital for a sustainable and resilient agricultural sector (Business Council for Sustainable Development Singapore, 2016). By removing barriers to trade, such as tariffs and non-tariff barriers, ASEAN countries can encourage the flow of agricultural products, ensure a diverse food supply, and enhance food security for their populations by developing resilient regional food supply chains. This calls for a 're-thinking of how supply chains should be organized' and economic integration to be further deepened by keeping markets open for trade and

investment, intensifying trade and investment facilitation, cutting down on non-tariff barriers, and digitalization of trade documents and processes (ASEAN, 2020). Collaborative efforts among ASEAN member states can lead to the development of integrated and sustainable food systems that contribute to long-term food security in the region. In this regard, the ASEAN Ministers on Agriculture and Forestry have pledged to ensure a sustainable supply of affordable, safe, and nutritious food that meets people's dietary needs and to collaborate closely to minimize disruptions in regional food supply chains by keeping markets open and facilitating the transportation of agricultural and food products (ASEAN, 2020).

4.8. Reinforcing regional and national food reserves

ASEAN has already taken significant steps to enhance food security and mitigate the impact of external shocks by establishing the AFSR and the APTERR. These mechanisms serve as regional food reserves and coordination mechanisms to address supply disruptions and manage price volatility. They act as a safety net, providing support to member states in times of emergency and reducing their vulnerability to external shocks. Their effective implementation should be strengthened to "reduce excessive price volatility, ensure adequate emergency food and reserves" (ASEAN, 2020). In addition, the AFSIS will provide timely and accurate market information.

Besides, the ASEAN Food Safety Regulatory Framework (AFSRF) Agreement developed by ASEAN (2020) should be finalized soon and implemented to ensure consumer health protection. To establish an effective AFSRF, ensuring the unrestricted flow of safe food within the region is essential. This will involve harmonizing sanitary and phytosanitary measures, reducing technical barriers to intra-ASEAN trade in food, and addressing disparities in national food control systems among member states (ASEAN, 2016). So far, progress has been made by ASEAN bodies in the economic, health and agricultural sectors toward harmonizing food safety requirements among member states. They include establishing harmonized minimum levels of pesticide residues, standards for food hygiene, principles for harmonizing food contaminants and additives, requirements for food contact materials, and traceability regulations (ARISE, 2021). Additionally, cooperation mechanisms such as the ASEAN Rapid Alert System for Food and Feed (ARASFF) and the ASEAN Risk Assessment Center (ARAC) have been established to facilitate information sharing and risk assessment (ARISE, 2021).

However, it is essential to note that while there have been advancements, most of these initiatives remain as voluntary guidelines, with the exception of the mutual recognition arrangement on food hygiene inspections and certification. To further enhance intra-ASEAN trade and reduce barriers, it is necessary to transform these voluntary guidelines into binding obligations for member states (ARISE, 2021). This will ensure the effective implementation of food safety measures across the region, ultimately strengthening consumer protection and facilitating smoother trade relations within ASEAN.

At the national level, ASEAN countries, such as Indonesia and the Philippines, have adopted a food self-sufficiency policy to mitigate the risks, focusing on the domestic production of food and lessening dependence on trade. For example, Indonesia's national food estate program, initiated by President Joko Widodo in 2020, aims to address potential domestic food security concerns. Designated as a national strategic project until 2024, the program seeks to enhance local food security by reducing the country's reliance on rice imports and improving the distribution system. The plan involves developing large agricultural areas, known as food estates, in several provinces across the country to cultivate crops like rice, cassava, potato, garlic, and shallots. Despite facing criticisms and setbacks, the government remains determined to expand the program, with ongoing construction in Maluku and plans for a corn food estate in Papua (Canada Asia Sustainability Tracker, 2023). The food estate program should be considered a long-term project, and some inherent challenges, such as the lack of planning, use of technology and sustainability, should be addressed. Besides, external and internal factors such as changes in economic conditions due to recession or other circumstances could also affect the viability of the project, which requires huge resource allocation from the government (Lasminingrat and Riza, 2020). Indonesia's performance in the Global Food Security Index is less than satisfactory, particularly in terms of sustainability and adaptation. The country's ranking highlights the need for increased research and development efforts and stronger political commitment to effective adaptation strategies (Canada Asia Sustainability Tracker, 2023).

Similarly, the Philippine government has revised its target for rice self-sufficiency to 97.5% by 2028, a departure from the previous goal of 100% by 2027 (Business World, 2023). This adjustment reflects a strategic shift in the government's approach to rice production and recognizes the challenges involved in achieving complete self-sufficiency. The government aims to increase farmer incomes by 54% and ensure availability and safety by maintaining an adequate rice buffer stock at the National Food Authority. Meanwhile, implementing the Masagana Rice Industry Development Program (MRIDP) by the Department of Agriculture will address industry challenges and support farmers through climate change adaptation, farm clustering, value chain approaches, and digital transformation (Business World, 2023). These initiatives aim to optimize production by adopting new technologies and leveraging economies of scale.

In contrast, others like Singapore and Malaysia have implemented a food resilience approach relying on international trade to augment the increasing domestic food sources, recognizing the advantages of importing certain food products. However, the COVID-19 pandemic exposed vulnerabilities in Singapore's reliance on international trade and highlighted the need to enhance its resilience strategy. With over 90% of its food supply imported from several countries, Singapore faced challenges when trade was disrupted and food exports were reduced. Although import source diversification has served Singapore well, the COVID-19 pandemic underscores the importance of local production, which provides a buffer supply in the event its import sources are disrupted (Singapore Food Agency, 2023). In response, the government implemented strategic policies and initiatives aimed at strengthening import stability, boosting production from existing farms, and significantly increasing domestic production (Teng, 2020). Singapore announced in 2019 its "ambitious goal to produce 30% of its nutritional needs locally by 2030, up from less than 10% currently" (Singapore Food Agency, 2023). The '30by30' goal will be met within 1% of the land designated for agricultural use. It will utilize "climate-resilient, resource-efficient and sustainable technologies" for farms to "grow more with less" (Singapore Food Agency, 2023). At the same time, Singapore will have to continue its resilience strategy for food

import sourcing for poultry and vegetables exploring new sources and supply chains besides stockpiling of key food items, including rice (Singapore Food Agency, 2000; Teng and Darvin, 2019).

In Malaysia's case, trade resilience and domestic production of food crops, alongside other crucial aspects, would need to be spotlighted. The government could focus on strengthening supply chains, improving import sources, and enhancing domestic production of essential food crops. While Malaysia has historically diversified its agricultural sector, the overreliance on palm oil has hindered the production of key food crops such as rice, fruits, and vegetables, leading to a growing trade deficit for food. Additionally, the impacts of climate change, including reduced crop yields, further underscore the need for a diversified agricultural sector and long-term resilience in Malaysia's self-reliance policy for food. To address these challenges, legislative policies, targeted investments in research and development, and partnerships with the private sector are vital for building a sustainable food system and ensuring food security in the country (Kearney, 2022).

Fostering partnerships with international organizations, multilateral banks, development partners, and regional institutions is crucial for addressing global food security challenges. Partnerships play a key role as the world responds to the COVID-19 pandemic, addresses food insecurity, tackles the global learning crisis, and boosts climate mitigation and adaptation (World Bank, 2022). Collaborating with international and regional entities like the United Nations, World Bank, OECD, FAO, WFP, ADB, APEC, and ASEAN's dialog and development partners allows countries to share knowledge, mobilize resources, and coordinate efforts to ensure stable and sufficient food supplies. These partnerships enable collective action and enhance the capacity to address food security issues on a global scale. Strong partnerships have become even more critical in the light of recent geopolitical tensions, such as the Russia-Ukraine conflict. Engaging in forums like the G-20 provides a platform to address potential disruptions in world grain markets and work toward mitigating any adverse impacts on global food supplies (Timmer, 2023).

5. Summary of findings

Table 2 encapsulates the progress, challenges, and options for enhancing food security in ASEAN. It highlights progress in areas such as policy development, emergency reserves, food safety regulations, sustainable farming, digital transformation, regional trade, climate change adaptation, and collaborations with international partners. Challenges include compliance variations, limited participation, funding constraints, and trade barriers. To address these challenges, key options include strengthening implementation and compliance, enhancing coordination, fostering public-private partnerships, promoting sustainable practices, improving access to technology, and investing in climate resilience.

The study's findings hold important theoretical implications, enriching our understanding of food security. They underscore the significance of comprehensive frameworks that consider the intricate interplay of factors like climate change, sustainability, regional cooperation, and international trade in shaping food security dynamics. Additionally, the research prompts theoretical exploration in the realms of resilience and global governance. It highlights the adaptive nature of food security systems and underscores the role of regional and international organizations in addressing global challenges. Resilience theory emphasizes not only the nature of food security adversity but also how the region responds to it. Similarly, global governance theory highlights the complexities of governance in a multi-polar world, emphasizing the need for collaboration with regional and international organizations to address food security issues effectively.

The limitation of this study should also be highlighted in terms of its findings. This is due to the reliance on secondary data sources, which may not capture the most up-to-date or region-specific information on food security in ASEAN, especially in the post-COVID-19 environment. Additionally, while content analysis provides valuable insights, it may not account for nuanced local variations and perspectives on the ground. Moreover, the study's timeframe, covering the period from January 2019 to September 2023, may not fully capture longer-term trends and developments in food security. Finally, the study's focus on existing literature and reports may have overlooked valuable insights that could be gained from primary data collection, such as surveys or interviews with stakeholders and field studies in the ASEAN region. In this regard, future research on ASEAN's food security could prioritize gathering quantitative primary data to capture local nuances and perspectives, especially during the post-COVID pandemic. Besides, in-depth evaluations of policy interventions and sustainable agricultural practices will provide critical insights into their impact on food security metrics.

6. Conclusion

The findings of this article call for immediate action by ASEAN policymakers and stakeholders to address the long-term food security challenges. Policymakers need to prioritize food security as a central component of their development agendas and adopt an integrated pathway encompassing various dimensions of the food systems. By promoting sustainable agricultural practices and climate change adaptation by embracing environmentally friendly approaches, adopting tailored and climate-smart agricultural methods to the local context and investing in infrastructure development, ASEAN could enhance its food systems to support food security. Adopting digital agriculture and technological innovation holds great potential for optimizing resource utilization, improving market integration, and mitigating climate risks. ASEAN countries should promote digital agriculture tools, provide technical training, and establish enabling policies and regulations to harness these opportunities. Additionally, promoting healthy and sustainable dietary patterns by encouraging the consumption of locally available nutritious foods and supporting indigenous crops can enhance nutrition, preserve agricultural diversity, and improve food security.

Strengthening local and regional food systems is crucial for building resilience and reducing vulnerabilities to supply chain disruptions. This entails focusing on domestic production, reducing post-harvest losses, and improving storage and distribution infrastructure. Besides, collaborative efforts among ASEAN member states and partnerships with international organizations can facilitate knowledge sharing, best practice exchange, and joint initiatives that enhance the overall resilience of the food systems. Furthermore, establishing effective food reserves, implementing robust food safety

TABLE 2 Progress, challenges, and policy options for ASEAN food security.

Focus areas	Achievements	Challenges	Options/pathways
1. Policy and Governance	Development of AIFS and Strategic Plan of Action	Lack of uniform implementation and compliance with AIFS	- Strengthen implementation and compliance of AIFS at national level - Enhance coordination and collaboration mechanisms among member states for effective policy compliance and implementation
2. Sustainable Agriculture and Diversification	Promotion of agricultural diversification and sustainable farming practices	- Limited access to resources and technology for small-scale farmers - Insufficient investment in research and development for agricultural diversification	- Promote sustainable farming practices and provide support to small-scale farmers - Increase investment in research and development for agricultural diversification
3. Digital Transformation of Agriculture	Integration of digital technologies in food supply chains	- Limited access to digital infrastructure and resources - Resistance to adopting digital technologies in agriculture sector	- Promote development and adoption of digital agriculture tools and platforms - Improve access to digital infrastructure and resources in rural areas
4. Regional Trade Cooperation	ASEAN Free Trade Area and free trade agreements with China, Japan, Korea and others	- Existing trade barriers that hinder free flow of agricultural products - Inadequate regional cooperation and coordination in addressing trade-related challenges	- Advocate the removal of trade barriers within ASEAN and with external trade partners - Strengthen and update regional collaboration to address trade-related challenges and enhance market integration
5. Climate Change Adaptation and Resilience	- Focus on climate change adaptation in agriculture sector - ASEAN's commitment to Paris Agreement	- Increasing frequency and intensity of climate-related disasters - Limited financial resources for climate change adaptation in agriculture sector	- Enhance climate change adaptation strategies and investments in agriculture sector - Mobilize additional financial resources for climate-resilient initiatives
6. Food Safety and Quality Assurance	Implementation of ASEAN Food Safety Regulatory Framework (AFSRF)	- Variations in food safety standards and regulations among member states - Inadequate compliance and monitoring of food safety measures	- Harmonize food safety standards and regulations within ASEAN - Strengthen compliance and monitoring of food safety measures - Signing of AFSRF Agreement
7. Extra-regional Cooperation	Collaboration with international organizations and development partners	- Limited financial and technical resources Insufficient collaboration and coordination with international partners	- Strengthen and deepen partnerships with international organizations and development partners - Mobilize additional resources for food security initiatives through international collaborations

(Continued)

TABLE 2 (Continued)

Focus areas	Achievements	Challenges	Options/pathways
8. Public Awareness and Education	- Efforts to raise public awareness of food security issues - Capacity-building programs on sustainable food systems	- Limited public awareness and understanding of food security issues and healthier food choices - Inadequate education and capacity building on sustainable food systems	- Implement public awareness campaigns on food security and public health and their importance - Enhance education and capacity-building programs on sustainable food systems
9. Gender Inclusion and Empowerment	ASEAN's recognition of importance of gender equality and women's empowerment in agriculture sector	- Gender disparities and inequalities in access to resources and decision-making - Limited participation of women in agricultural value chains	- Promote gender equality and women's empowerment in agriculture sector - Provide support and opportunities for women's participation in agricultural value chains
10. Strengthening Food Reserves and Emergency Response Mechanisms	- Establishment of AFSR, APTERR, AFSIS - ASEAN's collaboration with international partners for emergency response mechanisms	- Insufficient coordination, compliance and implementation of regional food reserves - Focus on building national food reserves - Limited collaboration with international organizations and development partners - Inadequate emergency response mechanisms for food security crises	- Strengthen coordination and implementation of regional food reserves - Enhance emergency response mechanisms for timely and effective response to food security crises

regulations, and fostering public-private partnerships are essential for ensuring a stable food supply and protecting consumer health. By implementing these options and embracing an integrated approach, ASEAN can achieve sustainable and resilient food systems, thereby enhancing food security for its population. This will not only contribute to the well-being of its people but also strengthen the region's capacity to withstand future food crises and related challenges.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

PS: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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