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Climate Change-Induced Shocks to Production: A Mounting Threat to ASEAN's Food and Nutrition Security

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Abstract

This academic paper seeks to assess ASEAN's sustained capacity to achieve food and nutrition security against a backdrop of climate change-induced more intensive, more frequent, and more extreme weather events and increasing food losses by farmers. At issue is whether the risk of natural disasters can be mitigated and whether ASEAN's agriculture and food systems can sustainably achieve the required production increases and lower the region's dependence on the productivity paradigm even as the negative impacts of climate change intensify and pressures on land and water resources mount. Discovery research was conducted. Data for this qualitative inquiry includes direct observation and secondary research data generated as part of organizational record-keeping by governmental and international organizations, agencies, and research institutes. The findings indicate that extreme weather events not only reduce agricultural outputs, but also have deleterious consequences on nutrition security. While the region is betting on biotechnology to reduce the vulnerabilities of its food production systems and on production intensification to increase its output, it needs to transition to more sustainable, resilient, and efficient agricultural systems. The onus should be on the development of organic and biodynamic techniques that minimize or eliminate the risk of chemical food adulteration and preserve the environment while increasing productivity. Measures strengthening national food control regulatory frameworks and enhancing food safety management along food chains should also be adopted.

Keywords: Food Security, Nutrition Security, Production Loss, Climate Change

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Introduction

Southeast Asia is prone to natural disasters (National Geographic Society, 2023; World Bank, 2022). Some of the world's worst catastrophes have occurred in the region (ADB, 2021; Whelley et al., 2015). The toll can be high (Torti, 2012; Reliefweb, 2011). A case in point is the flood that wreaked havoc in Thailand in 2011-12. It claimed an estimated 815 lives and submerged vast economic zones across the country; 65 of Thailand's 76 provinces were declared flood disaster zones and 13.6 million people were affected (Chongvilaivan, 2012). With over 20,000 square kilometers of farmland damaged, 25 percent of the expected rice crop did not survive the flood (Bangprapa, 2022).

Southeast Asia not only has to deal with too much water but also with too little as record floods alternate with record prolonged droughts –a pattern of extremes likely to grow worse as temperatures keep rising due to global warming (Wipatayotin, 2023; International Monetary Fund [IMF], 2022; Acevedo & Novta, 2017). Floods and storms tend to affect crops the most, droughts overwhelmingly impact livestock, and tsunamis, hurricanes, and cyclones cause the most damage in the fishery subsectors (Focus Global Reporter, 2021). Worldwide, the agriculture sector, which includes crops, livestock, fisheries, and forestry, absorbs an estimated 22o% of the economic impact caused by medium and large-scale natural disasters in developing countries (Food and Agriculture Organization of the United Nations [FAO], 2015). Given agriculture's inherent high dependence on climate, extreme weather events can present a real threat to a country's food and nutrition security.

As defined by the FAO's Committee on World Food Security (CFS), food security and nutrition are achieved when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." (FAO, 2022.). "The four pillars of food security are availability, access, utilization, and stability" (FAO, 2022.).

Nature has always disrupted agriculture. This is nothing new. It has been subjected to the caprices of Mother Nature from time immemorial. One thing has changed though. Global warming is fueling more frequent, more extreme, and more devastating weather events. As we just saw, Southeast Asia is no exception. Climate change-induced shocks to food production can be a major constraint on the ten members of the Association of South-East Asian Nations (ASEAN) access to sufficient, safe, affordable, and nutritious food. The big question is whether ASEAN can sustainably feed its growing population or, to put it another way, whether the region's agriculture and food systems can achieve the required production increases even as the negative impacts of climate change intensify and pressures on land and water resources mount. This paper seeks to address this question. Toward this end, the following broad research questions were developed:

1. Can ASEAN sustainably provide sufficient, nutritious, safe, and affordable food to its growing population?
2. Can the risk of natural disasters be mitigated?
3. Can the region decrease its dependence on the productivity paradigm and production intensification?

The paper offers a novel approach to the issue of food and nutrition security in the region.

Conceptual Background

Food and Nutrition Security

The complexity of food and nutrition security has been increasingly acknowledged by taking a systemic perspective on causes and solutions (Beddington et al., 2012; Garnett, 2014; Sundram, 2023). As stated in the Regional Report on Nutrition Security in ASEAN, co-produced by ASEAN and the UN International Children's Emergency Fund (UNICEF):

"Food and nutrition security exists when all people at all times have physical, social and economic access to food, which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services, and optimal feeding and care practices, allowing for a healthy and active life" (ASEAN, 2016, p. ix).

Both this definition and the FAO's acknowledge that "the nutritional dimension is integral to the concept of food security" (FAO, 2022, p. 6) and recognize "the importance of key nutrition concerns such as care and feeding practices, public health and sanitation issues" (CFS, 2012, p. 6). Until then, food security was mainly discussed from the angle of agriculture, and malnutrition, was predominantly considered as a health problem (El Bilali et al., 2018). Both definitions also enshrine the right to adequate food as universal (United Nations [UN], 1999). Giving the body all the nutrients it needs is deemed to be essential for all people.

The terms 'food security' and 'nutrition security' can be found in two combinations in relevant instruments: *Food and nutrition security* or *food security and nutrition* (El Bilali et al., 2018). The 'food and nutrition security' combination underlines the need for greater integration of nutrition and food security in programs and policies and regards appropriate levels of nutrients and protein as the ultimate goals of food security (Committee on World Food Security [CFS], 2012). This approach has become mainstream in academia and some international organizations (e.g. FAO and UNICEF). As to the 'food security and nutrition' combination, it underscores the importance of nutrition for achieving food security but maintains the traditional focus on food availability, access, and stability. This perspective emphasizes food security as a precondition to adequate nutrition (CFS, 2012). Since this paper refers to organizations and academic productions that use either one of these combinations, it will use both of them interchangeably.

The changes in the conceptualization of food security reflect growing public concerns about the dramatic increase in the prevalence of obesity in the last decades (Mason et al., 2017; World Health Organization [WHO], 2017). Worldwide obesity has almost tripled since 1975 and there has been a surge in diet-related Noncommunicable Diseases (NCDs) such as diabetes and hypertension (WHO, 2017, 2021). NCDs now surpass Communicable Diseases (CDs) as the main challenges to nutrition security. The UN World Health Organization (WHO) predicts that by 2030, half of the world's population will be obese and overweight (WHO, 2021). This will among other consequences place an additional burden on healthcare systems, already strained by the world's aging population and a growing number of elderly people, many of whom in need of extensive (and expensive) care (Saengpassa, 2018).

Obesity and related NCDs are largely preventable, though (WHO, 2021). At the individual level, people can limit their intake of foods high in fats and sugars, eat more fruit and vegetables, and exercise (WHO, 2017, 2021). The food industry can also play a significant role. It can reduce the fat, sugar, and salt content of processed foods, ensure that healthy and nutritious choices are

available to all consumers and affordable, and restrict the marketing of foods high in sugars, salt, and fats, especially those aimed at children and teenagers (Porter et al., 2014). Public policies promoting healthier dietary habits and curbing the aggressive marketing of unhealthy foods and beverages can help as well. Governments could, for example, impose a tax on sugar-sweetened beverages (Story et al., 2009). Adopting policies that promote healthy and nutritious food products at prices consumers can afford and curb the offering of unhealthy beverages and processed food, however, remains a challenge as they affect the bottom line of agribusiness giants and encourage aggressive lobbying.

Supply and Demand

The world's population is projected to grow from 7.9 billion today to approximately 9.5 billion by 2050 (WHO, 2017; US Census Bureau, 2020; UN, 2022a). Globally, the size of the middle class could increase from 3.2 billion in 2020 to 4.9 billion by 2030 (with 80% of it coming from Asia), and its purchasing power could grow from USD21 trillion to USD56 trillion, with most of it (85%) also coming from Asia (Organisation for Economic Co-operation and Development [OECD], 2010; IMF 2023). In Indonesia alone, some 8 million to 9 million people are expected to enter the middle class each year in the next decades, with millions of others in the region making a similar transition and eagerly embracing consumerism (Boston Consulting Group, 2013; ASEAN, 2023). Millions of Vietnamese are also projected to become middle class in the years to come as the country has been transforming its economy from a low-end agricultural exporter to a successful middle-range manufacturing exporter (ASEAN, 2023; IMF, 2023). More people are joining the ranks of the middle class in Malaysia, Thailand, and low-income member states, albeit at a slower rate (ASEAN, 2023; Bulman et al., 2017). Rising incomes are hastening "a dietary transition towards higher consumption of meat, fruits, and vegetables, relative to that of cereals" (WHO, 2017).

This is happening against a backdrop of rapid urbanization (World Bank, 2022). By 2050, more than 68% of the world's population will live in cities (UN, 2017a; US Census Bureau, 2020). In Southeast Asia, the number of people living in urban areas is projected to increase from 50 percent in 2020 to 64.2 percent in 2050 (UN, 2018, 2022a; Bulman et al., 2017). As cities grow, so do risks, including food insecurity and malnutrition. The rising proportion of urban dwellers will not only reduce arable land, exacerbate unsanitary conditions, and increase the risk of CDs (WHO, 2021; Tirziu, 2020). It will further change dietary patterns and accelerate the demand for processed foods. Since higher urban incomes tend to increase the opportunity costs of preparing food, city people often favor food products that have a large amount of labor embedded in them and are easy to cook. This includes fast and processed food (e.g. instant noodles), whose nutritional value generally tend to be considerably reduced (World Bank, 2022; WHO, 2017).

Food, however, is only one of two ways agricultural products are used. Non-food uses of agricultural crops include feed and raw materials for biofuels and various other industrial uses. One good example is bioethanol that is produced with either wheat, sugarcane, or corn, depending on the country where it is made (European Parliament, 2005). Rising oil prices favor the development of fuels, energy, and materials from agricultural products. Demand for crops for non-food use has been growing as a result. The need to produce more meat is also boosting the demand for feed. Consequently, whenever production is reduced by natural disasters, the risk of a price hike increases as demand remains stable.

On the supply side, rice remains Asians' main staple. Grown and consumed by millions, rice delivers much of their basic caloric need (International Rice Research Institute [IRRI], n.d.). This is still the case even though the importance of rice in meeting total caloric consumption has diminished in tandem with economic development and changing lifestyles and eating habits. As diets have diversified, the per capita consumption of rice has been decreasing. From 123kg/person on average in 1972, it has come down to approximately 70kg/person today (Fukagawa & Ziska, 2019). The focus on rice for food and nutrition security has led to a mix of government programs and interventions aimed at supporting the sector and encouraging domestic supplies (FAO, 2016).

Climate Change Induced Shocks to Food Production

The prevailing view among climate scientists is that, with temperatures likely to rise more rapidly than initially anticipated, weather conditions could be even more extreme (National Geographic Society, 2022; World Meteorological Organization [WMO], 2022). Whether wetter floods, drier droughts, and fiercer hurricanes will be the 'new' normal and mark the end of 'normal' times largely depends on climate change mitigation and the real level of commitment of the 196 countries-including ASEAN member states, who in December 2015 pledged to reduce greenhouse gas emission and limit the global average warming temperature increase to below 2° Celsius (3.6° Fahrenheit) under the Paris Agreement (UN COP21, 2015). ASEAN members states "have reaffirmed (their)commitments to the UNFCCC and the Paris Agreement, by upholding the principle of equity and common but differentiated responsibilities and respective capabilities" (ASEAN, 2021) and are committed-at least in theory-to forging a more resilient future by reducing existing disaster and climate-related risks and adapting to a changing climate. Only a concerted global effort to curb greenhouse gas emissions will help avert its worst effects (UN COP21, 2015).

The capacity of extreme weather events to upend food supply chains seems almost boundless (Malik et al., 2022; Focus Global Reporter, 2021; FAO, 2016). Low water levels on rivers may ground barges used to ferry food staples, air freight capacity for fresh produce can plummet as planes may be grounded by an act of God, and flash floods and mudslides may submerge warehouses and destroy roads and bridges, hampering food delivery. The list could go on and on. According to a report released by the FAO in March 2021, the annual occurrence of disasters is now more than three times that in the 1970s and 1980s (FAO, 2021a).

Relative to the secondary and tertiary sectors, agriculture absorbs a disproportionate 63% of the impact of natural disasters. Production losses suffered by farmers in the aftermath of a severe weather event are estimated to be twice as high as the direct damage to agriculture assets and infrastructure (UN, 2017b). Low and Middle-Income Countries, (LMICs) bear the brunt of it (FAO, 2021a). For the period analyzed in the FAO Report 2021 (2008-2018), Asia was the most hard-hit region, with overall economic losses adding up to a staggering USD 49 billion (FAO, 2021a). Destruction is all the higher as, unlike production units, farming activities obviously cannot be moved in areas less prone to the whims of Mother Nature.

The FAO Report 2021 identifies drought as the single greatest culprit of agricultural production loss, followed by floods and storms. Droughts impact agriculture almost exclusively. During the period examined, the primary sector sustained 82% of all drought impact, compared to 18% for the other two sectors (FAO, 2021a). And over 34% of crop and livestock production loss in LMICs was traced to drought, costing the sector USD 37 billion. Flood events can take many forms, ranging from slow-onset riverine floods and rapid-onset flash floods to coastal

floods caused by tidal and wave extremes (Few et al., 2004). They vary greatly in magnitude and impact. The sudden onset of flash flood makes them extremely difficult to predict and prepare for. Declines in sanitation in inundated areas increase the risk of CDs and the prevalence of vector-borne diseases (WHO, 2014; Ohl & Tapsell, 2000; IRRR, 1987). Losses due to food contamination come in addition to natural disaster losses and further reduce agricultural outputs. Extreme weather events have deleterious consequences on nutrition security as well (Focus Global Reporter, 2021; Ohl & Tapsell, 2000). For the first time ever, the 2021 edition of the FAO annual report converted economic losses into caloric and nutrition equivalents. Numbers are staggering. Crop and livestock production loss in LMICs between 2008 and 2018 were estimated to be equivalent to a loss of 6.9 trillion kilocalories per year, which equals the annual calorie intake of seven million adults (FAO, 2021a). Crop and livestock losses can cause prices to jump, which limits consumers' economic access to nutrient-rich food and further compounds malnutrition (WHO, 2022; Arunmas, 2020).

Investing in resilience and disaster risk reduction is of paramount importance to mitigate losses (Asian Development Bank [ADB], 2013; UN, 2012, 2017b). Powerful state-of-the-art assessment and data-gathering tools such as remote sensing, geospatial information gathering, drones and disaster robotics, and machine learning have much to offer in the quest to reduce disaster risks in agriculture (UN, 2022b). LMICs, however, often lack funds to acquire them.

This study is being conducted in the context of discovery as a means to: 1) make a critical assessment of the region's existing food and nutrition security strategies; 2) determine the impact of climate change-induced shocks to production on ASEAN's capacity to achieve food and nutrition security, and 3) make suggestions on possible ways to meet the challenges ahead. The study period is 2012-2022.

To this end, as noted in the introduction, the following research questions have been developed:

1) Can ASEAN sustainably provide sufficient, nutritious, safe, and affordable food to its growing population?

2) Can the risk of natural disasters be mitigated?

3) Can the region decrease its dependence on the productivity paradigm and production intensification?

Therefore, in order to discover answers to these questions two qualitative methodologies were chosen for use in collecting and analyzing the data available (Chatfield, 2020). First secondary research was used to identify and collect data for analysis. The secondary sources for use in this process included existing data generated as part of organizational record keeping by (a) governmental institutions (Census Bureaus, Food and Drug Administration Bureaus, National Science and Technology Development Agencies, and Offices of Statistics), (b) international organizations (The Food and Agriculture Organization (FAO), The International Monetary Fund (IMF), The Organization for Economic Co-operation and Development (OECD), The United Nations (UN), and The World Bank (WB)), (c) regional organizations (The European Union (EU), and The Association of Southeast Asian Nations (ASEAN)), (d) inter-governmental agencies (The Asian Development Bank (ADB), the United Nations Economic and Social).

In addition to the data obtained through the secondary sources described above, observations and conversations were conducted both pro and pre-COVID-19 pandemic at food markets, supermarkets, restaurants, food courts, and on roads lined up with street vendors in the Hua Mak, Bangkapi, and Silom areas in Bangkok, Thailand, the old quarter in Hanoi, Vietnam, and the market area in Surabaya, Indonesia. Added to this were observations and conservations at food exhibitions in Bangkok and in farming and rice-growing areas in Northeast Thailand and in the course of short trips to the Chonburi, Nakhon Phanom, Rayong, and Sakon Nakhon provinces. Like the secondary data, data obtained from these observations and conversations was content analyzed, in this case using the themes developed with the secondary data as the basis for categorization.

In addition to providing additional data, the observation and conversation data served as a triangulation to see if the data provided in the secondary sources aligned with what was actually happening at an empirical level across the region. The combined use of these methodologies allowed for what Heaton (2008, p. 9) referred to as "verification, refutation, and refinement" purposes and served to help ensure accuracy and avoid bias.

Discussion

Supply and Demand

ASEAN's population currently stands at 672 million (UN, 2022a). Although the average annual growth rate has declined to close to 1% in the last decade down from over 2% in the early post-colonial era (still a pre-transitional period of high fertility rates), the region's population is projected to reach almost 800 million by mid-century (ASEANStats, 2021). Thus, 27 years from now, ASEAN will be confronted with the burden of feeding an additional 130 million people.

Because of this added burden, the productivity paradigm remains at the core of the region's food and nutrition strategy (Lang & Barling, 2012; FAO, 2021b). Until recently referred to as 'production intensification', the strategy to boost agricultural output to meet the growing demand for food has since been re-termed – somewhat oxymoronically – 'sustainable intensification' in reference to the need to take into account environmental concerns when increasing production (Cassman & Grassini, 2020). Whether this semantic change in the food and nutrition security public discourse signals a change of direction and a real determination to look for green solutions, such as, for example, insect farming or smart farming, or simply is a public relations effort to assuage growing public concerns over environmental issues remains to be seen. While intensification continues to be disproportionately centered on productivity (arguably, inescapably so for the time being), it is this author's view that ASEAN leaders now realize that the environment can no longer be sacrificed on the altar of productivity. However, in spite of its negative outcomes such as the degradation of the ecosystem and the loss of biodiversity, until new technologies and cultivation techniques offer truly viable alternatives, intensification, or more to the point, a 'cleaner' version of it if one goes by the latest semantic, will continue to be the preferred solution. Since rapid urbanization is reducing arable land, the region's crop production growth will mainly be driven by increased productivity rather than increased land use. This is all the more the case as strong measures are now in place to curb deforestation, until recently a common way to increase acreage (Welch & Graham, 2000; OECD & FAO, 2023). Indeed, as can observed across much of the region, rice fields are being turned into residential areas and/or industrial zones as megapolis keeps expanding, a phenomenon unlikely to slow down soon since industrial policies favor a high

concentration of resources in capital cities and large urban areas. Increasing productivity also means that more inputs (e.g. fertilizers) will be needed. Input prices, however, may continue to rise (Langemeier, 2023), which could raise production costs and lead to higher prices for consumers and therefore greater risk of food insecurity and malnutrition since affordability would be reduced (OECD & FAO, 2023). Raising yields also requires more investments in technology, and in the case of LMICs, improvements in farm management (Prasertkhorawong et al., 2020).

Similar to crop production, the growth in livestock and fish production will require further improvements in per-animal productivity, most notably more efficient herd management and higher feed intensity (OECD & FAO, 2023). Pig meat production, however, is still recovering from the outbreak of African Swine Fever (ASF) in 2019 in Cambodia, Indonesia, Laos, the Philippines, and Vietnam, where 'backyard' farms generally lack capital and are unequipped to deal with viruses when outbreaks occur (Turton, Yon, & Yuichi, 2019). The disease ravaged the hog herd and left the business of small-scale pig raisers in tatters. In Vietnam alone, 4.7 million pigs were culled to contain the outbreak and prevent it from spreading further (Songwanich, 2019). The outbreak led to a wide-scale substitution of pork with poultry, which due to the slow return to the pre-2019 level of pig-meat production is likely to continue. The rising demand for poultry pushed prices up. Given its favorable meat-to-feed price ratios and sustained profitability, poultry will probably account for most of the regional growth in meat production.

Historical trends in net export/import status across the region persist. Southeast Asia's geography still determines natural rice production capabilities (ADB, 2010). The upshot is a consistent pattern of net imports by maritime member states and high production and net exports from mainland countries, dominated by large river systems that provide ample water and flat land well suited to rice production. Data covering the period 2010-2020 indicates that Viet Nam, Cambodia, Laos, Thailand, and Myanmar are still net exporters of rice, and Indonesia, Malaysia, the Philippines, Singapore, and Brunei are net importers (Suvannaphakdy, 2022; Viet Nam National Trade Repository [VNTR], 2022). In Indonesia and the Philippines, the majority of rice consumption nevertheless continues to be met by domestic production as self-sufficiency rates stand at 90% and 80%, respectively.

Rice stockholding dominates national food security policies, all of them unsurprisingly aiming for self-sufficiency (ADB, 2010). Since it currently imports about 90% of its food, Singapore has developed a multi-pronged approach to its own food security (Yong, 2017). First, rice imports are managed through a strategic reserve under which licensed importers are required to stockpile rice equivalent to twice their monthly import quantity. Second, to ensure that it is never held for ransom by the vagaries of any market, the city-state has also diversified its sources of imports and achieved contractual price stability. Third, local food production is to provide a buffer in times of sudden import disruptions. Due to obvious land constraints, Singapore is betting on agricultural innovation to increase productivity. Food projects lined up include an 18-acre Agri-Food Innovation Park to be used for high-tech vertical farming, insect farming, and food-related R&D, and a farm on the roof of one the malls, using vertical racks and hydroponics to grow leafy greens and herbs. Fourth, public-private partnerships have been forged to support these various strategies (Yong, 2017). While other member states do not need to set up farms on the rooftops of malls to grow vegetables, they nevertheless need to emulate Singapore's innovative approach and come up with their own creative solutions to substantially increase production without having to exclusively resort to production intensification. Regional cooperation may be the best avenue to devise sustainable alternatives and make the shift to high-tech farming.

Every ASEAN member state is now part of the ASEAN Plus Three Emergency Rice Reserve (APTERR). The scheme, initially established in 1979 on a trial basis by Indonesia, Malaysia, the Philippines, Singapore, and Thailand, was converted into the current APTERR in 2012, when Japan, South Korea, and China joined forces with ASEAN countries (APTERR, 2023). Each country pledges part of its own stocks, which can then be used to meet emergency requirements. Owning governments are responsible for the management costs of their stocks and for ensuring that they remain fit for human consumption. The agreement, though, does not require the holding of physical stocks. The three non-ASEAN members account for the largest amounts of earmarked stocks (APTERR, 2023).

In 2018, at the request of ASEAN, the Organization for Economic Co-operation and Development (OECD) explored the feasibility of a pan-ASEAN stockholding policy integrating every ASEAN rice market and concluded that it could reduce the rate of food insecurity (OECD, 2018). However, to capture all its benefits, significant trade barriers, all of them part of member states' food security policies, would have to be eliminated. Since member states currently heavily intervene in markets and impose high tariffs on rice imports, this means that, as part of transitioning to zero tariffs over the medium term, rice would have to be excluded from the General Exception List contained in the Agreement on Common Effective Preferential Tariff (CEPT) Scheme concluded in 1992 when ASEAN Free Trade Area (AFTA) was established (CEPT, 1992; Ahamat, 2017). Non-tariff barriers, most notably import licensing and monopoly import arrangements, would have to be removed as well (ASEAN, 2002). While ASEAN leaders recognized the benefits of an integrated trade rice market, given the many vested national interests and security imperatives at stake, its implementation may be a long way off.

Climate-Induced Shocks to Food Production

The scale of the damage caused by climate change-induced extreme weather events is staggering. A case in point is the widespread drought in Thailand in 2019 and the torrential rains that followed. They reduced the main rice harvest by 4-12.5% year-on-year and the second harvest by approximately 54% (Treerutkuarkul, 2021). Such 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 due to limited access to resources and adaptive capacities. With climate change intensifying, they 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).

Global warming also affects the region's food production in other ways. There is evidence that, as temperatures are rising, the distribution of inland fish species will shift and lead to the local extinction of some fish. Moreover, rising sea levels may threaten coastal aquaculture production in the deltas and estuaries (FAO, 2017, 2020).

Supply problems in one ASEAN country may be quickly felt in food-insecure states, including those on the other side of the globe. For example, when, in the aftermath of the 2019 drought, Thailand curbed its rice production, Vietnam saw its rice exports rose 31.7% year-on- year. This caused Hanoi to temporarily suspend its rice exports to ensure it had sufficient domestic supplies (Bangkok Post, 2020). For member states and other nations dependent on producer nations for their food imports, this meant growing food security fears.

To reduce the vulnerabilities of its food production systems, the region is betting on biotechnology. Efforts range from low-tech approaches, such as bio-fertilizers, to high-tech and advanced DNA-based methods, such as Genetically Modified Organisms (GMOs). Since rice is the region's main staple, the focus has been on crossbreeding various types of rice which, unlike conventional rice varieties less suited to warmer temperatures, have the desirable characteristics to survive hotter weather and heavier rains. Research by the ASEAN-based International Rice Research Institute (IRRI) has led to the development of varieties of rice more resilient to the changing environment, more resistant to diseases, and capable of better withstanding floods, droughts, high temperatures, and other harmful effects of climate change. Currently, more than half of Southeast Asia's rice area is planted with IRRI-bred varieties or their progenies (IRRI, n.d.).

In addition, joint research by Thailand's National Center for Genetic Engineering and Biotechnology, the National Science and Technology Development Agency, and two Thai universities has culminated with the development of a hybrid glutinous rice variety (Karnjanatawe, 2020). The plant is shorter than traditional glutinous rice varieties, which makes it more resistant to strong winds, less likely to be toppled in the rain, and easier to machine harvest. It also has a much higher yield (800 kg-1,200 kg per acre versus 500 kg-600 kg). Above all, it can resist diseases and withstand short-term droughts.

But while changing the DNA of some breeds may be the region's best chance to sustainably achieve food and nutrition security against a backdrop of climate change, diminishing water supply, ecosystem degradation; and biodiversity loss, GMOs might lead to a decline in nutritional quality and have undesirable effects on people's health, let alone on the environment (Ghimire et al., 2023). While conclusive scientific evidence is lacking on their actual repercussions, one additional concern that those opposed to GMO manipulations have pointed out is that new crop varieties could end up being developed by private sector companies that have no explicit commitment to public goods (and possibly no ethics) - only profit.

The trade-off between food security and food safety is not ineluctable, though. Technological breakthroughs and the introduction of new methods of cultivation may eventually become viable alternatives and therefore greatly reduce the need for more DNA manipulations. 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 (Teng, 2019). These technologies are revolutionizing agriculture and food systems and not only enable governments to enhance the efficiency and effectiveness of existing policies and programs, but also to design better ones (Montesclaros, 2023). In fact, if the resources allocated for the development of more GMOs were redirected towards research on greener farm practices, it is conceivable that the rate of innovation would substantially rise as attested by the strategy in place in Singapore. This would obviously reduce the need for more GMOs.

With the perspective of once-in-a-century disasters likely to arrive more frequently, there has been a shift from reactive to proactive disaster management (ASEAN, 2022a). Unlike pollution and rising temperatures, which can be dealt with providing there is governmental will to do so and a genuine global warming battle plan, natural disasters unrelated to climate changes (e. g. volcano eruptions) are beyond the control of state authorities. But whilst they cannot be stopped, their impact can be mitigated by effective disaster management.

At the domestic level, national disaster management agencies have been set up and tasked with coordinating disaster relief efforts with a focus on prevention, preparedness, detection, early warning, and greater reliance on new technologies (Few et al., 2004). Still, as reported by the WHO's Southeast Asia office, one area in need of improvement is the monitoring and surveillance of disease outbreaks during floods (WMO, 2022; Marks, 2020). There has also been extensive transnational collaboration. One example is the Integrated Disaster Risk Management (IDRM) fund established by ADB and Canada to finance technical assistance projects and knowledge-sharing activities in the region (ADB, 2021). Another is the Asia-Pacific Disaster Resilience Network, that focalizes on the communication of detailed preparedness plans before disaster strikes (UN, 2022b). The theme chosen by ASEAN for the commemoration of ASEAN Day for Disaster Management in 2022 underscores the importance for the region to work together. It reads as follows: Stronger together in balancing action to enhance localization for disaster resilience (ASEAN 2022b).

Conclusion

One of the mounting threats to ASEAN's ability to continuously achieve food and nutrition security in the region is climate change-induced shocks to food production. Despite ASEAN's success in increasing its food output through production intensification (recently renamed sustainable intensification), the perspective of more frequent, more intense, and more devastating extreme weather events reducing crop yields, the size of the livestock, and aquaculture production raises doubts as to whether ASEAN can sustainably supply food and water in sufficient quantities and nutrient-rich products at affordable prices. This is all the more doubtful as output imbalances are compounded by the food losses and wastage that occur at all stages of the food supply chain and claim an additional significant proportion of the region's agricultural production. The challenges posed by extreme weather events can be summarized as follows:

The region can be expected to experience more intense and more frequent production shocks associated with climatological, hydrological, and meteorological events. They could significantly undermine its sustained capacity to supply safe, nutritious, and affordable food to its growing population.

Regardless of the semantic used ('production intensification' or 'sustainable intensification'), both terms allude to a disproportionate emphasis on productivity that will continue to generate negative environmental outcomes such as land and water degradation and biodiversity loss.

Farmers remain hard pressed to shift away from conventional agriculture and the heavy use of chemicals and adopt new modes of cultivation and new technologies.

The measures taken by ASEAN to reduce greenhouse gas emission and limit the global average warming temperature increase to below 2° Celsius (3.6° Fahrenheit) under the Paris Agreement may tie up a large share of capital resources and meet with resistance as they are likely to involve painful changes.

While the causes of malnutrition are multifactorial, price hikes caused by reduced yields and changing eating habits and lifestyles are likely to increase the prevalence of NCDs.

One clear message emerging from this paper is that 'business-as-usual' is no longer an option. The region needs to transit to more sustainable, resilient, and efficient agricultural systems. Artificial Intelligence (AI) and smart farming may turn out to be promising avenues even though the issue of data ownership could, initially at least, be a substantial obstacle to their widespread use.

Robots, for example, are now capable of identifying through a series of algorithms weeds that need to be removed in say a rice field and pull them out, rendering unnecessary the use of herbicides. Under a business-as-usual scenario, though, the region's food and nutrition security are likely to be jeopardized. As part of moving away from a 'business as usual' scenario.

Recommendations

1. Since the additional amount of food needed in the coming decades is expected to be produced mainly through yield increase and the intensification of production, rather than through major expansion of cultivated areas, the onus should be on producers to develop appropriate techniques, preferably organic, biodynamic, or high-tech, to minimize or eliminate the risk of chemical food adulteration and preserve the environment while increasing productivity.
2. Loan schemes and subsidy programs should be made available to promote environmentally friendly farming systems and ensure farmers' commitment to sustainable farming practices, including those built upon indigenous and traditional knowledge.
3. Consistent with the Paris Agreement pledge, more attention should be paid to so-called 'nature-based climate solutions', including the conservation, restoration, and improved management of forests, wetlands, and agricultural lands to increase carbon dioxide sequestration and reduce its emission.
4. Since ASEAN LMICs are still unable to meet the international regulatory requirements set by international organizations, the application of food safety standards in trade agreements should be supplemented by measures to assist them in strengthening national food control regulatory frameworks and enhancing food safety management along food chains. Specifically, the science-based measures implemented by member states should cover the entire food chain from the primary production, processing, and storage of food products to their distribution and provide guidance for ensuring fair practices in food trade while facilitating their free movement across the region.

Recommendations for Future Studies

Future research could focus on empirical studies in the region that test the scope and efficiency of the measures implemented and on the application of digital technologies. It could also focus on further identifying and understanding the various threats to the region posed by climate change.

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