Smart farming: towards a sustainable agri-food system

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Abstract

Purpose – The objectives of this paper are firstly to investigate the relationship between smart farming and sustainable development goal (SDG) 2 i.e. zero hunger. Secondly, the paper applies SWOT analysis to better understand the strengths, weaknesses, opportunities and threats of implementing smart farming in Southeast Asia (SEA). Finally, the paper provides research and practical implications for smart farming in SEA.

Design/methodology/approach – This study applies SWOT analysis to evaluate the strengths, weaknesses, opportunities and threats of smart farming in SEA in its goal to achieve zero hunger. The SWOT analysis is performed by conducting a comprehensive review of past and relevant literature on smart farming and its relationship with SDG 2. The use of SWOT analysis provides a foundation to identify the desired future position, identifies existing issues and better informs leaders and policymakers on how to resolve the weaknesses and take advantage of the opportunities available.

Findings – Smart farming has shown great promise in increasing food production sustainably whilst maintaining a high standard of food safety and quality. Smart farming offers a path towards achieving SDG 2 by providing innovative ways into a more profitable, resilient and green agri-food system. It is also found that a regional approach towards ensuring food security should be taken in SEA due to the dependency of the states on one another for the supply of food and agricultural products. For smart farming to take off in the region, a stronger government initiative is needed to encourage Science Technology Engineering and Mathematics (STEM) learning to equip the local workforce.

Originality/value – This study contributes to the literature by highlighting the role of smart farming in achieving zero hunger. This may assist policymakers to understand the implications of adopting smart farming in the region when compared to other competing trade locations. In addition, this study uses SWOT analysis to evaluate internal and external factors which may assist in formulating strategies by allowing researchers to gain insights and to think of possible solutions for existing or potential problems.

Keywords SWOT analysis, Southeast Asia, Food security, Sustainable development goal, Smart farming, Zero hunger

Paper type General review

1. Introduction

The current pandemic of COVID-19 has resulted in a new dimension of food (in)security mainly due to the lockdown of several major cities, border closures and job or income losses. This results in disruption in the food supply chain affecting the status of food security in many countries. It is found that in Southeast Asia (SEA), the immediate impact of the COVID-19 pandemic is disruptions in the food supply, decreased household food consumption and declining consumer's trust in food safety and hygiene (Musa and Basir, 2021). COVID-19 has resulted in an abrupt change in the world's food consumption and production patterns, a reflection that nature has a limited capacity to meet human needs. To prevent another pandemic that is as damaging, the world urgently needs to prioritise more sustainable patterns of food production and consumption. In a way, the pandemic also provides farmers and researchers the opportunity to reconsider current approaches to agriculture and move towards greener and sustainable techniques.

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SWOT analysis to better understand the strengths, weaknesses, opportunities and threats of applying smart farming in SEA. Finally, the paper provides research and practical implications for smart farming in SEA.

This paper is organised as follows: Section 2 provides the background of agriculture in SEA, Section 3 provides the literature review on the relationship between smart farming and SDG 2. Section 4 outlines the methodology used for this study, followed by findings and discussion of the SWOT analysis in Section 5. Section 6 sets forth the research and practical implications of smart farming in SEA. Finally, the paper ends with concluding remarks in Section 7.

2. Agriculture in Southeast Asia

Approximately 115 million hectares of land across the region of SEA is devoted to the production of rice, oil palm, maize, rubber and coconut (ADB, 2009). Cambodia, Myanmar, Thailand and Vietnam, collectively known as the "rice bowl" of Asia, are among the world's largest exporters of rice; meanwhile, Brunei, Malaysia, Indonesia and the Philippines are importing countries that aspire to attain self-sufficiency. Apart from city-state Singapore, most of the other Association of South-East Asian Nation (ASEAN) member states remain heavily dependent on the agricultural sector for their food supply and livelihoods. Member states produce food for regional trade as well as export around the world. In 2017, it was recorded that ASEAN member states contributed to around 21% of global food exports (ASEAN, 2018). For the year 2018, Myanmar had the largest share of agricultural products in total exports at 28%, followed by Indonesia (19.3%) and Lao PDR (18.4%) (ASEAN, 2019).

Table 1 shows the percentage share of gross domestic product, employment, exports and imports of the agriculture sector among the ASEAN member states in 2018. Contrary to the rest, Singapore is a net importer of all food products. With a small landmass of 715 kilometress square and a population of more than 5 million, only less than one% of the land is available and set aside for agriculture purposes. Nevertheless, with the use of innovative technologies and urban farming techniques, the island nation is able to produce around 10% of its own food for consumption (Phang, 2018). Both open systems (Sky Greens vertical farm) and closed systems (Panasonic indoor LED lighting farms) have been utilised for the intelligent production of leafy vegetables such as Chinese cabbage, Kai Lan, Kang Kong, Lettuce and Spinach (Liu, 2017).

By 2030, the government aims to increase its self-sufficiency in food production to 30%, with more efforts devoted to promoting urban smart farming initiatives (Liu, 2020). In a way,

Table 1. GDP share, employment, exports and imports share of the agriculture sector in ASEAN, 2018

Country	GDP share	Employment share	Exports share	Imports share
Brunei Darussalam	0.8	1.1	0.2	12.3
Cambodia	16.3	–	5.5	7.5
Indonesia	12.5	28.8	19.3	10.5
Lao PDR	14.5	–	17.5	12.5
Malaysia	7.3	10.6	8.4	7.4
Myanmar	24.6	51.6	28.0	13.3
Philippines	8.1	32.0	8.9	11.9
Singapore	0.0	–	3.3	3.6
Thailand	6.1	35.8	14.0	6.1
Vietnam	14.3	41.9	11.0	8.2
Total in %			9.9	7.3
Total in million US$			142,158.8	101,188.8

Source(s): ASEAN Statistical Yearbook 2019 (ASEAN, 2019) vulnerability to food security issues has led the Singapore government to focus on increasing its domestic food production and transform the country into Asia's urban agri-food tech hub. However, one of the main challenges encountered is the lack of agricultural experience. This means that developers must often travel overseas or form partnerships to learn about established agricultural practices in order to further develop smart farming (Chong, 2019).

For the rest of SEA, however, farming practices remain largely traditional in nature. The problem is not only to do with consumer-side challenges i.e. population growth, urbanisation, changing patterns of consumption and demographic change (Teng, 2019), but there are also numerous supply-side challenges. In many of the SEA countries, farmers are ageing, and rural-urban migration is becoming more common among the youth. Young people prefer to seek work opportunities in cities and are also reluctant to participate in agriculture due to the many barriers of entry they face, such as weak funding mechanisms and inadequate governmental support. This inevitably leads to weaker adoption and poor implementation of new innovations in farming.

3. Literature review: smart farming and SDGs

To ensure enough food is produced for a population of nearly 10 billion by 2050 without critically degrading natural resources, a transition to a sustainable agricultural system is needed. Helms (2004) explains sustainability in terms of economic and social sustainability whereby the former entails production and consumption that serves to enhance the quality of life rather than degrade it, whereas the latter involves development that is socially acceptable and aims for global equity. The United Nations SDG 2 focuses on zero hunger, i.e. to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. The globalised conventional food system is found to be flawed with economic uncertainties, negative environmental and social effects (Helms, 2004). Further, with scarce natural resources depleting, inevitable consequences of climate change and growing global population, agriculture must be sustainable to ensure the achievement of zero hunger (United Nations, 2020).

Pivoto *et al.* (2018) defined smart farming as the incorporation of information and communication technologies into machinery, equipment and sensors for use in agricultural production systems. The emergence of smart farming is due to the rapid development of the Internet of Things (IoT) and cloud computing (Sundmaeker *et al.*, 2016), which are expected to introduce more robots and artificial intelligence into farming (Pivoto *et al.*, 2018). The term agri-tech is also exchangeably used, which refers to the use of technology and technological innovation to improve the efficiency and output of agriculture.

Food security is defined as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). This means that food security is achieved only when "all people," particularly the poor, have access to sufficient food and access to food must be stable over time. "Physical and economic access," on the other hand, indicates that food security may be assured by producing food or by obtaining it through the market. A country is considered food secure if food is available, accessible, nutritious and stable across the other three dimensions (FAO, 2008).

The availability and accessibility dimension of food security can be strengthened through smart farming, especially in urban areas. According to the World Bank (2020), globally, over 50% of the population lives in urban areas. A similar trend appears in SEA, where half of its population resides in urban areas, and it is projected that an additional 70 million more people are to live in cities by 2025 (ASEAN Secretariat, 2018). Arable land is scarce in urban areas; FAO (2016) anticipated that in 2050, arable land per person will decrease to one-third of the amount available in 1970. This rapid urbanisation leads to unpredictable food shortages in some parts of Asia and increasing urban sensitivity to variability in the food supply chain due to unstable labour availability (Benke and Tomkins, 2017).

One of the solutions to tackle the above issue is by promoting urban vertical smart farming, whereby urban spaces are converted into agricultural spaces. Vertical smart farming is a practical technology through which large quantities of food crops and medicinal plants can be produced in a very small space with the help of advanced technology (Saad *et al.*, 2021). Vertical smart farming has the potential to address the future trend of diminishing agricultural resources and climate change (Despommier, 2010). Singapore is a good reference in its efforts towards food security despite its limited land for agriculture using vertical smart farming. Sky greens vertical farms in Singapore are made up of rotating tiers of forming troughs connected by an A-shape aluminium frame. The troughs spin around the aluminium frame to ensure that the vegetation receives consistent amounts of daylight, drainage, and nutrients as they pass through the structure's unique features (Saad *et al.*, 2021).

On the environment front, vertical smart farming uses wind turbines and storage batteries for solar panels, which reduces the emission of carbon footprint. In addition, due to its strategic location in the urban area, it cuts greenhouse-gas emissions from automobiles due to its closer proximity to consumers (Benke and Tomkins, 2017). Local authorities and producers may consider the shift towards smart farming in order to reduce climate change impacts and supply chain breakdowns.

In terms of the improved nutrition aspect of SDG 2, smart farming can be implemented through the concept of nutrition smart agriculture (NSmartAG). Adequate nutrition has been a growing challenge all over the world in terms of undernourishment, micronutrient deficiency and over nutrition (Gómez *et al.*, 2013). Nutrition smart agriculture is a set of agriculture and agro-processing technologies and practices that contribute to the improvement of nutrition and increase farm and agribusiness-level productivity and revenue (World Bank, 2020b). It focuses on the production side of the food value chain, which enables the farmers and agribusinesses to decide "what" and "how" to produce, allowing the agriculture sector to design and implement actions and policies to improve nutrition in line with the goal of SDG 2 (World Bank, 2020b). There are four main steps in the identification of nutrition smart agriculture opportunities:

(1) Step 1 involves the identification of the local malnutrition problems from existing sources;

(2) Step 2 includes an analysis to extract nutrient consumption levels for a set of nutrients associated with the identified malnutrition problems and posing considerable health burdens;

(3) Step 3 uses the data and analysis from Step 2 to identify food groups for further investigation and

(4) Step 4 concludes with the identification of a sample menu of options of validated nutrition, smart agriculture practices and technologies.

The application of technology in food quality and logistics was also studied. Faccilongo *et al.* (2017) explore the opportunity for technology transfer in the monitoring and control of agri-food products based on the use of miniaturised, smart and innovative sensors. This aims to improve the quality and the logistics of the chain and offer cost-effective solutions to optimise production flows by networking the existing Italian hubs. Blockchain technology, for instance, has been utilised to track the journey of perishable food items from farm to plate. This system of traceability and accountability is helpful in tabling data, particularly in the event of safety recalls food fraud or supply chain inefficiencies (Xu *et al.*, 2020). Food producers and scientists are also developing new technologies using Big Data. This can help smallholders to make more informed decisions on, for instance, planting or harvesting times. With Big Data, the execution of work like the application of seeds, water, fertilisers and crop protection becomes more efficient.

To support SDG 2, the United Nations promotes the use of "sustainable agriculture," which refers to an agricultural system that will continue to be productive in the future (Feenstra, 2020). The main objectives of sustainable agriculture are to incorporate a healthy environment, economic profitability and social and economic equity into the production process (FAO, 2019). Due to environmental stress on water scarcities, insufficient land use, soil depletion, and greenhouse gas emissions, the demands for sustainable agriculture are rapidly increasing (Santiteerakul *et al.*, 2020). Thus, sustainable agriculture requires an innovative system that protects and enhances the natural resource base whilst increasing productivity. The use of technology or smart farming has allowed the agriculture sector to be more efficient in monitoring farms and applying minimum quantities of input such as water, fertilisers and pesticides to farm's target areas. This has resulted in a more productive, efficient, safer, environmentally friendly and profitable agri-food system in line with the goals of the SDGs.

4. Methodology: SWOT analysis

The strengths, weaknesses, opportunities and threats framework involves specifying the objective of the business venture or project and evaluating both the internal and external factors that are either favourable or unfavorable in achieving the objective (Ghorbani *et al.*, 2015). The strengths and weaknesses are generated from the internal environment of operation concerning image, structure, availability of tangible and intangible resources, capability and productivity. On the other hand, opportunities and threats are external factors, relating to political scenarios, economic volatility, social and technological changes, and environmental concerns (Lynch, 2012). SWOT analysis is a form of strategic planning tool and has been used extensively to formulate strategies for firms, industries, governments and countries alike. As indicated by Proctor (1992), SWOT analysis is suitable for countries, industries or organisations to follow as it identifies the environmental relationship between internal and external environment.

This study uses SWOT analysis to evaluate the strengths, weaknesses, opportunities and threats of smart farming in SEA in its goal to achieve SDG 2. The SWOT analysis is performed by conducting a comprehensive review of past and relevant literature on smart farming and its relationship to SDGs. A thorough search of the relevant literature using a number of keyword combinations such as "smart farming", "SDGs", "sustainability", "environmental impact", "social impact" and "economic impact" from leading databases like Web of Science and Scopus was carried out. The articles and reports were carefully chosen to meet the relevance of the topic. In addition to academic papers, a wide range of grey literature was also used for gathering data and discussions. News articles were also useful for learning about the latest happenings in the field in SEA. The articles were analysed, synthesised and further categorised either as strengths, weaknesses, opportunities or threats. Figure 1 shows the result of the SWOT analysis of the literature on smart farming and SDGs.

5. Findings and discussion based on the SWOT analysis

5.1 Strengths

5.1.1 Land productivity and profitable returns. The availability of suitable land has often been a major factor influencing levels of agricultural output, especially in small countries. In Singapore, sustainable urban farms (AeroFarms) that utilise aeroponic systems have been

Strengths	Weaknesses
Land productivity and profitable returns Efficient use of resources	High cost of technology and infrastructure Lack of understanding on the level adoption of smart farming services and technologies in ASEAN
Opportunities	**Threats**
Reduce ecological footprint More youth participation in agriculture	Technology divide Regulatory hurdles

Source(s): Author's own compilation

Figure 1.
SWOT matrix of smart farming in SEA

beneficial in boosting food production whilst maintaining high standards of quality and food safety and contributing to sustainability measures (Chen *et al.*, 2020). Compared to conventional farming methods, aeroponics technology farms on less than one% of land and uses 95% less water. Apart from the functionality and effectiveness features of modern agri-tech like aquaponics and aeroponics, it also aims towards a more sustainable consumption and production outlook.

In addition to land productivity, smart farming has the potential to make agriculture more profitable by reducing resource inputs and the cost of production. The use of certain techniques to reduce resource inputs can ensure that farmers save immensely on labour and secure reliable spatial data in risk reduction. This is attributable to the fact that smart farming encourages the use of technology in site-specific weather forecasts, probability mapping of disasters and diseases and yield projections. According to Pivoto *et al.* (2018) sensors, electrotechnical devices used in smart farming measure physical quantities from the environment and convert the measurements into a signal, which can be read by an instrument.

Site-specific information also enables new insurance and business opportunities for the entire value chain, from technology and input suppliers to farmers, processors, and the retail sector in developing and developed societies alike. If all farming-related data are recorded by automated sensors, the time needed for prioritising the application of resources and for administrative surveillance is decreased. Digital business models have also emerged, including peer-to-peer lending (Pucci, 2019). Agri-finance is an emerging subsector that helps rural and vulnerable smallholders to reduce risks and increase farm investment so that they can increase yields and earn a higher income. Apart from government investment and lending, governments can look into further developing agri-finance to give farmers the opportunity to afford appropriate new smart farming technologies for their day-to-day operations.

5.1.2 Efficient use of resources. New technologies with artificial intelligence (AI), analytics, connected sensors and other emerging technologies could further increase yields, improve the efficiency of water and other inputs and build sustainability and resilience across crop cultivation and animal husbandry (Godde *et al.*, 2020). Furthermore, agri-tech aims at maximising yields with fewer input and environmental costs. Agri-tech has the capacity to enable farmers to get connected with potential consumers directly, thus shortening the supply chain. A study on the sustainable food chain with small-scale farmers was carried out whereby Slamet *et al.* (2020) determined the enabler to implement sustainable food supply chain management (SFSCM) based on the participation of small-scale farmers in modern retail channels, focusing on fruit and vegetable products. The results show that some enablers, such as physical infrastructure and collaboration among supply chain members and stakeholders, are found to have strong and fundamental driving forces in SFSCM. The importance of SFSCM is a response towards consumer concerns on health, food security and social and environmental issues.

Thailand aims to enhance its farming efficiency in order to generate the highest optimum yield with the least amount of resources. For example, Wangree Health Factory Company in Thailand uses modern digital technology to produce fresh organic vegetables and fruits. It uses artificial intelligence light for its indoor farming system connected with a smart control system. The system results in high-quality and high-yield production year-round under a controlled environment. In addition, it allows farmers to plan their production by using mobile devices for monitoring and controlling their farming systems. The growth process is fully automated for watering, lighting, nutrient adding and temperature controlling. The 173.85 $m^2 \times 6$ m high plant factory produces approximately 50,552 heads of lettuce per month (Santiteerakul *et al.*, 2020).

The use of smart farming in the case of Wangree Health Factory Company in Thailand has resulted in effective resource use efficiency in terms of water use and land use. Less water is needed due to a water control system that reduces drained water in the growing area and recycles water vapor into liquid water. It also increases land-use efficiency (LUE). The vertical farming method provides a 99% reduction in land use (Santiteerakul *et al.*, 2020).

5.2 Weaknesses

5.2.1 The high cost of technology and infrastructure. In countries in SEA where farming is mostly undertaken by rural agricultural communities, this concern is very valid in several respects. First and foremost, in terms of cost, a precision spraying machine that utilises artificial intelligence to decrease the use of pesticides through efficient allocation may sound promising for vegetable farmers in rural West Malaysia, but the cost of such solutions are still out of reach. Secondly, it may also be the case that additional costs may be incurred in up-skilling workers and teaching them how to use new technologies, as well as for the hire of expert consultants like agronomists who can convert data into information that is useful for them. It has been suggested that the agri-tech landscape in SEA needs more input and involvement from professionals in various fields apart from agriculture, such as IT, in order to take off (Chandran, 2019).

With 5G, IoT devices and sensors can share data at significantly faster speeds and help farmers increase their level of efficiency and yields. However, the main issue with deploying 5G capabilities is the high infrastructure cost that is involved. In less developed countries where 3G, let alone 4G, infrastructure is absent or lacking, the challenge is even greater. The cost of developing such infrastructure is known to be even higher in rural areas where most agricultural activities take place. There exist limitations to cope with innovative technology at the current early stages. These technologies are still too expensive for most farmers, especially those with small farms, because scale economics make small individual farms less profitable. Nevertheless, the cost of technology decreases with time, and smart farming will be surely implemented in the future as an alternative to bring about higher production (Saiz-Rubio and Rovira-Más, 2020).

5.2.2 Lack of understanding on the level adoption of smart farming services and technologies in ASEAN. A clear understanding of the adoption of technology in farming is crucial in order to devise strategies and future directions. The countries in SEA need to be aware and understand the use of technology in competing trade locations for the region to maintain and improve its productivity and resilience. For instance, some farmers are using drones in Malaysia, the Philippines and Vietnam; however, their use is far from widespread in SEA (Pennington, 2019). Singapore, despite its potential to become an agri-tech hub, lacks agricultural experience. It is, therefore, vital to form partnerships and collaborations or travel abroad to learn established agricultural practices from other countries before embarking on technological transformation of the agriculture sector. In order to achieve this, cross-regional initiatives and projects should be prioritised to ensure SEA does not miss out on the wealth of opportunities that agri-tech brings. Some initiatives that are already in place to improve this are the ASEAN Integrated Food Security (AIFS) Framework and Strategic Plan of Action on ASEAN Food Security (SPA-FS), which serves as a platform on various levels for information exchange, transfer of new technology and knowledge sharing (ASEAN, 2019).

5.3 Opportunities

5.3.1 Reduce the ecological footprint. Many current farming practices damage the environment and are a major source (19–29%) of anthropogenic greenhouse gas (GHG) emissions such as carbon dioxide and nitrogen dioxide (Campbell *et al.*, 2014). Smart farming comes with so many opportunities with the aim of reducing the ecological footprint. In tackling environmental issues in agriculture, smart farming can help manage crop production inputs in an environmentally friendly way.

According to Stein (2021), moving from open-field farming to indoor farming could potentially have significant impacts on air quality and the production of GHGs, especially through the conversion of open-field agriculture to the forest. Waheed *et al.* (2018) modeled data from 1990 to 2014 and found that carbon dioxide emissions can be reduced by increasing renewable energy usage and forest area while decreasing agricultural use.

Thailand incorporates conscious use of smart technologies to generate a lesser carbon footprint with biomass conversion technologies such as the implementation of solar energy, biomass energy and greenhouse dryers (Mastoi *et al.*, 2014). This is in line with the commitment of net-zero gas emissions efforts by the year 2050 by the International Energy Agency, whereby the National Energy Policy Commission of Thailand pledged in 2013 to support solar installations by the following year (International Energy Agency, 2018).

5.3.2 More youth participation in agriculture. One of the pressing problems faced by agriculture globally is the lack of youth involvement to replace ageing farmers to ensure the sustainability of the agri-food sector. This problem is apparent in SEA, and it is believed that smart farming has the potential to boost youth participation in agriculture. Emerging new technologies can help demonstrate to youth that agriculture can be a viable and profitable business opportunity, increasing the desirability of agriculture-related careers. Engaging youth in agriculture will enable them to bring innovative and tech-savvy perspectives to solving some of the most difficult problems in agriculture (Musa *et al.*, 2021; Musa *et al.*, 2020).

Thailand is currently facing a farming society that is ageing and has constantly been working to attract more youth into the agriculture sector. In its effort to encourage youth in playing a bigger part in the main commodity trade of the country, the Department of Agricultural Extension has set up a “Young Smart Farmer’ programme to elevate the youth in the agronomic networks to replace over 50% of retired farmers. The initiative aims to produce new agricultural “young blood’ to achieve maximum agricultural capability by engaging technology to improve yields, as well as other commercial aspects, including production capacity, management and farm marketing (Bangkok Post, 2019). Similarly, Brunei, in its bid to attract more youth into the agriculture sector, has started to adopt smart farming. The presence of the Internet helps youths’ in experimenting with small farm systems from the comfort of their own homes. One example is S&R Aquafarm, founded by an inspiring youth who built an aquaponic farm that aims to promote sustainable smart farming (Musa *et al.*, 2020). The farm preserves environmental amenities by utilising clean energy, emitting less carbon and reducing water wastage. This farm is powered by solar energy and recycling water containing waste from fish as feed for the hydroponics, demonstrating that smart farming is possible, feasible and sustainable even with limited space.

Agribusiness start-ups, founded by youths, have developed rapidly in Brunei. They provide agricultural solutions using smart farming methods and technologies such as precision-farming software, censors and types of machinery. One example is Agrome IQ, a company that uses technologies and tools to help agripreneurs collect information and analytics to make effective business decisions with regard to yield. They utilise technology to simulate scenarios and case studies references before implementation for a more predictive and precise outcome. The COVID-19 pandemic outbreak led Agrome IQ to launch Brunei's first online marketplace for local farmers to sell directly to their potential customers. The motivation to launch the platform was to address the challenges facing smallholder farmers in marketing their produce amidst the COVID-19 crisis (Wong, 2020).

5.4 Threats

Technology divide smart farming may be out of reach for some groups, i.e. the poor, less educated, rural or aged farmers. While the shift towards smart farming has seen success in some areas where it has been introduced and implemented, there have been mixed responses elsewhere. Such reactions are inevitable considering how unfamiliar these new developments may be, especially to ageing farmers. One of the main issues raised during the Green Revolution was that the transfer of technologies often bypassed the poor due to discriminatory policies against smallholders with regard to ownership and tenancy rights, eligibility for subsidies on mechanisation and poorly developed input, credit and output markets. The problem therein was not with the technology itself but rather the policies that were introduced to promote the intensification of agricultural outputs (Pingali, 2012). Hence, scholars are cautioning against a technology divide.

The main concern, highlighted by Schwab (2016) with regards to disruptive technologies, is that if organisations and policymakers are unable to employ and regulate new technologies in a way that brings out its benefits, shifting powers can create new security concerns like increased inequality and fragmented societies. In hindsight, this was precisely the case following the third industrial revolution when low-income countries that lagged behind were not able to equally benefit from the digital revolution. As disruptive technologies emerge once again in our age, fears are that the existing digital divide will exacerbate the technology divide, widening inequalities in opportunity, outcome and impact across regions, countries and people (UNESCAP, 2018).

5.4.1 Regulatory hurdles. One of the complications linked to disruptive technologies is that new innovations can surpass existing business and regulatory models, hence raising legal and regulatory concerns. Drone technology has proven to be immensely useful in agriculture. They can be used for mapping and surveying crop conditions, spraying pesticides and fertilisers and monitoring livestock over a wide area. It was found that in Vietnam, farm workers' exposure to pesticides has had serious implications for their health (Dasgupta *et al.*, 2007). However, the use of drones in SEA is still limited in present times. The main problem with drone usage in many countries is regulation. Due to the risks that unmanned aerial vehicles (UAV) like drones pose to aviation and security, many governments have strict regulations in place regarding their usage. It is important for governments to have in place adaptive regulations so that they can still benefit from disruptive technologies whilst maintaining security and safety. Authorities in SEA need to modify licencing and operating regulations for drones used for farms, perhaps by looking towards the UK, where laws on farm drones exist (Pennington, 2019).

Another area where authorities may be concerned with the use of disruptive technologies in agriculture is cybersecurity. Since smart farming has very much to do with Big Data and IoT, data from farms are likely to flow through to third party farm advisors, such as those that deal with biology, chemistry, economics, marketing or engineering. On a larger scale, these data and those who handle the data can become vulnerable to data theft, sabotage or misinformation (Chi *et al.*, 2017). However, for SEA, cybersecurity frameworks are still underdeveloped and a coordinated digital strategy is first needed to combat data breaches and cyber attacks (Heinl, 2014).

The existing legal frameworks and regulations in some of the member states have been slow in responding to such technological disruptions. The way in which governments respond through regulation is imperative as technological disruptions need space to innovate, so impeding their development can lead to poor outcomes (Singh, 2019).

6. Strategies and way forward

6.1 Implications for practice

6.1.1 Youth participation and Science Technology Engineering and Mathematics (STEM) learning. More groundwork needs to be done to create a functional ecosystem for smart farming to thrive in countries in SEA. At the grassroots level, particularly in less developed member states, there are gaps in skills like language and digital literacy. This evidently hinders rural farmers from embracing new technologies that can ease and improve their work in the field. This problem is not unique to developing countries but can also persist elsewhere where the majority of farmers are ageing. It is, therefore, imperative that the barriers to entry for youth farmers be addressed accordingly. Some issues they may face in the early stages include access to markets, access to financing, and access to inputs or equipment (Musa, 2020). Young farmers should also be supported in terms of capacity development and empowerment. Considering the varying levels of social and economic development that persists across the bloc, the environment in which young farmers are nurtured will evidently differ from one country to another. Nevertheless, at the most basic level, governments can encourage STEM learning among students to stimulate students' interest not only in agriculture but also in other areas where technological disruptions are bound to take place, like healthcare and financial services.

An elaborate system of green education in the Netherlands has positively contributed to the development of qualified human resources for the green sector (agriculture, nature, food) (Kupper *et al.*, 2012). Countries in SEA may consider implementing a similar initiative in order to acquire a capable workforce that is able to address agriculture-related problems.

6.1.2 Institutional frameworks and regional cooperation. Governments have a very important role to play when establishing frameworks for the implementation of new technologies in farming. Close co-ordination between the different ministries involved is necessary to ensure that agriculture policies are relevant, effective and inclusive. Furthermore, considering the steady rate of technological disruption that is occurring in modern times, it is essential that policymakers are in the loop and dynamic and regulations adaptive so that they can adjust to the fast-changing technological interventions. Apart from manpower and technology, a great deal of investment is still needed for the research and development of smart farming products and solutions. Agri-finance is also a valuable subsector that governments should encourage and not over-regulate. The government should promote and provide an environment of training, knowledge sharing, support and incentives for farmers and agri-tech start-ups in order to create a strong ecosystem of agriculture, technology and innovation.

Creating a solid ecosystem for smart farming should not only be limited to efforts within the nation. Governments, research institutes and industry leaders must also work closely together to facilitate the research and development of smart farming solutions and products. The temporary breakdown of food supply chains that occurred as a result of COVID-19 panic-buying and labour and logistics limitations serves as a harsh reminder of what could become a reality if disruptions in food systems and the food trade prevail. None of the 10 ASEAN member states are self-sufficient in food production, and there is a heavy reliance on one another for food supplies (Lai, 2020); therefore, efforts to successfully adopt smart farming technologies should be combined.

As an example, the Common Agricultural Policy (CAP) of the European Union (EU) has long played an essential role in safeguarding Europe's agricultural sector. It is one of the grouping's most integrated policies and accounts for around 40% of the EU's budget to support the environment for food production and farm income across Europe (Pe'er *et al.*, 2019). While ASEAN does not have the same mechanisms as the EU, it can still seek ways to increase its efforts in cooperation to advance the food security agenda in the region. Some macro-level strategies are already in place such as the ASEAN Food Security Reserve that aims to set aside and share rice stocks during contingencies and the ASEAN Integrated Food Security (AIFS) Framework and Strategic Plan of Action on ASEAN Food Security (SPA-FS), which serves as a platform on various levels for information exchange, transfer of new technology and knowledge sharing.

6.2 Implications for research

There is still a lack of empirical and qualitative studies on the level of adoption of smart farming services and technologies in SEA. This study contributes to the literature by highlighting the role of smart farming in achieving zero hunger. This may assist policymakers to understand the implications of the adoption of smart farming in the region when compared to other competing trade locations, especially on technology use. An example would be on the appropriateness of technology with regards to countries with best practices in smart farming, especially on climate applicability.

In addition, this study uses SWOT analysis to evaluate internal and external factors that may assist in formulating and selection of a strategy as it allows researchers to gain insights and to think of possible solutions for existing or potential problems. Further, the use of SWOT analysis provides a foundation to identify the desired future position, identifies existing issues and better informs leaders and policy-makers on how to resolve the weaknesses and take advantage of the opportunities available. In addition, the study seeks to recommend policies to leverage the strengths and opportunities and resolve the weaknesses as well as overcoming the threats.

7. Conclusion

The steady onset of disruptive innovations in agriculture in recent times is a positive sign as the food crisis ahead looms large. Where it has been widely implemented, smart farming has shown great promise in increasing food production sustainably whilst maintaining a high standard for food safety and quality. Smart farming offers a path towards achieving zero hunger by providing innovative ways into a profitable, socially accepted agriculture that benefits the environment, sustain farmers' income and resilience and attract more youth into the sector.

Although smart farming in SEA is still in its early stages, it has also shown a positive response. For many of SEA's smallholders, it may appear out of reach especially if they lack the capital to do so, hence more intervention is needed in this area. It can be observed that regulatory hurdles and a digital divide especially in developing countries have stood in the way of the smooth adoption of smart farming methods. It is possible that the COVID-19 pandemic may become the catalyst that sets in motion smart farming in SEA.

The field of agriculture is multidisciplinary, and more input from professionals in other areas of expertise are needed to add value to the field. For smart farming to take off in SEA, stronger government initiatives are needed to encourage STEM learning and equip the local workforce. The agricultural landscape is now shifting, and the work is increasingly multifaceted. Farmers alone cannot meet the world's food demands but neither can technology without human knowledge and intervention. While policymakers may be wary over unfamiliar technological disruptions in agriculture and other areas, they should not be quick to inhibit their usage and development from avoiding lost opportunities for growth. International and regional collaboration and consultation on matters relating to policy and innovation are one of the ways forward to discover best practices in this regard.

This paper has explored the latest trend of agriculture and the adoption of smart farming methods in contributing towards meeting zero hunger and the growing global food demand. The source of information and data in this paper are mostly secondary; hence, future studies should consider the use of primary data and observation that will shed more light on related issues through in-depth empirical and observable evidence. Future research may consider more in-depth studies on the ASEAN member states' varying stages of social and economic development, their differing political and environmental landscapes and how they can more effectively respond to disruptions in smart farming.

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