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CHALLENGES AND POTENTIAL OF VERTICAL FARMING IN BRUNEI DARUSSALAM

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ABSTRACT

Brunei's food security issue highlights the importance of local agricultural production needs to be increased, particularly, constraints such as limited farming space and high soil acidity that affect crop yields. Furthermore, climate change has also changed traditional approaches to farming, which has an additional impact on the Brunei's agriculture. A growing trend in modern agriculture is vertical farming (VF). With a lot less land area than traditional farming methods, it allows for year-round agricultural production. This study focusses at the challenges involved in implementing VF and discusses alternative solutions in order to investigate the potential of VF for the purpose of improving food security in Brunei Darussalam. A total of twelve Bruneian modern farmers, one government staff from Department of Agriculture and Agrifood, one academics, and one services provider were interview using in depth- interview. The result of the study indicate that modern VF presents a number of challenges for Bruneians. Among these includes high initial cost, uncertain weather patterns, market dynamics and competition, uneven distribution of nutrient, disease and pest, light distribution and the need of skilled labour. The practice of VF holds promise for encouraging and involving youth in agriculture. The importance of this study lies in its understanding of how vertical farming may improve food security, which could help Bruneian farmers, young people, and policymakers.

Keywords: Vertical Farming, *Challenges, Potential, Food Security, Brunei Darussalam*

1. Introduction

Agriculture has always become an important sector on a global scale and continues to play a vital role in economic advancement and development (Blandford, 2011; Manescu et al., 2016). In 2018, agriculture represented 4% of the total gross domestic product (GDP), while some emerging countries showed contributions surpassing 25% of their own GDPs (World Bank, 2021). The rapid growth of the global population, forecasts suggest a rise to 10 billion people by 2050, requiring a 70 percent boost in global food production by then (UN, 2018; FAO, 2021). Furthermore, it is expected that around 7 billion people globally will live in urban areas (UN, 2018).

By the year 2030, urbanisation is anticipated to result up to 2.4% reduction of global agricultural land with the region in Asia believed to have the fastest rate of urbanisation; this region is expected to experience the most significant loss in farmland, while Africa is projected to face the highest percentage of farmland reduction (D'Amour et al., 2017). As a result, the food supply emerged as a crucial concern for countries at with varying degrees of economic advancement, as well as the agricultural industry serves an important role in enhancing food accessibility, furthermore, due to the rapid urbanisation, there is a growing demand for urban agriculture (Chatterjee et al., 2020; Pawlak & Kołodziejczak, 2020).

For the past nine decade, Brunei Darussalam has been recognised for its heavily reliance on oil and gas industry, including both upstream and downstream industries as well as for its exports and revenue (International Trade Administration, 2022). The commonwealth (2021) reported that in 2013, Brunei economy was impacted by the low price of oil which contribute to a fiscal deficit and slow economic growth. Furthermore, Brunei's unemployment rate rose from 6.8% in 2019 to 7.4% in 2020 (DOS, 2020). As a result, Brunei Darussalam would be prone to economic shocks, which would make life difficult for Bruneians.

The key sector of Brunei Darussalam for contributing to the nation's economic diversification is the agriculture sector (DoAA, 2021). Therefore, expansion and advancement of the agricultural sector will support the country's "Wawasan 2035" goal, which aims to achieve dynamic and sustainable economy. It was emphasised at the United Nations Food System Summit (UNFSS) that Brunei Darussalam is committed to strengthening the food system by accelerating the production growth of the agriculture and fisheries sector; promoting both domestic and foreign direct investment (FDI), and using technology to boost productivity in order to fulfil both domestic and export needs (PMOBD, 2021). In 2019, Brunei relied on food imports from more than 90 countries (MOFE, 2020). The trend on food imports has been steadily increasing while the food exports have been remained unchanged during the period of 2015-2020. As a result, it led to an increasing trade deficit in the food industry (DEPS, 2021a, 2021b). The contribution of agriculture to Brunei's GDP has shown an overall upward trend where the highest GDP recorded in 2018, the country's agricultural output was over B$91 million, while the lowest amount ever recorded in 2015 at B$89 million. Nonetheless, agriculture's GDP has contributed less towards Brunei's GDP. An average of 0.50% of Brunei's GDP was contributed by the agricultural sector between 2015 and 2020 (DoAA, 2021).

Grealish et al. (2008) reported that the soils in Brunei are highly acidic, with pH values ranging from 4.2 to 4.9. This affects the crop production due to presence of toxic chemicals and micronutrient deficiencies. Due to Brunei's climate, topography, and soil composition, a large portion of the nation is vulnerable to waterlogging (Grealish et al., 2008). High rainfall, a shallow groundwater table (often less than 0.5 meters below the surface), perched water tables above unsaturated soil, inadequate surface drainage, and the tendency of runoff to accumulate in low-lying places are the main causes of this (Grealish et al., 2008).

According to FAO (2021) more than 750 million people, primarily in developing countries suffers from undernourishment despite recent decades of advances in global food supply Due to increases in population and the increased frequency of environmental crises including catastrophes such as flooding, drought, and extreme weather events, food security in these regions is under serious risk (Ahmed et al., 2017). Climate change is projected to intensify existing obstacles by causing shifts in suitable crop types, seasonal factors, and increasing the frequency of intense of weather conditions such as heatwaves and heavy rainfall (Lin et al., 2022). According to Ahmed et al. (2017), inadequate food supply is only one factor contributing to food insecurity while other factors include low consumer buying power and problems with access at both household and national levels (Ahmed et al., 2017). Due to reduction in food availability caused by climate change, consumers face higher expenses obtaining food, limiting their access to it (Liu et al., 2022).

The human history has relied on traditional food production systems have encountered many obstacles and scrutiny. In many countries, the amount of organic matter in soils used for

agriculture has decreased as a result of conventional cultivation methods. (ITPS, 2015). Among the challenges faced by farmers who use the conventional farming method are dealing with extreme weather events, working long hours, inconsistent crops yield, facing threats from diseases and pests, as well as poor investment returns (Sreedhar & Kumar, 2020). Additionally, conventional farming worldwide utilises a large amount of water supply, making up to 70% of total consumption (FAO, 2017). Literature by Coyle & Ellison (2017) point out that conventional farming, particularly for growing lettuce, utilise almost doubles water consumption when compared to greenhouse and VF methods. Furthermore, conventional farming has been also been linked to several environmental problems, including loss of biodiversity, soil degradation, air and water pollution, and underground water contamination (ITPS, 2015). The number of agricultural chemicals used worldwide has increased up to 3.5 million tons annually (Sharma et al., 2019). The excessive of these pesticides in Southeast Asia has harmed the environment and human health by degrading agricultural soils (Aisyah et al., 2019; Md Ibharim & Salim, 2020).

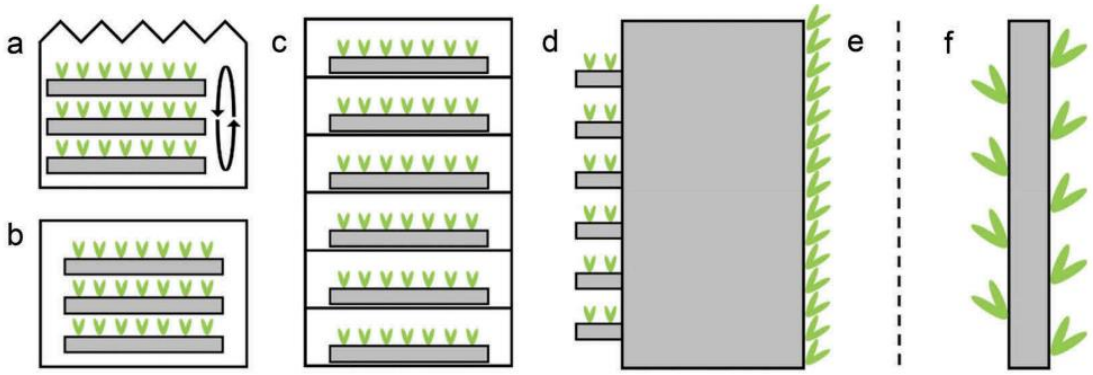
Food security will depend on our capacity to boost crop yields and preserve quality utilising the agricultural land that is already in use, since the global population is projected to surpass 10 billion people in the next 3 decades and food production must rise by 70%. The effects of climate change and increased competition for land and water resources further intensify this problem (Spanner, 2015).

One potential solution to challenges in local vegetable production is the adoption of modern farming method, vertical farming (VF). VF is an indoor or building-based urban farming method used to cultivate grains, fruits, and vegetables within cities or urban centres (Al-Chalabi, 2015; Lu & Grundy, 2017). It is a commercial farming technique that involves vertically stacking plants, animals, fungi, and other species to produce food, fuel, fibre, and other goods or services (Banerjee & Adenauer, 2014). According to de Oliveira et al. (2020), VF specifically refers to the production of food through hydroponic systems that utilize vertical space to grow crops efficiently.

VF can be categorised into three main types: (i) Hydroponics, the most commonly used cultivation method utilised in vertical farms, where it involves of growing plants in a nutrient-rich solutions, without the use of soil. (Birkby, 2015; Al-Kodmany, 2018). (ii) In aeroponic, plants are grown with their root systems suspended in midair with sprayed with a nutrient solution at the roots frequently to ensure moisture and nutrient absorption (He & Lee, 2013), (iii) Aquaponic is a technique biotic relationship between fish and bacteria to grow plants and fish in the same system (Santos et al., 2021). As shown in Fig. 1, Beacham et al. (2019) mentioned that there are two forms of the VF systems; one uses conventional horizontal growth platforms with several layers are used, whereas in the other, crops are grown on surfaces that are orientated vertically.

Essentially, VF may be set up in almost any location. It can provide a consistent method of cultivating food even in extreme temperature or adverse weather conditions brought by global warming (Miller, 2020). Successful VF initiatives in the Singapore, China, Korea, Japan, Holland, Sweden US and Canada highlighted by Kalantari et al. (2018).

Fig 1: VF types include (a) stacked horizontal systems with many levels of horizontal growing surfaces, (b) controlled-environment facilities, and (c) multistory towers with each floor isolated from the surroundings. (d) balconies and a stacked horizontal VF system (e) Green wall, on building sides, and other vertical surfaces; (f) cylindrical growth units in addition to the vertical plant arrangement



Source: Beacham et al. (2019).

In addition to lowering transportation costs, increasing food safety and biosecurity, and lowering input costs like fertiliser, pesticides, and herbicides, VF has the ability to generate crops continuously in a controlled environment (Benke & Tomkins, 2017). Additionally, by farming vertically as compared to horizontally, it relieves pressure on agricultural lands; hence, adopting soil-free growing methods can be appealing in urban settings (Beacham et al., 2019). By 2030, the VF market is anticipated to have grown from its 2020 valuation of $3.24 billion to $24.11 billion (Allied Market Research, 2021). Thus, in the years to come, the food sector will be redefined by these agricultural innovations.

Modern technologies combined with vertical farm will make it possible to grow crops in cities (Januszkiewicz & Jarmusz., 2017). Fresh vegetables and fruits can be grown domestically for emerging cities due to this innovative plant production method (Rameshkumar et al., 2020). Additionally, VF can yield up to 13.8 times as much per unit of cultivation area (Touliatos et al., 2016). Also, it has lower freshwater pollution rates (eutrophication is decreased up to 90% due to limited usage of too much fertilisers), consumes $1/18^{th}$ of water with a partially enclosed water loop system, and drastically reduces transport distance, which lowers CO2 (Wildeman, 2020).

The literature outlines several challenges and factors to consider in VF system. For instance, He (2015) notes that the food needs of densely populated, land-constraint cities like Singapore may not be adequately supplied by micro-scale vegetable production techniques, such as soil-dependent hydroponics, and aquaponic systems employed in vertical farms and rooftop. Furthermore, the effects of climate change can further contribute to this problem. Meanwhile, O'Sullivan et al. (2019) stress that to solve issues related to food security, human nutrition, and environmental sustainability, modern farming especially VF needs comprehensive study and innovation. According to Benke and Tomkins (2017), one of the major challenges to VF is the substantial initial investment, which makes site selection crucial. Similar to this, Moghimi and Asiabanpour (2021) stress that VF systems can be costly to run because of their high energy requirements and labour-intensive nature. A projected vertical aquaponic farms of high building, equipment, water and electricity costs were found in a cost analysis by Banerjee and Adenaeuer

(2014). Despite this cost, the study discovered that a 0.25-hectare vertical farm could significantly boost crop production. Several levels of the design are allocated to waste management, crop cultivation, aquaculture, environmental control, plant germination, processing, and sales. With dimensions of 44 meters for length and width and 167.5 meters for height, the constructions have an aspect ratio of 3.8. To manage waste transportation and harvesting, the farms also need a big space lift. With the help of an effective water recycling system, it consumes more than 200,000 litres of water daily for operation.

However, the substantial capital investment and the need on specialised workers present a major obstacle to the implementation of VF in Brunei. Furthermore, VF requires workforce intensive than traditional farming (Lubna et al., 2022). Having a reliable and competent worker is crucial because vertical farm operate year-round, benefitting more from consistent domestic workforce than traditional farms, which frequently rely on seasonal workers. Additionally, there is a greater demand for a larger domestic workforce because of the majority vertical farms are in urban areas (Lubna et al., 2022). However, urban domestic workers frequently lack the skills and knowledge needed to run a vertical farm successfully (Wood et al., 2022). Training programs are crucial since VF necessitates a significant number of specialise workers such as data collection, food safety and handling, integrated pest control, and farming practices (Lubna et al., 2022). Relying on unskilled labour rather than skilled labour may pose a serious risk to a newly established vertical farm (Lubna et al., 2022). Thus, supervisors must encourage an open communication in the workplace so that new workers can voice their concerns about farm operations, identify possible inefficiencies, and seek for advice on matters that requires specialise knowledge (Lubna et al., 2022). Building human capital is an essential to support the growth of VF. This should begin with education and training at the school level. Furthermore, offering upskilling courses to existing farmers and workers will reinforce this effort to contribute to its success.

It has been shown that Brunei has a scarcity of land for agriculture, and that most of the country's soil is unsuitable for farming because of its high acidity, which has an impact on crop productivity, climate, landscape, and soil composition. Therefore, this paper aims to investigate the potential of This study explores VF as a solution for food security by examining the challenges faced and suggesting possible solutions for implementing VF practices in the country. To address these issues, VF is a cutting-edge method used in modern agriculture for urban agriculture. This paper employs the use of content analysis and in-depth interviews method.

Methodology

Although there are 3,187 farmers and business owners in Brunei Darussalam's fruits and vegetables sector, there is a lack of statistical information on VF operations in Brunei. A total of 15 respondents were interviewed in-depth as part of this qualitative study. The list of modern farmers from the Department of Agriculture and Agrifood's (DoAA), nine Bruneians were chosen, along with one DoAA officer and one instructor from the Institute of Brunei Technical Education's (IBTE) School of Agrotechnology and Applied Science (Table 1). Even though there was an opportunity to select additional responses from the DoAA's list, those who are chosen were particularly notable for their promptness and openness to sharing their thoughts and experiences.

Table 1: List of Respondents

Company name	Area (ha)	Type of Farming	Current produce	Technology Used
I Am Food Agritech	2	Aquaponics, Fertigation and Outdoor Natural Farming.	Melon Royale, leafy vegetables, chilis, capsicums, herbs, freshwater fish, Kelulut honey, jams, sauces	Greenhouse, HAVVA aquaponic system, natural & LED grow lights, automated weather & fertilising systems, rainwater harvesting
Rz Prisma Enterprise	3	Hydroponics (Vertical & Horizontal in Greenhouse)	Lettuce, asparagus, rock melon	Greenhouse, hydroponic system, natural light, 'A' frame vertical & horizontal hydroponic systems
Springhill	4	Agrivoltaic, Aquaponic, Organic Natural Farming	Dwarf pak choy, choy sum, basil, cherry tomato, strawberries, pandan leaf, papaya, moringa leaves	Aquaponic system, cylindrical vertical structure, solar power, natural & LED grow lights, automated systems, rainwater harvesting
Natural Healing Enterprise	1	Hydroponics (Vertical Rack) & Fertigation	Lettuce, cherry tomato, basil, mint	Hydroponic system, VF rack, natural & LED grow lights, automated weather & dosing systems
Hua Ho Agricultural Farm	42	Mixed Farming (Poultry, Fruits, Vegetables, Hydroponics, Greenhouse)	Variety of tropical fruits and vegetables	Hydroponic system, greenhouse, organic compost
S&R Aquafarm	0.01	Aquaponic in greenhouse	Lettuce, cherry tomato, chilli, basil and mint.	Aquaponic system, greenhouse, 1-floor stacked beds, vertical towers, rainwater harvesting
UZ Farm	0.01	Hydroponic in greenhouse	Lettuce	Hydroponic system (vertical and horizontal)
Kabunku Aquaponic	0.1	Aquaponics & Hydroponics in Greenhouse	Lettuce, pak choy, basil, aloe vera	Aquaponic & hydroponic systems, rainwater harvesting, insect farming (for fish feed)
Perusahan Teratak Jaya	4	Fertigation & Hydroponics in Greenhouse	Lettuce, chilli	Vertical farming system
Ibnu Anwari	1.2	Fertigation System	Various fruits and leafy vegetables	Greenhouse
FR Agro Farm	2.5	Fertigation and hydroponic	Chilli and Lettuce	Greenhouse, 'A' frame vertical system
Cahaya Agro		Fertigation (Drip Irrigation)	Chilli	Drip irrigation system
Agrowmetro	-	Hydroponic Supplier		-
IBTE instructor	-	-	-	-
DoAA Government staff	-	-	-	-

As a result, snowball sampling method was also used in this study, and three more modern business farms owned and operated locally were chosen. Over the period of three months, the researcher conducted semi-structured, in-depth interviews with an emphasis on open-ended

questions to meet the research objective. For accuracy and focus, the 30 to 60 minutes interviews were recorded. Data obtained from these interviews is analysed and arranged using content analysis. Content analysis is a research technique that is used to derive valid and trustworthy findings from texts or other significant materials within their particular settings (Krippendorff, 2004). In order to methodically describe and analyse the content of various communication mediums, such as spoken words, written texts, or visual media like books, newspapers, TV shows, or interview transcripts, it uses methodologies (Krippendorff, 2004).

Overall, the study gathered opinions from respondents that engaged in modern farming techniques in the fruits and vegetables sector of Brunei Darussalam, offering insightful viewpoints on VF.

2. Results and Discussion

3.1 Status of VF in Brunei

In the context of Brunei Darussalam, VF is relatively a new industry in the Brunei's agricultural sector. Wasil (2018) claims that Brunei launched the first program in 2018 to encourage young people to participate in VF. According to Hirman Hj Abu, the department's Head of International Affairs and Public Relations, the program called 'Introduction to Simple and Affordable Technology Course' also known as 'Kursus Pendedahan Teknologi Mudah dan Murah,' was designed to educate young people about low-cost methods to start agricultural companies (Wasil, 2018). To address the issue of requiring land to begin a farm, the program encourages young people to create vertical gardens using limited space and cost-effective materials like wooden boards and recycled plastic bottles (Wasil, 2018). ''The objectives of the initiative provide the youth a head starts in the world of agriculture, and we will help them to overcome common problems faced by other agriculture start-ups like pests'' he said (Wasil, 2018). Furthermore, ''Upon the completion of the first course, participants who are interested in pursuing this venture will be encouraged to register for a second and more intensive course (Wasil, 2018). We will give them more in-depth information on the technicalities and economics of running their vertical farms'' (Wasil, 2018).

RZ Prisma Enterprise, which is situated at the Brunei Agricultural Research Centre in Kg Kilanas, is one example of the current VF in Brunei. In late 2017, the farm was first one of the Department of Agriculture and Agrifood's pilot projects. The farm's hydroponic vertical technology allows the ability to cultivate over 7000 lettuces in that year. On February 23, 2018, the company harvested for the first time ever. The farm increased its agricultural land plot to three hectares in the ensuing years. By 2023, the company had already grown to the point where it could grow 20,000 lettuces at once.

Natural Healing Enterprise is a one-hectare commercial hydroponic farm founded in 2018. It is in Agrotechnology in Kg Tungku. Initially, it was established as a health business but later changed its focus to agribusiness in 2020 during the COVID-19 epidemic because local Bruneian supermarkets were running low on fresh vegetables. The company's mission is to provide nutritious food and support the local community while achieving self-sustainability in technology-based agriculture. Its goal is to guarantee food security while maintaining environmental sustainability. The company uses two different cultivation techniques and has two greenhouses that are 8.8 meters by 39 meters. One greenhouse employs 980 Dutch buckets to grow cherry tomatoes, and the second greenhouse has 49 VF racks that can hold 12,740 plants at once. With a

goal of producing 15,600 kilograms a year, worth BND$200,000 (about USD 148,000), the company is hoping to meet the demand for fresh vegetables while keeping sustainability in focus.

Springhill Farm is a 4-hectare farm located in the agrotechnology park in Kg Tungku, Brunei dan Muara, registered in 2022. With the use award-winning Agrivoltaics & Aquaponics system (HAVVA technology) and natural soil enhanced with beneficial organic inputs, the company is dedicated to maintaining the land's inherent health and beauty through sustainable and natural agricultural practices. The company's goal is to produce Brunei's finest natural vegetables and fruits. The company's mission is to establish and market safe, natural, and nutrient-dense products for the market, promote environmentally sustainable green practices and technologies, and operate as a platform for best practices, knowledge, and awareness in Brunei's agro-tech farming industry. The aquaponic VF system at Springhill Farm can grow 4,100 plants in a month, including amaranth, pak choy, kale, and lettuce. 1000 kg is the projected monthly yield, which is worth BND$2,820.51 (USD9,486.32).

I AM Food is a 2-hectare agritech farm that uses three farming systems—aquaponics, fertilisation, and outdoor natural farming—to increase the productivity and efficiency of agricultural processes. The company harvests herbs, chillis, capsicums, green vegetables, and Melon Royale as part of its mission to create safe, hygienic, and high-quality crops. Freshwater fish, Kelulut honey, jams, and sauces are examples of additional produce. According to estimates, the farm's agricultural production can produce 2400 kg of fish every cycle and 30,000 kg every month.

Biz Brunei (2023) reported that the country's first indoor vertical strawberry farm, located in Kg Tungku's Agrotechnology Park, occupies less space than the average Bruneian home. This innovative project consists of four five-layer vertical racks that can hold 2,000 plants in total. In 2019, Superfish Grower's co-founder and chief technology officer, Lee Wei Sheng, began experimenting with this pilot setup with two main objectives: exporting their proprietary strawberry farming system and building a commercial farm that could support 10,000 to 15,000 plants by the next year. It estimated that it can yield between 40 to 60 tonnes of strawberries every eight months. Four strawberry breeds have been successfully grown as seedlings in the pilot setup: Beni-hoppe (Japan), Sweet Sensation (Netherlands), Seolhyang (Korea), and Ozark Beauty (US). Over the course of a five months, plants from the pilot project have produced 1.5–2 kg of strawberries, twice as much as current indoor farms and four times as much as typical field farms. The company offers BND$500,000 to BND$1 million for the setup and consulting services of its vertical strawberry farming for 4,000 to 7,000 plants, while larger operations for 10,000 to 15,000 plants cost BND$1.5 million to BND$2 million. With a five-story system, 10,000 plants can fit within 2,000 square feet, while the amount of space needed varies with building height.

The findings in Table 2 show several challenges mentioned by the respondents. These challenges are explained in the following section.

Table 2: Summary of the challenges in VF in Brunei Darussalam

Challenge	Farmer's Opinion	Percentage of farmers agreed on the challenges of VF in Brunei Darussalam

High Investment Cost	‘‘Large-scale modern farming involves a slow rate of return on investment, for e.g., 2 hectare of land requires BND 1.9 million (USD 1,430,843.45)’’	100%
Weather- Related Condition	‘‘The adverse weather condition in Brunei such as strong winds, storms that can damage the greenhouse and water shortage during the hot seasons’’ ‘‘Due to heavy rain, our greenhouse was affected by flash flood’’	40%
Market Dynamics & Competition	‘‘To sell it profitable enough that it justifies the investment cost, because right now in Brunei, we import a lot from Malaysia and locally grown using the cheapest and fastest method’’ ‘‘Trying to stay sustainable with imported crops from neighbouring countries. For example, cost of planting chillies is BND8 per kilo but imported chillies is only BND3.90 per kilo’’ ‘‘Limited market size in Brunei leading to competition among local farmers growing similar crops’’	46.67%
Limited Crop Variety	‘‘limited range of crops that can be economically produced in VF systems’’	46.67%
Pest & Diseases	‘‘VF is susceptible to water-borne disease and pest’’ ‘‘the crops have bacterial spot’’	46.67%
Light Distribution	‘‘The inconsistent distribution of light sources affects the development of plants’’ ‘‘When I used to sell VF system, I received a lot of feedback from the customers that some plants are not exposed to sunlight’’	20%
Nutrient Deficiency	‘When I first started my journey in aquaponics, experience nutrient deficiency in the crops that I grow’’ ‘‘The challenge is to maintain optimal nutrient levels for plant growth’’ ‘‘Nutrient delivery and distribution to all plants can be challenging especially in VF’’	20%
Need for Technical Knowledge	‘‘Managing VF operations must possess proper knowledge to ensure successful implementation and operation’’ ‘‘Farmers need to be equipped knowledge before starting VF business’’	46.67%

3.2 High investment cost

The major financial challenges associated with modern agricultural practices in Brunei were highlighted by the respondents. The majority believed that advanced systems including fertigation, hydroponics, aquaponics, and VF as well as large-scale agriculture demand high cost and substantial capital investments. As a result, it presents a significant challenge for aspiring Bruneian farmers with limited financial resources. Furthermore, modern farming has recurring operational costs like workers and utilities, and maintenance, which increase the entire financial burden. Furthermore, the cost of current agricultural techniques is far higher than that of conventional soil-based approaches, highlighting the economic challenges that farmers who choose to use innovative methods such as VF. Further adding to the financial strain is the poor rate of return on investment in large-scale modern farming, which may discourage investors and hinder the agricultural sector.

Because of its high capital requirements, large-scale VF adoption in Brunei can be challenging to farmers, making it unprofitable Al-Kodmany (2018).

3.3 Weather Related Conditions

Several weather-related factors in Brunei were mentioned by the respondents, including heavy rain, and strong winds, and high temperature- contribute to the depletion of reservoirs in the water nutrient system. Brunei's hot climate is a major problem for crops, and greenhouses typically need to be modified to minimise heat exposure. Heavy rains can generate flash floods, which can harm crops and greenhouse facilities. Crop management may become even more challenging when hot days and rainy nights combine to provide the perfect environment for pests like caterpillars. These weather-related issues show how important it is for Brunei to adopt resilient farming methods and adaptable solutions.

3.4 Market Dynamics & Competitiveness

The interview revealed the problem of market competition, where local farmers who use modern farming techniques find it hard to compete with lower-priced imports from neighbouring countries. Because consumers frequently choose low-cost imported agricultural items, this price difference poses a serious barrier to the profitability of locally grown crops by making it challenging for farmers to sell their produce to both supermarkets and local shops. Due to competition from other local farmers who raise comparable products, Brunei's small market size presents additional challenges for farmers. It is also difficult for modern farmers to sell their produce at a justified price because local stores typically price vegetables based upon weight.

3.5 Limited Crop Variety

The respondents perspectives made clear that the VF method only produces a small number of commercially viable crops. According to the respondents, VF has a smaller variety of crops than traditional farming methods, which provide the freedom to grow a wider variety of crops, including tropical fruits and different kinds of vegetables. They also acknowledged that leafy greens and microgreens are frequently grown in VF. On the other hand, opinions on the possibility of increasing crop diversity in VF systems vary. While some respondents believe that crops like microgreens and leafy greens are the ideal choices for the VF, others believe that fruits like strawberries and tomatoes might also be grown, especially in vertical systems that are orientated horizontally.

3.6 Pest & Disease

According to respondent's opinions, VF systems are susceptible to disease and pests that are carried by water, which may have an impact on crop growth and health. Concerns regarding issues like bacterial spots and pest infestations, which can lower crop quality and yield, were expressed by several respondents. Crop loss and damage tend to occur even with efforts to reduce these issues using greenhouse technology and pest management techniques like integrated pest management plans. It's important, though, that a few respondents stated that issues with insects have a minimal effect on total operations- less than 5% per crop cycle.

3.7 Nutrient Deficiency

The challenges posed by an unequal distribution of light sources in VF techniques were highlighted by respondents. Concerns were raised by the respondents about how inconsistent treatment could affect plant growth, as certain plants might not get enough direct sunlight in VF. Furthermore, incorporating artificial lighting becomes critical during gloomy or wet days. However, the respondent pointed out that VF operations would have an additional financial strain as there are additional costs associated with introducing LED.

Table 3: Respondent's perspective on skilled labour in VF

Respondent	Perspective on skilled labour in VF	Percentage respondents indicating skilled labour is necessary	Percentage of respondents indicating skilled labour may not be necessary
R1	''It does not require skilled labour; however, they must follow the standard operating procedure, exercise a strict discipline and passion''	66.67%	33.33%
R2	''Yes, VF do need skilled labour but not highly skilled labour. One needs to resolve problem when arise''		
R3	''Yes.''		
R4	''Yes, VF requires skills such as knowing how much nutrients to put in and size and colour of vegetables etc''		
R5	''Yes.''		
R6	''No.''		
R7	''Yes.''		
R8	''Yes. Initially, we did on the job training for new employee, but now we realised that we need more skilled labour to do job properly''		
R9	''No.''		
R10	''No.''		
R11	''No, skilled labour may not be necessary as we can provide training to our workers. Hiring skilled labour would result in higher labour costs''		
R12	''You don't need a lot of labour; however, you need skilled labour. So yes.''		
R13	'Having skilled labour is essential''.		
R14	''Yes, that's why I believe in the importance of acquiring skills myself before imparting knowledge to others''		
R15	''Yes.''		

3.8 Advanced technical knowledge

The respondents highlighted how important knowledge is to VF success. They agreed that having a solid technological basis is essential to starting and running a vertical farm. Farmers who want to work in the VF industry need to have the proper knowledge from the start. Effective management abilities are also necessary to guarantee profitable and productive VF operations. The applicability of expertise from non-tropical countries was also questioned, showing the necessity of context-specific knowledge appropriate for Brunei's agricultural conditions. All things

considered, the lack of knowledge and awareness of VF in Brunei makes it clearly evident that educational programs are required to raise public awareness of the approach nationally.

3.9 Perception of skilled labour

In VF, skilled labour is essential because of the specialised jobs and cutting-edge technologies needed to maintain ideal growth conditions and produce high crop yields. The lack of competent labour and reliance on unskilled or inexperienced workers can be a major danger to the success of a recently created large-scale vertical farm (Lubna et al, 2020). In order to maintain optimal growing conditions, VF requires specialised jobs and cutting-edge technologies that call for technical expertise and particular skill sets. Table 3 shows the opinions of the respondents on the importance of skilled labour in VF. Of the respondents, 66.7% agree that skilled labour is necessary for VF, while 33.3% do not think that skilled labour is necessary.

The opinions of respondents regarding young people's involvement in agriculture provide valuable information about how farming is evolving and how technology might help attract in and engage the future generation. One important finding is that many people, particularly young people, may be discouraged from pursuing a career in agriculture by traditional farming, which usually involves physically demanding work and exposure to adverse weather conditions. VF, on the other hand, presents an appealing choice because to its conducive environment and lower physical labour needs. Furthermore, the shift towards modern farming practices blends in nicely with current generation's tech-savvy preferences. Educational programs like the HnTEC program are crucial in stimulating student's interest and promoting their engagement in agriculture as methods like hydroponics gain popularity. Exposing students to a variety of farming practices, particularly horizontal hydroponics, facilitates the integration of both traditional and modern agricultural approaches. Although modern farming is becoming more and more popular, there still remain significant barriers, particularly for young farmers, such as the substantial financial investment needed. The two most important factors influencing young people's engagement in agriculture are passion and financial resources. Nonetheless, the fact that modern farming may create jobs for coming generations highlights how important it is to the agricultural industry's long-term sustainability.

In conclusion, farmer's perspectives highlight how crucial it is to successfully engage younger generations in agriculture through educational initiatives and technology. The agriculture industry can attract and retain young farmers by addressing issues including financial constraints and providing hands-on learning opportunities, ensuring its long-term viability and resilience.

3.10 The Potential of VF in Brunei Darussalam

VF has huge potential for Brunei by addressing significant challenges in the Brunei agricultural industry. Utilising VF can reduce reliance on traditional farming practices and optimise the use of limited land. Its capacity to generate large quantities in controlled environments, such greenhouses, can increase self-sufficiency and food security in Brunei.

Furthermore, VF presents an opportunity to increase crop production beyond Brunei's typical limited crop types. Even though VF usually is focused on leafy greens and microgreens, improvements in infrastructure and technology may make it possible to grow a wider range of fruits and vegetables. This diversification would increase food sovereignty, lessen reliance on

imports, and help meet local demand for fresh vegetables. Additionally, VF offers economic advantages by utilising less fertiliser, herbicides, and water than traditional farming practices.

VF in controlled environments provides a more resilient alternative given Brunei's vulnerability to weather-related difficulties such intense heat, heavy rains, storms, and strong winds. It contributes to protecting crops from uncertain weather, guaranteeing steady yield and health. Additionally, by increasing demand for skilled labour, VF may promote economic growth, create jobs, and reduce the unemployment rate. The development of a skilled labour force and the development of a sustainable agriculture industry follow from this. Food safety and quality can also be improved by VF since it lowers exposure to toxins and contaminants that are frequently present in conventional soil-based farming. This guarantees that consumers will have access to healthy, secure, and nourishing food. Thus, the potential of VF in Brunei resides in its capacity to tackle a number of issues by utilising current technology and innovation, a trained labour force, and financial backing to strengthen the economic sector.

3. Conclusion

In conclusion, Bruneian farmer's perspectives highlight a number of key problems dealing with modern farming, including high start-up costs, risks associated with the weather, market competition, a lack of crop diversity, challenges with pest and disease control, unequal light distribution, and the need for highly skilled technical workers. Considering such challenges, VF presents a viable way to address some of issues. It offers chances to increase production, make better use of resources, diversify crops, and provide new employment. The paper emphasises the substantial investment in capital needed in Brunei for modern farming practices like VF. Government support is therefore crucial. Providing farmers with subsidies would assist in reducing the initial start-up expenses associated with setting up a vertical farm. Additionally, farmer's capacity to compete in the local market might be enhanced by lowering production costs. Although large-scale VF may not be urgently needed in Brunei due to its abundance of agricultural land, VF adoption can nevertheless boost the development of resilient and sustainable farming methods and increase food security.

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