

## **SCALING COMMERCIAL URBAN AGRICULTURE IN SINGAPORE: AN ASSESSMENT OF THE VIABILITY OF LEAFY VEGETABLE PRODUCTION USING PLANT FACTORIES WITH ARTIFICIAL LIGHTING IN A 2017 LAND TENDER (FIRST TRANCHE)**

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## Contents

Executive Summary.....	3
I. Background.....	4
Singapore’s Urban Food Security .....	4
Recent Strategies in Improving Singapore’s Food Security through Local Food Production .....	5
II. Objective of the Study .....	7
III. Analytical Framework and Methodology .....	7
IV. Key Findings from Demand Side Assessment.....	11
Vegetable Attributes Cost Matrix.....	11
Key Findings from Demographic Analyses.....	12
Paired Comparison Analysis .....	12
V. Key Findings from Supply Side/Profitability Assessment.....	12
VI. Analysis and Recommendations .....	16
Recommendation 1: Explore ways of getting low cost financing for firms.....	16
Recommendation 2: Encourage farms to develop relationships with restaurants, or to sell directly to customers, in order to increase the amount of imports that can be captured by local farms.....	18
Recommendation 3: Require product labelling for vegetables imported by Singapore and sold in wet markets. ....	18
Recommendation 4: Design and promote organic certifications for locally grown vegetables. ....	19
Recommendation 5: Require firms to list vegetables under specific product codes that allow for accurate product identification for products under ‘Other vegetables fresh or chilled’ (HS Code: 07099900).....	19
VII. Conclusion .....	19
Appendix.....	20
Appendix 1: Demand Side Assessment.....	21
a. Methodology for Demand Assessment .....	21
b. Sample Demographics .....	21
Appendix 2: Supply Side Profitability Assessment .....	22
a. Methodology for Profitability Assessment.....	22
b. Data, Assumptions and Uncertainties in Adapting Financial Model to Singapore.....	22
About the Authors .....	25

## Executive Summary

In May 2017, the Agri-Food & Veterinary Authority (AVA) of Singapore issued tenders for land to be used for high-technology agriculture that maximizes land and labour productivity. This NTS report provides an assessment of the financial viability of one form of high technology agriculture for growing leafy vegetables -- plant factories with artificial lighting (PFAL) on the tendered plots of land. This assessment integrates findings from a consumer survey on what could drive consumers to 'go local'. Key recommendations from this report are:

**Recommendation 1: Explore ways of getting low cost financing for firms**, to maximize the amount of financially viable food production in the tendered land, so that as much as 29,269 tonnes of leafy vegetables can be viably produced, in contrast to the base scenario when financing is more costly (only 7,210 tonnes viably produced).

**Recommendation 2: Encourage farms to develop relationships with restaurants, or to sell directly to customers, in order to increase the proportion of domestic leafy vegetable consumption that can be captured by local farms.** This effort can be coordinated with Singapore's Taskforce for Promotion of Local Produce.

**Recommendation 3: Require product labelling (product safety, country source) for vegetables imported by Singapore and sold in wet markets**, to allow local firms to leverage the price premium that locals are willing to pay for safer vegetables locally produced. If the firms do not have access to vegetable testing services, then they may apply to do so at Plant Health Laboratory Services by the AVA, and pay the needed costs, per consignment.

**Recommendation 4: Design and promote organic certifications for locally grown organic vegetables**, as locals were found to be willing to pay the highest premium for this vegetable attribute. This will require exploring organic certification approaches and definitions adopted in other countries, especially regarding hydroponics and other non-soil farming systems.

**Recommendation 5: Require firms to list vegetables under specific product codes that allow for accurate identification of the vegetable, for vegetables under 'Other vegetables fresh or chilled' (HS Code: 07099900).** This is to allow firms to identify which among the 52 vegetables types, making up potentially more than 50% of total leafy vegetable import expenditures and presently listed under an ambiguous title, can be viably grown in Singapore.

## I. Background

### Singapore's Urban Food Security

Singapore produces about 10% of the total food it consumes, made up respectively of 26%, 10% and 12% of eggs, fish and leafy vegetables consumed.<sup>1</sup> However, like many other cities, Singapore may not desire to produce all of the food it consumes, given the opportunity costs of land and cheaper cost of importing certain commodities. Those food items which can be frozen and kept for long time periods, or transported fresh under cold chain management are likely to still be imported. For those which Singapore has space/facilities to produce, or which cannot be stored for a long time period, there is scope for some level of self-production.

Producing a limited share of total food consumption makes Singapore vulnerable in some aspects of food security. First is on the side of food availability. There is the long-term trend that by 2050, two-thirds of the world's population will reside in cities<sup>2</sup>. As up to 80% of food production is done in rural areas, greater urbanization will mean a growing bulk of food will need to be transported from rural areas to urban areas.<sup>3</sup> The problem with this is that warmer temperatures from climate change, coupled with inadequate transport and storage facilities increase the amount of food that spoils along the way, especially in developing countries.<sup>4</sup> Another challenge is that warmer temperatures and more erratic precipitation threaten to reduce farming yields outdoors or in the fields.<sup>5</sup> These trends are relevant to Asia, which holds 34% of the world's arable land,<sup>6</sup> and 36% of its freshwater resources,<sup>7</sup> but has more than 60% of the world's population.<sup>8</sup> In this regard, a key risk in Singapore is whether there will be sufficient food available for it to import, especially from Asian sources of food, and in the face of competing, larger importing countries.

On one hand, Singapore takes up only a small share of the global food import demand, in particular, 0.8% of the world's vegetable imports ('Edible vegetables and certain roots and tubers', HS Code: 07), 3.1% of total shelled egg imports ('Birds' eggs, in shell, fresh, preserved or cooked', HS Code: 0407), and 0.7% of total fish/crustaceans ('Fish and crustaceans, molluscs and other aquatic invertebrates', HS Code: 03) in 2016.<sup>9</sup> Singaporeans are

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<sup>1</sup> AVA, AVA Annual Report 2016/17, accessed 15 November 2017, <https://www.ava.gov.sg/docs/default-source/publication/annual-report/ava-ar-2016-17>.

<sup>2</sup> United Nations, Department of Economic and Social Affairs, Population Division, World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352), 2014, accessed 28 November 2017, <https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf>.

<sup>3</sup> Paul Teng, Food security: Cities as part of the solution and not the problem, RSIS Commentary No. 142, 2012, accessed 28 August 2017, <https://www.rsis.edu.sg/rsis-publication/nts/1804-food-security-cities-as-part/#.WaPF5z6g-M8>.

<sup>4</sup> Jenny Gustavsson Christel Cederberg, Ulf Sonesson Robert van Otterdijk and Alexandre Meybeck, Global food losses and food waste: Extent, causes and prevention, UN FAO, 2011, accessed 17 November 2017, [http://www.fao.org/fileadmin/user\\_upload/sustainability/pdf/Global\\_Food\\_Losses\\_and\\_Food\\_Waste.pdf](http://www.fao.org/fileadmin/user_upload/sustainability/pdf/Global_Food_Losses_and_Food_Waste.pdf).

<sup>5</sup> Nelson GC, Rosegrant MW, Koo J, Robertson RD, Sulser T, Zhu T, Ringler C et al, Climate change: Impact on agriculture and costs of adaptation, IFPRI Food Policy Report, IFPRI, Washington, D.C., 2009, accessed 28 August 2017, <http://www.ifpri.org/publication/climate-change-impact-agriculture-and-costs-adaptation>.

<sup>6</sup> 'Land use – FAOSTAT database', Food and Agriculture Organization of the United Nations (UN FAO), Accessed 29 August 2017, <http://www.fao.org/faostat/en/#data/RL>.

<sup>7</sup> 'Water for Life Decade - Asia and the Pacific', UN, accessed 29 August 2017, <http://www.un.org/waterforlifedecade/asia.shtml>.

<sup>8</sup> 'Annual population - FAOSTAT database', UN FAO, accessed 28 August 2017, <http://www.fao.org/faostat/en/#data/RL>.

<sup>9</sup> HS Codes refers to the Harmonized System Codes used to determine the types of commodities being traded, with the first two digits referring to the general category of a commodity, and further digits pertaining to more specific categories to further describe/identify

likewise to some extent buffered against food price increases, given high per capita income and the relatively low proportion of household income spent on food. These provide buffers for Singapore's food security.

However, there remain less tolerable vulnerabilities related to critical infrastructure for food logistics which would impede physical access to food, such as when ports in source countries are closed, such that food deliveries may be delayed, or lost completely due to spoilage.<sup>10</sup> Food utilization is likewise a concern, as the freshness of vegetables and other commodities can be lost in the process of transporting them, especially if there are delays.<sup>11</sup> Moreover, threats such as food borne diseases can reduce the quantity of safe food that Singapore's sources can export.

These trends point to the need for new alternative farming methods. Urban agricultural technology (agtech), an emerging subset of alternative farming in cities, leverages new technologies that use a fraction of land and water of traditional farming. Case studies reveal that its proximity to cities can yield many benefits such as employing the urban poor and reducing food miles, a measure of the amount of energy and fuel required to transport food from one location to another.<sup>12</sup> Of particular importance here is the growing trend of plant factories with artificial lighting (PFALs), which are indoor agriculture facilities wherein lighting, temperature, nutrients and other growing conditions are manipulated in order to maximize yields, combined with space-saving vertical farming technologies whereby multiple layers of vegetables are grown, mostly using hydroponics technologies.<sup>13</sup>

### **Recent Strategies in Improving Singapore's Food Security through Local Food Production**

Local food production is among the 'Three National Food Baskets' (TNFBs) that buffer its food supply and help to ensure food security amid the limitation of space, as shared by Senior Minister of State, Dr. Koh Poh Koon (Trade and Industry, and National Development) in the March 2017 Committee of Supply Debate in the Singapore Parliament.<sup>14</sup> This is apart from food source diversification, or having a variety of accredited sources to import from, and internationalisation, wherein Singapore seeks alternative production sites to overcome its land constraints. Examples of the latter include the Singapore-Brunei venture for high-tech vertical fish farms, and a venture in Hainan, China for vertical vegetable production.<sup>15</sup>

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the traded commodity. Data is sourced from: 'Trade Map Database,' International Trade Centre, accessed 28 November 2017, <http://www.trademap.org>.

<sup>10</sup> 'The food we eat', AVA, accessed 28 November 2017, <https://www.ava.gov.sg/explore-by-sections/food/singapore-food-supply/the-food-we-eat>.

<sup>11</sup> Jenny Gustavsson et al. (2011), *ibid*.

<sup>12</sup> Holly Hill, Food miles: Background and marketing, National Center for Appropriate Technology, 2008, accessed 16 November 2017, <https://attra.ncat.org/attra-pub/viewhtml.php?id=281>.

<sup>13</sup> Toyoki Kozai, Genhua Niu and Michiko Takagaki, Plant factory: An indoor vertical farming system for efficient quality food production, 1st Edition. Academic Press: Cambridge, MA, USA, 2015.

<sup>14</sup> Koh Poh Koon, 'Speech by Minister of State Koh Poh Koon for the Ministry of National Development at the Committee of Supply Debate, 7 March 2017', accessed 16 October 2017, <https://www.gov.sg/microsites/budget2017/press-room/news/content/speech-by-mos-dr-koh-poh-koon-for-mnd-at-the-committee-of-supply-debate>.

<sup>15</sup> *Ibid*.

Today, local food production in Singapore is done mostly in six agrotechnology parks, covering 1,465 hectares in total. Some of the commodities produced include vegetables, eggs, and fish.<sup>16</sup> To bolster this, the government has provided financial support to companies which wish to engage in technologies that boost yields in food production, through the Agriculture Productivity Fund (APF).<sup>17</sup> A key type of technology being promoted is vertical farming, which allows for planting multiple layers of plants over the same land area. Yields from vertical farming can be maximized through indoor farming in which vegetables are grown under controlled environments. In fact, as of August 2016, the number of vertical farms in Singapore which produce vegetables, crabs, and fish had increased to seven, up from only one in 2012.<sup>18</sup>

In March 2017, AVA launched the Farm Transformation Map, which sought to help farms 'to creatively and more efficiently create spaces to support agriculture activities'; 'grow more with less and translate research into commercially viable farming solutions;' to '(build) a future local workforce' that can support farms, and to develop 'strategies to create an enabling environment for the farming industry to thrive, and to produce for both local and international markets'.<sup>19</sup>

As part of the strategies to boost local food production, AVA opened fixed-price tenders in May 2017 for 12 plots of land in the Turut Track / Neo Tiew areas, with approximately two hectares each, which can be used for leafy vegetable production, as well as vegetable production combined with fish production (aquaponics).<sup>20</sup> Another three plots (of 1.5-2.3 hectares each) in Neo Tiew Crescent area are to be allocated exclusively to fish production. Last, by the 2<sup>nd</sup> Quarter of 2018, two more plots (one hectare each) are to be tendered for general agricultural production, two more plots for quail egg production (1.5 hectares each), and three more (two hectares each) for leafy vegetable production.

Leafy vegetables are among the strategic commodities in Singapore, as stated in a recent document by AVA.<sup>21</sup> While Singapore is already producing 12% of the total vegetables it consumes (computed at 92,000 tonnes per year),<sup>22</sup> it was included among the target commodities to produce in the May 2017 AVA tenders. This commodity group is relevant given that there is still a substantial amount that is imported from abroad, which when converted into dollar values, present potentially lucrative markets to be captured by local firms/farms.

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<sup>16</sup> 'Farming in Singapore', AVA, accessed 28 November 2017. <http://www.ava.gov.sg/explore-by-sections/farms/land-farms/farming-in-singapore>.

<sup>17</sup> AVA, Agriculture Productivity Fund (APF) Research & Development (R&D) – Open Call Guidelines for Application, 2017, accessed 16 November 2017, [https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/guidelines-for-application---apf-r-amp-d-\(open-call\)\\_14082017.pdf?sfvrsn=2](https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/guidelines-for-application---apf-r-amp-d-(open-call)_14082017.pdf?sfvrsn=2).

<sup>18</sup> Bryna Singh, Vertical farms on the rise in land scarce Singapore. The Straits Times, 10 July 2016, accessed 3 November 2017, <http://www.straitstimes.com/lifestyle/vertical-farms-on-the-rise-in-land-scarce-singapore>.

<sup>19</sup> AVA, AVA Annual Report 2016/17, accessed 15 November 2017, <https://www.ava.gov.sg/docs/default-source/publication/annual-report/ava-ar-2016-17>.

<sup>20</sup> AVA, 'AVA to launch tenders for new agriculture land for food farming', 2017, accessed 15 November 2017, [https://www.ava.gov.sg/docs/default-source/default-document-library/pr---ava-to-launch-tenders-for-new-agriculture-land-for-food-farming-\(11-may\).pdf](https://www.ava.gov.sg/docs/default-source/default-document-library/pr---ava-to-launch-tenders-for-new-agriculture-land-for-food-farming-(11-may).pdf).

<sup>21</sup> AVA, Agriculture Productivity Fund (APF) Research & Development (R&D) – Open Call Guidelines for Application, 2017, accessed 16 November 2017, [https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/guidelines-for-application---apf-r-amp-d-\(open-call\)\\_14082017.pdf?sfvrsn=2](https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/guidelines-for-application---apf-r-amp-d-(open-call)_14082017.pdf?sfvrsn=2).

<sup>22</sup> AVA, AVA Annual Report 2016/17, accessed 15 November 2017, <https://www.ava.gov.sg/docs/default-source/publication/annual-report/ava-ar-2016-17>.

International Trade Centre statistics show that in 2016, Singapore imported approximately USD 8 million worth of Kohlrabi kale & similar edible brassicas, based on the Harmonized System (HS) code 07049090; USD 11 million worth of 'cabbage lettuce' (HS Code: 07051100); USD 12 million worth of 'other lettuce' (HS: 07051900); USD 167,000 worth of witloof chicory (HS Code: 07052100); USD 6 million worth of celery (HS Code: 07094000); and USD 12 million worth of 'spinach New Zealand spinach & orache spinach' (HS Code: 07097000).<sup>23</sup>

Apart from these, there are over 52 types of leafy vegetables under 'Other vegetables fresh or chilled' (HS Code: 07099900) although data is not available to compute the total amount of leafy vegetables under this category as the HS Code lumps leafy and non-leafy vegetables together. The value of vegetables categorized under this HS Code is large, making up approximately USD 62 million, but how much of these are leafy vegetables cannot be determined. As such, the total value of imported fresh/chilled leafy vegetables amounts to USD49 million at the minimum, and potentially as much as USD 111 million worth, when taking into account the vegetables under HS Code 07099900, which lumps leafy and non-leafy vegetables together.

## II. Objective of the Study

Given the attention to high value local food production, as well as the release of the fixed-price tenders, we conducted an economic analysis of scaling urban agri-tech farms in Singapore for leafy vegetables.

The objective of this study is to determine to what extent PFAL-based commercial farming of leafy vegetables can be scaled up, by investigating both the demand and supply of locally grown leafy vegetables. The study is limited to the tendered land by AVA (first tranche, announced in May 2017, for leafy vegetable production), but can be expanded to assess the financial viability of commercial urban agriculture in other settings. Findings will be relevant to cities around the world which face the same land constraints as Singapore; ASEAN countries which share a similar culture and climate; and the local Singaporean government which has embarked on a number of initiatives to further leafy vegetable production in the country.

## III. Analytical Framework and Methodology

The analytical framework adopted to assess the feasibility of expanding domestic vegetable production in the land tendered by AVA takes into account three key factors, captured in the analytical framework below (Figure 1).

The first requirement is the profitability of domestic vegetable production, which has implications on returns on investments and the financial viability of vegetable production *in toto*. This is shaped by production costs, land costs, and prices of the commodities. The next requirement is land availability, which is tied to land cost and the Singapore Master Plan for land use. These two are inter-linked, as even if there is sufficient land area, high costs for renting the land can prevent its use for agricultural production; alternatively, there is a limited supply of cheap land for agriculture which would make vegetable production financially viable. Given the inter-

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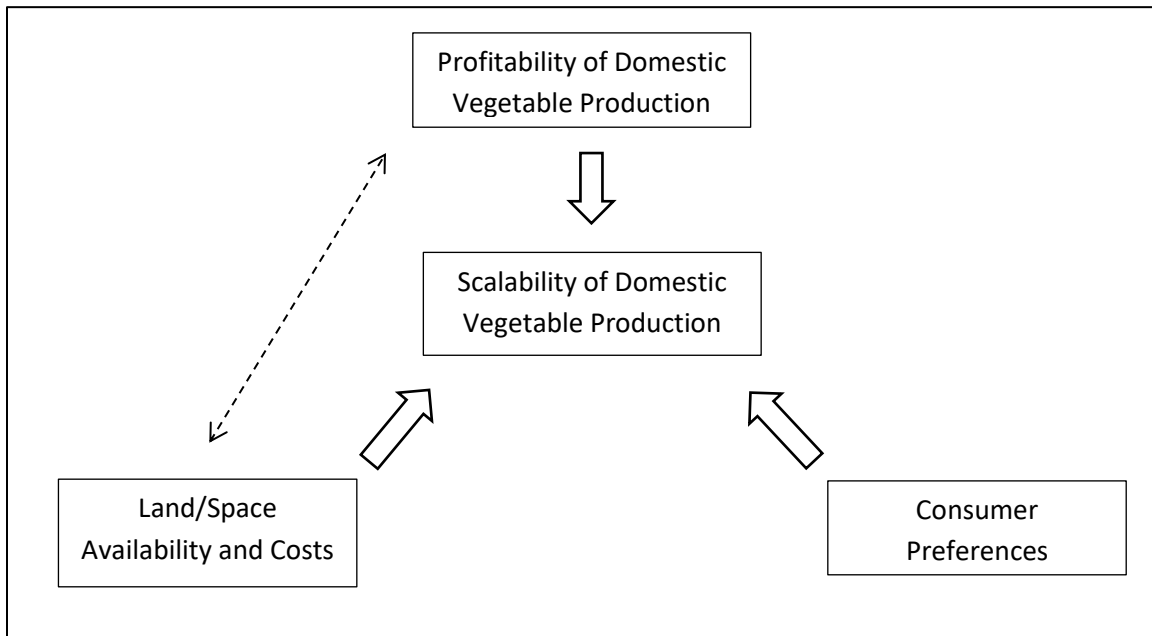
<sup>23</sup>'Trade Map Database,' International Trade Centre, accessed 28 November 2017, <http://www.trademap.org>.

linked nature between land/space availability and the profitability of local vegetable production, a dashed arrow is drawn between these factors.

The last requirement is sufficient demand on the part of Singapore consumers. Consumers set the upper limit to how much can be produced domestically in a commercially viable manner, because they provide the market for these commodities. We pay particular attention to the amount of food that is imported from overseas sources, as highlighted in the previous section. This is also to avoid a scenario wherein vegetables producers operating in the tendered land have to compete with local producers for the same vegetables. The focus here is thus on domestic agricultural production which is intended to supplant/replace imports, rather than compete with local producers.

Figure 1

**Analytical Framework for Scalability of Domestic Vegetable Production**



Source: Author analysis

This report provides a policy-focused interpretation of findings from two separate studies conducted in 2017 – a demand side study and a supply side study. The respective methodologies, data and assumptions for both studies are included in the Appendices 1 (Demand Side) and 2 (Supply Side) of this report, accordingly. We provide a quick summary of the assumptions and limitations behind these studies below.

For the demand study, 544 working Singaporean adults were surveyed on their attitudes toward locally grown vegetables and imported vegetables, their willingness to pay for different vegetable attributes and awareness and effort to buy locally grown vegetables. The study developed a baseline understanding of consumer knowledge, attitudes and practices as these relate to local and imported leafy vegetables in Singapore.



1. The survey respondents' attitudes toward locally grown vegetables and imported vegetables were measured through a paired comparison analysis. In this section, consumers were presented with two vegetable profiles that differed on four cues: price, amount, type of vegetable and country of origin. They were prompted to select one vegetable profile and their reasons why. The reasons listed were: Availability, Freshness, Appearance, Price, Safety and Taste.
2. The respondents' willingness to pay for different vegetable attributes were calculated from a vegetable attributes costing matrix. Different vegetable attributes such as 'more fresh', 'individually packaged' and 'organic', and their subsequent payment levels (i.e., 10% cheaper, original price, 10% more, 20% more and 30% more) were presented to the survey respondents. The payment level that they selected was interpreted as their willingness to pay for that vegetable attribute.
3. The survey tested the respondents' awareness and effort to purchase locally grown vegetables through a series of questions on government campaigns, knowledge of country of origin and reasons for purchasing locally grown vegetables.

Demographic characteristics of age, gender, education level, annual income and race were captured.

Next, in the supply study, to identify the types of vegetables that could be farmed in a financially viable manner, under a PFAL, the following process was taken:

- 1) We started by customizing a financial model published by the San Francisco Environment office to Singapore's context. Appendix 1 contains the key production, financial, price, cost and space assumptions.<sup>24,25</sup>
- 2) The model was run across different vegetables which were imported by Singapore in 2016, with HS Codes for leafy vegetables identified based on a published AVA listing.<sup>26</sup> Data from the International Trade Centre was used, to provide information on the total value and the prices of these imports, the types of vegetables, and the country sources.

Each vegetable, from each country source, was treated as one item or distinct product, given price differences. 80 distinct pairs of countries and types of vegetables imported per country were used,

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<sup>24</sup> Shivani Ganguly, Piper Kujac, Miranda Leonard, Jennifer Wagner & Zachary Worthington, Lively'Hood Farm financial analysis: A feasibility study of commercial urban agriculture in the City of San Francisco, San Francisco Environment, 2011, accessed 20 October 2017,

[https://sfenvironment.org/sites/default/files/fliers/files/sfe\\_of\\_feasibility\\_study\\_cua.pdf](https://sfenvironment.org/sites/default/files/fliers/files/sfe_of_feasibility_study_cua.pdf).

<sup>25</sup> In the reference farm Spread Co., the size of the total land area was 4,780 sq. m., the building structures took up 2,868 sq. m., and the cultivation area took up 1,800 sq.m. In these calculations, we focus on the building structures, rather than the cultivation area alone (which could lead to a gross underestimation of the building requirements), but we do not take into account the total land area, as the objective is to assess the bare minimum quantity of land that will be needed for this PFAL.

<sup>26</sup> This was downloaded from the AVA Website, under the heading, 'Resources for Businesses,' at: AVA, 'Product codes for fresh fruits and fresh vegetables. TN4.1 5TH EDITION - March 2014', March 2015, accessed 24 November 2017, [https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/tn41\\_frtveg\\_17mar2015](https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/tn41_frtveg_17mar2015).

## Singapore, January 2018

assuming that the farm would produce only the same type of vegetable. For example, one run of the model is with the most expensive product 'Spinach New Zealand spinach & orache spinach fresh or chilled' (HS code: 07097000), and imported from Japan (with import price of SGD 18 per kg). The model was then run again with the next highest price commodity, 'Kohlrabi kale & similar edible brassicas fresh or chilled' (HS Code: 07049090), also from Japan (import price of 17 per kg), all the way until the last (80<sup>th</sup>) commodity.

- 3) After running the model across all 80 commodities from various sources, we then eliminated all products which, if adopted by the company, would lead to a negative net present value for the company, by the 20<sup>th</sup> year of the company's operation (taking into account the net present value of cash flows in all 20 years).

Last, by cross-referencing the viable products from this financial viability assessment with the total amount of specific vegetables that Singapore imports from specific sources, we were able to capture the total amount that could be produced in Singapore via import substitution.

- 4) The same process was repeated for each scenario identified.

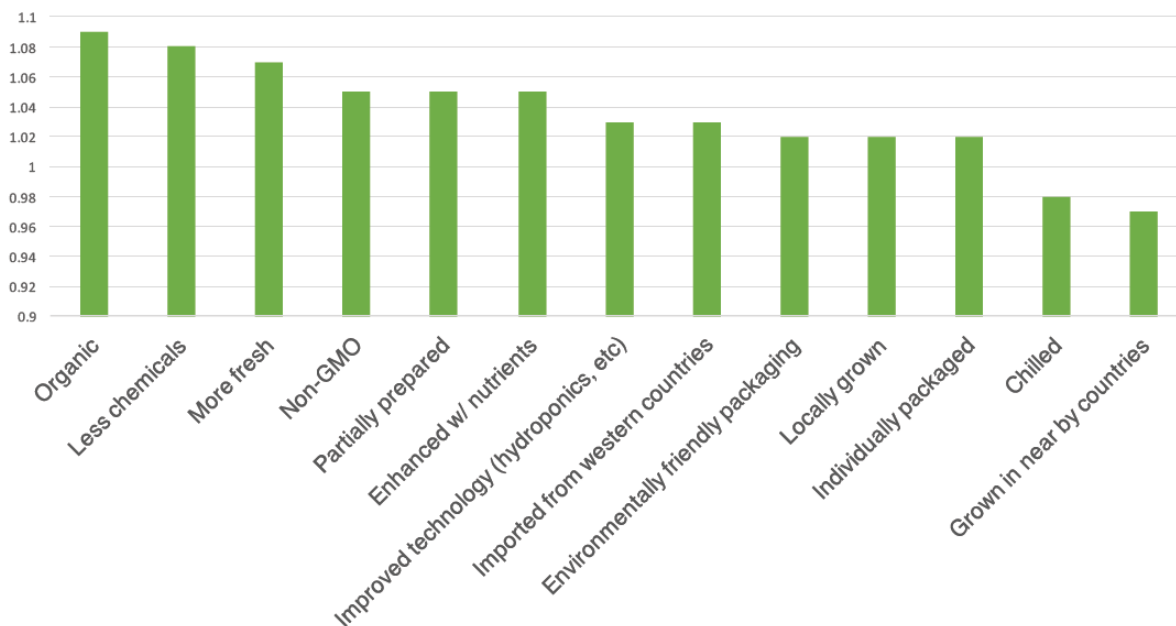
## IV. Key Findings from Demand Side Assessment

Below are the key findings from the demand side assessment, which will contribute to data analysed in the section on policy analysis and recommendations.

### Vegetable Attributes Cost Matrix

The demand side study surveyed consumers on the extent to which they were willing to pay more for vegetables, given the presence of certain vegetable attributes such as ‘more fresh’, ‘organic’ and ‘individually packaged’. The payment levels (i.e., 10% cheaper, original price, 10% more, 20% more and 30% more) selected by the consumers were interpreted as their willingness to pay for the vegetable attribute. The list of vegetable attributes included are copied below, as well as the percentage by which they are willing to pay more, when those vegetable attributes were present. For instance, if vegetables are locally grown, it is interpreted that the consumers surveyed were willing to pay 2% more for those vegetables.

**Figure 2**  
**Willingness to Pay Matrix Results**  
 Willingness to Pay Matrix Mean Results



Source: Author analysis

Note: The vertical axis points to the willingness to pay price premia, or alternatively, the desire to pay lower prices, given the presence of specific traits in the vegetables. The value of 1 implies no willingness to pay either a premium, nor desire to pay a lower price. A value greater than 1, e.g. 1.08, implies a desire to pay more (i.e. 8% more). A value less than 1 (e.g. 0.9) implies the desire to pay a lower price (i.e. to pay 90% of original price, or 10% less than original price).

### Key Findings from Demographic Analyses

In the study, there were strong intergenerational differences in responses. Regression analyses revealed that older respondents were more likely to select locally grown vegetables over imported vegetables ( $r_{370} = .26, p = .00$ ). In the section that tested the survey respondents' awareness and effort to purchase locally grown vegetables, it was found that the older generation indicated that they purchase locally grown vegetables in order to support local producers and for safety concerns.

### Paired Comparison Analysis

A few findings are worth highlighting from the paired comparison analysis section. The results demonstrated that consumers held different assumptions on the vegetable's safety depending on the vegetable's country of origin. Overall, Singaporean vegetables were perceived to be more safe than vegetables imported from Malaysia and China. 68% who chose the Singapore option over Malaysia selected the 'safety' reason and 80% of respondents chose the Singapore option over China for the 'safety' reason too. Additionally, safety was more important than price. The majority of consumers were willing to pay a price premium on the Singapore vegetable when compared to vegetables grown from Malaysia and China.

## V. Key Findings from Supply Side/Profitability Assessment

### Description of Scenarios

Given the information above, we now proceed to the scenarios tested and simulation results. Based on review of literature and analysis, we identified four factors to test. We took an incremental approach, first testing different **land prices**, given that the prices per parcel of land tendered varied (Highest price: SGD 1.44380 per sq ft; Lowest price: SGD 1.37571 per sq ft). The base assumption is that the highest price estimates are used, to be conservative.

When we found that the model outcomes were not sensitive to land prices (within the bounds of the prices for the tendered land), we then proceeded to testing the next factor, **interest rates for funding/capital**.<sup>27</sup> We tested three assumptions, namely, when social venture capital is used, with returns of 21.4% based on analysis of the Livelihood Farms dataset;<sup>28</sup> public equity financing, in case companies investing were already publicly listed companies and able to acquire funding at the market rate;<sup>29</sup> and capital cost that is equivalent to the long-

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<sup>27</sup> While the base value for this was 10.2% based on the San Francisco scenario, we updated this with a value of 9.15%, which is the based on the industry which companies like Del Monte, Alico Inc., and Total Produce fall under.

<sup>28</sup> This was based on analysis of the rates derived by the SF Environment team, after they interviewed an angel investor. Shivani Ganguly, Piper Kujac, Miranda Leonard, Jennifer Wagner & Zachary Worthington, Lively Hood Farm financial analysis: A feasibility study of commercial urban agriculture in the City of San Francisco, San Francisco Environment, 2011, accessed 20 October 2017, [https://sfenvironment.org/sites/default/files/fliers/files/sfe\\_uf\\_feasibility\\_study\\_cua.pdf](https://sfenvironment.org/sites/default/files/fliers/files/sfe_uf_feasibility_study_cua.pdf).

<sup>29</sup> While the base value for this was 10.2% based on the San Francisco scenario, we updated this with a value of 9.15%, the industry-wide return on investment for industry which companies like Del Monte, Alico Inc., and Total Produce fall under. 'Fresh Del Monte Produce Inc (FDP.N)', Reuters, accessed 15 September 2017, <https://www.reuters.com/finance/stocks/overview/FDP.N>; 'Alico Inc (ALCO.OQ)', Reuters, accessed 15 September 2017, <https://www.reuters.com/finance/stocks/overview/ALCO.OQ>; 'Total Produce PLC (T70.I)', Reuters, accessed 15 September 2017, <https://www.reuters.com/finance/stocks/overview/T70.I>.

term government bond yield rate, computed at 2.04%.<sup>30</sup> We tested this factor given the capital-intensive nature of PFALs, which imply high capital and depreciation costs. Interest rates were found to be a significant factor influencing the profitability of production, and in turn, the scalability of farming. We therefore continued to test different financing scenarios in all succeeding tests.

We then tested **different marketing channels**, given the insight that more profits can be gained by selling directly to customers or restaurants rather than selling simply wholesale. In particular, farms can double the price of the product if they package it and sell it direct to customers, via retail; alternatively, they can also increase prices by up to 75% when selling direct to restaurants.<sup>31</sup> We found this to have a significant impact on the profitability of farming. Last, we tested the demand side finding that locals would be **willing to pay a premium for fresher vegetables**, under different interest rate and marketing channel assumptions, and found this to have a significant impact too.

In the **base scenario (Scenario 1)**, we used the highest land price among the plots of land tendered; the highest interest rates, i.e. through social venture capital; wholesale as market channel / point of market entry (rather than retail or restaurant sales); and we assumed consumers were not willing to pay a premium for fresher Singapore vegetables. The different combinations arising from the four factors (Table 1) resulted in 16 scenarios to be evaluated. Table 1 sums up the alternative scenarios tested relative to the base scenario.

**Table 1**  
**Brief Summary of Scenarios Tested**

Factor Tested	Description
<b>1. Land Prices</b>	<ul style="list-style-type: none"> <li>• Tested lower land prices (<b>Scenario 2</b>).</li> <li>• Following factors were held constant: interest rate for funding, marketing channel, and consumers' willingness to pay</li> </ul>
<b>2. Interest Rates for Funding</b>	<ul style="list-style-type: none"> <li>• Tested for lending rates for public equity funding (<b>Scenario 3</b>) and lending rates equivalent to long-term government bond yield rates (<b>Scenario 4</b>).</li> <li>• Following factors were held constant: land prices; marketing channel; and consumers' willingness to pay</li> </ul>
<b>3. Marketing Channels</b>	<ul style="list-style-type: none"> <li>• Tested scenario wherein products were sold direct to restaurants, using social venture capital (<b>Scenario 5</b>); public equity funding (<b>Scenario 6</b>); and lending rates equivalent to long-term government bond yield rates (<b>Scenario 7</b>).</li> <li>• Tested scenario wherein products were sold direct to customers (retail), using social venture capital (<b>Scenario 8</b>); public equity funding (<b>Scenario 9</b>); and lending rates equivalent to long-term government bond yield rates (<b>Scenario 10</b>).</li> <li>• Following factors were held constant: land prices, and consumers' willingness to pay</li> </ul>
<b>4. Willingness to Pay a</b>	<ul style="list-style-type: none"> <li>• Tested scenario wherein locals were willing to pay a premium for fresher Singapore vegetables, sold wholesale, and using social venture capital (<b>Scenario 11</b>), public</li> </ul>

<sup>30</sup> We used the average buying rates of govt securities dealers, 10-year bond yield rate, at 'Benchmark Prices and Yields', Monetary Authority of Singapore, accessed 15 September 2017, <https://secure.sgs.gov.sg/fdanet/BenchmarkPricesAndYields.aspx>.

<sup>31</sup> Shivani Ganguly, Piper Kujac, Miranda Leonard, Jennifer Wagner & Zachary Worthington, Lively'Hood Farm financial analysis: A feasibility study of commercial urban agriculture in the City of San Francisco, San Francisco Environment, 2011, accessed 20 October 2017, [https://sfenvironment.org/sites/default/files/fliers/files/sfe\\_uf\\_feasibility\\_study\\_cua.pdf](https://sfenvironment.org/sites/default/files/fliers/files/sfe_uf_feasibility_study_cua.pdf).

<p><b>Premium for Singapore Products</b></p>	<p>equity funding (<b>Scenario 12</b>); and lending rates equivalent to long-term government bond yield rates (<b>Scenario 13</b>).</p> <ul style="list-style-type: none"> <li>• Tested scenario wherein locals were willing to pay a premium for fresher Singapore vegetables, sold direct to customers (retail), and using social venture capital (<b>Scenario 14</b>), public equity funding (<b>Scenario 15</b>); and long-term government bond yield rates (<b>Scenario 16</b>).</li> <li>• Following factor was held constant: land prices</li> </ul>
<p>Note: In Scenario 1, all factors were held constant, and base assumptions adopted, i.e. higher land prices, social venture capital lending, wholesale marketing channel, and zero willingness to pay a premium for Singapore products, were assumed. Sources: Author analysis</p>	

### Key Findings

Findings from scenario analysis are captured in Table 2. Across all scenarios, we found that the highest quantity of total production that can be done on the tendered land in a financially viable manner, within a 20-year period, is 30,527 tonnes, which meets 33.18% of domestic leafy vegetable consumption. This best case outcome means that 80,759 square meters of land (up to 8 hectares), taking up approximately 4 out of the 12 plots of land tendered by AVA can be used in a financially viable manner. This outcome can be achieved under **Scenarios 6, 7, 9, 10, 14, 15 and 16**.

We found that the next best outcome, of production between 29,269 tonnes and 30,509 tonnes (31.81% to 33.16% of domestic leafy vegetable consumption), can be achieved through **Scenarios 4, 5, 8 and 13**. This is followed by the third best outcome, of production between 13,122 tonnes and 15,834 tonnes (14.26%-17.21% of domestic leafy vegetable consumption), which can be achieved through **Scenarios 3, 11 and 12**. Last, the lowest production levels, at 7,210 tonnes, was found in the baseline scenario (**Scenario 1**) and even with lower land prices (**Scenario 2**), with negligible impacts of differences in land prices across the 12 plots of land tendered out in the first tranche (SGD 1.37571 to SDGD 1.44380 per square foot).

**Table 2**  
**Scenario Findings based on Simulations**

Scenario	Scenario Details				Findings		
	Land Price (per Square Foot) Note: 1) Highest Price: SGD 1.4438 2) Lowest Price: SGD 1.37571	Interest Rate for Funding Note: 1) Social Venture Capital: 21.4% 2) Public Equity Financing: 9.15% 3) Long-Term Government Bond Yield Rate: 2.04%	Market Channel Note: 1) Wholesale: Base price 2) Direct to Restaurants: Prices are 75% higher than wholesale prices 3) Direct to Customer: Prices are 100% higher than wholesale prices	Willingness to Pay by Locals Note: 1) No Premium: Base price 2) With Premium 7% higher price for local produce	Total Production (tonnes)	% of Local Consumption Met in Tendered Land	Total Space Occupied (sq. m.)
#1	Highest Price	Social Venture Capital Funding	Wholesale	No Premium	7,210.00	7.84%	19,074.07
#2	Lowest Price	Social Venture Capital Funding	Wholesale	No Premium	7,210.00	7.84%	19,074.07
#3	Highest Price	Public Equity Financing	Wholesale	No Premium	14,898.00	16.19%	39,412.70
#4	Highest Price	Government Bond Yield Rate	Wholesale	No Premium	29,269.00	31.81%	77,431.22
#5	Highest Price	Social Venture Capital Funding	Direct to Restaurants	No Premium	29,269.00	31.81%	77,431.22
#6	Highest Price	Public Equity Financing	Direct to Restaurants	No Premium	30,527.00	33.18%	80,759.26
#7	Highest Price	Government Bond Yield Rate	Direct to Restaurants	No Premium	30,527.00	33.18%	80,759.26
#8	Highest Price	Social Venture Capital Funding	Direct to Customers (Retail)	No Premium	30,509.00	33.16%	80,711.64
#9	Highest Price	Public Equity Financing	Direct to Customers (Retail)	No Premium	30,527.00	33.18%	80,759.26
#10	Highest Price	Government Bond Yield Rate	Direct to Customers (Retail)	No Premium	30,527.00	33.18%	80,759.26
#11	Highest Price	Social Venture Capital Funding	Wholesale	With Premium	13,122.00	14.26%	34,714.29
#12	Highest Price	Public Equity Financing	Wholesale	With Premium	15,834.00	17.21%	41,888.89
#13	Highest Price	Government Bond Yield Rate	Wholesale	With Premium	30,509.00	33.16%	80,711.64
#14	Highest Price	Social Venture Capital Funding	Direct to Customers (Retail)	With Premium	30,527.00	33.18%	80,759.26
#15	Highest Price	Public Equity Financing	Direct to Customers (Retail)	With Premium	30,527.00	33.18%	80,759.26
#16	Highest Price	Government Bond Yield Rate	Direct to Customers (Retail)	With Premium	30,527.00	33.18%	80,759.26

Note: In the case of Scenarios 14-16, we first computed the price premium from customers (7%), and then doubled this, given that sales are done directly to customers (via retail).

Sources: Author analysis.

## VI. Analysis and Recommendations

Below are insights derived from scenario findings as well as the demand side assessment.

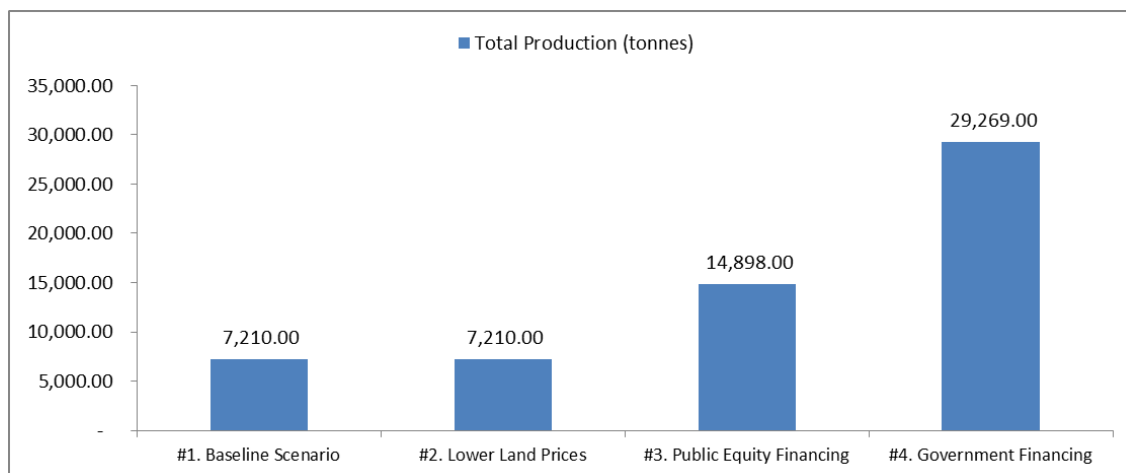
### Result # 1: Financing choices by firms impact on the amount of vegetables that can be viably to produce on tendered land.

The first finding from this study is that financing, or the cost of capital, is a critical component that influences the profitability of producing vegetables on the land tendered out by by AVA. The capital-intensive nature of PFALs, and the high infrastructure costs for putting them up and maintaining them, make the viability of vegetable production sensitive to the choice of the financing option. We found (Figure 3) that public equity financing can make it financially viable to produce as much as 14,898 tonnes, a more than two-fold increase in the amount of local production in the tendered land, compared to the baseline scenario of social venture capital funding (7,210 tonnes). If financing costs can match the long-term government bond yield rates, then total production in the tendered land is at 29,269 tonnes, almost double the results in the scenario when public equity funding alone is used for leverage. In this regard, it would be ideal if the farms bidding to win the tendered land can merge, or can go public, to allow them to finance the needed infrastructure required for building high productivity farms. This allows firms to qualify for public equity funding, rather than venture capital funding.

### **Recommendation 1: Explore ways of getting low cost financing for firms.**

Figure 3

### **Visualization of Scenario 1-4 findings on total quantity which can be produced in a financially viable manner**



Source: Author analysis

### Result # 2: Marketing channels adopted by firms impact on the amount of vegetables that can be viably produced on tendered land.

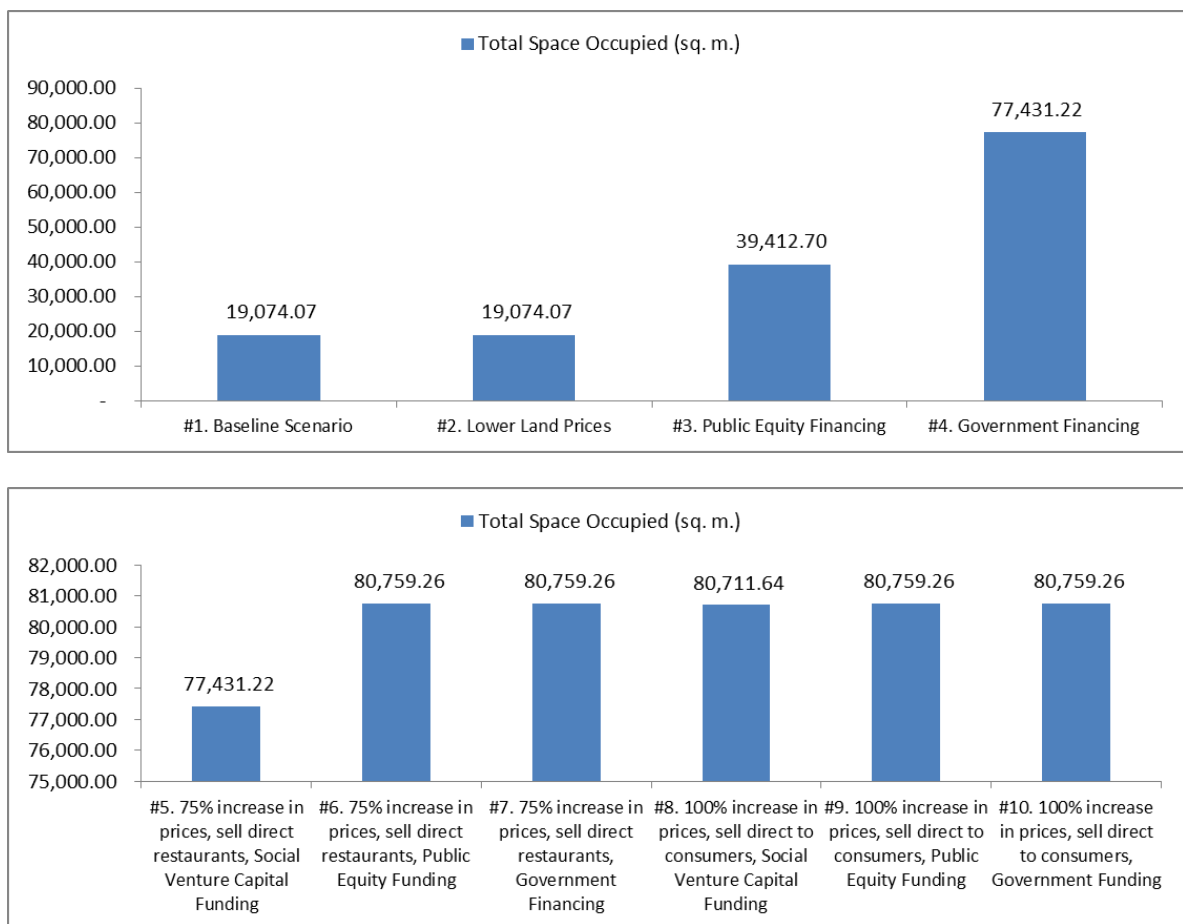
An alternative approach to reach close to 8 hectares of land, is if firms can sell directly to either restaurants or through retail. In order to increase the amount of land that is utilized in a financially viable manner, farmers will need to establish strong ties with restaurants, so that they can sell their produce directly to them. This effort



can be coordinated with the Taskforce for Promotion of Local Produce, which includes the Kranji Countryside Association, the Restaurant Association of Singapore, and the NTU Fairprice Co-operative Ltd, among others.<sup>32</sup> This could allow for approximately 4 out of the 12 plots of land tendered out to be utilized in a financially viable manner, assuming either public equity funding or capital with lending rates equivalent to long-term government bond yield rates are used. In particular, it leads to between 7.7 and 8.1 hectares of land being used in a commercially viable manner if firms sell directly to restaurants, and between 8.07 and 8.08 hectares if firms sell directly to consumers, via retail (Figure 4).

Figure 4

**Visualization of Scenario 1-10 findings on total space which can be occupied in a commercially viable manner**



Source: Author analysis

The demand survey suggests that there is a high market demand for locally grown vegetables in Singapore. In the paired comparison analysis section, the majority of consumers (>50%) selected locally grown vegetables over imported ones.

<sup>32</sup> AVA, Delegate Handbook, Food Industry Convention 2017, 1 November 2017.

**Recommendation 2: Encourage farms to develop relationships with restaurants, or to sell directly to customers, in order to increase the amount of imports that can be captured by local farms.**

Result # 3: Factors affecting consumer decisions to 'go local', and the potential to capture a large product segment if product labelling is applied.

The only remaining segment which could not be captured in a financially viable manner, even if firms were to sell directly to customers, was the product, '07097000 Spinach New Zealand spinach & orache spinach fresh or chilled' imported from Malaysia. This is a significantly large segment, amounting 12,898 tonnes.

Simulation results show that this segment is not captured partly because the price of this product is very low, at only 24 cents (SGD) per kilogram. Even if firms sell directly to restaurants, the price goes up to only 43 cents (SGD) per kg. Compared to the next cheapest item ( 'Cabbage lettuce fresh or chilled', HS Code: 07051100) from Vietnam, priced at 79 cents (SGD), one can observe that the price of spinach imported from Malaysia ( 'Spinach new zealand spinach & orache spinach fresh or chilled'; HS Code: 07097000) is 54% less. As such, finding ways of addressing this gap will be crucial. In fact, if successful, this could mean an additional 14.01% of total leafy vegetable consumption is met through domestic production on the tendered land alone.

Based on the demand survey, it was found that the top reasons why consumers would choose to purchase Singapore farmed vegetables, rather than vegetables from Malaysian producers, are safety (66% of respondents) and freshness (66% of respondents). In fact, in the more general question on why they would choose locally grown vegetables over imported vegetables (regardless of source), they identified freshness (56%) and safety (53%) as top reasons, and price came only as the third top reason (44%).

The problem with this is that, based on conversations with shoppers interviewed (see Appendix 1 for further information on Demand Side Assessment), there are still vegetables which are purchased in wet markets rather than in supermarkets. In wet markets, product labelling is not a requirement, such that even if farmers were using large quantities of pesticide, and regardless of the toxicity of the pesticides used, the consumers would not be able to judge safer from less safe vegetables. This information gap may explain the significantly low prices of Malaysian vegetables under the label '07097000 Spinach new zealand spinach & orache spinach fresh or chilled'.

In this regard, the third recommendation is to require product labelling for each consignment of imported vegetables sold in wet markets. If the firms do not have access to vegetable testing services, then they may apply for Plant Health Laboratory Services by the AVA, and pay the needed costs, per consignment.<sup>33</sup>

**Recommendation 3: Require product labelling for vegetables imported by Singapore and sold in wet markets.**

Result # 4. The importance of organic trait to consumers.

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<sup>33</sup> 'Application for Plant Health Laboratory Services', AVA, accessed 16 January 2018, <https://www.ava.gov.sg/e-services/lab-services/application-for-plant-health-laboratory-services>.

Out of all the vegetable attributes tested, 'organic' was the most premium vegetable attribute selected by the respondents. This suggests that an organic label for locally grown vegetables can enable local producers to sell their produce at a higher price. Given the debates on considering plants grown in artificial environments as organic, an immediate imperative will be to look into organic certification approaches adopted in other countries as regards hydroponics and other non-soil farming practices, in order to develop an objective definition for 'organic' which can apply to these farming systems.

**Recommendation 4: Design and promote organic certifications for locally grown vegetables.**

Result # 5. The ambiguity of vegetable categories.

There are over 52 types of leafy vegetables under 'Other vegetables fresh or chilled' (HS Code 07099900) that cannot be studied as they are not allocated according to specific product types. This limits the ability of farms to identify more vegetable types that could potentially be produced in the tendered land. Government should therefore mandate that these vegetables be reported under more specific HS Codes. In doing so, more firms will be guided on other types of vegetables which they can explore producing on the tendered land. This has large potential, as this makes up more than 50% of total vegetable import expenditures.

**Recommendation 5: Require firms to list vegetables under specific product codes that allow for accurate product identification for products under 'Other vegetables fresh or chilled' (HS Code: 07099900).**

## VII. Conclusion

For farming to continue to contribute to Singapore's food security in the long-term, farming practices will need to transform in order to be commercially viable and justify the use of space allocated to it.

Singapore can potentially produce as much as approximately 30,000 tonnes of additional leafy vegetables in a financially viable manner in the land tendered by AVA, apart from what is presently produced, if the recommendations arising from our study are considered. However, this will require support to firms, helping them to market directly to restaurants, or to package their products and sell them directly to customers (retail). Firms will also need support to ensure they are able to find/access low-cost financing.

Beyond these, additional efforts will be needed in product labelling. This provides consumers who buy from wet markets with better information on standards used in producing vegetables. It could potentially expand the vegetables that can be produced viably, to meet an additional 14% of consumption needs, if consumers decide to 'go local' for food safety reasons. Organic labelling, and development of related standards and certification, can likewise allow local production to better compete with foreign leafy vegetable sources.

Lastly, additional vegetables that can be produced locally in a viable manner may be identified, if information gaps are bridged for presently uncategorized vegetables falling under the heading 'Other vegetables fresh or chilled' (HS Code: 07099900).

## Appendix

## Appendix 1: Demand Side Assessment

Below is an excerpt from Liu and Soo (forthcoming), discussing the key methodology behind the demand side assessment, as well as information regarding the survey sample.

### a. Methodology for Demand Assessment

The paired comparison analysis section was modelled after best practices with measuring the country of origin effect. Four cues (price, amount measured in grams, type of vegetable and country of origin) were selected because multi-cue models can more strongly infer the country of origin effect relative to other cues. The vegetable profiles were created based upon market information at the time. The reasons elicited, safety, availability, freshness, appearance and taste. A summary of descriptive statistics was completed for every vegetable profile and regression analyses with different demographic traits were done.

For the vegetable attributes cost matrix, surveyed individuals were presented with the purchase of a hypothetical vegetable. Assuming that the vegetable cost \$3.00, they were asked to tick how much more they were willing to pay for 13 vegetable attributes. The responses were averaged across the different vegetable attributes. Additional regression analyses with different demographic traits were also computed.

For the awareness and effort to purchase locally grown vegetables portion, respondents were asked a series of questions to gauge their knowledge of locally grown vegetables. They were also asked an open-ended question of why they purchased locally grown vegetables. The frequencies of different responses were measured. The main ones were safety, freshness, 'to support Singapore', and price.

### b. Sample Demographics

A total of 544 working adults in Singapore were included in the survey with the age range 21 to 87. The sample was generally representative of the demographic profile of Singapore when compared to the latest census data available from 2016. The survey was representative across income, age, education and race demographic characteristics. The strongest bias in the survey was gender with a ratio of 2:3 relative to Singapore's census data ratio of 49:50. The results of the survey should therefore be interpreted accordingly.

## Appendix 2: Supply Side Profitability Assessment

Below is an excerpt from Montesclaros (forthcoming), discussing the key methodology behind the profitability assessment, as well as the data, assumptions and uncertainties in adapting the financial model to Singapore.

### a. Methodology for Profitability Assessment

The team leveraged on a financial model developed by the San Francisco Department of the Environment (SF Environment), in partnership with Presidio Graduate School's Team Lively'Hood, to assess if commercial urban agriculture could be feasible in San Francisco, under different mixes of vegetables and different farming systems.<sup>34</sup> This study is relevant, given high land costs in San Francisco, California, a condition which Singapore shares. The model included a standard set of assumptions, but provided additional analysis on the cost of capital or of amortizing loans, which was not conducted in other studies reviewed.<sup>35,36</sup> In addition, the SF Environment team publicized their financial model, and this model served as their basis as well for providing strategic recommendations that could make urban farming commercially viable from the perspective of farmers. We utilized the SF Environment's model in a similar manner, except that recommendations are aimed at the government level, to complement the policies being implemented by the Singapore government to further high-productivity agricultural production in the city-state.

### b. Data, Assumptions and Uncertainties in Adapting Financial Model to Singapore

The shortcoming of the SF Environment's model, however, is that while it was focused on high productivity agriculture, the type of agriculture promoted was not sufficiently advanced in technology, i.e. indoor agriculture was not considered. The agricultural technology implemented in the SF model was only hydroponics on two levels/layers/tiers of plants, whereas we tested for more levels/layers/tiers in our analysis. We therefore revised the model to take into account vegetable production which could accommodate more layers of vegetable production.

#### 1. Production Assumptions

The first change involved adopting production assumptions for high-tech agriculture which could provide significantly higher yields. While the author attempted to collect data from firms in Singapore that made use of PFALs, especially those that grew plants on more than two tiers of vegetables per square meter (sq.m.), the pilot of three firms interviewed were not open to sharing data. This was given the sensitive nature of revenues and

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<sup>34</sup> Shivani Ganguly, Piper Kujac, Miranda Leonard, Jennifer Wagner & Zachary Worthington, Lively'Hood Farm financial analysis: A feasibility study of commercial urban agriculture in the City of San Francisco, San Francisco Environment, 2011, accessed 20 October 2017,

[https://sfenvironment.org/sites/default/files/fliers/files/sfe\\_uf\\_feasibility\\_study\\_cua.pdf](https://sfenvironment.org/sites/default/files/fliers/files/sfe_uf_feasibility_study_cua.pdf).

<sup>35</sup> MIT Sloan School of Management, Leafy Green Machine: Business feasibility evaluation for Hannaford Supermarkets, 2016, accessed 20 October 2017, <http://mitsloan.mit.edu/actionlearning/media/documents/s-lab-projects/Hannaford-Report-2016.pdf>.

<sup>36</sup> Suzette P. Galinato and Carol A. Miles, Economic profitability of growing lettuce and tomato in Western Washington under high tunnel and open-field production systems. Hort Technology, 23 (4), 2013, accessed 20 October 2017, <http://horttech.ashspublications.org/content/23/4/453.full>.

production cost-related information. We therefore resorted to adopting information from other case studies in order to derive proxies for variables which were not available, such as infrastructure, and depreciation costs. In particular, the company for which data was extensively available, which we adopted in this study, was the indoor farm Spread Co., based in Japan. Spread Co. grows vegetables in PFALs, using multitiered deep flow hydroponics. Information was drawn from a case study of the said company, documented in the book *Plant Factory*.<sup>37</sup>

## 2. Assumptions and Uncertainties in Total Production Costs

In spite of the extensive data published about Spread Co., there were still a number of uncertainties which had to be addressed. Most importantly, the total production cost under normal operations was not shared, making it almost impossible to estimate production costs purely based on the data shared (rather only the portion of total cost allocated for each cost item was shared, in percentage terms). To address this gap, we leveraged on information from other studies. We used the formula below for depreciation, following the normal straight-line depreciation method. We assumed a 10-year lifetime for infrastructure, as this was also the assumption used in another study on the financial viability of PFAL technologies.<sup>38</sup>

$$\text{Annual Depreciation Cost} = \frac{\text{Total Infrastructure Cost}}{\text{Lifetime of Infrastructure}}$$

With this information, we were able to derive annual operating costs for the firm, taking into account total costs for electricity use, manpower, inputs, and others. This assumption still brings up a few uncertainties, however, given that specific information such as manpower count, the exact supplies and seed used, and the prices for these, were not available. In this regard, the approach we took was to convert the costs in the farm into Singapore Dollar terms. We then applied increases in production costs which were forecasted in the original model based on interviews conducted by the study team for the SF Environment model, with experts and practitioners, similarly to Singapore.

## 3. Assumptions and Uncertainties in Costs for Specific Farm Production Factors

In adapting the farm to Singapore, we assumed the same gross area for farming, the same area allocated for circulation within the farm, and corresponding yields. Given that the PFAL of Panasonic, which runs an indoor farm based in Singapore, produces several varieties of plants, and given that the conditions in the farm are similarly controlled, we extended the types of plants which could grow in the model farm beyond simply lettuce.<sup>39</sup> As such, the same yields were used, which the Spread Co. farm used for lettuce, and these were applied to all other leafy vegetables grown in the PFAL. Last, as discussed earlier, the input costs for the farm (including seeds, and amount of nutrients to use per seed), were not separated into individual cost items, making it impossible to customize the specific costs for these items. We therefore retained the input costs as were used in the PFAL of Spread Co., i.e. the ones used for lettuce production.

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<sup>37</sup> Toyoki Kozai, Genhua Niu and Michiko Takagaki, *Plant factory: An indoor vertical farming system for efficient quality food production*, 1st Edition. Academic Press: Cambridge, MA, USA, 2015.

<sup>38</sup> MIT Sloan School of Management, *Leafy Green Machine: Business feasibility evaluation for Hannaford Supermarkets*, 2016, accessed 20 October 2017, <http://mitsloan.mit.edu/actionlearning/media/documents/s-lab-projects/Hannaford-Report-2016.pdf>.

<sup>39</sup> Hedy Khoo, Room to grow more local veggies at Panasonic's farm, *The Straits Times*, 10 July 2017, accessed 28 November 2017, <http://www.straitstimes.com/singapore/room-to-grow-more-local-veggies-at-panasonics-farm>.

#### 4. Financial Assumptions and Costs

The other revision, when applying the model to the Singapore context, was focused on the cost of capital. In the case of interest rates for venture capital, we made use of the market rates and betas of publicly listed companies in Asia. The risk free rate of capital was also adjusted according to Singapore's 10-year government bond yield rates in 2017. We likewise used the headline corporate tax rate in Singapore. Next, we used similar cost and revenue growth factors (5% each) as in the original model. We likewise used the same loan amortization formulae, as well as debt payback periods (5 years) and payment terms (annual), as was assumed in the original model. For social venture capital, we used the same rate that was derived by the study team for the SF Environment model, after they interviewed an angel investor, as well as their suggested changes when customizing the model. On credit card financing, we used the market rates available in Singapore, after reviewing financing charges of DBS and OCBC Bank. Last, in deciding the share of the total capitalization to be sourced from social venture capital as opposed to credit card loans, we assumed purely social venture capital in the baseline, given the high infrastructure costs which need to be covered in the more high-tech farm.

#### 5. Sales and Prices

The product prices we used in the model are the import prices for the vegetables in Singapore. Given that there are no HS Codes specifically for 'leafy vegetables,' we referred to the AVA's list of leafy vegetables imported,<sup>40</sup> and used the HS Codes for these commodities as basis for selecting vegetables to include in simulations, using International Trade Centre statistics.<sup>41</sup> Marketing assumptions in the original SF model are likewise adopted, such as the share of vegetables that are successfully sold.

#### 6. Target Land Area and Land Prices

We used land areas and prices published in the May 2017 AVA fixed-priced tenders for leafy vegetable farming only (first batch, 12 plots of land, each approximately 2 hectares large).<sup>42</sup> As the price of land ranged from SGD 1.26-1.33 per square foot, based on author computations, we used the higher cost as our base assumption. We then added to this the costs related to buyer stamp duties, Goods and Services Tax (GST), cadastral survey costs, firm startup costs, and miscellaneous fees for processing the transaction, and allocated the full payment of these costs in year 0 (before the start of farm operations), and re-computed costs per unit area (sq ft).

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<sup>40</sup> AVA, 'Product codes for fresh fruits and fresh vegetables. TN4.1 5TH EDITION - March 2014', 2015, accessed 24 November 2017, [https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/tn41\\_frtveg\\_17mar2015](https://www.ava.gov.sg/docs/default-source/tools-and-resources/resources-for-businesses/tn41_frtveg_17mar2015).

<sup>41</sup> 'Trade Map Database,' International Trade Centre, accessed 28 November 2017, <http://www.trademap.org>.

<sup>42</sup> AVA, 'AVA to launch tenders for new agriculture land for food farming', 2017, accessed 15 November 2017, [https://www.ava.gov.sg/docs/default-source/default-document-library/pr---ava-to-launch-tenders-for-new-agriculture-land-for-food-farming-\(11-may\).pdf](https://www.ava.gov.sg/docs/default-source/default-document-library/pr---ava-to-launch-tenders-for-new-agriculture-land-for-food-farming-(11-may).pdf).



## About the Authors

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