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The Evolving Singapore Agrifood Ecosystem

By Paul Teng, Jose Ma. Luis Montesclaros,
Rob Hulme and Andrew Powell

The Singapore agrifood ecosystem is fast changing from one focused primarily on food security to one which also addresses a new economic sub-sector for export of processed food and “disruptive technologies”. Recently there has been a marked convergence of various technologies including FoodTech, AgTech, FinTech and MedTech. In 2019, exciting initiatives were announced which included the development of a new 18 ha AgriFood Innovation Park (AFIP), a new food security strategy of 30% food self-sufficiency by 2030, the launch of the Enterprise Singapore backed Seeds Capital investment for several new AgriFoodTech Accelerators and the launch of the new Singapore Food Agency (SFA) under the Ministry of Environment and Water Resources (MEWR). All these have come at a time when there is an increasing number of new startups and commercial enterprises engaged in farming and food processing, including indoor plant factories growing a range of fruit and vegetables and land-based fish farms. How do all these developments compare with similar ecosystems in successful agrifood countries like the Netherlands? Building on a previous [NTS INSIGHT on developing a successful urban food cluster](#), this INSIGHT will explore ways to successfully integrate the key elements such as research and development; retail and consumers; human resources and education; financing; and policy. It concludes with some foresighted insights on the future direction of the ecosystem.



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Contents

- Background
- Ecosystem Components and Players
- The Agriculture-Aquaculture Component
- Alternative Protein
- The Food Manufacturing/Processing Component (Post-Farm-Gate, Pre-Consumer)
- The Retail and Consumer Component
- Human Resources and the Education Component
- Financing the Ecosystem
- Policy Enablers and Implications
- Future Directions

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Background

The food production (farming) and food industry (processing) sectors have gone through spectacular changes in Singapore during its bicentennial period! When Singapore was established as a British colony in 1819, it grew and traded in a variety of spices like cinnamon and nutmeg, and until the 1970s, there were still orchards, chicken and pig farms on the main island. But as the country transformed economically from third world to first, post-independence, it shifted resources from land-intensive agriculture to other more value-adding sectors. By the 1990s, Singapore's primary production had become confined to six agricultural zones occupying some 1,500 hectares of land or less than 1% of its total area. Increasingly during the 2000s, emphasis was placed on productivity and use of technology to enable increased outputs per unit area in vegetable, fish and egg enterprises. The then Agri-Food and Veterinary Authority of Singapore (AVA), as the Government agency responsible for food, animal and plant health, rolled out a number of initiatives to support farmers and research. Others contributed to support R&D (basic and applied) in various aspects of plant agriculture and aquaculture, although an explicit national coordinated plan that included investment for research, education and extension was not apparent.¹

In 2008 the artificially precipitated "food crisis" shocked the world through its supply disruptions and became a wake-up call for a country which depended almost entirely on imports, and was thereby viewed as a significant threat to food security. The Resilience Strategy was initiated, spearheaded by various scouting teams who scoured the world aimed at diversifying the various sources of food supply, establishing and strengthening strategic partnerships with various key export countries.

Singapore has for a long time had a small food manufacturing and processing sector. Recently more calls for a renascent food production and processing sector have been heard from various sources, not just to encourage increased production for domestic food security but also as a potential value-adding sector² which could foster new livelihoods and contribute to value-added exports of products, intellectual property and services across ASEAN, Asia Pacific and globally.³ This Singapore "Food Industry 4.0" is linked to Singapore's aspirations to be a leading player in the new farming and food processing paradigm which is technology-based and not labour intensive. Singapore also announced in March 2019 that it will develop a new 18ha Agri-Food Innovation Park in Sungei Kadut, which will be ready in phases from the second quarter of 2021.⁴ This

¹ Paul Teng (2019). Commentary: Is Singapore's decades-long shift away from agriculture about to take a U-turn? Channel News Asia, 10 March. <https://www.channelnewsasia.com/news/commentary/time-for-singapore-s-decades-long-shift-away-from-11308450>.

² Jose Ma. Luis Montesclaros and Paul Teng (2018). Ensuring a Successful Singapore Urban Food Cluster. NTS Insight No. IN180-02, February 2018. <https://www.rsis.edu.sg/rsis-publication/nts/ensuring-a-successful-singapore-urban-food-cluster/#.XVZFm-MzaM8>.

³ Paul Teng (2019), *ibid*.

⁴ Ministry of Trade and Industry Singapore (MTI) (2019). Factsheet: Agri-Food Innovation Park (AFIP). https://www.mti.gov.sg/-/media/MTI/COS-2019/Factsheet_AFIP.pdf.

park will bring together high-tech farming and research and development activities, including indoor and vertical farming operations, insect farms and animal feed production facilities. The new Singapore Food Agency (SFA) came into being in April 2019, combining the previous food-related functions of the Agri-Food and Veterinary Authority of Singapore (AVA), the National Environment Agency (NEA) and the Health Sciences Authority (HSA), and with a more expansive agenda to support growth in the agrifood sector.

So does this constitute the emergence of a new Food Industry 4.0 for a small city-state? What would it look like and what lessons are there from other countries with similar aspirational goals?

China, the USA and Brazil are major food producers and/or exporters in total volume and value of produce. Clearly, a land-limited country like Singapore cannot produce the commodity crops such as soybeans, corn, wheat and rice. Singapore can, however, learn lessons from other countries like the Netherlands, Belgium and Italy which top the league of food exporters when measured by value and production efficiency (total value (\$) of food exports per unit land area, i.e. land productivity).⁵ The Netherlands and Belgium both import significant quantities of primary produce from which subsequent multi-phased processing is carried out to convert it into other value-added products in varying degrees of sophistication.

Without exception, the countries which rank highest in total volume of food exports, and those which perform well in terms of \$ value/ha (land productivity) have several enabling features in common, in **Box 1**.

An active ecosystem, in which many components function well individually but derive further synergies when working together, characterizes such high-performing and productive food exporting countries. In the recent shift in focus by Singapore in addressing domestic food security, it will be important to develop a sustainable, fully functioning agrifood ecosystem that combines a more intensive approach to domestic primary production accompanied by investment in capability and capacity building, infrastructure and strategic country partnerships.

- Existence of focal organizations (“champions”) that coordinate food production
- Coordinated infrastructure for R&D, commercial enterprise and supply chain
- Investment in relevant human resources, education and training
- Engagement of the capital markets and financing mechanisms
- Supportive government policies, regulations and instruments
- An innate culture of innovation and entrepreneurship (technology-enabling), and
- The existence of an active *ecosystem*

Box 1: Enabling Features for Successful Agrifood Ecosystems

Source: Authors

⁵ Paul Teng (2019). Commentary: Is Singapore's decades-long shift away from agriculture about to take a U-turn? Channel News Asia, 10 March. <https://www.channelnewsasia.com/news/commentary/time-for-singapore-s-decades-long-shift-away-from-11308450>.

Ecosystem Components and Players

An agrifood ecosystem (Figure 1) requires a number of actors at multiple levels. At the first level are the “**Core**” components involved in the direct production, processing and distribution of the agrifood products.

- 1) **Agtech On-Farm**: high-tech farms using advanced agricultural technologies in order to produce more food with less inputs, crop waste and land;
- 2) **Distribution**: optimized supply chain platforms that allow the products to transition through distribution and retail networks to reach consumers in a timely manner with consistent forecasting, quality, transparency and provenance. This includes wholesalers, retail supermarkets, wet markets, ecommerce vendors and direct sales from the farms;
- 3) **Post Farmgate/Pre-Consumer Sector**: efficient processing of primary produce into ingredients that can be readily used by the market;
- 4) **Foodtech**: development of food ingredients, flavours and processing technology;
- 5) **Industrial**: utilization of crop and food waste to generate biofuels, repurposed food products and biomaterials.

Apart from these actors involved in the direct production and distribution of agrifood products, additional “**Supporting**” components” complete the ecosystem:

- 1) **Research Institutions**: industry and government-backed research and development programs to innovate and optimize food production, processing and distribution;

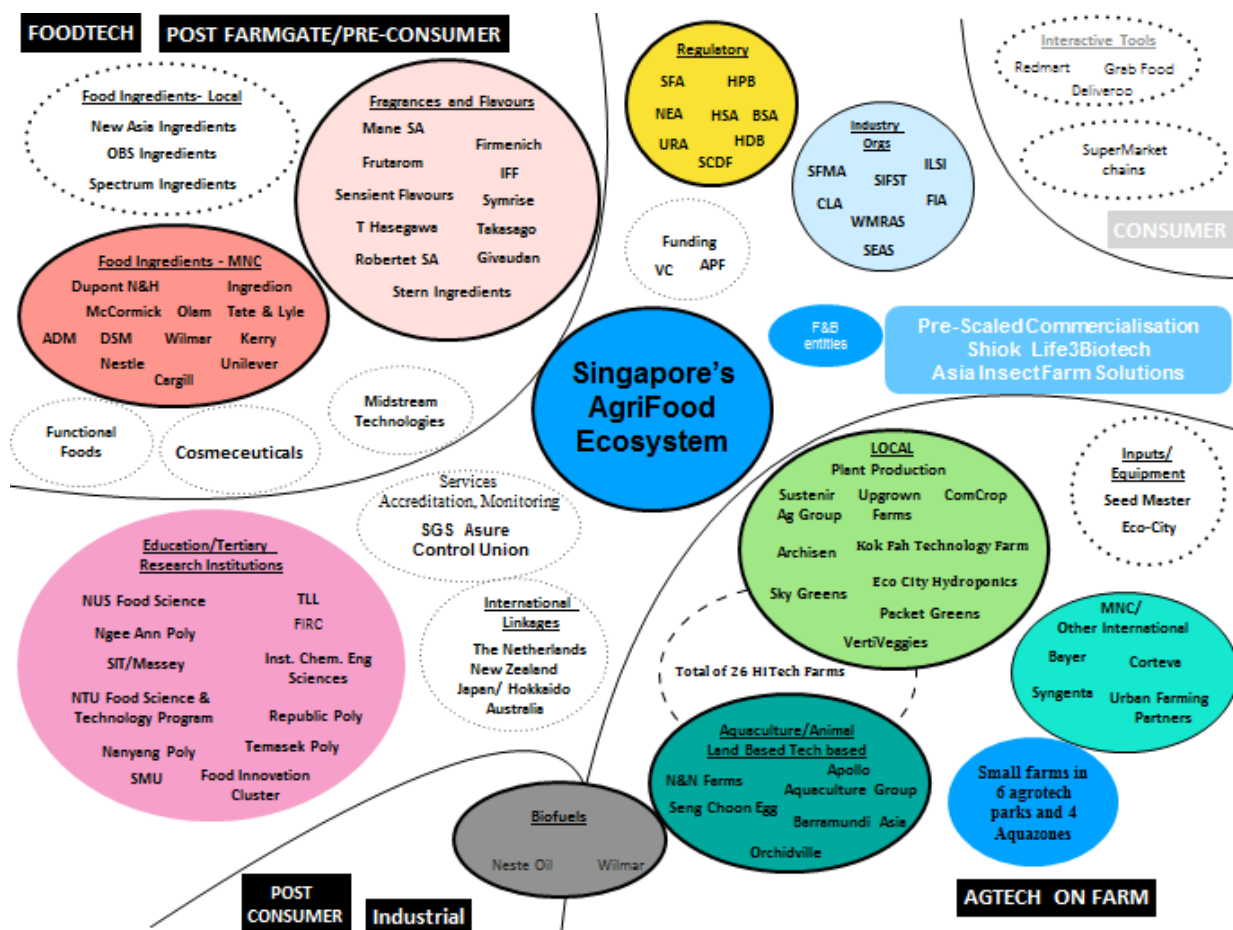


Figure 1. Abbreviated representation of Singapore Agrifood ecosystem and its components.

Source: Authors

- 2) **Education and Extension:** polytechnic institutes and national universities, in collaboration with strategic country partner education programs, to deliver a new generation of graduates aimed at building capacity and capability in domestic food production and processing.
- 3) **Regulation:** regulators to harmonise policies and interests to allow the scaling of the firms involved in the direct production, processing and distribution of food products without compromising safety;
- 4) **Industry Representation:** both industry and NGO interest groups to serve as effective linkages to connect, communicate and collaborate in order to address challenges and realise opportunities faced by companies;
- 5) **Quality Assurance:** accreditation and certification bodies to ensure that products are produced to standard and safe for consumption, and to develop and implement standards for healthy competition across companies;
- 6) **International linkages:** to provide catalysts for best-practice extension and technology transfer, learnings from other countries that have been able to successfully develop agrifood ecosystems;
- 7) **Financing:** intermediaries to link producers, processors, distributors and technology developers with funding sources, so that the former can be scaled.
- 8) **Incubators and Accelerators:** funded programs aimed at supporting startups (idea generation, business planning, mentoring, pitch deck presentations, capital raise, market access and scaling)

Figure 1 is available in expanded form from the authors.

The Agriculture-Aquaculture Component

Singapore's foremost experience has been in the growing of three key food items, leafy vegetables, eggs and fish, which comprise approximately 10% of the nutritional needs of Singaporeans. More recently, several enterprises have shown good progress in technology-enabled farming, such as in the indoor farms for vegetables, large scale commercial aquaculture and technology-enabled egg farms. Singapore, to date, has had limited experience with the conventional types of agriculture being practiced by the majority of food producing countries in Asia, given the limitations of land, growing systems and varieties.

The production component of the Singapore agrifood ecosystem, i.e. agriculture and aquaculture, may be described as urban/periurban agriculture. Most of Singapore's land-based agriculture is confined to six agricultural parks occupying some 1,500 hectares of land or less than 1% of its total area, in peri-urban areas (Figure 2). Within these six parks are conventional vegetable farms (using greenhouses, screenhouses or shaded plantings), ponded and tanked fish and prawn farms, and an eclectic mix of other enterprises farming frogs, goats for milk and quails. The truly urban agriculture within the city and townships consists of several plant factories with artificial light (PFAL), community gardens and rooftop gardens.



Figure 2. Map of Singapore showing location of agritech parks and aquazones
Source: Authors

The country also has marine aquaculture in four designated “aquazones”, with licenses granted for leases of half hectares of sea surface for most of the small “Kelong” fish farms to the largest 19 hectare Barramundi Asia production site. Singapore has over one hundred fish farms, most of which comprise an off-shore floating cage pontoon. Together, they supply approximately 9% of the country’s fish demand.

Vegetables are perhaps the most successful of Singapore’s agriculture sub-sectors. By 2020, there will be several relatively large indoor commercial vertical farms operating in Singapore, including SkyGreens and ComCrop (local farms using natural light), and additional “Plant Factories with Artificial Light” (PFAL), namely Panasonic, Vertivegies, Sustenir and Archisen. These, together with the many small conventional vegetable farms located in the agritech parks are expected to boost the supply of local vegetables, and further contribute to the ‘30 by 30’ initiative.⁶

Alternative Protein

Recently there has been a shift towards exploring alternatives to augment the supply of traditional (animal based) protein. The key drivers are increased protein demand (particularly in Asia), the issues around sustainable use of arable land for animal feed production, and consumer sentiment around animal ethics of intensive feedlot production systems. This has driven research and investment in three key substitute categories namely:

(i) Plant Based Proteins

Four key sources of plant-based proteins are legumes, meat mimics, fermentation-based meat alternatives and algae. Legumes (processed pea, chick pea, lentil, soybean and mung beans) are the largest segment and seek to mimic the texture and taste of mainstream foods.⁷ Next, meat mimics include banana blossom, eggplant and jackfruit, all with a (processed)

⁶ Ministry of the Environment and Water Resources (2019), Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the Committee of Supply Debate 2019, on 7 March 2019, <https://www.mewr.gov.sg/news/speech-by-mr-masagos-zulkifli--minister-for-the-environment-and-water-resources--at-the-committee-of-supply-debate-2019--on-7-march-2019>.

⁷ Examples include JUST scrambled egg replacement, and the burger replacements from Sunfed Meats, Impossible Foods, and Beyond Meats.

texture similar to meats.⁸ Fermentation-based meat alternates (e.g. Quorn brand) are usually fungi-based mycoproteins, fermented in nutrient rich media. Last, algae have emerged as an attractive protein source based on production efficiency.

(ii) Insect Based Protein

Insects are arguably some of the oldest sources of protein, particularly across parts of Asia and Africa, and include several sub categories such as crickets, termites and grasshoppers, used as a high quality protein additive. Black soldier flies are being developed as a sustainable protein source for fish feed and pet food (e.g. Protenga).

(iii) Cellular Agriculture

This emerging category focuses on culturing actual meat by utilizing stem cells gained from the tissue (e.g. feather) of a living animal combined with growth media and scaffolding material (e.g. jackfruit). Although in the early stages, a number of companies that have entered this sector have developed minimum viable products and are now moving to invest in alternative growth media, processing and production scaling.⁹

Alternative proteins have the potential to augment existing traditional meat (protein) supply, while using less water and arable land and addressing concerns around animal ethics and food security.¹⁰ The primary opportunity for Singapore presents itself in the diversification of and reduced reliance on imported protein sources, thereby addressing future food security concerns. In addition, the opportunity to build capability, IP and global expertise in alternative protein production systems also presents potential export revenue and job creation opportunities for Singapore.

The Food Manufacturing/Processing Component (Post-Farm-Gate, Pre-Consumer)

Few products from primary production, apart from fruit and vegetables, reach the consumer without some form of processing and value addition to create the final product.

The food manufacturing sector is well populated with local companies (the Singapore Food Manufacturers Association has 72 members in its manufacturing category). Raw materials for manufacturing are sourced from local and international traders.¹¹ Supporting the manufacturers, most of the multi-national food ingredient providers have a presence in Singapore;¹² similarly, international food flavouring companies are well represented.¹³

Local companies are actively engaged in later stage research particularly in product development, packaging and processing technology. Here, they are partnering well with local tertiary institutions such as the Food Innovation Research Centre. However, the research base in the tertiary institutions to support the food sector is relatively small and dispersed amongst

⁸ These include pork, currently being developed by Karana, a Singapore-based Startup.

⁹ Examples of companies operating in this segment include Shiok Meats (Singapore Startup focused on crustacean replacement), Finless Foods (fish) and Memphis Meats (meat).

¹⁰ This is driving value from both investors and mainstream food manufacturers such as Cargill, Tyson Foods and Temasek.

¹¹ These include Cargill, Bunge, Olam, Wilmar, ADM and Dreyfus, among others.

¹² Companies include Ingredion, Dupont Nutrition and BioSciences, Kerry, DSM, Tate and Lyle, McCormick etc.

¹³ Examples of international flavouring companies include Givaudan, Firmenich, Takasago, Symrise and IFF.

the polytechnics and universities. If the food manufacturing sector was to be supported by a more vibrant R&D culture in earlier stages (e.g. in ingredient and flavouring development) the ecosystem would grow to be considerably stronger.

The functional food space has considerable scope for expansion in a convergence of medtech, agtech and foodtech, particularly in the areas of healthcare, sports science, aged care and therapeutics. A future is envisaged whereby residents of aged care facilities and patients in hospitals are prescribed specific, daily dietary mixes of plants with specific therapeutic properties, all grown in adjacent aseptic vertical/indoor farming operations. The key value proposition here is the quality of life for patients and residents, and benefits to insurance companies, hospital and facility administrators in advancing care and minimizing operational costs. Strengthening of the validation of the functionality of the ingredients and building of business models is an area which could be focused upon in the tertiary institutions.

It is important that the food system be protected from threats such as malicious contamination, economically motivated adulteration, extortion, espionage, and counterfeiting. Threats to the ecosystem are becoming considerably more complex and traceability technology is being employed to maintain the trust that is vital for the ecosystem to function effectively. Research in this area could be actively supported in Singapore.

Already, we are seeing so called “Next Generation Sequencing” technologies being used to identify and validate multiple species in products such as dried mushrooms, seafood and ready meals, all of which are readily substituted without consumer consent. The latest advances include metabolomic approaches where the complex chemistries in different fish/meats are being used to “fingerprint” specific species to ensure provenance and authenticity. In Singapore, ‘teapasar’ is using a metabolomic fingerprinting and taste mapping technology – ProfilePrint © that generates a specific taste profile, that allows taste matching between consumers’ taste preferences and profiles of every tea on the teapasar database.¹⁴, ¹⁵

The Retail and Consumer Component

The Singapore food retail market is relatively small in terms of value but it is often seen as a bellwether for market trends and developments for other Asian markets, and international grocery research organisation IGD Asia has projected retail market growth to US\$9.9 billion by 2023.¹⁶ Supermarkets are projected to have the dominant position in food retail (approx. 55%) with the traditional wet markets shrinking to approximately 30% of the market.¹⁷

This component of Singapore’s agrifood ecosystem has evolved considerably in the last 10 years and Singapore now sources food from over 170 countries. The Singapore consumer has become increasingly sophisticated and demands a considerably more diversified selection of products. Few global cuisines are not represented on Singapore supermarket shelves. Singapore consumers are also demanding that more attention be paid to sustainability of the food they consume, the way products are made, the safety of the product, the provenance, how food companies do business (ethical considerations) and how they

¹⁴ Teapasar is the first global tea marketplace, featuring local and international tea brands, as well as exclusive and rare tea direct from farms.

¹⁵ “Next Generation Sequencing”, including “Whole Genome Sequencing” has a dual-purpose as it can also be applied to sequence, analyse, and track food-related diseases in food products. For further information, see: Jose Ma. Luis Montesclaros, Mely Caballero-Anthony, Joergen Schlundt (2018). Supporting the Genome Microbial Identifier and Whole Genome Sequencing in Addressing Food Borne Diseases in ASEAN. RSIS Policy Report, Singapore: S. Rajaratnam School of International Studies, Nanyang Technological University Singapore, <https://tinyurl.com/yxfjmf3f>.

¹⁶ Singapore Business Review (2019). Singapore’s grocery market to be worth \$9.9b by 2023. <https://sbr.com.sg/retail/in-focus/singapores-grocery-market-be-worth-99b-2023>, accessed 31 July 2019.

¹⁷ Alice Kwek (2018). Global Agricultural Information Network (GAIN) REPORT: Retail Foods Annual 2018 – Singapore. *USDA Gain Report* SN8002. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Retail%20Foods_Singapore_Singapore_6-29-2018.pdf.

engage with customers.

The increasingly demanding consumer has put significant pressure on the retail sector. The large supermarket groups – Hong Kong-based Dairy Farm's Cold Storage and Giant, and local players NTUC FairPrice and Sheng Siong, are already operating in a highly competitive, price-sensitive market. They have also been placed under pressure from new online grocery portals, and have responded by establishing their own e-commerce initiatives. There have been some high-profile casualties in this environment with Carrefour and their hyper market model exiting in 2012; more recently Big Box has ceased operations.

Singapore's online grocery market has been projected to reach S\$0.5 billion (US\$0.35 billion) by 2020, according IGD Asia. While there has been impressive growth in this sector, it still represents less than 4% of the overall grocer market.¹⁸

Redmart, now part of the Alibaba-backed shopping platform Lazada, has a market leading position in online grocery shopping providing a large array of products for delivery across Singapore often within 24 hours of ordering but faces stiff competition from Amazon Prime and the online arms of the major supermarket chains. Other online portals offer bespoke product selections ranging from seafoods, organic vegetables and products for dieting and lifestyle choices and healthy living.¹⁹ In a meeting of traditional culture and ecommerce, specially selected products and cooked meals for new mothers in confinement are available from a number of online providers. The online niche of the retail sector is also highly competitive and has had a significant number of recent failures e.g. Honest Bee.

Many Singaporeans eat at least one or two of their daily meals at hawker centres, food courts, and restaurants. Few of these are supplied with locally grown fresh produce; rather, most are supplied by growers in neighbouring Malaysia and Indonesia. This challenge may be addressed by the growing number of intensive (vertical) farms that are being developed in Singapore. However, the current cost of production is a key limiting factor that will remain an issue without economies of scale, purpose-bred varieties and a strong "buy local" campaign supported by consumers.

Increasingly, Singaporeans are relying on food delivered by companies that source meals from the wide variety of restaurants around the island. Deliveroo, GrabFood and Food Panda are most visible in this space but other small groups are also active. The challenge here is to ensure that the safety and quality of the food is maintained after it leaves the restaurant kitchens.

Human Resources and the Education Component

An adequate supply of expertise at different levels of the agrifood ecosystem is essential to ensure not just the sustainability of the sector but also its growth. The human resource needs range from those with practical operational knowhow, to those with in-depth knowledge of domains as disparate as plant or fish disease diagnosis and compost and fish feed preparation.

Three Polytechnics are active in the agrifood space to produce graduates with diplomas, such as the Diploma in Marine Science and Aquaculture, and a part-time Diploma in Agriculture Primary Production by Republic Polytechnic, the Diploma in Applied Science (Aquaculture) by Temasek Polytechnic, and the Diploma in Food Science and Technology by Singapore

¹⁸ IGD (2017). Singapore online grocery to more than triple by 2020. Food Industry Asia, 27 February. <https://foodindustry.asia/singapore-online-grocery-to-more-than-triple-by-2020>.

¹⁹ Examples include Yolo and My Cuistot.

Polytechnic. Additionally, Temasek Polytechnic is host to an Aquaculture Innovation Centre, launched in June 2019, and formed as a consortium of ten public and private entities to accelerate the research to application momentum.

In contrast, no university in Singapore currently offers a degree program in agriculture or aquaculture, although NTU, NUS and James Cook offer programs with opportunities to specialize in aspects of the agrifood ecosystem. Universities are forming alliances with recognized centres of excellence in agriculture and food science & technology e.g. the NTU – Wageningen UR relationship for research and training. Country-to-country agreements such as the Singapore Australia Comprehensive Strategic Partnership provide a mechanism to foster skills development and research exchange between Singapore entities and Australian entities like universities and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Two Australian universities with strength in the agrifood space (James Cook and Murdoch) have campuses in Singapore.

The immediate ASEAN region is home to well-established agricultural universities such as Kasetsart University in Thailand and Institut Pertanian Bogor in Indonesia. Under the auspices of the Southeast Asian Ministers of Education (SEAMEO) is the only inter-country education/research institution called the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) located in Los Baños, Philippines. Since its founding in 1966, SEARCA has contributed greatly to build post-graduate expertise in agriculture and food. Singapore needs to tap into these institutions in a collaborative manner to meet some of its human resource needs but also to conduct pre-commercialisation applied research in relevant ecosystems.

Financing the Ecosystem

Venture capital is vital to support the development of the Singapore agrifood ecosystem, but historically, venture companies have been sector-/subsector-specific with defined risk/reward structures. AgriFoodTech in Singapore is a relatively nascent sector²⁰ that is being driven by new enabling technologies and which requires patient capital, typically in a 7-10 year investment cycle which is much longer than the Silicon Valley approach. Although it is understandable that Singapore does not yet have a significant number of venture capital firms with the expertise to assess these new technologies, this is changing with the emergence of players such as Vis Vires New Protein Capital, ID Capital and Temasek all making investments.

Several venture capital companies are being supported by the SEEDS Capital Group of Enterprise Singapore, which has provided a S\$90 million (~US\$65 million) pool of matched funding to support the establishment in Singapore of several new accelerators including GROW (Agfunder+Rocket Seeder), Trendlines Agrifood Fund, VisVires New Protein, ID Capital, Hatch, The Yield and Open Space Ventures.

In a move that will further stimulate the Singapore agrifood ecosystem, Temasek Holdings, US food giant Tyson Foods, and Enterprise Singapore have backed [Big Idea Ventures](#), a new fund looking to raise US\$100 million to invest in startups focused on plant-based food, alternative protein and related food technologies. The fund will have a global focus but will require portfolio companies to establish a base in Singapore or North America.

²⁰ Jose Ma. Luis P. Montesclaros and Paul Teng (2018). Singapore's Nascent Urban Farming: Potential Future Regional Centre?. RSIS Commentary CO18195, 23 November, 2018. <https://www.rsis.edu.sg/rsis-publication/nts/singapores-nascent-urban-farming-potential-future-regional-centre/#.XVZE0-MzaM8>.

Further, several companies are focused on actively supporting the growth of the AgriFoodTech ecosystem in Singapore, including startups. Asia-BioBusiness, founded in Singapore in 2005, has a special focus on agriculture and food, leverages on its global networks and activities to help companies and organizations foster innovation, providing critical support to assist entrepreneurs in nurturing ideas, sourcing partners and identifying opportunities. Beanstalk Agtech has established a presence in Singapore with the aim of helping agribusiness corporates and large, family owned operations across Asia adopt and scale innovation into their operations to solve problems and capture opportunities. Padang&Co, an innovation company working across a number of sectors, has established a coworking space that has become the home to several agriculture corporates (e.g. Syngenta, Meat & Livestock Australia, Cargill) and startups. They also established Singapore's first AgrifoodTech Acceleration Program in 2018 along with MUFG, Grow Asia, Ferrero and Yarra. Budding Innovations helps bridge innovation between corporates and startups, including food and nutrition. Importantly all companies see opportunities to collaborate, acknowledging that the importance of Singapore as an AgriFoodTech hub for Asia will be an important step in helping both Singapore and Asia reinvent the current food system.

Policy Enablers and Implications

Singapore plays an increasingly important role across the ASEAN region in supporting regulations governing safe agricultural production through Good Agricultural Practices (GAP) and imports of safe food. What may be improved is better coordination of the different regulatory agencies associated with the agrifood ecosystem as there is no "one stop" agency which potential investors in agrifood enterprises can secure the authorization to practise. There is ongoing research in RSIS on how to create a more supportive taxation regime for achieving the 30 by 30 objective, with implications on agencies such as the Economic Development Board, the Inland Revenue Authority of Singapore, and the Singapore Food Agency.²¹ Unlike most manufacturing sectors, PFAL technologies for growing food on multiple layers/tiers within controlled growing environments are not exempt from property taxes on the fixed machinery, which impacts the return on investment (ROI) calculation in high-tech farm proposals and in turn the amount of vegetables which can be viably grown locally.

Quality Assurance Providers (QAPs) are another key enabler who provide consumers with guarantees of agrifood products' quality and safety. QAPs may provide labels and accreditation to local food outlets, such as organic certification to show that vegetables sold in their outlets are pesticide free; that aquaculture produce is grown (or presented for sale) without the use of harmful growth promoters, or addition of dangerous chemicals to enhance appearance; or that produce is grown under recognised sustainable practices. It is important that local businesses have ready access to QAPs in order to ensure locally grown produce can be readily supplied to the market.

Future Directions

For the ecosystem to be truly sustainable and circular, the issue of waste must be addressed during the production, post-production and pre-processing (logistical phase), processing, distribution, and post-consumer stages. Technology will be key but mindsets and cultures will also need to adapt. Looking to future developments in production in Singapore, the tightly

²¹ Analysis is done using the UrbanAgInvest (UAI) tool, copyrighted as an invention by Jose Ma. Luis Montesclaros (first inventor) and Paul Teng (second inventor/co-inventor), Reference Number 2018-259, © Nanyang Technological University, Singapore. The tool can be utilized via standard licensing agreements with the university, in collaboration with the inventors.

controlled environments of vertical farms will likely reduce losses due to insect pests and diseases, while the non-edible parts of the plants will still have to be collected and recycled. Waste to energy systems could be considered to reduce energy costs of these producers, and composts or value-added products developed. The produce, which would undergo relatively little further processing, would benefit from advances in packaging so that waste is reduced on supermarket shelves and in consumers' homes.

Advances in cold storage, logistics, forecasting systems and management of the transfer of the primary produce to processors will also reduce waste. Food and beverage processing can produce large volumes of potentially valuable waste that often is simply discarded with little thought of potential value in other applications, e.g. brewing waste. There is considerable waste at the later stages of distribution as a result of poor packaging/handling during transport and in the retail outlets themselves where further selection of "perfect" produce is made to satisfy the demand of consumers.

Perhaps the area where the biggest impact can be made is the post-consumer stages, in particular the waste from meals prepared at home and at restaurants. This is perhaps most challenging as it will require considerable change in public attitudes and behaviours. The predominance of a service-based food industry (i.e. hawker centres, restaurants and home deliveries) in addition to packaging at retail level creates significant additional volumes of packaging and food waste. While the Singapore Government continues to invest in the latest technologies around recycling and waste treatment, more can be done to encourage correct sorting, decentralised processing (of food waste) and adoption of innovative alternatives to single use plastics and packaging materials. Incentives could be provided to encourage recycling of food waste using biodigesters such as Bio24 being sold by Tria, a Singapore based company focused on sustainable and innovative packaging and recycling. In the long-term, new infrastructure could be included in the designs of tower blocks and waste directed to fermenters that could be used to generate power. Several companies are making strong progress in this area; however, they require scale in order to deliver solutions that are price competitive ²².

With the recent refocusing of efforts by the Singapore government, underscored by the '30 by 30' announcement, most of the key components of the Singapore agrifood ecosystem are either in place or are actively being developed. There are still some critical areas that require particular attention, though, including building expertise and research capabilities, integrating operational expertise, growing start-up entrepreneurs and creating an environment where companies can scale-up effectively. To become a true ecosystem will require facilitation, management and momentum. While pure research is important, most of the applied research should be market driven with specific outcomes in mind. Activities in the Singapore agrifood sector will further have relevance to other jurisdictions and present market opportunities in urban and rural agriculture for Singapore companies, even beyond Singapore's shores.

Once Singapore is able to prove that scalable models for agricultural technologies highlighted in this NTS Insight article (hi-tech agriculture and aquaculture, in-doors and out-doors; alternative proteins; food manufacturing) are viable within urban and peri-urban settings, a potential next step is to export these technologies to other countries in Asia with rapidly growing cities. Singapore has seen such a development trend for its own water industry - initially developing technology to solve local challenges but now exporting technology to other countries. For this to happen new research is also needed to focus on the contextualisation, financial viability, and ideal industrial organisation arrangements for adapting these technologies to other

²² Examples of companies involved in packaging innovation include Tria, Carapac, Full Cycle Bioplastics, Lactips, Shrilk, Ecoproducts and Ulma.

countries. Further research, as noted in a publication by the International Food Policy Research Institute, can draw investment, business and engineering lessons from scalable intensive urban/peri-urban agtech applications, and apply these to extensive agriculture as well.²³ For instance, the concept of smart or data-enabled farming indoors, in which ideal environmental conditions are provided for plant growth, has been to some extent applied to extensive farming by an Australia-based company, MPT Agtech. The company has developed a prototype 'smart seeder' which analyses soil characteristics to identify the ideal level of depth for seed planting.

There is no doubt that achieving 30% nutritional supply by 2030 presents a challenging target for Singapore, effectively flagging a 200% increase in domestic production in a little over a decade. The goal is bold and aspirational, calling on the innovation and resourcefulness of Singapore as a small island state to collaborate and grow, driving new export value while acknowledging that continued strong economic ties with key trading partners will need to be maintained in order that the remaining 70 percent of food supply is secured. As part of the evolving agrifood ecosystem in Singapore towards a future-ready, dynamic and responsive part of its economy, our foresighted view is that it is important at this early stage to ensure there is coordination to achieve synergy and accelerated progress. This has to be accompanied by a rigorous process of identifying priorities for investment into areas which meet Singapore's food strategy and also addresses the needs of the wider regional and global market.

²³ Jose Ma. Luis Montesclaros, Suresh Babu and Paul Teng (2019). IoT-enabled farms and climate-adaptive agriculture technologies: Investment lessons from Singapore, IFPRI Discussion Paper 01805, February 2019, Washington D.C.: International Food Policy Research Institute, Director General's Office. <http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/133079/filename/133287.pdf>.

About the Authors

Professor Paul S. Teng serves as Adjunct Senior Fellow (Food Security) in the at the Centre for Non-Traditional Security Studies (NTS Centre) at the S. Rajaratnam School of International Studies (RSIS), Nanyang Technological University (NTU), Singapore, while serving also as Dean and Managing Director of the National Institute of Education International Pte Ltd ("NIE International") at NTU.

Jose Ma. Luis Montesclaros (MPP), Associate Research Fellow with the same Centre, collaborates with both public and private sector actors in developing dynamic models for addressing policy challenges in food security; he is first inventor of the UrbanAgInvest tool (© Nanyang Technological University) mentioned in this NTS Insight.

Dr. Andrew Powell serves as Chief Executive Officer of Asia-BioBusiness, a Singapore-based company founded in 2005 which has a special focus on agriculture and food, leveraging on its global networks to help companies and organizations foster innovation and effective communication, and providing critical support to assist entrepreneurs in nurturing ideas and turning them into profitable businesses.

Rob Hulme is Co-Founder and Head of Asia at Beanstalk Agtech, a challenge-led innovation company which focuses on building Singapore as an AgriFoodTech Catalyst Hub for Asia, and helping agribusiness drive adoption and scale of sustainable food production systems across Asia Pacific.

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