More Food, Less Earth

Investigating emerging methods to grow more horticulture produce with less space and fewer inputs

A report for

NUFFIELD AUSTRALIA FARMING SCHOLARS

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2016 Nuffield Scholar

March 2017

Nuffield Australia Project No: 1623

Supported by:

The WILLIAM BUCKLAND FOUNDATION

WBF

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Executive Summary

With global population estimated to reach 10 billion people by 2050 (United Nations, 2017) and an industrial food system that is continually scrutinised, a select group of companies and associations have emerged which have started developing green cities, based on concepts that produce more food utilising less earth.

On the outskirts of many Australian and global cities there are traditional market gardens producing many of the vegetable and fruits that the nearby city dwellers require to consume at the kitchen table or at a nearby restaurant.

The idea of cultivating food has been in our culture since humanity decided to no longer be hunter gatherers. In the beginning, cultivating food was a community activity, getting people involved in the process and reaping the rewards of the fresh produce that provided nourishment required for the community.

Since the industrial revolution, big food companies have won our hearts and minds as we all opened our wallets to purchase the new, well designed, marketed and advertised food items with all the right artificial preservatives and flavourings. These companies, fuelled by the modern consumer's desire for more variety, have removed the natural seasonality of food products and resulted in produce travelling up to half way around the world before it is consumed (Kowitt, 2016).

Coinciding with the industrialisation of our food, was the commoditisation of our agricultural food source, which has challenged farmers profitability for decades as productivity was the measure for survival, not value or nutrition. This commoditisation has further disconnected urban societies from engaging and pursuing careers in farming.

However, in recent years the trend has been changing, as the modern consumer is seeking information about the food items that they are putting in their bodies, as health and wellbeing extends the traditional consumer-choice drivers of price, flavour and convenience (Deloitte, 2016).

This backdrop of industrialised food, the commoditisation of the farmer and the evolving trend in consumer preferences has created an opportunity for a new type of high value farming that is commonly referred to as urban farming.

Urban farming is one of the oldest methods of farming, in fact, it is where it all started. The resurgence of urban farming varies from the simple community gardens that are reconnecting urban societies and encouraging our younger generation to learn how to cultivate plants for consumption, to more sophisticated farm systems utilising new growing methods, such as vertical and factory farming. These new developments utilise modern technology and "big data" to try and cultivate plants more efficiently.

This study evaluates four globally emerging concepts and frameworks for urban farming and discusses five business cases, with a particular focus on leafy green vegetable production, highlighting five key recommendations which would generate more food using less earth.

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Foreword

As a first-generation farmer and founder of Australian Fresh Leaf Herbs (AFLH), now one of Australia's leading fresh herb growers and suppliers to retailers, chefs and shortly, health practitioners, I have had the opportunity and challenge of looking at a traditional industry in a very different way to the rest of the participants in horticulture.

My personal journey into horticulture did not start with me sitting on a tractor or learning about soil composition; instead, my journey started with a chef complaining that his herbs were not impressive and I thought it might be a great idea to fix this problem. As I took my first steps in what at the time was a very foreign industry to me, I quickly learned some of the challenges that farmers face on a daily basis. Just like many before me, I had the real-life experience of losing crops to heat waves, hail storms, diseases and animals.

Luckily, I was not on this ride alone; working with my business partner, William Pham, we decided that conventional, outdoor farming was not for us. The risk of cultivating herbs through conventional farming, while ensuring we could fulfil our value proposition of delivering high-quality, fresh herbs to our consumers year-round at fair prices was not a viable option.

Starting Australian Fresh Leaf Herbs in 2008, I didn't envisage that this journey would eventually see me named Australian Young Farmer of the Year (2011), Rabobank Emerging Leader of the Year (2016) and finally publishing this report as a Nuffield Scholar looking into methods, ideas and challenges around how leafy green vegetables could be cultivated into the future.

We produced a mere 2,000 bunches of hydroponic basil a week when we commenced in 2008 The market quickly rejected this crop, and it took years of trial and error until we really started to see stability in this method of cultivation. When we eventually got this right, we found we were able to produce stable, high-quality crops while mitigating the risks of hydroponics with additional conventional farming methods. From 2008 through to 2016 our focus was to expand our knowledge into new and more modern practices while continuing to build stability in our cultivation systems. Through these years Australian Fresh Leaf Herbs was very much an R&D platform with a careful balance of commercial delivery to ensure that we survived and grew.

After being named the Australian Young Farmer of the Year in 2011, I felt like I needed to do something to contribute to the horticulture industry outside of my own business, and it became very evident that a lot of people valued my insights because I was positioned as a first-generation farmer. This leads me to solidify two key objectives that I wanted to personally achieve in my tenure in the horticulture industry:

1) To encourage new farmers to join the industry, and
2) To build a new way of farming, using not only popular and emerging hardware but also software and algorithms.

When Coles Supermarkets launched their Coles Nurture Fund initiative we thought that this was our opportunity, so we applied for a $500,000 interest-free loan to build a new urban farming operation. We were successful in obtaining a loan and moved forward and built a 3,200-sq. meter concept greenhouse to showcase to the industry and prove that we could utilise software and existing/emerging technologies to provide a different perception of horticulture and farming in general. After we launched this footprint, I immediately left on my Nuffield journey with the intention to study what the rest of the world was doing in sustainable horticulture and how could I benchmark our approaches to the rest of the world.

This paper is not only a glimpse into what I found in the industry but very much a validation of some of the vision that needed to deliver a new platform for the future for leafy green vegetables.

Acknowledgments

It would have not been possible to undertake this journey if it was not for the belief that the Nuffield selection panel had in me and my passion for the industry.

Thank you to my investor, The William Buckland Foundation; without the Foundation's support, I would have not been able to complete my travels or this study.

Also, my family and in particular my wife Jillian Vydra, who has supported and encouraged me throughout this journey.

Australian Fresh Leaf Herbs director, William Pham and the whole management team that allowed me to step out of my duties at Chief Executive Officer, after and during a challenging time of growth and expansion for the business.

To the GFP team (Japan 2016) and all the friends that I have made through the Nuffield network, it was wonderful to be engaged with so farmers and industry leaders.

And finally, thank you to all the farms, businesses and governments I have visited that enabled me to compile this study, just to name a few:

- Sky Green – Singapore.
- Spread Vegetable Factory – Kobe, Japan.
- Koppert Cress – Netherlands.
- Aarav Research Facility – Israel.
- Smart Farms – South Korea.
- Gotham Greens – NY, USA.
- Aero Farms – NY, USA.
- Freight Farms – Boston, USA.
- Farmed Here – Chicago, USA.

Abbreviations

ABARES – Australian Bureau of Agriculture and Resource Economics and Sciences

ABS – Australian Bureau of Statistics

DWC – Deep Water Culture

FAO – Food and Agriculture Organization of the United Nations

GDP – Gross domestic product

HBR – Harvard Business review

IoT – The Internet of things

ISS – International Space Station

LED – Light-emitting diode

NFT – Nutrient Film Technique

UN – United Nations

Objectives

‘Urban Farming’, ‘Vertical Farming’, ‘Agtech’; these are ideas that have found their way into mainstream vernacular in recent years, but what does it all mean?

The objectives of this study are to critically analyse a number of emerging technologies found around the world which have the potential to change and define modern horticulture in the future, with a distinct focus on leafy green vegetables, whilst also framing these approaches against the present-day Australian horticulture industry as we know it and how industry might take advantage of these approaches to produce ‘more food with less earth’.

Key Objectives

- To evaluate at least four emerging horticulture models and validate if they are viable to deliver on their proposition of producing more food with less earth.

- To understand changing consumer perceptions and define what consumers want from their horticulture produce.

- To develop knowledge on current Australian horticulture practices in leafy greens.

- To understand how some of these new technological approaches may provide solutions to resolve some of Australia’s horticultural challenges.

Chapter 1: Introduction

The art and science of horticulture is a subset of broader agriculture and its origins has been retraced back to at least 6950-6440 BC to the cultivation of the taro and yam in Papua New Guinea (Fullagar, Field, Denham, Lentfer, 2006). However, it is indicated that the origins of modern-day horticulture eventuated when humanity started making its transition from hunter-gatherer to sedentary or semi-sedentary communities, who started growing small scale crops around their dwellings or cultivation areas developed during nomadic migration from one area to the next following the seasons. An example of this are the maize or 'mipa' fields developed by the Mesoamerican cultures (von Hagen, 1957).

Today these sedentary communities have become urban settlements or cities. In 2016 the United Nations (UN) published a report indicating 54.5% of the world's population resides in these urban settlements, it was also estimated that urban inhabitants would increase to 60-70% of the world population by 2030 (United Nations, 2016). Coinciding this rapid rate of urbanisation is the alarming fact that in 100 years the world's population has grown from 1.5 billion to 7.5 billion and is further expected to reach 10 billion by the middle of this century (Roser & Ortiz-Ospina, 2017), despite the fact that population growth rates are already declining (Figure 1).

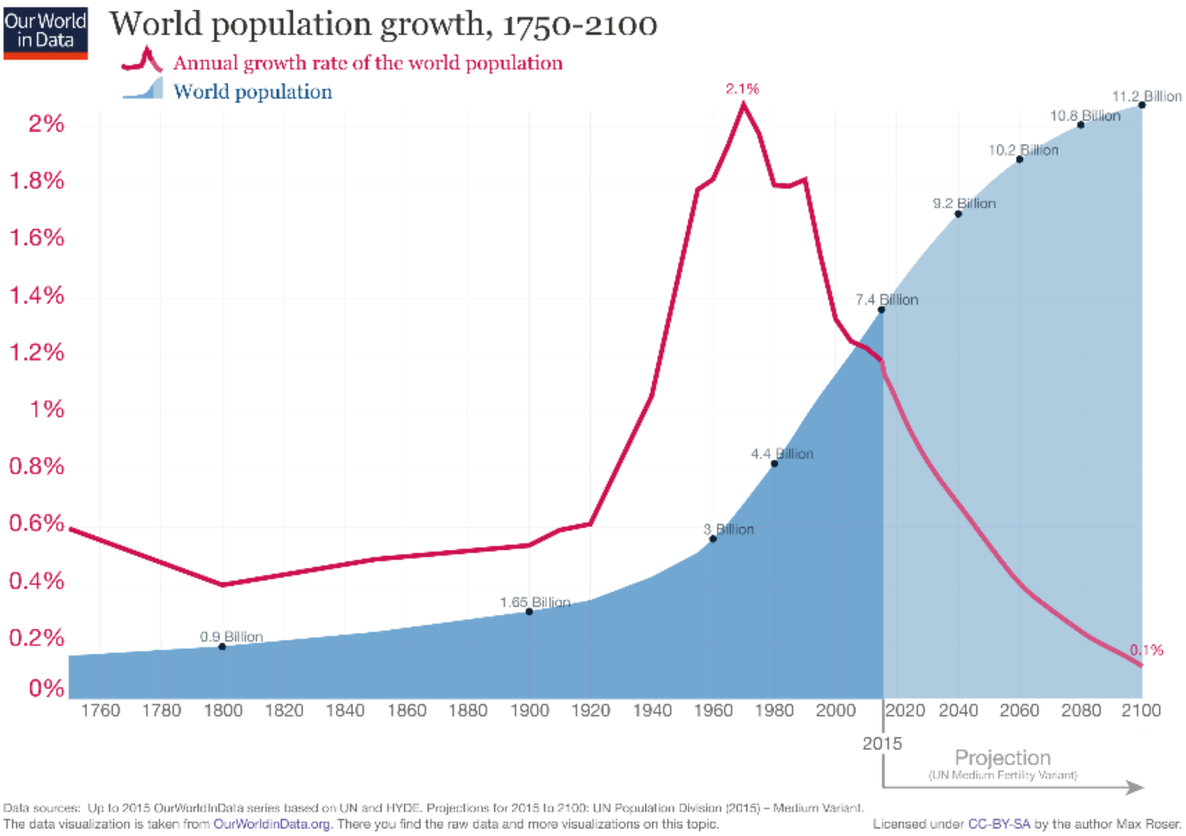

Figure 1: World Population Growth (Roser & Ortiz-Ospina, 2017)

This population growth will naturally increase the global consumption of food, forcing the evolution of agriculture practices as farmers adapt to satisfy global demand. As outlined in the Harvard Business Review (HBR) '*Global Demand for Food Is Rising. Can we meet it?*' (Elferink & Schierhorn, 2016), food demand is expected to increase by 59% to 98% by 2050. This demand for food is not only driven by population growth but rather the greater rate of urbanisation is growing a global middle class that has started demanding higher quality and nutritious food as their disposable incomes increase past $10,000 US per annum (Future Centre, 2017).

Historically, as dwellings were transformed into larger urban settlements, agriculture had to evolve and industrialised agriculture was developed to ensure that farmers could adequately fulfil growing food demand arising from the increasing global population and appetite. The World Bank estimates that 37.5% of total land area was categorised as agricultural land in 2014 (The World Bank, 2017). This has been steadily declining as the population continues to increase; Australia, for example, has lost 16% of its arable land since 1973 while its population almost doubled (Moncrief, 2012). Further, growing social awareness regarding industrial agriculture's negative impacts on the environment and human health**,** due to the nature of its consumption of arable land, water, synthetic fertilisers, lack of bio-diversity, depletion of soil fertility, use of chemicals as well as heavy machinery adding to the carbon footprint, has turned the conversation towards alternative farming methodologies (Union of Concerned Scientists, N.D).

The growth in sophistication of the modern consumer in developed countries is driving new demands on farmers and challenging the once-heralded industrial agriculture system. The key message being repeated by consumers is that they '*desire to know what they are putting into their bodies*' (Miller, 2016). First world consumers want to develop a sound understanding of where and how food is farmed, processed and delivered, taking into consideration factors like fresher ingredients, organic food production, as well as local and ethically sourced products (Miller, 2016).

All indications seem to uncover a demand for rapid change in the agriculture sector, with horticulture positioned for growth as Australian consumers seek fresher, healthier, locally grown products with a reduced environmental impact. However, modern farmers are constrained in meeting these opportunities, primarily due to the dilemma of the ageing farmer. In 2014, the FAO estimated that average age of a farmer globally is 60 years old in developed countries (FAO, 2014). Society faces the challenge of making horticulture interesting and appealing to not only younger consumers but also the next generation of farmers.

Luckily over the last decade, a movement has occurred globally called urban farming; urban farming is by definition '*The practice of cultivating, processing and distributing food in or around a village, town, or city*' (Bailkey & Nasr, 2000). Urban farming examples started to establish first as community gardens then, roof top gardens and finally vertical farms using the latest technologies (Bailkey & Nasr, 2000). Many of these urban farm concepts are extremely appealing as an alternative proposition to industrial farming and hold the potential to harness the concept of producing more food with less earth. They can also attract younger generations to the traditional horticulture industry; however, they are still largely misunderstood.

This report will present a backdrop of the Australian horticulture industry, emerging consumer trends and present new and innovative urban farming technologies. Five case studies will be summarised, looking into the inner workings of some unique urban farming concepts presented around the world, including urban gardens, small format urban farms, vegetable factories, rooftop greenhouses and vertical farms. This report will conclude with recommendations on how Australia's horticulture industry can engage with new and emerging cultivation methods to produce 'More food with less earth'.

Chapter 2: Australian Horticulture Today

Contribution to GDP

Australian horticulture contributed $9.20 billion (or 18% of total agriculture) to Australia's gross domestic product (GDP) in 2014/2015, with $0.90 billion in value successfully exported.

This is broken down into four key categories as detailed below:

- Vegetables: $3.3 billion
- Fruits and nuts (excl. grapes): $3.5 billion
- Nursery cut flowers and cultivated turf: $1.3 billion
- Grapes (total): $1.1 billion

Currently, vegetables make up 35% of total horticulture GDP, while the industry is predicted to grow at a rate of 8% per annum, exceeding $10 billion by 2020 (Horticulture Innovation Australia, 2016).

Vegetable industry statistics

Aligning to the key objectives of this report, the statistics in Table 1 have been provided to show industry context regarding the opportunities for green leafy vegetables best suited to emerging technologies. Statistics comparing outdoor and covered vegetable cropping, leafy green category performance as well as individual crop performance are highlighted.

	Outdoor vegetable growing	**Covered vegetable growing**
Revenue	$3.1 billion	$575.9 million
Historical Annual Growth (2012 – 2017)	1.1%	3.3%
Projected Annual Growth (2017 – 2022)	1.3%	1.9%
Industry Profit	$224.3 million	$39.7 million
Exports	$303.7 million	NA
Total Businesses	5,488	843 businesses

Table 1: 2016-2017 Outdoor vs covered vegetable growing statistics (Horticulture Innovation Australia, 2016; IBISWorld, 2016a; IBISWorld, 2016b)

Priority	Vegetable Category	Production Value ($m)	Production (t)	Average value (t)
1	Parsley and Other Herbs	$131.4	10,087	$13,026
2	Leafy Salad Vegetables	$271.9	49,126	$5,534
3	Eng. Spinach/Silverbeet/Kale	$20.2	7,110	$2,841
4	Leafy Asian Vegetables	$63.0	28,310	$2,225
5	Leeks	$18.5	9,379	$1,972
6	Head Lettuce	$145.5	126,635	$1,148
	TOTALS	**$650.5**	**230,647**	

Table 2: 2016 Leafy Green vegetable production (Horticulture Innovation Australia, 2016; IBISWorld, 2016a; IBISWorld, 2016b)

Traditional cultivation approaches in leafy green vegetables

Market gardens

Traditionally, green and leafy vegetables are cultivated close to cities in smaller to medium sized market gardens. Market gardens employ a range of production systems and approaches but the most common is row cropping. Row cropping refers to a system of growing crops in a linear pattern, to enhance maximum yields and light absorption (Bareja, 2011). This type of row cropping can be found near every major city in Australia and plays a major part in leafy green vegetable production to national markets around Australia. Market gardening and this production system of row cropping has been in existence since Australia was settled (IBIS World 2016).

Whilst this type of farming is effective, it has been shown that downward pressure on price really puts pressure on smaller farmers to increase production and cut costs to remain viable (IBIS World, 2016).

Covered cropping

Covered cropping, or undercover cropping is a method of growing vegetables in a protected environment which is normally called a greenhouse. Covered cropping has been increasing in popularity in Australia over the last 20 years.

A greenhouse is a ridged structure covered with transparent materials such as glass or plastic. Greenhouses are commonly referred to as glasshouses or, if heated, hot houses. The structures are designed to allow UV and thermal energy in while enabling growers to accurately regulate, environmental conditions that drive plant growth such as temperature, humidity, $C0_2$ and solar radiation (Morteza et al., 2016). Dutch growers were the key innovators in developing the covered cropping industry in Australia, starting with flowers and high value vegetable crops such as tomatoes, capsicums and cucumbers. Over the past five years the covered cropping industry has grown by 3.3% to reach $575.9 million through 2016-17 (Table 1) and is expected to continue to grow at 2.3% per annum (IBISWorld, 2016b).

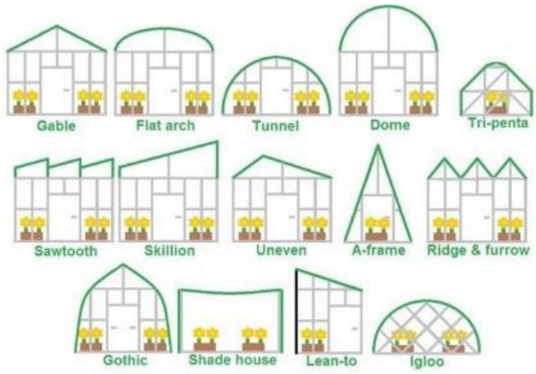

Figure 2: Greenhouses structures (Global Spec, 2017)

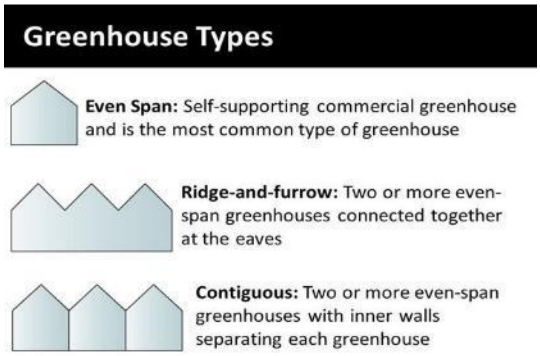

Figure 3: Greenhouses designs (Quora, 2016).

Figure 2 outlines a number of popular styles of greenhouses, as the base ridged structure can be of any type of design this creates a vast array of iterations from the standard Gable design.

Once a structure style is chosen then the type of construction material is selected, this really depends on the size and design of the greenhouse that is being built or the type of cultivation that will take place in the facility (Table 3). The below table highlights the three most common greenhouse structures built today.

Greenhouse Type	**Description**	**Advantages**	**Disadvantages**
Tunnel & raised dome (Figure 4)	Basic arch shape, from ground level or with straight walls elevating the dome 2-2.5 meters above the ground, covered with plastic sheets.	Simple structure, cheap to construct, can allow multiple spans to connect together (in raised domes).	Ventilation challenges, difficult to automate, requires gutters between connecting structures.
Sawtooth (Figure 5)	Similar to raised dome, however with rigid sawtoothed shaped roof.	Easy to ventilate, opening up the flat side of the roof area, greater choice in building material.	More expensive construction compared to tunnel and raised dome.
Gabel (Figure 6)	Most common greenhouse structure built with glass or polycarbonate panels, triangle-shaped roof with vertical sides	Low maintenance, able to construct up to 10 meters high, allowing for enhanced ventilation and airflow	Most expensive construction costs, especially with glass or poly carbonate construction.

Table 3: Greenhouses types (J Vydra, 2018)

Figure 4: Tunnel Greenhouse (Growers Supply, 2014)

Figure 5: Sawtooth Greenhouse (Agratech, 2017)

Figure 6: Gable greenhouse (Gothic Arch Greenhouses, 2017)

Hydroponics

Greenhouses of all designs, frequently utilise hydroponic growing methods to cultivate crops. Hydroponics refers to growing plants without soil in a water-based nutrient solvent, that can be of organic nature (fish or waste products) or synthetic, such as fertilisers (Santos et al. 2013).

There are a number of hydroponic systems that are commonly used, including Nutrient Film Technique, Wick Systems, Deep Water Culture, Ebb and Flow, Aeroponics & Drip systems, outlined in further detail below

Nutrient Film Technique (NFT)

NFT is a hydroponic technique where a very shallow stream of water with dissolved nutrients flows down a gully in which plants are positioned.

Figure 7: NFT Channels (J.Vydra, 2016)

Nutrient rich water comes in contact with the plants bare roots, providing the necessary irrigation, nutrition and oxygen that enables plant growth.

Water reticulates through the gullies and back to a holding tank where fresh water and nutrients are added. This system is highly effective for growing crops and traditionally uses only one tenth of the water and one third of the fertiliser when compared to traditional field farming (Ferrarezi & Testezlaf, 2016).

Seedlings are normally placed into the NFT gully system in a supporting media, such as Rockwool, perlite or peat. This approach is widely adopted around the world in leafy green and fruit crops such as tomatoes, cucumber and capsicums.

There have been disease concerns using this method historically, as recycled water can breed diseases; however improved water sterilisation and sanitation solutions have vastly mitigated these risks. Other concerns have been power outages and system failures as, in most cases, plants require a constant flow of water and nutrients (Ferrarezi & Testezlaf, 2016).

Wick systems

Figure 8: Wick System (Epic Gardening, 2017)

This is one of the most basic system in hydroponics as it doesn’t have many moving parts. The system comprises of a pot/container filled with growing media, such as vermiculite, perlite, coconut fibre or peat, and seeds or seedlings are planted into the media.

Below the pot /container is a reservoir with nutrient rich water, dipped into this reservoir is a wick which goes into the growing pot and comes in contact with the media (Ernst & Busby, 2009).

The plants absorb water and nutrient from the reservoir as required through the wick, providing necessary irrigation and plant nutrition (Ferrarezi & Testezlaf, 2016). This system is considered a passive system and once the reservoir is setup, monitoring of water level is all that is required.

However, this system is not suitable to larger plants, as they require more water and nutrients than the wick can provide. Furthermore, incorrectly positioning the wicks can result in the incorrect levels of irrigation.

Deep Water Culture (DWC)

Deep water culture is the opposite to NFT where plants are exposed to a thin film of water. In DWC plants are suspended above a deep vessel of water and roots dangle into the water. Just like other hydroponic systems, the water is nutrient rich, but also aerated to ensure that plants receive appropriate levels of oxygen to allow effective growth to occur (Just 4 Growers, N.D).

Water temperature and oxygen are critical in this style of system because of two key reasons;

- If water temperature exceeds 21^{0}C, the dissolved oxygen is reduced, causing growth of bacteria that attack the plant roots and ultimately impact the plant health. The most common disease seen in these system is root rot.
- If water temperatures fall below 16^{0}C, plant growth beings to slow increasing the potential for plants to move into dormancy stages.

Therefore, optimal temperatures are kept between 17 and 21^{0}C, which is achievable within a controlled growing environment, however the energy cost trade-off needs to be evaluated (Just 4 Growers, N.D).

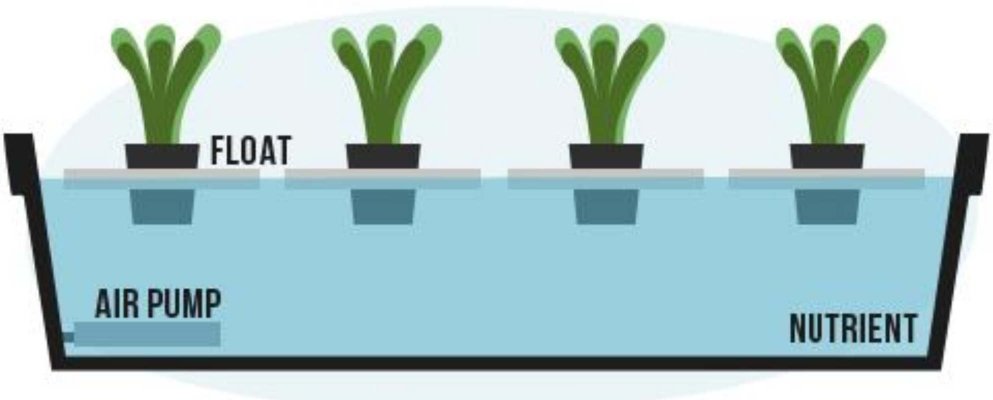

Figure 9: Deep Water Culture (The Moor Mart, N.D).

Ebb and Flow (Flood and Drain)

Ebb and Flow is a technique in which individual pots/containers, filled with growing media and the seeds or seedlings are placed on a larger tray which fills with water and then evenly drains away.

As the trays fill with water, the individual pots/containers take up the moisture and nutrient through, directly feeding the plants.

Figure 10: Ebb & Flow tables (J.Vydra, 2016)

Ebb and Flow systems adjust irrigation cycle, depending on the requirements of the plant as well as how well the media retains water. Some systems run just once a day and other system run six-to-eight times a day. This system has advantages over other hydroponic systems, as plants are not constantly standing in water, reducing the likelihood of root-born mould such as Pythium. Furthermore, plants can receive the optimum level of nutrient and irrigation (Ernst & Busby, 2009)

This system also presents challenges regarding disease management; careful sterilisation of equipment and water sources needs to be managed regularly to ensure bacteria and pathogens are controlled. This level of sterilisation can add complexity in infrastructure setup and operational costs.

Aeroponics

Aeroponics refers to growing plants without any media or aggregate; seeds are sown onto a cloth that is suspended over a tray. Beneath the cloth are a series of micro-fogging/misting jets that mist the cloth from below. The mist comprises of water and nutrients, which is atomised to a micro size and then sprayed consistently to the root mass, allowing the plant to take up high levels of oxygen, nutrients and water. The plant roots are suspended in the air and the foliage grows above the tray (Carruthers, 1992).

Figure 11: Aeroponics (Powerhouse Hydroponics, 2017)

This method has been utilised since the 1950s and more recently, NASA have deployed aeroponic systems to grow lettuce on the International Space Station (ISS). (NASA, N.D). Currently this style of growing has been proven and is practiced commercially on smaller scales, as it is limited to green and leafy vegetables. It has been shown that this method of growing has been the most efficient for water use, requiring only 3% of the water used by traditional farming. It has also been shown that this method is also the most technical method, and near-perfect conditions regarding droplet water distribution need be created, otherwise plants dry out, grow unevenly or lack nutrition (Carruthers, 1992).

However, disease management is more robust than with other hydroponic techniques, as the nutrient fluid can be sterilised and plant to plant contact is minimised. Furthermore, the high levels of oxygen in the root zone control the growth of pathogens and bacteria.

Drip systems

Drip feed system involve running individual drip irrigation lines to each plant, and drip feeding them with a water and nutrient solution (Graham, Zhang, Woyzbun & Dixon, 2011).

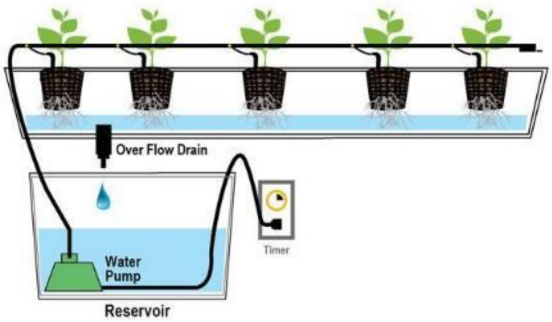

Figure 12: Drip Systems (Epic Gardening, 2017)

This technique is commonly used in larger fruiting crops like tomatoes, capsicums and cucumbers. Each dripline is inserted into the growing media, commonly Rockwool, peak perlite or vermiculite.

Just like other hydroponics systems, water and nutrients are drawn from a holding tank or reservoir, and efficient nutrient and irrigation control ensures plants receive their optimal requirements while any excess water or nutrient is washed away (Ernst & Busby, 2009).

Whilst this system is fairly straight-forward, it is quite laborious to setup and requires continual monitoring and maintenance to ensure that the driplines do not fall out of place or get blocked. The major advantage is that using hydroponic methods in covered cropping environments has over traditional outdoor vegetable farming is protection from the weather as well as the control these production systems provide growers. This, in turn, has allowed growers to deliver a greater level of consistency and quality to their consumers.

Companies such as Costa's, Perfection fresh, Flavorite and recently Sundrop Farms have grown rapidly to establish themselves as major market shareholders. These companies have continued on with what their counterparts started many years ago, by cultivating the major fruiting crops such as tomatoes, capsicums, and cucumbers (IBISWorld, 2016a).

In the leafy green space of herbs, lettuce and Asian vegetables, the move to covered cropping has been slower, as these are smaller markets with highly volatile prices, which favour outdoor vegetable farmers that are able to work at a lower cost price throughout their season. However, farms like Fresh Zest (NSW), Hydro Produce (NSW), Australian Fresh Leaf Herbs (VIC), Holla Fresh (SA) and Costal Hydroponics (QLD) have begun to establish themselves using this approach which gives them the ability to supply year-round to their customers.

Production risks and examples of challenges

The largest risk to cultivation is the weather and climate; both outdoor vegetable and covered cropping farmer experience weather challenges that adversely and positively affect their crops.

In the southern states of Australia, temperature is a major risk factor for growers. Many parts of Australia south of Brisbane, or 27 degrees south latitude, can regularly experience temperatures between zero and five degrees through the winter months (Bureau of Meteorology, 2017), significantly increasing the risk of frost damage outdoors as well as high humidity in undercover cropping. Some of the hardier crops can survive through these conditions, however the cold weather can cause many plants to enter a state of dormancy, delaying crop rotations and increasing their susceptibility to disease.

On the other end of the spectrum, as Australia's southern states enter the warmer summer season, higher temperatures can result in extreme heat waves lasting for days if not weeks of above 35^0C temperatures. These sweltering heat waves cause young seedlings, as well as harvest ready crops in the outdoor paddocks, to burn. This in turn leads to inconsistent supply or lower quality produce (ABC, 2017).

Throughout Australia's tropical regions, north of 27 degrees south latitude, growers face a different set of challenges. Throughout the months of May – October the climate is stable, producing night temperatures of 15^0C and day temperatures of 25^0C (Bureau of Meteorology, 2017). However, as the tropical wet season starts in October, growers find it difficult to produce leafy greens, primarily due to the high humidity rates attracting fungus disease, the inability to get machinery into a paddock due to flooding and leached fertilisers due to heavy rain (Applied Horticultural Research, 2013). These conditions also make it difficult to start the profitable winter season, as the end of the wet season is very unpredictable. Some years the wet continues heavily throughout March and April, damaging or washing away new seedlings and sowings, therefore delaying the first crop in May to be harvested on schedule (Applied Horticulture Research, 2013).

The tropical regions in Australia are also prone to regular extreme weather events, such as cyclones, high winds, king tides and flooding. This makes it very difficult to justify heavy investment in infrastructure and large scale covered cropping investments (Food and Beverage, 2009).

Water

Access to safe water and rainfall is critical for vegetables; over the last decade many vegetable farmers growing in outdoor conditions have been exposed to changes in rainfall, effecting stream flow and directly impacting access to farm water supplies.

The Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) annual 'Australian vegetable-growing farms economic' survey (Ashton & Weragoda, 2017), stated that most vegetable farms were unable to rely on rainfall and required to be part of an irrigation scheme, groundwater or have on-farm water catchments and storage (Ashton & Weragoda, 2017). Whilst farmers have shown to be very resilient in drought conditions, many have confirmed that drier than average years have directly impacted their annualised production performance (Steffen, 2015).

Labour

The Australian horticulture industry relies on a large pool of low-skilled labour to perform tasks that are not at present easily automated. Vegetable farming staff are required to perform tasks such as planting, weeding, harvesting and packing goods. Unlike other industries, the Australian horticultural industry relies on international tourist workers to fulfil these functions (Patty, 2017). This, in combination with recent changes to working holiday visa conditions, has caused a nation-wide shortage of labour. Recent estimates suggest more than two-thirds of vegetable growers have difficulty retaining adequate labour supply, causing an estimated 63% of produce in these farms to remain unharvested (Patty, 2017).

Both outdoor vegetable production and covered cropping are affected by these labour shortages; however, as covered cropping operations are much more intensive, they lend themselves to automation more than outdoor vegetable farming, providing alternative methods of solving labour shortages.

Food safety

The expectation consumers and supermarkets hold regarding the safety of their food has continued to increase, which is evident in the increase in food recalls (Food Standards Australia & New Zealand, 2017). While everyone should have access to quality and safe produce, this shift in consumer expectations has especially increased the risk associated with outdoor vegetable farming, regarding the handling and use of raw fertilisers.

The major concerns of contamination vary significantly across all food groups, however within the vegetable industry, microbial activity for E. coli, Listeria and Salmonella are the most problematic contaminants. E.coli is found in the intestines of humans and animals and can affect vegetable crops through a contaminated water source. Listeria is a bacterium found in soil and water, while Salmonella is a common animal bacterium, both of which are likely to contaminate vegetables through the use of organic fertiliser, or animal pollutants such as bird droppings, rabbit or rodent activity (Lawley, Curtis, & Davis, 2008).

While good farming practices should mitigate the risk of contamination through humans, outdoor cropping has a greater risk of having these bacteria introduced to the system. This has been evident in the most recent case of a major Salmonella outbreak in Australia in February 2016. Tripod Farms supply both domestic and international markets with pre-packaged salad leaves, grown in conventional outdoor production systems. Despite having robust quality systems in place to protect against any outbreak, there were still close to 100 cases of Salmonellosis recorded around the country ("Tripod Farmers", 2016).

Chapter 3: Changing Consumer Expectations for Horticultural Produce

Larger marketing campaigns, elaborate packaging, and industrialised products no longer have the consumer advantages that they had over the last two decades. Today the modern consumer is searching for transparent, natural and honest offering from smaller local companies (Kowitt, 2015).

The norm for consumer preferences is now changing and while conventional factors such as price, taste, and convenience are present in the consumers purchasing decisions, the emerging drivers of choice are health and wellness, safety, social impact, and experience (Deloitte, 2016). The important common factor in these new drivers is the notion of transparency. Companies, and their products need to earn higher levels of trust than ever before, as consumers become even more discerning, searching for honest products and companies who align to their values and beliefs (Deloitte, 2016).

The following sections will delve into these the four emerging drivers.

Health and wellness

Consumers are increasingly concerned with what we are putting into our bodies, giving greater attention to things such as nutritional content, organic certification, and source, as well as artificial foods, colours and flavourings (Deloitte, 2016).

The growth in available organic foods, fortified foods, local production, as well as the emergence of super foods has been evidence of this trend. Women are leading this trend, as well as those with higher education, as they make themselves aware of the positive impacts of healthy food choices and building a knowledge base of where and from who their food is coming from (Deloitte, 2016).

Given that one person’s definition of health and wellness will be different to the next, it is difficult for companies to identify what consumers are searching for and position their products a way that will align with the consumers desires.

Because the consumer is in search of more information regarding health data, product labelling has now shifted from relying on a single attribute, such as carbohydrates or sugar content, to providing a broader range of attributes such as whole grains, low sodium, high fibre, no preservatives, no GMO and natural (Deloitte, 2016).

According to a Deloitte (2016) study on consumer trends, today’s consumers actively seeks an average of 5.4 claims on the packaging of their products and considers 9.9 nutritional facts about the product when making a purchasing decision, a total of 15.3 claims and facts that consumers are seeking around health and wellness when considering a product purchase.

Furthermore, consumers are willing to spend a 10% increase in cost if their health and wellness requirements are satisfied.

Safety

A fundamental concern for consumers is ensuring their food has been grown, packaged and transported using methods to ensure the safety of the product, eliminating the risk of contamination from carcinogens, chemicals and unknown allergens. This has spurred on the rise in popularity of the organic and local food movement.

The popularity of organic food has continued to grow, as concerns regarding toxicity and chemicals in food continue to increase. While organic food has been around since the 1920s, the higher costs associated with production methods has resulted in a primarily affluent customer base. As its popularity continues to increase however, it is expected over the next five years that downward pressures on prices will make organic food easily accessible to the masses (Hempel & Hamm, 2016).

In addition to organic food, the popularity of locally produced food is continuing to grow as consumers consider the environmental, safety and quality concerns of production. Studies have suggested that consumers prefer locally grown to organic produce (Hempel & Hamm, 2016), but are willing to pay a premium for both local and organic produce (Mugera, Burton & Downsborough, 2016).

Social impact

The social impact refers to the consumers desire to align themselves to companies that operate in a responsible way.

Drivers of the social impact are factors such as;

- Animal welfare.
- Local sourcing (measured as food miles).
- Commitment to food safety.
- Environmental responsibility.
- The producing company's role in their community.
- Ethical treatment of employees and their safety.
- Company mission and values.

Examples of these social drivers in Australia are evident in recent matters such as the union involvement and media coverage around exploitation of the use of labour hire and seasonal migrant workers in the horticulture industry (Meldrum-Hanna & Russel, 2015; Blucher, 2015 etc.)

Consumers identifying with food miles is a symptom of globalisation and free trade, enabling year-round availability of normally out of season product. Unfortunately, as produce travels, carbon emissions are accumulated. Increased emissions have prompted consumers to look for locally gown or manufactured products and further enabled $C0_2$ labelling to be applied to the products for consumers to identify clearly what the carbon footprint is for the products that they are purchasing.

Consumers are increasingly aware of the significant environmental and social cost of food waste, it is estimated that on average 1.3 billion tonnes of food, or one third of all food produced is lost or wasted each year, with the majority of that coming from developed nations FAO, 2017a). This has led to consumers favouring products that use compostable or recycled packaging, or single serve products, such as home meal delivery kits which promote delivering the perfect amount of fresh produce to eliminate wasting any fresh food.

It has been identified that millennials and wealthier consumers in particular, go beyond the direct attributes associated with the supply chain and are looking to connect and understand the core values of the company and what the people behind the company represent (Deloitte, 2016).

Experience

Consumers are looking for a genuine, authentic experience with food, and a diverse range of food products to choose from. This is evident in the increasing diversity, and speed of new product launches, as well as the rise in specialty produce stores, farmers markets and alternate supply opportunities such as meal delivery services. Meal delivery services such as Marley Spoon and Hello Fresh offer a unique proposition as a subscription based service delivering fresh food and ingredients to the consumers home, with convenient recipes and instructions for easy preparation of fresh, nourishing meals. The global market size of this sector is expected to increase from $1B USD to $5B USD in the next ten years (Thomas, 2016).

Increasingly, it has been shown that it is the large food companies which are the ones that are struggling to diversify to meet this shifting customer demand. This has been shown in studies such as Kowitt (2015), who have identified that since 2009, 25 of the largest US food and beverage companies have cumulatively lost almost $18(USD) billion in market share, while smaller enterprises are making the most of this opportunity and diversifying to meet the consumers demands.

Chapter 4: Types of Emerging Urban Horticulture

Urban farming has begun to take shape over the last decade as populations in developed countries have become more concerned about food origins, labour ethics, how produce has been farmed, how healthy it is and the impact that food production is having on the environment.

In its most simple form, urban farming is returning the cultivation of fruits and vegetables back to the city centres rather than relying on large scale industrial farming model. A basic example of urban farming can be seen in many inner city residential homes that have a vegetable patch in their garden or pots on their balcony.

As greenhouse technology has advanced in recent years, in particular with light emitting diode (LED) lighting, heating, robotics, energy storage, solar, computer technologies and the Internet of Things (IoT), the concept of urban farming has become more appealing to the younger, techno-savvy generations. This is evident with the most recent research from the FAO (Food and Agriculture Organisation of the United Nations) showing that over 800 million people are now active participants in urban farming in over 150 countries, (FAO, N.D).

All around the world, there are examples of urban farming methods, from simple farming at local parks, on factory roofs or in shared backyards, to more complex vertical factory farms, cultivating in used shipping containers and designing closed loop production systems in aquaponics (waste produced by fish to feed plants).

This chapter will analyse five of these emerging urban farming systems in further detail, explaining how they work from a high-level perspective, whilst correlate each system back to three key imperatives presented in this paper:

- Sustainable cultivation.
- Financial feasibility.
- Ability to improve industry the attraction of the industry to new entrants.

Urban community gardens

Urban community gardens are small farms developed on urban plots of land ranging from 1/10th of a hectare to two hectares in size. The majority are not run as a for-profit exercise, rather more as a community engagement tool, with many located in less affluent areas, designed to enable members of the community to have access to fresh, quality and affordable produce (Lanier, Schumacher & Calvert, 2015).

These urban gardens have an extremely low running cost as they have an enormous advantage of proximity to the end-consumer. Most community gardens are within a few blocks of their consumers and the majority of consumers pick up their produce directly from the garden. This means that packaging, transport and handling costs are removed from the supply chain which vastly improves cost performance. Furthermore, many consumers of the produce cultivated actually work on the farms in their spare time as a part of the community involvement. This not only creates engagement but also drives operating costs down.

Because community gardens are not essentially cost focused, they can grow produce to the requirements of the gardens local community and not be concerned with crop rotations. This allows a much wider assortment of produce to be grown such as grains, root vegetables, mushrooms, fruits and in some case animals and animal products. This is vastly different to the larger commercial vertical and indoor farming models that will be presented later in this chapter, which require fast growing, leafy green vegetables to justify capital and operational costs.

It has further been shown that community gardens are up to 15 times more productive on a square meter basis than that of conventional horticulture. Community gardens have also shown the ability to generate one job every 100 square meters of garden production (FAO, 2017b). Besides providing localised fresh food and increased local employment, another benefit that urban gardens provide to their communities are an opportunity to recycle urban wastes, to create greenbelts within cities and to improve city food security, whilst building resilience to climate change (FAO 2017b).

The key concerns raised by local governments, health departments and the FAO is mainly around health and environmental risks from the potential use of contaminated land, pollution from industry or cars impacting on toxicity levels in the produce. Also, run-off from the urban farms through the use of fertilisers, pesticides, waste from composting and use of animal fertilisers have been a concern. Local officials have also identified that due to the microscale of community farms, there have been instances where farms are not appropriately registered businesses and lack required accreditation. In some countries these farms have been identified as illegal (FAO, 2017a).

Some examples of working community gardens in the United States include:

- Detroit has a vibrant urban farming community, producing more than 180,000kg of produce in 2014 across its more than 1300 community, market and school gardens. (Royte, 2015).
- Philadelphia's squatter gardens and community gardens produced 900,000kg of produce across 226 gardens, worth approximately $4.9 million in retail value in 2008 (Royte, 2015).
- Brooklyn, NY, Added-Value Farms supply the low-income neighbourhood of Red Hook with around 180,000kg a season of fresh fruits and vegetables (Added Value Farms, N.D).

- Camden, New Jersey which is a city of 80,000 with only one supermarket (in 2008), 48 community gardens harvest almost 14,000 kilograms of vegetables through the summer season, generating almost 140,000 individual servings of fresh, nutritious fruit and vegetables (Royte, 2015).

In Australia, one of the most populous community garden initiatives is Stephanie Alexanders 'Kitchen Garden'. This school-based program combines community gardening in primary schools around Australia. This initiative has been incorporated into the extended curriculum targeted at 8 to 12-year-old children learning gardening and cooking skills that can be useful in the rest of their lives. Currently over 1,000 schools nationally have subscribed to the program and have active gardens operating in Australia today (Kitchen Garden Foundation, N.D).

Figure 13: Stephanie Alexander's Kitchen Garden Program, Wendouree Primary School (Wendouree Primary School, N.D).

To conclude, it is evident that urban community gardens have a positive impact on urban communities, in particular by providing access to food for the lower socio-economic demographic. Programs outlined above such as Stephanie Alexanders 'Kitchen Garden' in Australia and 'Add-value' in Brooklyn NY, allow a range of people that would not normally come in contact with farming, to adopt cultivation experiences. However, reviewing the statistics, as well as understanding the growing need of food demand, it is evident that 'Community Gardens' simply cannot provide the throughput in produce required to feed an entire city.

Rooftop greenhouses

Rooftop greenhouses are traditional styles of greenhouses built on commercial rooftops. The majority of these greenhouses utilise hydroponic production techniques such as NFT. The ability to utilise existing roof space mitigates the problems in finding available land in urban areas.

CASE STUDY 1: Gotham Greens, Brooklyn New York

Figure 14: Gotham Greens, Brooklyn NYC (Gotham Greens, 2017c).

Gotham greens was founded in 2008 by Viraj Puri and Eric Haley and currently operates approximately 1.5 ha of rooftop greenhouses across three sites in New York and one site in Chicago. The company has built locally manufactured gable-style greenhouses and utilises traditional NFT style hydroponics on top of rooftops such as warehouses, bowling alleys and also a popular supermarket, 'Wholefoods' in Brooklyn, NYC.

The founder's motivation to start the enterprise was the fact that through the winter months in New York many vegetables were coming from California, Mexico and as far as Israel. This prompted the founders to take a broader view of the current industrial agricultural system in the US and from their findings, were confident they could establish a viable rooftop greenhouse system that could deliver year-round, pesticide free, environmentally friendly produce to the New York community.

Produce is grown in 3.6m NFT channels, as detailed in Chapter 2. Seedlings are germinated within each facility, planted into the NFT system and harvested at the end of their growth cycle, which varies from four to six weeks depending on the time of year and variety. Throughout the growing process, climate is regulated through heating and venting, whilst supplementary lighting is supplied to the plants throughout the winter months to ensure that healthy plant growth is achieved.

The company has designed its greenhouses with sustainability in mind, by installing solar panels to offset its energy usage. Furthermore, taking advantage of their elevated rooftop position, the greenhouses utilise natural breezes as passive ventilation instead of running energy-consuming fans and extractors (Gotham Greens, 2017a). They grow 10 types of leafy greens including herbs, salads and Asian vegetables, as well as gourmet tomatoes. A small percentage of the produce is supplied directly to supermarkets below (in the case on the Brooklyn site), with the remainder of produce sold to local retailers, restaurants and food service distributors within their geographical catchment area (Gotham Greens, 2017b).

Gotham Green's lead grower, Aaron Fields, confirmed that the company, with the support of their 120 plus workforce, run a viable operation, delivering consistent products to its local customers (A. Fields, personal communication July 24, 2016).

Fields explained that he saw three key challenges in delivering the Gotham Greens proposition;

- Return on investment: due to the nature of building on rooftops, the capital costs of construction are high, so return on investment can be challenging.
- Access to sites: as the sites are sharing loading docks with warehouses and supermarkets, access can be restricted and needs to be managed carefully.
- Shading in summer: New York, with its vast skyscrapers, cause problems with shading in the greenhouse when the sun is low in the sky, which has an adverse effect on plant growth.

Small format modern urban farming

Small format modern urban farming refers to new popular urban production methods, usually utilising temporary structures and delivering agricultural production on a small footprint, normally small enough for one person to operate. Some examples of these include shipping containers being converted into vertical production systems, instore/restaurant growing systems and cool rooms being converted into vertical growing systems.

This production method frequently incorporates fully-enclosed hydroponic systems operating LED's, dehumidification and heating to cultivate their leafy green produce. With a strong emphasis on technology adoption, such as the use of integrated applications allowing operators to connect with their growing system as well as local customers, these start-ups are catering to younger generations who are excited to see the adoption of technology within the horticulture space.

CASE STUDY 2: Freight Farms

Brad McNamara and Jon Friedman founded Freight Farms in 2009 when they identified that people are increasingly living in populated cities and becoming more educated about where their produce is coming from (Freight Farms, 2017).

As a small format urban farm, Freight Farms developed a transportable vertical farm utilising 13m shipping containers called the 'Leafy Green Machine'. The company has cleverly adopted a suspended channel in which the plants are positioned and hang from the ceiling on hooks.

The water and nutrient solution are dripped down each tower and come in contact with the root mass, allowing the plant to feed and grow. LED strips are positioned vertically between the towers and provide the correct levels of light to allow the plants to photosynthesize, this allows the plant to grow horizontally towards the light source (B.McNamara, personal communication July 26, 2016)

Figure 15: Planting seedlings in tower (J. Vydra, July 2016)

Figure 16: Germination drawers (J. Vydra, July 2016)

Figure 17: The Leafy Green Machine (J. Vydra, July 2016)

Operators perform all necessary farming functions within the container from germination to packing. Seeds are germinated onsite and placed into dark drawers to enable the plants to strike. Once the seedlings are established, they are positioned in the tower, and held in place between two lines of foam. The tower is then returned to the racking, and are regularly irrigated and heated under LED lights to enable the plant to grow to its full size within 21-35 days from planting.

Once produce is ready to harvest, the towers are taken back to the work bench, and produce is picked and packed into cardboard boxes and delivered to local restaurants, cafes and caterers.

The company indicated that one container is easily operated by a single operator spending around 15-20 hours a week and would be estimated to generate around $45,000-$50,000 USD in gross sales per year.

Each Leafy Green Machine holds 4,500 plants across 256 towers and produces crops such as butter lettuce, basil, dill, kale, arugula and many others. However, their 4,500 plants a month model is based on cultivating only mini heads of lettuce. Calculating yield for a more diverse range of crops would need to take into consideration the different growing profiles and conditions of the varieties.

The company has built a small footprint with very small, and environmentally friendly, operating inputs including:

- 100kw/h a day of energy.

- 18-75 litres of water per day.
- Approx. $300 USD overhead costs per month (seeds, media, nutrients).

The effort that the operator puts in is really what they are getting paid for with this system, however it was identified that inner-urban leases can be challenging and cost of power needs to be closely reviewed.

In discussions with CEO Brad MacNamara of Freight Farms he indicated that over 100 Leafy Green Machines have been deployed and his system was not only reducing food travel miles, but making farming accessible to the urban society (B. McNamara, personal communication July 26, 2016)

Vertical Farming & Vegetable Factories

Extending on the small format modern urban farming concept are the larger, more industrial sized modern urban farms, frequently built inside factories around the urban fringe. These are generally technologically advanced, fully enclosed and sterile systems that produce mainly leafy greens in a vertical farming style format.

CASE STUDY 3: Spread in Japan

Since the Fukushima nuclear disaster in 2011, there has been unprecedented growth in vertical factory farms in Japan, with over 200 farms established around the country in the past six years.

'Spread' near Kobe in Japan is an operating vegetable factory producing 21,000 heads of lettuce a day. The factory is positively pressurised, creating a sterile environment throughout the 2,870m^2. facility. Estimates indicate the facility uses 13 times less water than if their crops were produced using traditional agricultural practices. Furthermore, all evaporated water is captured by the conditioning system and recycled to be used again to water the plants (J Price, Personal communication, 23 June 2016).

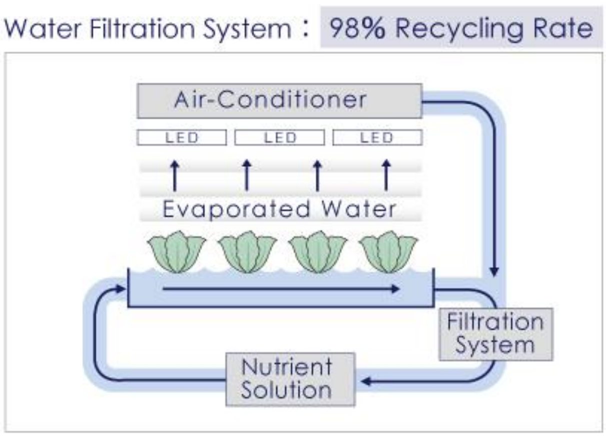

Figure 18: Water Filtration System (Spread, N.D)

Further environmental considerations include creating an herbicide or pesticide-free system, eliminating potential harmful run-off into waterways. Distribution is also localised, reducing transport costs and environmental impacts.

Seedlings are cultivated onsite in a high-humidity chamber. Once the seedling has established, they are transported to the planting bays. The hydroponic system enables the root mass to be exposed to nutrient rich water from below, with LED lights above to drive plant growth. As the plants and system evaporate water this is then recycled by the conditioning system and re-used.

The factory is currently producing four varieties of lettuce; frill lettuce, pleated lettuce, Mediterranean lettuce and red and green lettuce. A company representative outlined that only four varieties are being grown, primarily because the company found that getting plant conditions correct is much more challenging compared to outdoor agriculture. The average growing time to maturity for these varieties is approximately 21 days (J Price, Personal communication, 23 June 2016).

CASE STUDY 4: Sky Greens, Singapore

Sky Greens, founded by Jack Ng in 2010, claims to have the world's first low-carbon footprint vertical farm. The system itself is not an enclosed system or indoor factory, the innovation is in the plant movement process itself.

The system is built on a steel A-frame that sits on a footprint of about 5.5m^2. Hydroponic channels filled with growing medium and seedlings, are rotated up and then down the A-Frame structure for 10 hours each day. This enables each plant to get an even amount of sunlight and air circulation to achieve successful cultivation of leafy greens such as Asian vegetables, lettuces and herbs (Ng, Personal communications, 10 June 2016).

The site in Singapore is not in a glass house or enclosed factory but rather stands almost out doors and is covered by a basic PVC roof with fly wire screen sides to keep the insects from getting to the produce.

The system can produce approximately 4,500 plants per square meter, vastly more in comparison with 600 units per square meter with convention farming (Sky Greens, 2014). Each tower only uses 40 watts of energy a day, as the tower trays movement is simply driven by a basic water pump, filling the trays one by one and the weight of the water creates the movement for the rest of the trays.

Figure 19: Sky Greens A-Frames (J.Vydra, June 2016)

While the system runs highly efficiently and profitably in Singapore, it is important to note that Singapore is close to the equator and has long daylight hours with the sun high in the sky for much of the year. Deploying this style of growing system in the same format in Australia would require modification and supplementary lighting to sustain an even plant growth.

The company had claimed that an individual tower producing 4,500 plants a year/m^2 delivered a positive return on investment in around seven to eight years, assuming similar growing conditions (Ng, Personal communications, 10 June 2016).

CASE STUDY 5: AeroFarms in New York, USA

AeroFarms was founded in 2004 with the mission to mix data science and controlled agricultural systems to deliver safe, dependable, nutritious food to local communities. Aero farms have adopted an aeroponics style of hydroponic cultivation, further detailed in Chapter 2.

AeroFarms do not use soil, instead they lay their seeds on a micro fleece stretched in between a channel. There are three tubes in the channel with micro-misting jets, these jets atomise the nutrient rich water on a timer causing the mist to come in contact with the bare roots and nourishing the plant.

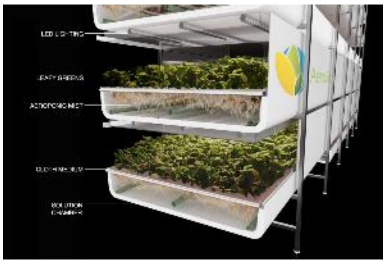

Figure 20: AeroFarms Technology (AeroFarms, 2017a)

Figure 21: AeroFarms Racks (AeroFarms, 2017a)

Figure 22: AeroFarms LED Lights (AeroFarms, 2017a)

Above the plant are LED lights to provide sufficient light levels for photosynthesis to occur, ensuring that healthy plant growth is achieved.

Similar to previous vegetable factories the company claims a 95% saving on water usage, no pesticide usage, no soil and no sunlight requirements.

Currently the latest facility grows 20 different types of short stem leafy greens including arugula, spinach, rockets, basil etc. Their system claims to have 16-day crop cycles which allows 22 crop rotations a year, considerably more than the standard three per year achieved in outdoor farming (Aerofarms, 2017b).

Aero Farms also has installed thousands of sensor and Internet of Things (IoT) devices that are recording over 130,000 million sets of climate and sensing data in each crop rotation. This is allowing them to start fine-tuning their cultivation processes to ensure that they are always harvesting their produce when the plants are at peak flavour and nutrient content (S. Oberman personal communications 15 September 2016).

Their business model is certainly attracting new industry entrants and has created over 100 new jobs in the Newark area alone after the addition of their newest facility. The financial feasibility of their operations is unknown at this point as the company has not published financial returns.

Conclusion

Farming began with small plots around villages. This approach is now enjoying a resurgence in a new modernised version, driven by consumer demand for organic and local forms of production, and the global demand for *more food from less earth*. Australia has a vibrant and growing horticulture industry that is poised for further growth, however it faces many challenges that are not limited to the ones raised in this report.

The key highlights of these challenges in Australian horticulture include:

- Young people getting involved in producing food.
- Critical labour issues.
- Growing demand for horticultural produce.
- The tyranny of distance and varying climatic weather patterns.
- The changing preferences and perceptions of 'fresh and local' for the modern-day consumer.

Whilst methods of new urban agriculture are still emerging and can be a highly speculative investment, they are openly addressing some of the challenges identified in their own unique way. For example,

- **Community gardens** are bringing back interest and engagement in cultivating plants within urban communities, whilst greening our cities as well as feeding some of our lower socio-economic demographic regions.
- **Rooftop greenhouses** are giving consumers a different perception of fresh food, greening our cities and creating farming employment in the middle of the "urban desert".
- **Vertical farming** and vegetable factories are combining data and the internet of things to fine-tune their production systems.

The commonality between all of these production methods is that they are all examples of producing *more food with less earth*. Some save water, others reduce the chemical run off into waterways and all save valuable arable land.

Not one of these methods is better than the other and that is because they serve very different purposes, while building their own unique communities that believe in their existence and purpose.

While on their own they may not solve the overarching problem of producing enough food for our ballooning population, they are certainly a piece of the puzzle. Even if the only thing achieved through urban farm is that it makes the next generation consider farming as a viable career, then the entire proposition of urban farming should be considered a success.

Recommendations

Establish Community Gardens

Community gardens have a great impact on their community, by nurturing the younger generations and getting people of all ages together, whilst producing food. The profound impact of the Stephanie Alexander Kitchen Garden programs in schools has been a shining example in Australia.

Utilise technology as a learning platform to improve the efficiency of urban farming

Technology is vital in encouraging new entrants especially for millennials, and invaluable as a platform to understand how plants are grown. This will enable true engagement and shift the current confused perceptions that urban societies hold on what it means to be a modern-day farmer.

Align horticulture to consumer trends to deliver better industry outcomes

Gone are the days that a farmer can cultivate some produce, and send to a central market hoping for the highest price. Today, the modern farm needs to align with the evolving trends of the modern-day consumer.

Urban agriculture won't feed the world, but it will feed the mind

As consumers continue to care about how their food is produced, urban farms will bring agriculture closer to the consumer, in turn creating jobs, exposure to farming and nurturing the passion vital for the innovation of the industry.

Producing more food with less earth

It is evident in this study that as a society we need to encourage new technologies to produce more nutritious foods whilst conserving inputs. Enormous savings in water, fertiliser run-off and wastage have been outlined and this needs to be considered if the industry is serious about creating a sustainable pathway for the next generation of food production.

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Plain English Compendium Summary

Title:	**More Food, Less Earth**
Project No.	1623
Scholar:	Jan Vydra
Organisation:	Australian Fresh Leaf Herbs 30 Clyde – Fiveways Road Clyde VIC 3978
Phone:	1800 065 900
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Objectives	To evaluate emerging next -generation horticulture models and determine if they are viable and able to produce more food with less earth. Furthermore, to investigate the current market conditions in the Australian horticulture industry, whilst understanding emerging consumer trends.
Background	Modern, high-tech urban agriculture has been operating in Australia for a number of years. This report investigates whether it is a viable alternative to the current market gardening approach of cultivating vegetables.
Research	Travel and visits through the Nuffield Global Focus program 2016, as well as private travel directly meeting with vegetable factories, rooftop greenhouses, vertical farms and community gardens have supported academic research; all have been conducted to complete this report.
Outcomes	This study revealed that urban agriculture is in a new and emerging industry. While a number of concepts may fail, the emergence of a new industry is evident and will result in a changing perception of farming.
Implications	Engaging with a new generation to get involved in farming and produce more leafy greens with less inputs within and around urban fringes.
Publications	Department of Foreign Affairs Conference in Seoul, South Korea, September 2016 Casey Cardinia Business Breakfast, November 2016 Horticulture Innovation Australia AGM, November 2016 Nuffield Australia National Conference, Darwin, September 2017