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Can vertical farming replace New Zealand's productive land to deliver high quality fruits and vegetables in the future?

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EXECUTIVE SUMMARY

Urban expansion is reducing the availability of some of New Zealand's most versatile productive land for growing food. Between 2002 and 2016 there has been a 30% reduction in vegetable-growing land across New Zealand (Deloitte, 2018). Due to the abundance of land available, there is a misconception that food crops can simply be grown elsewhere, outside land in demand for housing (Curran-Cournane, 2018). However, New Zealand soils vary widely in quality and versatility. Also, the climate varies across New Zealand. Fruit and vegetable crops generally need high class and versatile soils and climate requirements vary for crops.

It is estimated that by 2043, demand for fruits and vegetables will be 33% higher than it is in 2018 (Deloitte, 2018). A new way of thinking is required if the challenge of meeting New Zealand's growing demands for fresh fruit and vegetables is going to be met by the horticultural industry. New Zealanders cannot rely on the way they have always done things to find the answers the country needs now (Deloitte, 2018). This study investigates the potential for vertical farming (that does not rely on productive land) to resolve this issue in New Zealand.

Vertical farming is described as an urban agricultural system of large-scale food production that utilises sophisticated greenhouse methods and technologies within a closed environment to maximise productivity (Kalantari, et al, 2017; Graamans, et al, 2017; and Januszkiewicz and Jarmusz, 2018). High productivity is achieved by fully controlling aspects of cultivation, such as; lighting (exposure levels and time), temperature, humidity, levels of nutrient, growing medium composition and air composition (Graamans, et al, 2017; and Januszkiewicz and Jarmusz, 2018; Pascual, et al, 2018; and Wang, 2018). Crop trays are stacked vertically above one another to maximise the use of space (Banerjee and Adenaeuer, 2013; Molin and Martin, 2018)

While there are many recognised benefits of vertical farming, with the most prevalent being growing independent of weather conditions, the requirement to replace solar energy with electricity for artificial lighting and temperature control, combined with the high capital investment and operational cost, currently outweighs the benefits. This is a limitation in New Zealand where we enjoy high levels of sunshine hours and have enviable growing conditions (KPMG, 2017).

It was found that the type of crops that can be grown in a vertical farm are limited (e.g. leafy greens and herbs) and that vertical farms cannot grow the full range of fruits and vegetables currently grown in New Zealand.

Nothing is currently known about how vertical farming aligns with the cultural values of Maori.

A survey was conducted to gain insight into the understanding of vertical farming in the New Zealand horticulture industry. Interestingly, three respondents had investigated establishing a vertical farm in New Zealand. They did not proceed due to the economic feasibility. There may come a point in the long-term future where vertical farming is economic in New Zealand. Produce grown in a vertical farm may supplement a local market, but would not be suitable for export due to the crop types that can be grown.

The New Zealand Government and Horticulture New Zealand should take a balanced approach to the issue of New Zealand's diminishing productive land and food security. This would include the proposed National Policy Statement to protect New Zealand's versatile land and high-class soils; a full review of the risks to vegetable growing in New Zealand; the development of a strategy for the sustainability of domestic fruit and vegetable supply; and earmarking investment into internationally leading technology and innovation for the field of growing, including vertical farming.

1 INTRODUCTION

1.1 THE ISSUE – DIMINISHING PRODUCTIVE LAND AND FOOD SECURITY

Horticulture New Zealand (HortNZ) has been advocating for the protection of New Zealand's productive soils to ensure enough fruit and vegetables can be grown to feed New Zealanders in the future. With New Zealand's population expected to reach 5,045,000 by 2020 (based on annual growth between 1.5 - 2 percent), domestic food supply will not be able to sustain future population consumption needs (KPMG, 2017). However, New Zealand does not have an over-arching policy that protects food security (Curran-Cournane, 2018).

Land is becoming an increasingly contested resource in New Zealand. There are multiple uses competing for finite areas (Curran-Cournane, 2018). In particular, urban expansion is reducing the availability of some of our most versatile productive land. Studies based on changes in land cover indicate that between 1990 and 2008 29% of new urban areas were developed on some of New Zealand's most versatile land (Ministry for the Environment, 2018). Based on estimates from Statistics New Zealand, approximately 86% of New Zealand's population now lives in an urban centre, compared to 73% in 2013 (Ministry for the Environment, 2018). In parallel to this, between 2002 and 2016 there has been a 30% reduction in vegetable-growing land across New Zealand (Deloitte, 2018).

As urban populations grow and demand for housing increases, rural areas located close to urban areas are coming under pressure for land use change. Prime fruit and vegetable growing land is being squeezed by rapid growth in towns and cities and high demand for new housing (KPMG, 2017). While housing may achieve the highest value for the land, this encroachment reduces New Zealand's ability to support horticulture and secure year-round supply of fresh fruit and vegetables.

There is a misconception that food crops can simply be grown elsewhere, outside land in demand for housing, due to the abundance of land available (Curran-Cournane, 2018). Growing vegetables for commercial supply requires the right soils and microclimates (KPMG, 2017). Although land and suitable soil may exist in some other parts of New Zealand regions, the climate may not permit year-round production of a variety of crops (Curran-Cournane, 2018). New Zealand's vegetable-growing regions supply markets at different times of the year. For instance, Pukekohe supplies the market with Christmas new potatoes, while Oamaru is famous for Jersey Benne potatoes that are harvested around November. During winter, there are times when Southland is the only region supplying the domestic market with carrots (KPMG, 2017).

Adding to the shortage of suitable growing land are the pressures of changes in weather patterns across regions and extreme unseasonal weather events such as rain, hail, snow, frost or drought becoming more frequent and damaging, are impacting the supply of fresh, healthy food (KPMG, 2017).

It is estimated that by 2043, demand for fruits and vegetables will be 33% higher than it is in 2018 – slightly below population growth, as not everyone will consume the same amount of fruit and vegetables (Deloitte, 2018).

With an increasing population and therefore increase demand for food, New Zealand cannot continue to convert versatile land from agriculture to housing without affecting its food production capability (Curran-Cournane, 2018). There also needs to be recognition that when food supply is short and demand high, prices are subject to wide variations. (KPMG, 2017).

We currently lack substantial knowledge of how these trends will impact the country's self-sufficiency as a food producing nation and how this will affect the food system for society and future

generations and research needs to start addressing this multi-dimensional research (Curran-Cournane, 2018). Also, we lack a systematic view of the environmental, social, cultural and economic impacts of changes in soil and biodiversity (Ministry for the Environment, 2018).

Meeting growing demands in the face of the challenges of competition for productive land, climate change, access to freshwater and biosecurity are central to the sustainability of New Zealand's horticultural industry and ultimately the health of its people. A new way of thinking is required. New Zealanders cannot rely on the way they have always done things to find the answers the country needs now (Deloitte, 2018).

The 2018 Agribusiness Agenda stated that sustainability strategist Henry Gordon-Smith of Agritecture Consulting visited New Zealand in 2017 and reported that New Zealand should focus on vertical farming to grow fresh local produce (KPMG, 2018). With New Zealand's productive soils being compromised, could vertical farming be the solution for New Zealand to meet fresh fruit and vegetable demands?

1.2 HORTICULTURE IN NEW ZEALAND

The success of New Zealand's horticulture is due to its reputation for delivering high quality produce that commands a premium in overseas markets (Plant and Food Research, 2017). A range of fruit and vegetable crops are currently grown in New Zealand[1]. Approximately 80% of all vegetables grown in New Zealand are consumed in New Zealand. Whereas, most of the fruit crop is exported. Major exports include kiwifruit, apples, avocados, onions, buttercup squash, processed vegetables and potatoes. Citrus, Summerfruit, and berryfruit are developing export products.

New Zealand has an international reputation for producing safe, high quality produce because growers have proactively set up initiatives demanding accountability and environmental best practice. In 2017, the industry generated $5.68 billion in value, with export revenue accounting for $3.49 billion, having increased by 49% over the last five years. The growing strength of horticulture exports illustrates the trust the world places in New Zealand-grown food, and our ability to meet that demand. (Deloitte, 2018).

It should be acknowledged that it is not just the economic benefits associated with horticultural production that are important in New Zealand. The rural economy supports rural communities and rural production defines much of the rural landscape. Food production values provide a platform for long term sustainability of communities, through the provision of food security, jobs and tourism.

The total investment in New Zealand's horticultural sector is estimated to be in excess of $52b (Plant and Food Research, 2017).

[1] Fruits - Avocado, Blackcurrant's, Blueberries, Boysenberries, Citrus fruits, Feijoas, Tomato, Kiwiberry, Kiwifruit, Nashi, Passionfruit, Persimmons, Pip fruit (Apples, Pears), Strawberries, Tamarillos, Summerfruit (Cherries, Plums, Peaches, Nectarines, Apricots)

Vegetables - Alliums (Garlic, Leek, Shallot, Ginger, Spring Onion,), Asparagus, Brassica (Broccoli, brussel sprouts, cabbage, kale, cauliflower, swedes, turnips, radish, broccoflower and Asian greens), Corn, Covered Crops (Capsicum, Chilli, cucumber, eggplant, sprouted beans, witloof, courgette), Leafy Crops (Silverbeat, spinach, mesclun, salad leaves, watercress, beans, peas, snow peas), Lettuce, Onion, Root and tuber crops (carrots, kumara, beetroot, parsnips, yams, taro), Squash, Stalks, vines, artichokes, celeriac, celery, courgette, gherkins, marrow, melon, pumpkins, chokos, fennel, parsley, herbs, rhubarb, squash, sweetcorn.

To maintain New Zealand's position in the marketplace, the horticulture industry must continue to enhance quality and innovate – delivering new products with characteristics desired by the consumer and new technologies that allow us to deliver high quality with minimal environmental and social impacts (Plant and Food, 2017).

Horticulture New Zealand (HortNZ) represents the interests of New Zealand's 5,000 commercial fruit and vegetable growers who employ over 60,000 workers. Land under horticultural crop cultivation in New Zealand is calculated to be approximately 120,000 hectares.

The vision of HortNZ is *'Healthy food for all forever'* and the HortNZ mission is *'creating an enduring environment where growers prosper'*.

1.3 PROJECT OBJECTIVES

The following objectives have been formed for this project:

1. To review international literature on vertical farming.
2. To develop an understanding of vertical farming.
3. To identify benefits and limitations of vertical farming.
4. To gain insight into current understanding and desire for vertical farming within the New Zealand horticulture sector through an industry survey.
5. To make recommendations to address any knowledge gaps identified.

1.4 RESEARCH QUESTIONS

The research is focused around the following research questions:

1. What is vertical farming?
2. What fruit and vegetable crops can be grown successfully in vertical farms?
3. What are the benefits of vertical farms?
4. What are the limitations of vertical farms?
5. Can vertical farming replace traditional horticultural growing on productive land in New Zealand to deliver high quality fruits and vegetables?
6. What information and/or research gaps are there?

2 LITERATURE REVIEW

2.1 LIMITATIONS

The limitations of this literature review arise from the fact that vertical farming is a young industry. Literature referenced in this report is very recent, with much of it being published in 2018. In communicating with vertical farm proponents Chris Higgins, Founder and Owner of Hort Americas[2] and Henry Gordon-Smith, Managing Director of Agritecture[3], it was confirmed that there has not yet been enough time to research successful projects and publish peer-reviewed literature. However, Gordon-Smith is now planning to compile a list of reputable vertical farming literature and share this through the Agritecture webpage and blog to make locating literature on the subject easier in the future.

2.2 WHAT IS VERTICAL FARMING?

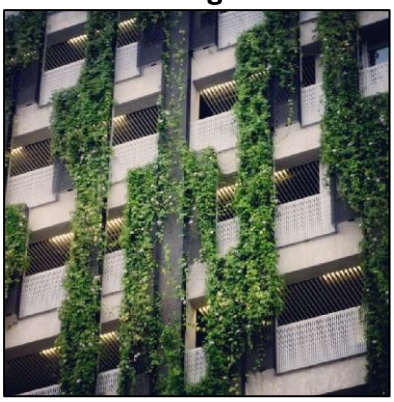
Vertical farming is a term that has been applied broadly to describe a wide range of urban architecture that aims to grow fresh local produce. Vertical farming seeks to ensure the sustainability of our cities proactively, by addressing food security to the world's ever-increasing urban population (Kheir, 2018).

At the simplistic end, vertical farming has been used as a term to describe household horticultural systems, such as repurposed roof spouting attached to a fence or structure for strawberry growing in a home garden (refer Photo 1). Vertical farming is also used to refer to architectural features such as; green façade (refer Photo 2), living wall and roof top terrace gardens. However, the crop yields from these types of 'vertical farming' would be limited, possibly supplementing a household's food supply or a local facility or restaurant.

Photo 1 – Household vertical growing

Source: Mrs B. Baynon, Rangiora

Photo 2 – Living Wall



Source: Flickr

A demonstration of rooftop farming that provides produce for a facility was the Singapore's Changi General Hospital rooftop garden in the 1990's. The project was run by a group of hospital staff and the produce generated was used for inhouse consumption by patients. In time, however, the farm

[2] https://hortamericas.com/ - Hort Americas work closely with manufacturers from around the world to bring high quality, technically advanced and cost-effective products to the greenhouse growers, vertical farmers and indoor agriculturalist in Canada, the United States, the Caribbean and Mexico.

[3] https://www.agritecture.com/ - Agritecture has been researching and evaluating approaches to urban agriculture. What began as a blog, has evolved into a global consulting business offering clients technology-agnostic guidance.

was replaced by a garden. The viability of the project was compromised by the day-to-day management requirements (Astee and Kishnani, 2010).

To appropriately test the project aim and for the purposes of this project, vertical farming is required to be of a commercial scale and produce must be of market quality. Therefore, vertical farming in this report refers to a type of vertical farming known as 'Plant Factories'. A plant factory is a contemporary concept of vertical farming (Januszkiewicz and Jarmusz, 2018). This kind of vertical farming can be described as follows:

An urban agricultural system of large-scale food production that utilises sophisticated greenhouse methods and technologies within a closed environment to maximise productivity (Kalantari, et al, 2017; Graamans, et al, 2017; and Januszkiewicz and Jarmusz, 2018). High productivity is achieved by fully controlling aspects of cultivation, such as; lighting (exposure levels and time), temperature, humidity, levels of nutrient, growing medium composition and air composition (Graamans, et al, 2017; and Januszkiewicz and Jarmusz, 2018; Pascual, et al, 2018; and Wang, 2018). Crop trays are stacked vertically above one another to maximise the use of space (Banerjee and Adenaeuer, 2013; Molin and Martin, 2018). Photo 3 below shows inside a vertical farm.

Photo 3: Example of an Aerofarm vertical farm

Source: www.aerofarms.com

Vertical farming is highly technical and requires a great amount of interdisciplinary knowledge – varying from economics, marketing, horticulture, engineering, chemistry, plant pathology and physiology, to IT and production chain automation (Al-Kodmany, 2018; Kalantari, et al, 2017; Januszkiewicz and Jarmusz, 2018).

Technologies include; hydroponics, aquaponics and aeroponics[4] (Januszkiewicz and Jarmusz, 2018). These systems and associated technologies are rapidly evolving, diversifying, and improving (Al-

[4] Hydroponics – engages a water-based method of growing plants using mineral nutrient solutions. Although they do not utilize soil, the roots can be either exposed to a mineral solution or supported by an inert medium e.g. perlite, gravel. (Januszkiewicz and Jarmusz, 2018)

Kodmany, 2018). Robotics is also now being promoted as a future vertical farm technology to address labour requirements[5]. Perhaps, in the distant future, there is the prospect of developing fully automated vertical farms (Al-Kodmany, 2018).

AeroFarm Company from Newwark New Jersey (USA) is an example of this type of Vertical Farm. Reportedly, the *Aerofarm* horticultural systems are 130 times more productive (per square foot) than a traditional commercial field farm and need 95% less water than traditional field farming and 40% less water than traditional hydroponics (Januszkiewicz and Jarmusz, 2018).

Japan has experienced great growth in vertical farming and no other country has as many vertical farms (Molin and Martin, 2018 – 2). In 2009, there were 35 vertical farming factories in the country, increasing to 150 in 2017 (Molin and Martin, 2018 – 2). The projects in Japan have sometimes been government funded and they have also been a connecting point for different industries such as electronics, chemical, transport, as well as agriculture and food companies (Molin and Martin, 2018 - 2).

2.3 WHICH FRUIT AND VEGETABLE CROPS CAN BE GROWN SUCCESSFULLY IN VERTICAL FARMS?

Vertical farming can only suit a selection of crops, mainly salads and herbs, that will not grow taller than the average height of the shelves, which is around 40 cm (Molin and Martin, 2018). The crops in the vertical farms must also be fast-growing, meaning they will be harvested within roughly one month after planting, and require low intensity of light and high density of plants. Furthermore, they must also be valuable plants, fresh and high in nutrition, where more than 85 % of the actual crop can be sold (Molin and Martin, 2018). Good examples of crops, besides salad, that could be cultivated indoors with artificial lighting are fruit-vegetables like tomatoes and peppers and berries (Molin and Martin, 2018). Crops that are not well suited for this kind of cultivation are staple crops including; rice, corn and potatoes (Molin and Martin, 2018).

Due to concerns regarding the impact of climate change, food security and forestland degradation, a study has been conducted in Nueva Ecija, a land locked province in the Philippines, to determine the applicability of vertical farming to onion production (Pascual, M.P., et al, 2018). The country is known as the onion capital of Southeast Asia. The results showed that it is possible to grow onions successfully in a vertical farm and that the use of vertical farming is acceptable to the onion growers (Pascual, M.P., et al, 2018). However, the study concluded that there is a need for government and pioneering organisations to support the growers, and provide them training for technology adoption and financial assistance for the construction of the vertical farms (Pascual, M.P., et al, 2018).

The Philippines onion study demonstrates that when regions are unable to meet demands for fresh produce, they may commission further research into new vertically farmed crop types. Possible factors that will contribute to the inability to meet fresh food demands could include; population increase, climate change, food security, international trade restrictions, arable land availability, access to water and environmental degradation. However, currently the variety of crop types that are known to grow successfully in vertical farms are limited to those listed above.

Aquaponics – engages a closed water cycle system combining aquaculture with hydroponics in a symbiotic environment with participation of nitrifying bacteria. Water from an aquaculture system is fed to a hydroponic system where bacteria purify it by gradually breaking down the aquaculture's by-products to the nitrates utilized by plants as nutrients. (Januszkiewicz and Jarmusz, 2018)
Aeroponics – engages cultivation in airborne or misty environment. Aeroponics needs a high measure of control, yet it features in this group the highest efficiency in water-saving techniques. It's the only one that does not utilize soil or any aggregate medium. (Januszkiewicz and Jarmusz, 2018)

[5] http://ironox.com/

2.4 WHAT ARE THE BENEFITS OF VERTICAL FARMS?

The Resource Management Act 1991 (RMA) is the key environmental legislation in New Zealand. It manages the use, development, and protection of New Zealand's natural and physical resources. The purpose of this Act is the sustainable management of natural and physical resources. Therefore, it is appropriate to consider the benefits of vertical farming under the sustainable management well-being pillars of Environmental, Social, Economic and Cultural.

Environmental

Vertical farming has the benefits of being independent from weather conditions, protecting crops from harsh environments with changing weather conditions, and resulting in higher productivity than traditional farming (Molin and Martin, March 2018-2; Al-Kodmany, 2018; Tajudenn and Taiwo, 2018; Fatemeh et al, 2017). Climate change threatens the basic elements of life for people around the world—access to water, food production, health as well as the overuse of land and the environment (Januszkiewicz and Jarmusz, 2018). Countries with harsh growing conditions could use vertical farming to provide year-round production of fresh vegetables and herbs (Molin and Martin, 2018-2; Al-Kodmany, 2018).

Besides the protection from the weather, the closed environment keeps insects, weeds, dust and other harmful deterrents to the plants at a distance (Al-Kodmany, 2018) reducing the need for pesticides (Molin and Martin, March 2018-2). As such, vertical farming could possibly offer a healthier environment to grow food (Molin and Martin, 2018-2).

The energy use is higher for vertical farms than conventionally grown vegetables and herbs, but other resources i.e. water, nutrients, arable land and pesticide are used more scarcely (Molin and Martin, March 2018-2).

When comparing vertical farms to conventional farming (greenhouses and open fields) vertical farms have larger yields per square meter (Molin and Martin, 2018-2). Vertical farms efficient use of land area could contribute to releasing pressure on arable land (Molin and Martin, 2018-2).

Furthermore, vertical farming provides a low-impact system that can significantly reduce travel costs and greenhouse gas emissions as cultivation takes place in urban areas close to consumption, reducing travel distance from distant farms to local markets (Al-Kodmany, 2018; Molin and Martin, 2018-2). However, due to the close proximity of growing to market and relatively small geographic area of New Zealand, this benefit is not as applicable to New Zealand as it would be in the United States of America for example.

Social

Vertical farming could have an important role in social well-being and strengthen resilience. It offers an opportunity for communities to be more self-sufficient and less dependent on global food production system, and long delivery chains. By growing food locally there are new job and research opportunities, the possibility to sell the produce, and create other products from the crops grown (Molin and Martin, March 2018; Banerjee and Adenaeuer, 2013)

Building a vertical farm requires a multi-disciplinary team of architects, engineers, scientists, farmers, horticulturists, environmentalists, marketers, and economists (Al-Kodmany, 2018). For example, industrial, mechanical and electrical engineers will be needed to design water recycling systems, lighting systems, heating, ventilation and air conditioning systems, seed and plant growth monitoring and harvesting systems. Computer experts will be needed to build databases and software applications. Further, robotics and software engineers could also be needed if an automated system was sought (Al-Kodmany, 2018). As such, the vertical farm offers new exciting careers in biochemistry, biotechnology, construction, maintenance, marketing, engineering, robotics and research and development opportunities for improving the involved technologies (Al-Kodmany,

2018). A technology-savvy younger generation may be enticed by the practice, grooming a new breed of farmers (Al-Kodmany, 2018).

Several Swedish studies have also found that consumers prefer locally labelled foods, outlining customer beliefs that regionally produced foods have the potential to reduce environmental impacts and strengthen local economies, and are even of higher quality and taste compared to imported varieties (Molin and Martin, March 2018-2).

Food security has become an increasingly important issue. In the United States of America food security has come to refer to not only the ability to avoid hunger, but also the ability to access healthy foods (Wang, 2018). Governments looking for ways to boost domestic food security have been funding vertical farming endeavours (Al-Kodmany, 2018). Numerous countries including South Korea, Japan, China, Germany, the United Arab Emirates, China, France, India, Sweden, Singapore, and the United States, have convened to discuss vertical farming (Al-Kodmany, 2018). They have repeatedly endorsed the concept as integral to the long-term sustainability of their cities (Al-Kodmany, 2018).

Research opportunities and technology developed for vertical farming may prove to be useful not only for domestic food security, but also for application at remote research stations (e.g. the poles), and also in refugee camps, especially in flooded or earthquake affected areas where camp dwellers need to be fed for a prolonged period of time (Banerjee and Adenaeuer, 2013). It could also be used to support life in space. Production of food is essential in order to realise successful space missions for extended periods of time (Meinen et al, 2018). Soilless farming has been tested and adapted for use in space jets and other planets given there is no soil for planting (Tajudeen and Taiwo, 2018). A priority is production of fresh vegetables which has been shown to have beneficial psychological effects for crew members (Meinen et al, 2018).

Economic

Proponents of the vertical farm claim that it would enhance the economy and provide new employment opportunities (Al-Kodmany, 2018). In addition, costs associated with fertilizers, herbicides, pesticides, water consumption and capital investment required for traditional farming machinery, such as tractors, are reduced or eliminated (Al-Kodmany, 2018; Tajudeen and Taiwo, 2018). Improved productivity results in greater crop yields and more consistent, year-round certainty of crop yields, assists in meeting market demands. This could result in contract opportunities that may not have otherwise been available.

Cultural

In the New Zealand context, the RMA requires consideration of cultural well-being. It is a matter of national importance to recognise and provide for the relationship of Maori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga. It is not known if research has been undertaken with respect to vertical farming and the cultural well-being of Maori. None was discovered.

It is possible that a cultural assessment would be undertaken as part of a resource consent process should a vertical farm be developed in New Zealand. However, it would be helpful to understand how Maori culture and traditions align with the principles of vertical farming before initiating plans for development. This could be a future research project for those interested in establishing a vertical farm in New Zealand.

Summary of key sustainable benefits of the vertical farm

Table 1 below provides a summary of the sustainable benefits of vertical farming this is helpful in the New Zealand policy context. Although it is acknowledged that cultural benefits are not included.

Table 1. Key sustainable benefits of the vertical farm

#	Benefit	Environmental	Social	Economic
1	Reducing food-miles (travel distances)	Reducing air pollution	Improving air quality improves environmental and people's health. Customers receive "fresher" local food	Reduce energy, packaging, and fuel to transport food
2	Reducing water consumption for food production by using high-tech irrigation systems and recycling methods	Reducing surface water run off of traditional farms	Making potable water available to more people	Reduce costs
3	Recycling organic waste	Save the environment by reducing needed land fills	Improve food quality and subsequently consumers' health	Turn waste into asset
4	Creating local jobs	People do not have to commute to work and hence will decrease ecological footprint	Create a local community of workers and social networks with farmers	Benefit local people economically
5	Reduced fertilizers, herbicides, and pesticides	Improve the environmental well-being	Improve food quality and subsequently consumers' health	Decrease costs
6	Improve productivity	Needs less space	Reduce redundant, repetitive work, and save time to do productive and socially rewarding activities	Offer greater yields
7	Avoid crop losses due to floods, droughts, hurricane, over exposure to sun, and seasonal changes	Decrease environmental damage and clean-ups of farms after damage	Improve food security	Avoiding economic loss
8	Control product/produce regardless to seasons	Produce regarding season	Increase accessibility year-round and improve respond to population demand	Fuel economic activities year-round
9	Using renewable energy	Reducing fossil fuel	Improve air quality	Reduce costs
10	Bringing nature closer to city	Increase bio-diversity	Improve health, reduce stress and enhance psychological well-being	Create jobs in the city
11	Promoting high-tech and green industry	"green technology" reduce harm and improve environmental performance	Encourage higher education and generate skilled workers	Provides new jobs in engineering, biochemistry, biotechnology, construction and maintenance, and research and development
12	Reducing the activities of traditional farming	Preserving natural ecological system	Improve health of citizens	Saving money required to correct environmental damage
13	Repurposing dilapidated buildings	Enhance the environment. Remove eye sores and stigma from neighbourhoods	Create opportunities for social interaction	Revive economy

Source: Al-Kodmany, 2018

2.5 WHAT ARE THE LIMITATIONS OF VERTICAL FARMS?

As above, the limitations of vertical farming have been considered under the sustainable management wellbeing pillars of Environmental, Economic, Social and Cultural.

Environmental - natural environment

Vertical farms generate an opportunity to grow crops in locations and altitudes that are not optimal for the plants to begin with (Molin and Martin, March 2018-2). If the land can be prioritised for horticultural use over other competing land uses (Curran – Cournane, 2018), New Zealand has an ideal growing environment with excellent soils and climate conditions suited to growing quality produce for a range of crop types (HortNZ, 2017).

Research that compared the resource use efficiency of plant factories (closed system vertical farm) with greenhouses concluded that greenhouses excel as they use freely available solar energy for photosynthesis (Graamans et al, 2017). Figure 1 below demonstrates the research findings geographically. New Zealand has good levels of sunlight and water; therefore, it is not surprising that the figure shows there is relatively low electricity use efficiency in New Zealand, and that water is not a scarce resource. Similarities can be drawn with crops grown in New Zealand greenhouses. In winter produce is more expensive due to heating costs, whereas in summer, when solar energy is used to heat greenhouses, prices are lower. Therefore, New Zealand's natural environment works against it as an ideal location for a vertical farm to thrive.

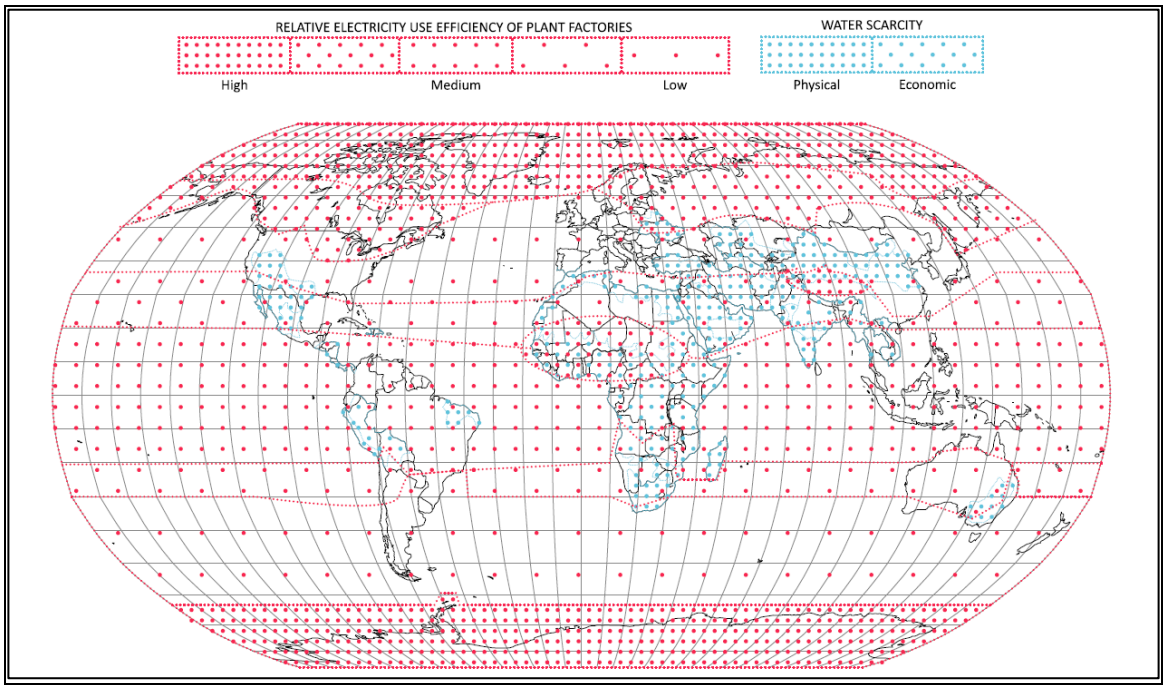


Figure 1: Estimation of the advantages of plant factories (closed system vertical farm) versus greenhouse based on relative electricity use efficient (red) and water scarcity (blue). Source: Graamans et al, 2017

Environmental – built environment

Adaptive-reuse for vertical farming of an existing vacant structure, such commercial or industrial buildings, may appeal to communities (Wang, 2018). Abandoned urban buildings can be converted into vertical farms to provide healthy food in neighbourhoods where fresh produce is scarce (Al-Komany, 2018). However, opportunity for adaptive reuse is more limited in New Zealand than in other developed countries. The high land and property values in Auckland and Dunedin would work against the economic feasibly of use for vertical farming. Many commercial and industrial buildings in Christchurch were destroyed in the 2010 and 2011 Canterbury earthquakes. Those that remained have generally either been strengthened and repurposed or demolished. While new commercial and industrial building is occurring in Christchurch, it is taking longer than expected and the lease for newly constructed buildings is very high. Dunedin City Council is promoting a regeneration of 'The Warehouse Precinct', which may present an opportunity. The area was once the hub of Dunedin's commercial and industrial growth, but declined in the second half of the 20th century. One objective promoted by the Dunedin City Council is for this Precinct is to be a hive of creative employment (Dunedin City Council, 2011).

Economic

Economic feasibility remains a major obstacle in the path to implementing the vertical farm (Al-Kodmany, 2018). Financing is a key challenge as most urban farming initiatives are struggling for economic viability (Thomaier et al, 2014). The costs of producing food in vertical farms are typically

higher than those of traditional farms (Wang, 2018; Molin and Martin, March 2018-2; Kalantari et al, 2018). The high initial investment cost required for construction and ongoing maintenance costs is a limitation of vertical farming (Tajudeen and Taiwo, 2018).

The evident shortcoming of vertical farming is the high energy (electricity) demand for artificial illumination and temperature control, which is needed for photosynthesis (Graamans, et al, 2017; and Molin and Martin, 2018-2). Furthermore, the lack of natural ventilation within the closed environment system is likely to induce a high demand for cooling and vapour removal (Graamans, et al, 2017). Those that reduce upfront costs by investing in less energy saving or renewable energy technologies, incur higher operational costs, especially for heating systems through cold winters (Wang, 2018). Therefore, in order to achieve economic viability, increased productivity and/or the value of additional services would have to outweigh the disadvantage of the absence of solar energy (Graamans, et al, 2017). This will never be the case in New Zealand where growers with good land can grow outside, in the right climate. It will be very difficult for vertical farming to be commercially competitive in New Zealand's market driven system.

Social

At current levels of technology, the ability of vertical farms to compete with established farming processes is limited. There are many multidisciplinary issues the vertical farm concept would have to meet and therefore, multidisciplinary collaboration is required to enable ultimate delivery of a fully-functional solution. Furthermore, many of the skills required to establish and operate a vertical farm are specialist and technical. There are limited people with these specialist skills and as the technology is still evolving, it is unlikely that training institutes will be running specialist courses on vertical farming. Therefore, the transition from current, traditional horticultural modus operandi to vertical farms still requires a lot of effort over the course of the next few decades (Januszkiewicz and Jarmusz, 2018). Meanwhile, it is extremely important to keep the vertical farming discussion opened and to engage with organizations, authorities and entities who effectively shape the global polices (Januszkiewicz and Jarmusz, 2018).

Due to production taking place indoors, vertical farming may not have the same level of socio-economic advantages as urban green areas or community gardens (Molin and Martin, 2018-2). As a recreational activity, community gardens have been widely noted to improve both physical and mental health, as well as having a positive health impact on food choice and dietary knowledge (Wang, 2018). Participating in gardening involves sustained physical activity, which helps to combat obesity and other ailments (Wang, 2018). It has been reported that gardening helps reduce stress and is a valuable mental health resource in neighbourhoods (Wang, 2018). Community gardens offer a range of social benefits that would be difficult to achieved in commercial vertical farming.

Food justice activists have criticized urban farming projects that claim to increase accessibility to healthy food in the neighbourhood where they are located but, in reality, distribute it to wealthier residents that can afford to pay off the higher costs of production and who did not have a food security issue in the first place (Wang, 2018). However, this counterproductive effect can be avoided with support from government incentives, partnerships with non-profit organizations, and strategic pricing strategies (Wang, 2018).

3 STUDY METHODS

A typeform survey containing 14 questions was distributed through the HortNZ weekly newsletter on Tuesday 7th August and Tuesday 21st August, 2018. The newsletter is sent out via email to the subscription list of 3070 subscribers. Those who subscribe to the newsletter are generally New Zealand growers, horticultural professional, academics and media.

Twenty-one responses were initially received. In order to increase survey participants, a further email was sent out by the secretary of the Pukekohe Vegetable Growers Association members on 1st October, 2018. This resulted in a further two surveys being completed.

Typeform observed that the average time taken to answer the survey was ten minutes and that while 52 individuals had viewed the survey, only 23 had completed to it.

The survey was open from 7th August to 10th October. In total, 23 responses were received.

The survey questions are enclosed at **Appendix 1**.

4 RESULTS AND FINDINGS

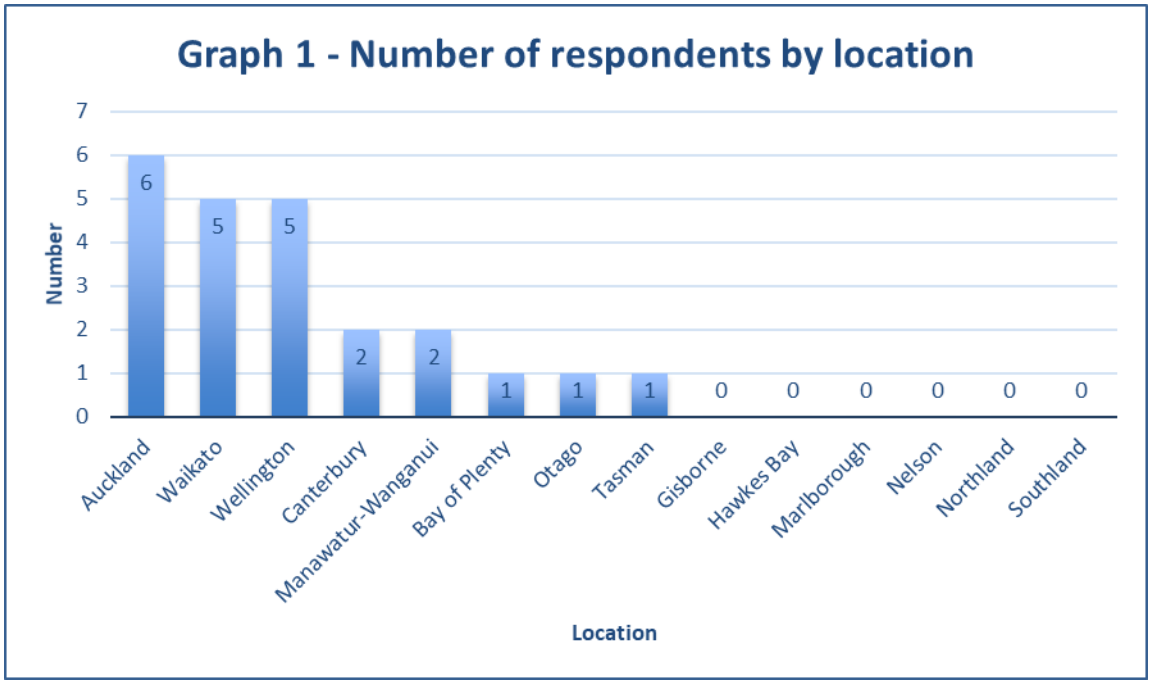
4.1 OVERVIEW OF SAMPLE

There was a total sample size of twenty-three respondents. The survey findings are limited by the small sample size.

Questions 1 to 3 sought information on the respondent's location, age range and involvement with horticulture, respectively.

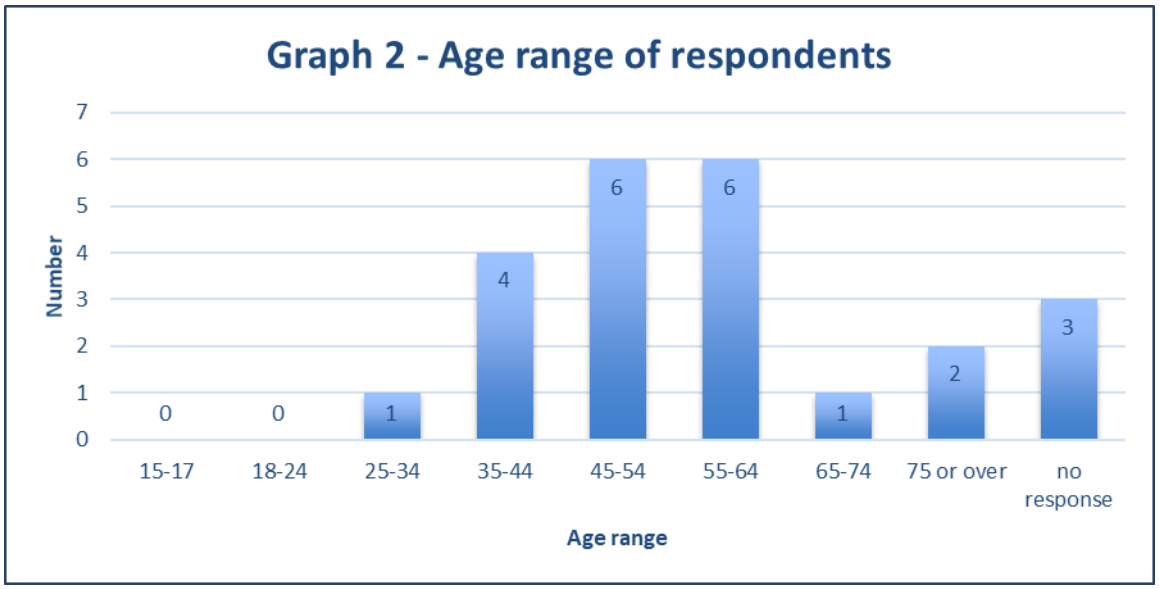
Question 1 – Location of respondents

Graph 1 below shows that the highest number of respondents were from Auckland (6), Waikato (5) and Wellington (5).



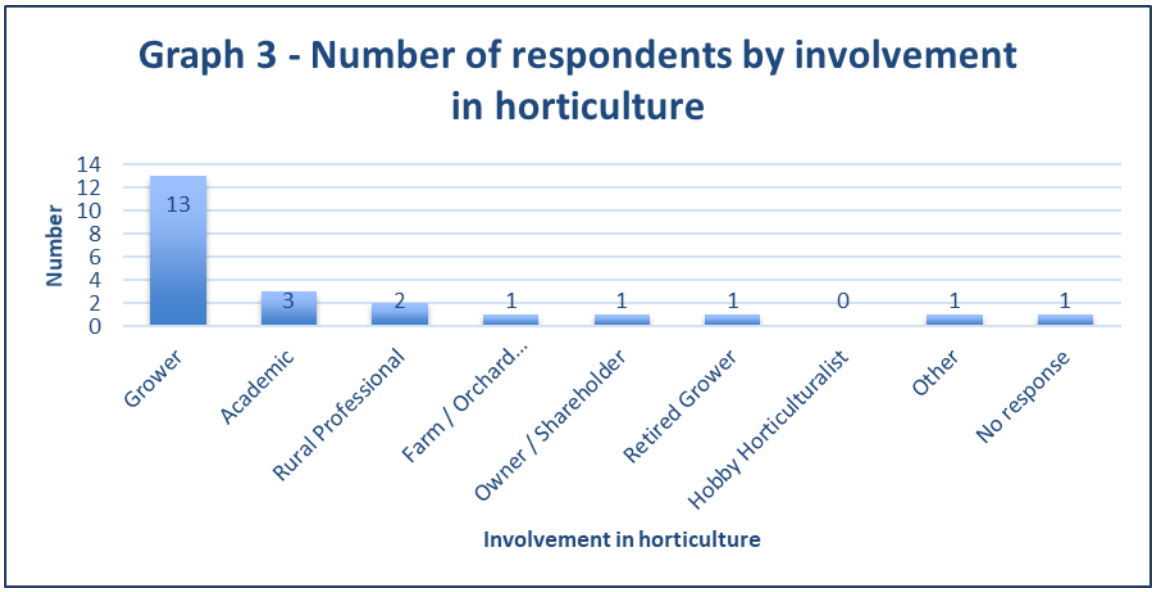
Question 2 – Age range

Graph 2 shows the age ranges of respondents. The majority of respondents were in the age ranges of *45-54* (6) and *55-64* (6).



Question 3 – Involvement in Horticulture

As can be seen in Graph 3 the majority of respondents were growers (13).



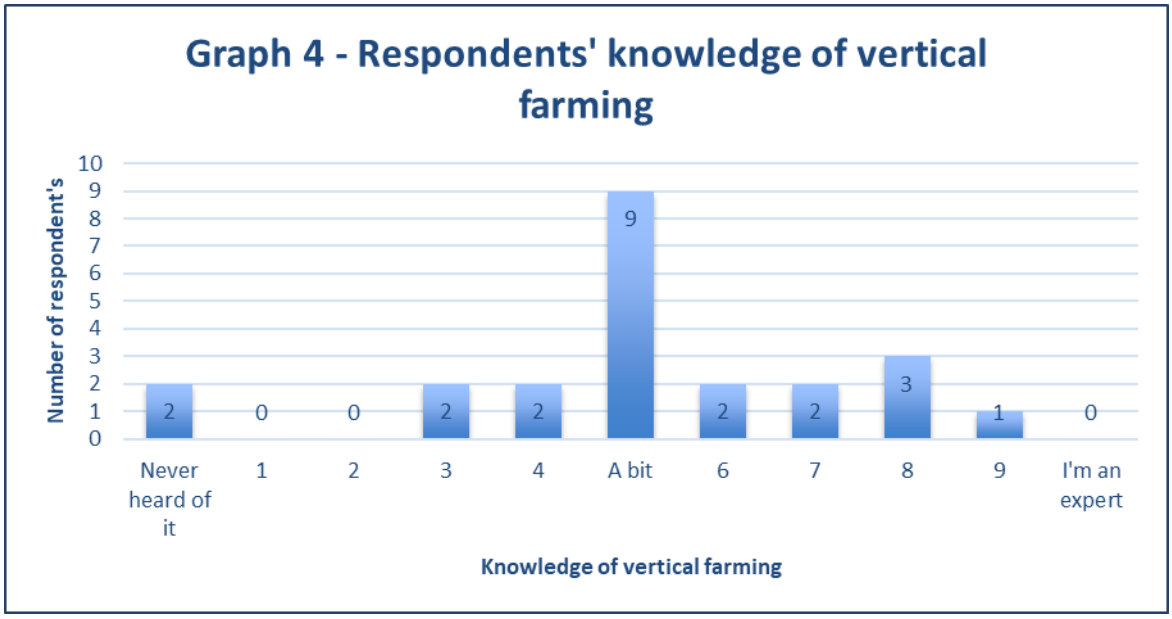
4.2 FINDINGS

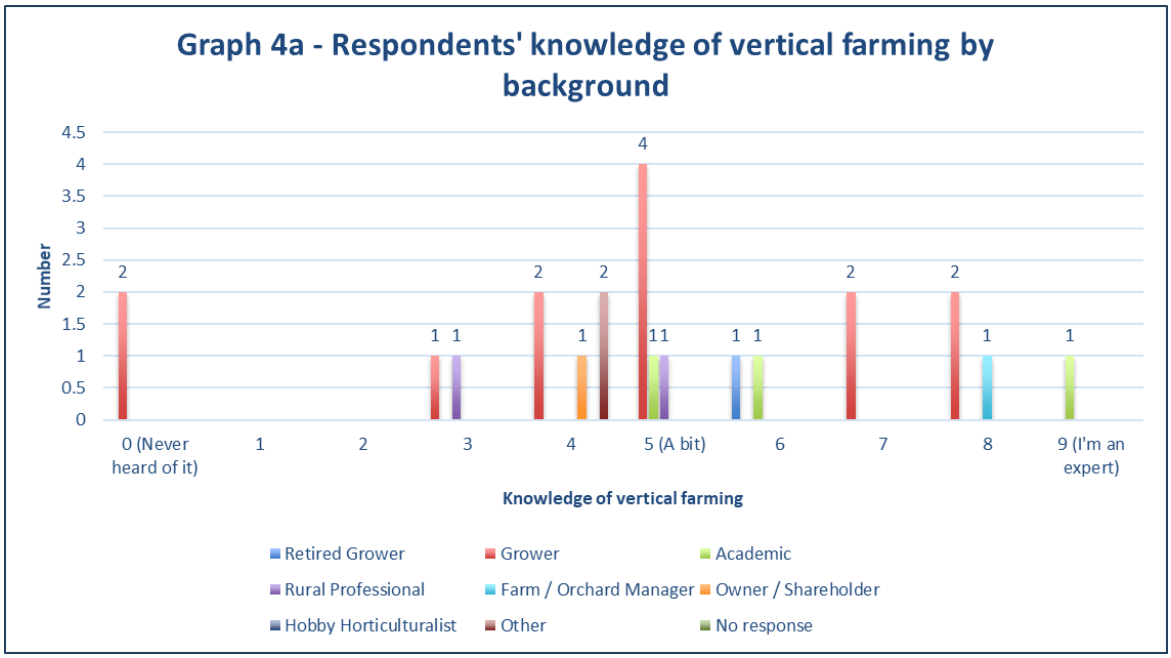
The following graphs and discussion relate to the survey Questions 4 to 14 that sought greater insight into the understanding of vertical farming. They findings are as follows:

Question 4 – Perceived knowledge

Respondents were asked to rank how much they knew about vertical farming on a scale from 0 – *'Never heard of it'* to 10 – *'I'm an expert'*, with 5 being *'a bit'*. As can be seen in Graph 4, the majority of respondents felt that they had a reasonable knowledge of vertical growing with 17 of the 23 respondents choosing a response of 5 - *'a bit'* to 9. There were only two respondents who had not heard of vertical farming before. Graph 4a shows respondents knowledge of vertical farming by their

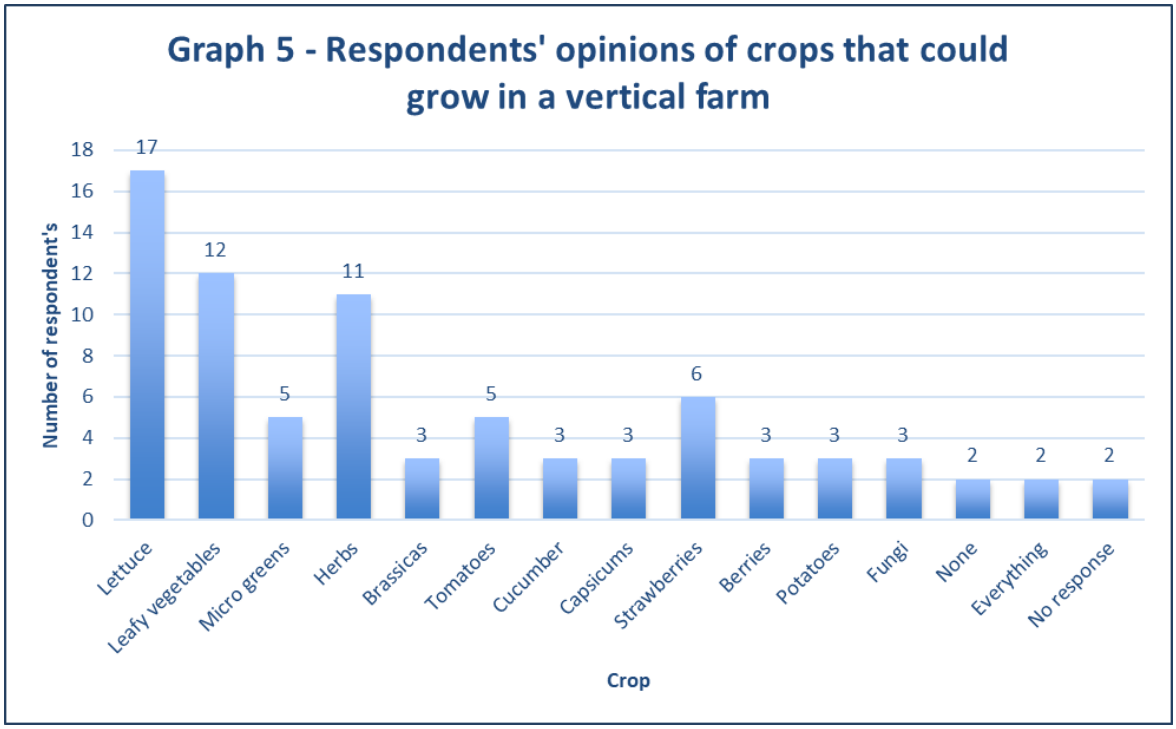
background. The one respondent that answered '9' was an academic and the three respondents who answered '8' were growers.





Question 5 – Crops that could grow

Respondents were asked which fruits and vegetables they thought could grow successfully in a vertical farm in New Zealand. As can be seen in Graph 5 below, responses varied from '*everything*' to *'none'*. A range of crop types were identified by respondents. Most popular were lettuce (17), leafy vegetables (12) and herbs (11).



Question 6 – Why?
Question 6 related to question 5 and asked respondents why they thought certain crops could be grown in vertical farms in New Zealand.

Those who were of the view that certain crops could be grown in vertical farms in New Zealand were of this opinion for the following reasons:

- The crop is quick growing / has a short crop rotation
- The crop is space efficient
- The crop could be grown in a layered system
- The crop has already grown successfully in greenhouses
- The technology is available
- Growing in a vertical growing system avoids seasonal and weather problems.

Some respondents considered that crops that required soil, or grew tall, would not be able to be grown in a vertical farm.

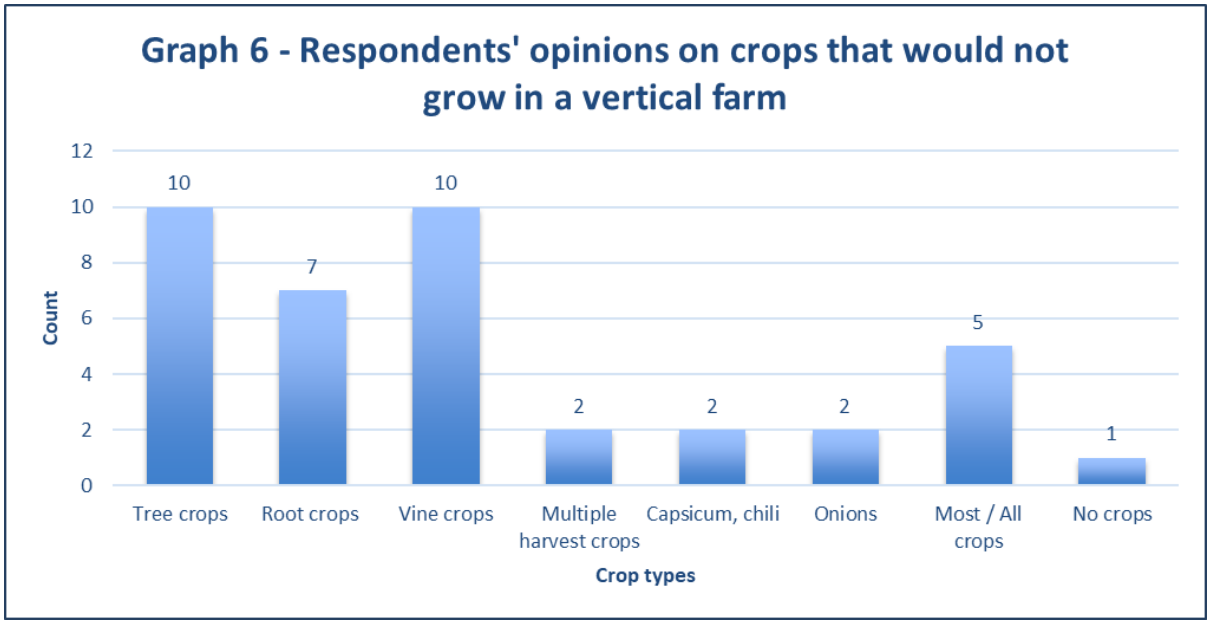
Those that responded that no crops could be grown reasoned that this was because the input costs (lighting and heating) would be too high compared to traditional growing systems in New Zealand.

Question 7 – Crops that couldn't grow
Respondents were asked which fruits and vegetables they thought could not grow successfully in a vertical farm in New Zealand. 22 respondents answered the question. Most respondents listed more than one crop type that they believed could not be grown in a vertical farm. They are themed as follows:

- Tree crops (e.g. avocado, pipfruit, summerfruit, citrus, nuts)
- Root crops (e.g. carrots, parsnips, potato)
- Vine crops (e.g. grapes, tomatoes, cucumber, pumpkin, squash, eggplant)
- Capsicum, chili
- Onions
- All crops, except herbs and leafy greens

- Multiple harvest crops (e.g.: kale, beans)
- Most / All crops
- No crops

As can be seen in Graph 6 below, it is the opinion of all but one responded that there are limitations as to the types of crops that could be grown in a vertical farm. It was the view of five respondents that most, if not all crops would not grow in a vertical farm. Tree crops, root crops and vine crops were the most common types of crops listed as not being able to grow in a vertical farm.



Question 8 – Why

Question 8 related to Question 7 and asked respondents why they thought certain crops would not grow in vertical farms in New Zealand.

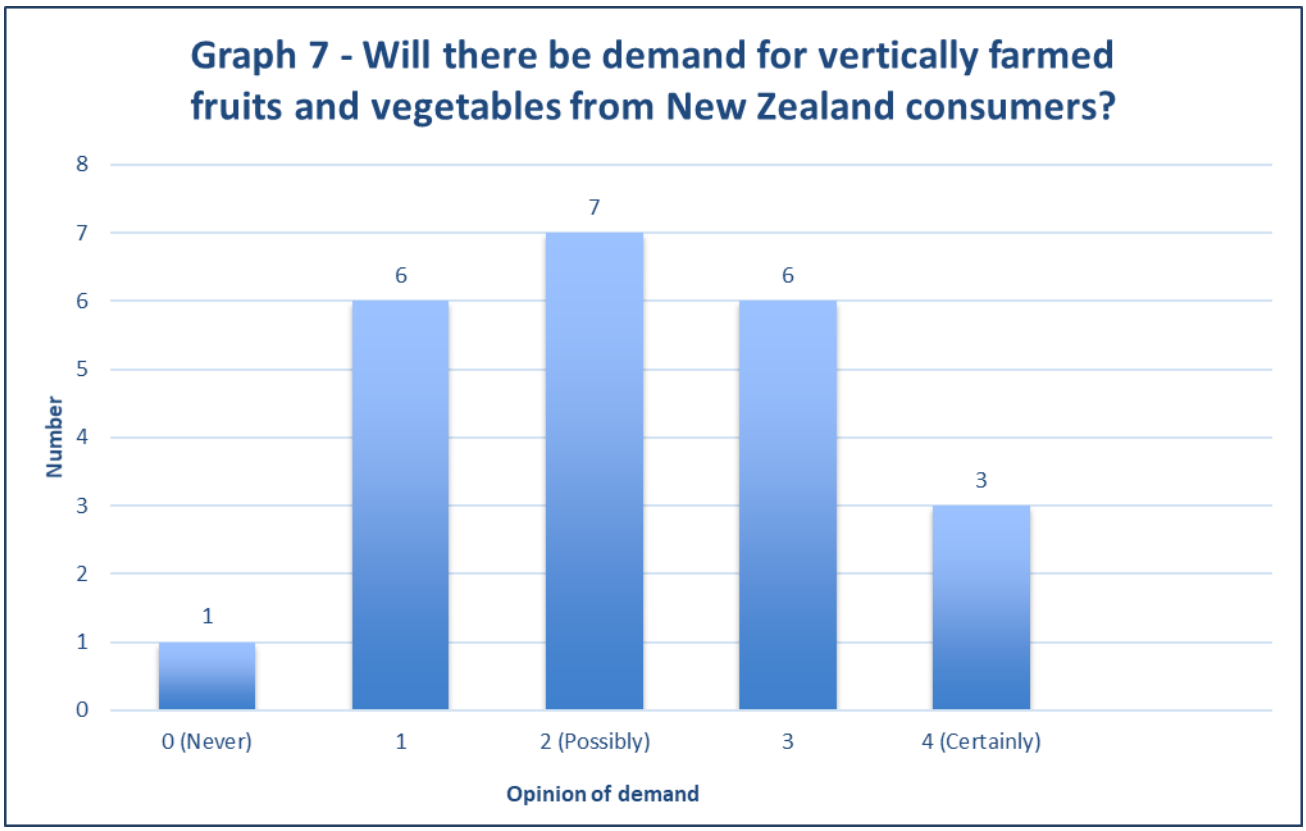
The reasons provided are themed as follows:

- Tree crops require chilling and pollination
- Root crops require soil and need a depth of soil
- Crops require more space / the crop does not respond well to enclosure
- Takes too long to produce a crop
- Some fruits and vegetables cannot be hydroponically grown
- Crop weight and volume
- Economics / too costly
- Consumers do not want it
- Technology not advance enough
- Labour requirements

Comments were also made that grains and fodder beet could not be grown in a vertical farm. However, this survey focuses on fruits and vegetables for human consumption.

Question 9 – Consumer demand in New Zealand

Respondents were asked if they thought there would be a demand for vertical farming in New Zealand. The question sought answers on a scale from 0 to 4, with 0 being *'never'* to 4 being *'certainly'*. Graph 7 below shows the responses. All but one respondent considered that there would be some level of demand for vertical farmed fruits and vegetables.



Question 10

Question 10 related to Question 8 and asked respondents why they thought there would be consumer demand in New Zealand.

The reasons provided are themed as follows:

Reasons for consumer demand

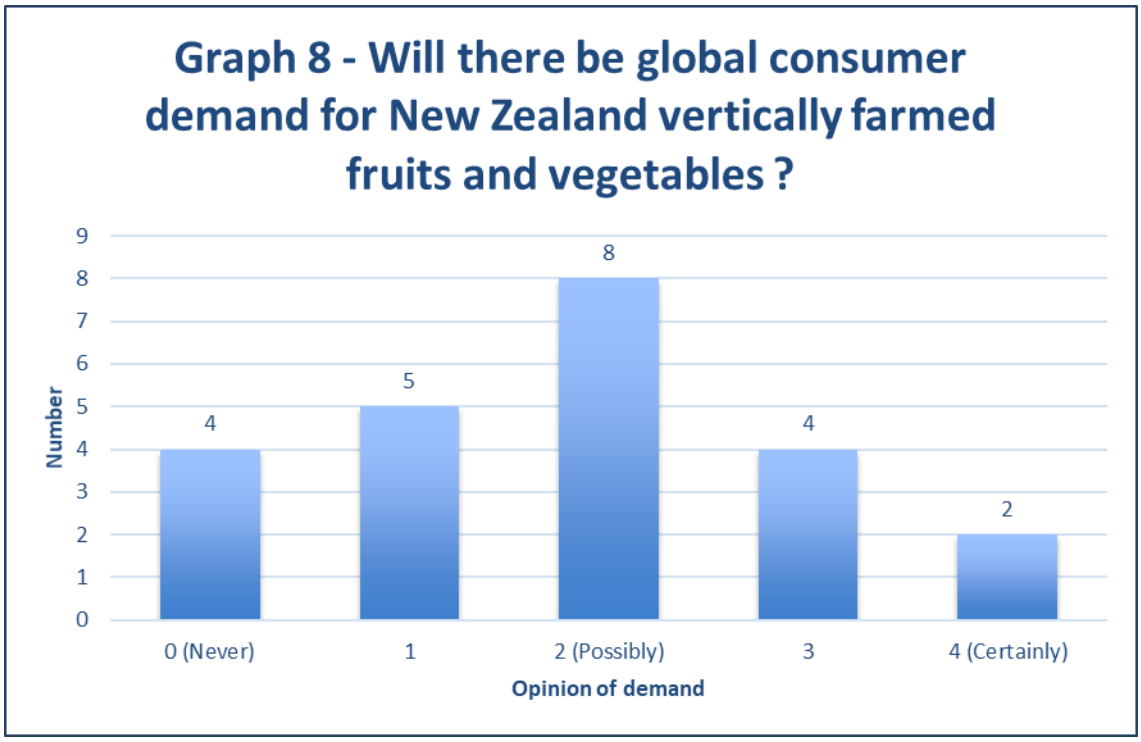
- Loss / scarcity of versatile and elite soils
- Increased population will mean increased demand for fresh produce
- Not subject to weather extremes
- Potential to minimise agricultural footprint and release more land for housing
- Marketing
- Subsidy could make the produce affordable
- Consumers don't care how the produce is grown, as long as it is fresh and reasonably priced
- Vertical farming isn't a big leap from a greenhouse
- Consumers care about quality, not farming systems
- Niche customer demand
- Trend towards organic produce worldwide.

Reasons against consumer demand

- There is a demand for 'authentic food' and less for factory food
- Abundance of growing land
- New Zealanders like 'natural'
- Consumer pushback against the technology
- Artificial lighting means produce will be expensive.

Question 11 – Global consumer demand

Respondents were asked if they thought there would be a demand globally for New Zealand vertical farmed fruits and vegetables. Similar to Question 9 above, Question 11 sought answers on a scale from 0 to 4, with 0 being *'never'* to 4 being *'certainly'*. Graph 8 below shows the responses. In comparison to responses to Question 9, there was a higher number of respondents (4) who believed there would never be a global demand.



Question 12 – Why?

Question 12 related to Question 11 and asked respondents why they thought there would be consumer demand in New Zealand.

The reasons provided are themed as follows:

Reasons for global consumer demand

- Global loss / scarcity of versatile and elite soils
- Global population growth will increase demand
- Consumers don't care about growing systems as long as the produce is fresh and affordable
- Vertical farms overcome seasonality and weather extremes
- New Zealand image
- Low cost of production.

Reasons against global consumer demand

- Limited market
- Other countries will be growing this way
- Won't be grown close to the consumer
- Transport costs
- Airmiles
- New Zealand has free sunshine
- High cost of production/ cost prohibitive – prices won't meet global consumer expectations
- Doesn't meet New Zealand's 'Clean and Green' image

- New Zealand is too remote. Crops suited to vertical farms are not suited to export due to short shelf life.

Question 13 – Limitations
Respondents were asked what they thought the limitations for vertical farming in New Zealand were. The responses were as follows:

- Government and Council compliance costs
- Lack of investment
- High capital and operational costs / cost of buildings
- Limited fruits and vegetables that could grow
- Not cost effective / cost of energy supply
- Scale of productions (large scale still some way off)
- Lack of consumer demand / niche market
- Lack of qualified skilled labour/ shortages of labour
- Lack of knowledge – both grower and consumer
- Still horticulture land available within short distance from NZ cities
- Plentiful supply of outdoor grown vegetables

Questions 14 and 15 – Vertical farm investigations
Question 14 asked respondents if they have considered establishing a vertical farm in New Zealand and if they had, then Question 15 asked where they had considered building it.

Of the 23 respondents, 19 had not considered establishing a vertical farm and three had. All three respondents that had considered establishing a vertical farm were growers. Two had considered locating a vertical farm in Auckland, while one had considered the Tasman area. All three commented that the capital investment/costs were the reason for not proceeding.

5 DISCUSSION

5.1 CROP TYPE

The findings of the survey align reasonably well with the finding of the literature survey. Both lead to the conclusion that vertical farming is only suited to a selection of crop types – namely leafy greens, micro greens, herbs, strawberries and with potential for tomatoes, cucumbers, capsicums and berry crops. These are crops that are currently grown in open field and greenhouses in New Zealand.

There are those who believe crop type is only restricted by current technology and others who are of the view that vertical farming could never provide the right environmental conditions for some crop types (e.g. tree crops and root crops). Only further research, testing and time will provide clarification on the matter.

5.2 BENEFITS AND LIMITATIONS

While there are many recognised benefits to vertical farms, with the most prevalent being growing independent of weather conditions close to consumers, the requirement to replace solar energy with electricity for artificial lighting and temperature control, combined with the high capital investment and operational cost, currently outweighs the benefits in New Zealand. This is a limitation as even though New Zealand is experiencing pressure on its productive land, it enjoys high levels of sunshine hours and enviable growing conditions (KPMG, 2017).

The additional economic limitation of a costly capital investment for building and technology means that vertical farming is currently seen as being an uneconomic growing system in New Zealand. Three growers who responded to the survey have investigated establishing a vertical farm in Auckland and Tasman, but responded that their investigations lead to the conclusion that is was uneconomic. Similar to the Philippine Onion study findings (refer Section 2.3 above), in the absence of government subsidy, vertical farming will remain uneconomic in New Zealand in the short to medium term (next 30 years). There may come a point where the cost of technology is economic, however, this would also need to align with affordable building space and affordable ongoing operational costs.

5.3 CAN VERTICAL FARMING REPLACE TRADITIONAL HORTICULTURAL GROWING ON PRODUCTIVE LAND IN NEW ZEALAND TO DELIVER HIGH QUALITY FRUITS AND VEGETABLES?

It is clear from the literature review and survey results that it is not possible for vertical farming to replace New Zealand's productive land to deliver the full range of high-quality fruits and vegetables currently grown in New Zealand. The vertical farm crop types are limited, and as discussed in Section 5.2 above, the benefits of vertical farming in New Zealand do not outweigh the limitations. However, New Zealand must remain mindful that by 2043, demand for fruits and vegetables will be 33% higher than it is in 2018 (Deloitte, 2018).

Unlike other countries, New Zealand currently has no food security policy. We complacently believe that we will always be able to sustainably grow enough food to feed ourselves, and contribute to the country's economic well-being (KPMG, 2017). However, with prime production land being lost, climate change, competition for water resources, extreme weather events and the constant threat of pests and disease we must turn our minds to food security issues for the future of New Zealand's domestic production (KPMG, 2017).

Most arguments against vertical farming arise when it is proposed to replace conventional farming of crops that are efficiently grown outdoors (Kozai, et al., 2016). However, proponents of vertical farming suggest it is not a replacement, but a complement to food production (Kozai, et al., 2016). This perhaps is the view that should be taken in New Zealand. The vertical farm has the potential to play a role in food supply in urban areas (Al-Kodmany, 2018). This potential is currently not seen in New Zealand due to the large capital investment and operations costs.

For these reasons, vertical farming will not resolve the issue of New Zealand's diminishing productive land. Vertical farming will at best, be a complementary growing system for a limited range of crops. This will however only happen at a point when vertical farming becomes economic.

Therefore, in order to address the issue of diminishing productive land and food security, New Zealand cannot continue the status quo approach. A precautionary approach could include protecting New Zealand's versatile land and high-class soils through a proposed National Policy Statement and investment into research on vertical farming, as well as a government fund to assist the establishment of vertical farms in urban areas. However, given that vertical farming is still in its infancy, it may be wiser for the Government to take a balanced approach whereby they introduce the proposed National Policy Statement and review the risks to vegetable growing in New Zealand and the security of the industry over the long term. This would then inform the develop a strategy for the sustainability of domestic fruit and vegetable supply in New Zealand.

There may also come a time where vertical farming in other countries becomes a disrupter to the New Zealand export market. As more international investment is put into research of crop varieties, a wider range of produce may be able to be grown in vertical farms e.g. dwarf fruit tree varieties and advanced technology that effectively mimics chilling requirements. This research would most likely be led by NASA or others considering the benefits of vertical farming in space

exploration. Therefore, a watching brief should also cover the evolution of crops being grown in vertical farms.

5.4 WHAT RESEARCH AND/OR INFORMATION GAPS ARE THERE?

Currently there is a gap in the understanding of vertical farming and the cultural well-being of Maori. If vertical farming is to become a growing system for New Zealand, then it would be helpful to understand how Maori culture and traditions align with the principles of vertical farming. This would be an interesting future research topic and could contribute towards refinement of vertical farm design. There may be learnings from the Maori culture that could be applied to vertical farming.

There may be the opportunity to further vertical farming technology and crop varieties through New Zealand research institutes or universities. This opportunity was not looked into for this study.

There is currently no specific economic research on the capital costs and operational cost for vertical farming in New Zealand. Proponents of vertical farming may wish to investigate this more closely.

There is not enough known about New Zealand domestic fruit and vegetable supply, in particular the importance of each growing region, the crops they grow, which regions they fed and when. The New Zealand Food Story – The Pukehohe Hub provides some insight to the Auckland situation. However, this is not the only growing region in New Zealand. This report needs to be replicated across all New Zealand growing regions.

6 CONCLUSIONS

Vertical farming will not replace traditional farming systems in New Zealand, but it may supplement it in the future when technology and start-up costs are economic. Currently the cost of capital and operation costs of a vertical farm is the veto factor for establishment in New Zealand.

Limited crops types can be grown in vertical farms and vertical farms could not grow the full range of crops currently grown in New Zealand.

Vertical farming is akin to current New Zealand greenhouse growing, but has the added expense of artificial lighting in the absence of solar energy. Even so, there is a lack of skilled labour to operate and manage the technology associated with vertical farming. This is directly related to the fact that the vertical farming technology is new and still developing.

Produce grown in a vertical farm may supplement a local market, but would not be suitable for export due to the crop types that can be grown. Approximately 80% of all vegetables grown in New Zealand are consumed in New Zealand, whereas, most of the fruit crop is exported. Therefore, vertical farming is most likely to be a disrupter to vegetable growing in New Zealand.

The New Zealand Government should take a balanced approach to the issue of New Zealand's diminishing productive land and food security. This would include progressing the proposed National Policy Statement (NPS) to protect New Zealand's versatile land and high-class soils. Also, more needs to be known about the role New Zealand's growing regions play and therefore to support the development of the NPS the Pukehohe Hub report needs to be replicated across all New Zealand growing regions.

There may come a point in the long-term future where vertical farming is economic in New Zealand. The Government and HortNZ should also actively invest in a full review of the risks to vegetable growing in New Zealand, particularly the security of this industry over the long-term. Together, the

Government and HortNZ should develop a strategy for the sustainability of domestic fruits and vegetable in New Zealand.

The Government and HortNZ also need to invest into research and development of internationally leading technology and innovation in the field of food growing, including vertical farming technology.

7 RECOMMENDATIONS

It was found that vertical farming will not replace New Zealand's productive land to deliver high quality fruits and vegetables in the short to medium term (next 30 years). However, with the evolution of technology, vertical farming may supplement traditional farming methods in New Zealand's long-term future (beyond 2048). Therefore, the following recommendations are made:

Develop National Policy

- The New Zealand Government takes a balanced approach to the issue of New Zealand's diminishing productive land and food security through the development of a National Policy Statement to protect versatile land and high-class soils; including replicating the Pukekohe Hub report across all New Zealand growing regions.

Undertake Risk Assessment and Sustainability Strategy

- The New Zealand Government, in conjunction with HortNZ, proactively invest in a full review of the risks to vegetable growing in New Zealand and the security of the industry over the long term and develop a strategy for the sustainability of domestic fruit and vegetable supply in New Zealand.

Investment in technology

- The New Zealand Government and HortNZ earmark investment into internationally leading technology and innovation in the field of food growing, including vertical farming.

Advocate for funding

- On behalf of New Zealand growers, that HortNZ actively advocate for research and development funding to ensure the industry is world leading in technology and development in relation to sustainable growing practices; such as vertical farming and including new crop varieties that could be grown in new systems.

Investigate export disruption

- On behalf of New Zealand growers, that HortNZ actively investigate the potential disruption to export crops.

Research alignment with cultural values

- Research is undertaken to better understand how Maori culture and traditions align with the principles of vertical farming.

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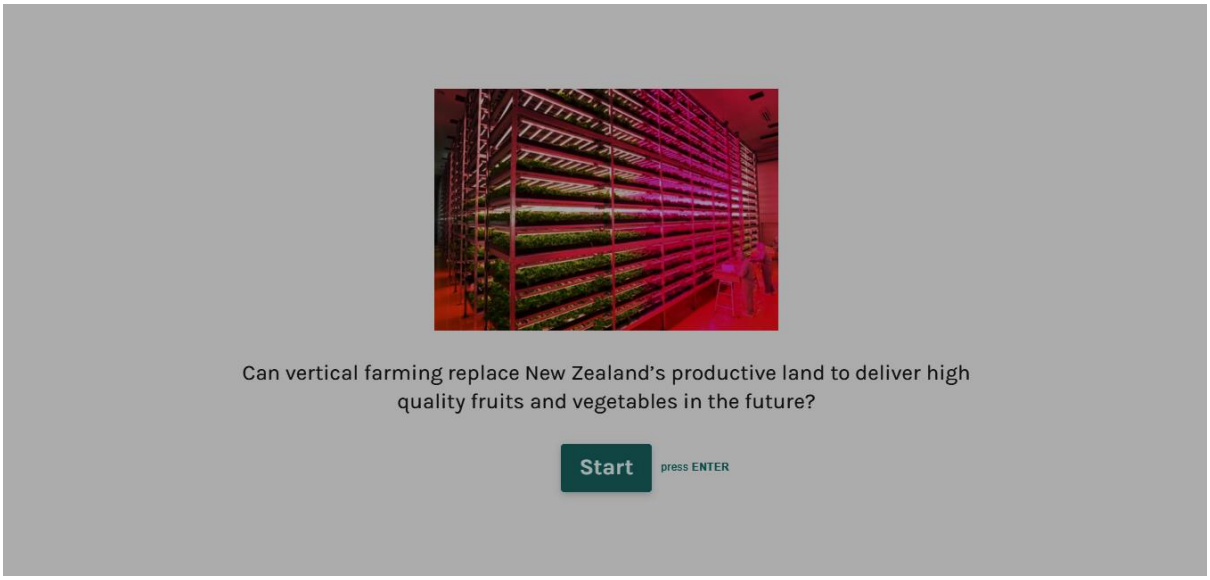
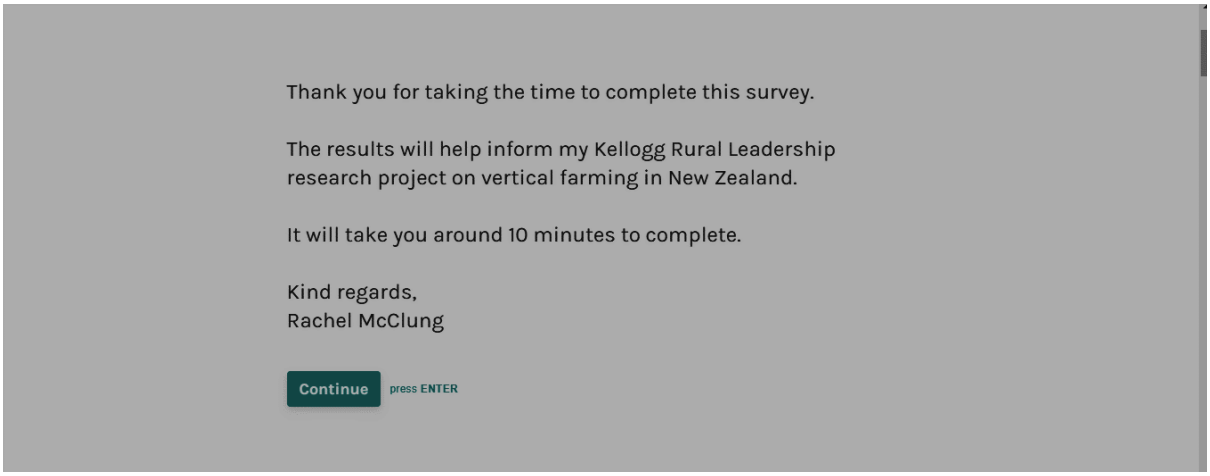
APPENDIX I – SURVEY QUESTIONS

The following are screenshots of the online survey questions. Typeform.com was used to conduct the survey. https://rachelmcclung.typeform.com/to/GkNM0y





2 → Please select your age range from the list below:

- A 15-17
- B 18-24
- C 25-34
- D 35-44
- E 45-54
- F 55-64
- G 65-74
- H 75 or over

3 → What best describes your involvement in horticulture? Please select the best description for you:

- A Grower
- B Retired Grower
- C Farm / Orchard Manager
- D Owner / Shareholder
- E Rural Professional
- F Hobby Horticulturalist
- G Academic
- H Other

Thanks for telling us about your background. Now for the questions on vertical farming...

Continue press ENTER

4 → How much do you know about vertical farming?

0	1	2	3	4	5	6	7	8	9	10

Never heard of it — A bit — I'm an expert

5 → In your opinion, which fruits and vegetables could grow successfully in New Zealand using a Vertical Farming system?

Type your answer here...

SHIFT + ENTER to make a line break

6 → Why do you think this?

Type your answer here...

SHIFT + ENTER to make a line break

7 → In your opinion, which fruits and vegetables could not grow successfully in New Zealand using a vertical farming system?

Type your answer here...

SHIFT + ENTER to make a line break

8 → Why not?

Type your answer here...

9 → In your opinion, will there be demand for New Zealand vertically farmed fruits and vegetables from New Zealand consumers?

0	1	2	3	4

Never Possibly Certainly

10 → Why is this your view?

Type your answer here...

11 → In your opinion, will there be a demand for New Zealand vertically farmed fruits and vegetables from global consumers?

0	1	2	3	4

Never Possibly Certainly

12 → Why is this your view?

Type your answer here...

13 → In your opinion, what are the limitations for vertical farming in New Zealand?

Type your answer here...

14 → Have you considered establishing a vertical farm in New Zealand?

A Yes

B No

Thank you for taking the time to contribute to this Survey.

The results of the survey will be published with the final study report in late November 2018 and will be available at hortnz.co.nz.