Feeding the New Zealand Family of Five Million, 5+ a Day of Vegetables?

Fiona Curran-Cournane 1 and Elaine Rush 2,3,*

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Abstract: New Zealand (NZ), a food-producing, geographically isolated nation has set a domestic dietary guideline of 5 servings a day/person of vegetables. The question “does New Zealand produce enough servings and diversity of vegetables to meet dietary recommendations of 5 diverse servings/day?” was explored. Publicly available data for weight of vegetables produced and hectares of land used in relation to five vegetable diversity groups of white roots-and-tubers, vitamin-A-vegetables, other vegetables, dark-green-leafy vegetables, and legumes were examined. Overall, the equivalent of 11.7 servings of vegetables/day/NZperson was produced. Potatoes, onions, carrots, and squash were produced in the largest quantities (total 7.7 servings/day/NZperson) but most onions, squash, and some potatoes were exported (2.5 servings/day/NZperson). There was inadequate production of legumes, 0.6 servings/day/NZ person (peas and beans) and dark-green-leafy vegetables, 0.03 servings/day/NZ person (silverbeet and spinach). Only 0.2% of the total land area of NZ is used for growing vegetables. Expansion of the area used for vegetables should be considered in the context of sustainable production and irreversible pressures confronting the unique land and soils the land use requires, as well as current environmental impacts of intensive conventional outdoor vegetable production. An environmentally sustainable and diverse supply of vegetables for domestic use needs to be strategically and actively protected.

Keywords: nutritional health; vegetable production; land and soil characteristics; sustainable land management; dietary diversity; food system

1. Introduction

Across the lifecourse, healthy diets comprised of whole and minimally processed foods protect against malnutrition in all its forms including non-communicable diseases [1]. Globally, dietary guidelines for a healthy diet include at least 400 g of a variety of vegetables and fruit a day for adults. The FAO has identified a minimum dietary diversity score for women of reproductive age (MDD-W) designed to indicate adequate micronutrient intake for 11 micronutrients from 10 food groups [2]. The MDD-W differs from other diversity scores because of the attention to micronutrients rather than macronutrients and 5 of the 10 groups are vegetable-based: legumes, starchy staple foods, dark-green-leafy vegetables, other vitamin-A rich fruits and vegetables, and other vegetables. The MDD-W has validity for micronutrient adequacy and also for household food security and farm production diversity [3].

By volume and weight, vegetables should make up the largest proportion of the foods eaten [4]. Vegetables are more nutrient dense, produce less greenhouse emissions, use less land and water than animal source foods [4] but globally, and in New Zealand (NZ), consumption of vegetables is low [5].
Historically, and now, it can be argued from an economic perspective that production of vegetables should meet both domestic [6] and global [7] demand. From a public health point of view this would mean domestic production matching the dietary guidelines. The national and inextricably-linked global food system requires integrated whole-of-system solutions that address competing nutrition, economic, and sustainability challenges. Part of this challenge in a food-producing nation is to assess and protect the land available for the domestic production of food and specifically land-based vegetable production, Figure 1. It is recognized that the earth and natural systems are the basis of sustainable food production as well as human health and wellbeing [8]. The 2030 agenda for sustainable development and the goals [9] provides a plan of action for people, the planet, and prosperity.

The capability of land to grow outdoor vegetables is dependent on many factors. The New Zealand Land Use Capability (LUC) classification system determines how the conditions of contour and erosion, soil, climate, and wetness limits or advantages the use of land. It treats class 1 land as the most versatile class of land with versatility decreasing down the scale toward LUC class 8 land [10]. Only LUC classes 1–3 land are capable of growing crops including vegetables. “Highly versatile” LUC class 1 and class 2 land with “negligible” or “minor” physical limitations for arable use, represent 0.9% and 4.5% of the total land area in NZ, respectively. An additional 9.2% of total land area is described as Class 3 land, or “versatile”, with “moderate” physical limitations for arable use [11]. While certain rural land use activities, such as outdoor vegetable production, are limited to versatile land, other forms of farming such as dairying are also heavily reliant on these unique land and soil characteristics [12]. Such finite land and soil resources therefore have very high importance to the food system and the national economy.

Soil is also considered taonga (sacred treasure) by Māori, the indigenous people of Aotearoa New Zealand. Soil sovereignty is critical in a Māori food sovereignty context who approach its use for food from a regenerative perspective [13]. Māori food sovereignty is the self determination of producing food and about having the choice of what is being

![Figure 1. System outcome framework applied to the relationships between the earth, land, soil and water use, and the retail supply of vegetables to the consumer.](image-url)
eaten and how it is being grown. Soil sovereignty prioritizes local food production and collective gardens. Food security, food sovereignty, and locally grown vegetables in this context are closely associated.

Both the availability of this versatile land and its sustainable management are equally important to ensuring a sustainable and resilient food system. This is becoming increasingly apparent with growing evidence that identifies the need to move towards more sustainable diets to help achieve both combating the climate crisis and the growing prevalence of malnutrition, food insecurity, and non-communicable disease [4,14]. Such literature recognizes that various food categories have varying climatic and environmental implications. What may not always be obvious, however, is that by shifting towards diets that include high amounts of whole plant-based foods requires these unique, yet uncommon, land and soil characteristics that are becoming increasingly pressurized. This negatively impacts a nation’s ability to sustain current and increasing populations. For example, as a result of urban sprawl onto productive food-growing land in Melbourne, local vegetable production is expected to reduce from 82% of Greater Melbourne’s needs to 21% by 2050, when the population is projected to reach 7 million [15]. Other research that explored whether enough fruit and vegetables were being produced to meet global health needs reported that the global supply of these food categories falls, on average, 22% short of population needs according to dietary recommendations (supply:need ratio: 0.78) [16]. Global issues regarding the inadequate supply of fruit and vegetables have been long-standing, and while substantial regional variation exists, such issues are projected to persist particularly for regions such as sub-Saharan Africa, parts of Asia, and the Pacific [17]. These analyses have not, however, examined the diversity of vegetables produced in relation to micronutrient adequacy.

New Zealand is a net exporter of foods [18] that are high in protein and fat, and imports carbohydrate foods such as rice and sugar. In an analysis of food exported and imported between 2017 and 2019, it was calculated that for vegetables 3.2 servings/day/NZperson were exported and 0.3 servings/day/NZperson were imported [18]. Exports were mainly unprocessed onions and potatoes and imports were potatoes in the form of chips and tomatoes mainly canned and in the form of tomato sauce and ketchup.

Data on total domestic production of foods are limited however for fruit and vegetable production and land use. Horticulture™ New Zealand (HortNZ), who represents the interests of NZ’s 6000 commercial fruit and vegetable growers, publishes with Plant and Food™ Research annual reports of production [19–22]. These publications, “Fresh Facts”, include information about the land area planted, crop volume, and domestic and export sales value of fresh and processed vegetables. From this, and information about the use and capability of NZ’s land, the question was asked “does NZ produce enough servings and diversity of vegetables to meet dietary recommendations of 5 diverse servings/day” [23]? Based on findings, a secondary aspect was to assess whether additional land is required for vegetable production taking into account the land and soil characteristics required for vegetable production as well as sustainable management practices.

2. Materials and Methods

Vegetable production was accessed from the Fresh Facts publications from 2017 to 2020 [19–22] and is reported in tons. Average production was determined as a mean value over the four years, the land area in hectares was as reported for 2020. Area of land planted in brassicas, encompassing broccoli, cabbage, and cauliflower was divided by three to represent each vegetable type. Vegetable production for a year in grams was divided by the population of NZ (5 million [24]), 365 days a year and a serving size of 75 g to determine servings/day/NZperson produced (Table 1). Vegetables were classified according to the MDD-W groups [2]. Vegetables were ranked from highest to lowest for tons produced and the top 12 were considered in detail. Fresh and processed are combined. In addition, as there were no dark-green-leafy vegetables in substantial quantities the data for silverbeet and spinach were also considered.
Table 1. Fresh and processed average vegetable production in tons 2017–2020 and hectares covered 2020 for New Zealand [19–22].

| Vegetable Type (Alphabetical Order) | Diversity Group | Average Annual Production Ton (2017–2020) | ¹ Servings/Day/ ² NZ Person | Hectares Planted |
|-------------------------------------|-----------------|------------------------------------------|-----------------------------|-----------------|
| Asian Greens incl Kale              | DGLV            |                                         |                             | 57              |
| Asparagus                           | Other           | 1875                                     | 0.014                       | 520             |
| Beans (f)                           | Legumes         | 3000                                     | 0.022                       | 300             |
| Beans (p)                           | Legumes         | 14,725                                   | 0.108                       | 500             |
| Beetroot (f)                        | Other           | 7000                                     | 0.051                       | 199             |
| Beetroot (p)                        | Other           | 20,550                                   | 0.150                       | 260             |
| Broccoli                            | Other           | 24,700                                   | 0.180                       | 956             |
| Cabbage                             | Other           | 58,000                                   | 0.424                       | 956             |
| Capsicums                           | Vitamin-A       | 21,440                                   | 0.157                       | 103             |
| Carrots (f)                         | Vitamin-A       | 88,000                                   | 0.643                       | 916             |
| Carrots (p)                         | Vitamin-A       | 70,350                                   | 0.514                       | 800             |
| Cauliflower                         | Other           | 33,000                                   | 0.241                       | 956             |
| Cucumbers                           | Other           | 6388                                     | 0.047                       | 71              |
| Eggplant/aubergines                 | Other           | 925                                      | 0.007                       | 9               |
| Garlic                              | Other           | 1200                                     | 0.009                       | 178             |
| Herbs                               |                 | 8070                                     |                             |                 |
| Kumara                              | Other           | 24,000                                   | 0.175                       | 1600            |
| Lettuce outdoor                     | Other           | 1532                                     |                             |                 |
| Lettuce greenhouse                  | Other           | 50                                       |                             |                 |
| Melons                              | Other           | 4800                                     | 0.035                       | 222             |
| Mushrooms                           | Other           | 8500                                     | 0.062                       | 25              |
| Onions                              | Other           | 211,452                                  | 1.545                       | 5296            |
| Peas (f)                            | Legumes         | 59,850                                   | 0.437                       | 4075            |
| Peas (p)                            | Legumes         | 38,000                                   | 0.278                       | 603             |
| Potatoes (f)                        | White roots-and-tubers | 244,597                                    | 1.787                       | 10,417          |
| Potatoes (p)                        | White roots-and-tubers | 366,588                                 | 2.678                       |                 |
| Pumpkins                            | Vitamin-A       | 38,000                                   | 0.278                       | 603             |
| Shallots                            | Other           | 1200                                     | 0.009                       | 30              |
| Silverbeet/Spinach                  | DGLV            | 3500                                     | 0.026                       | ³ 100           |
| Squash                              | Vitamin-A       | 87,884                                   | 0.642                       | 6530            |
| Sweetcorn (f)                       | Other           | 22,000                                   | 0.161                       |                 |
| Sweetcorn (p)                       | Other           | 77,700                                   | 0.568                       | 3871            |
| Tomatoes indoor                     | Other           | 42,200                                   | 0.308                       | 120             |
| Tomatoes outdoor                    | Other           | 53,000                                   | 0.387                       | 408             |
| Truffles                            | Other           | 0.2                                      | 0.000                       | 0.2             |
| Total                               |                 | 1,604,493                                 | 11.7                        | 41,676          |

¹ One serving is estimated at 75 g. ² Population of New Zealand assumed as 5 million from StatsNZ. ³ The figure of 2028 ha for area of land planted for silverbeet/spinach provided in FreshFacts 2020 was an order of magnitude of land greater than any other vegetable type—a more realistic revised estimate of 100 ha alternatively was used (pers. comm. Vegetables New Zealand). f: Fresh, p: processed, DGLV: dark-green-leafy vegetables.

Land use information for area of land planted by vegetable type (hectares) was accessed from the Fresh Facts publications [19–22]. Retail price of vegetables was sourced from Stats NZ consumer price index for June 2020 to June 2021 [25] with the cost of other vegetables sourced from the PakNSave website (https://www.paknsave.co.nz/shop) accessed on 21 August 2021.

Data used in this analysis are publicly available and referenced. No ethical review is required. Numbers are rounded to significant figures to reflect accuracy of measured and derived values.

3. Results

According to figures presented in Fresh Facts (2020), in the order of 45,000 ha of land was used for vegetable production in NZ. This represents 0.2% of the total land area of New Zealand. The planted area of land with corresponding tonnage, diversity dietary group, and servings/day/NZperson for each vegetable type is presented in Table 1.
The equivalent of 12 servings of vegetables/day/NZperson was produced (Table 1). Twelve vegetables represented 94% by weight of total production which is equivalent to 10.6 servings/day/NZperson (Table 2). Silverbeet and spinach were added to this table otherwise no dark-green-leafy vegetables were included.

### Table 2. Annual production of thirteen vegetables in New Zealand: ranked by tons/year [2,18–21].

| Vegetable                           | Hectares in 2020 [22] | Tons/Year [19–22] | 1 Servings/Day/2 NZperson | Dietary Diversity Group [2] | $/kg   | $/Serving |
|-------------------------------------|-----------------------|-------------------|---------------------------|----------------------------|--------|-----------|
| Potato (f + p)                      | 10,417                | 611,185           | 4.5                       | White roots-and-tubers     | 2.20   | 0.17      |
| Onions                              | 5296                  | 211,452           | 1.5                       | Other veg                  | 0.99   | 0.07      |
| Carrots (f + p)                     | 1716                  | 158,350           | 1.1                       | Vitamin-A                  | 2.24   | 0.17      |
| Sweetcorn (f + p)                   | 3871                  | 99,700            | 0.7                       | Other veg                  | 2.00   | 0.15      |
| Tomatoes indoor + outdoor           | 528                   | 95,267            | 0.7                       | Other veg                  | 14.99  | 1.12      |
| Squash                              | 6530                  | 88,179            | 0.6                       | Vitamin-A                  | 4.00   | 0.30      |
| Peas -processed                     | 4075                  | 59,850            | 0.4                       | Legumes                    | 2.66   | 0.20      |
| Cabbage                             | 956                   | 58,000            | 0.4                       | Other veg                  | 2.89   | 0.22      |
| Pumpkins                            | 603                   | 38,000            | 0.3                       | Vitamin-A                  | 1.00   | 0.08      |
| Cauliflower                         | 956                   | 33,000            | 0.2                       | Other veg                  | 4.00   | 0.30      |
| Broccoli                            | 956                   | 24,700            | 0.2                       | Vitamin-A                  | 11.79  | 0.88      |
| Capsicum                            | 103                   | 21,440            | 0.1                       | Vitamin-A                  | 12.00  | 0.90      |
| Silverbeet/spinach                  | 100                   | 3500              | 0                         | Dark-green-leafy veg       | 5.00   | 0.38      |

1 PakNSave July 2021. f + p fresh and processed total. 2 Population of New Zealand assumed as 5 million from StatsNZ.

Servings of potatoes of 4.5 servings/day/NZperson far exceeded that of any other vegetable type with 2.7 servings/day/NZperson being processed potato, the majority of which is for fries. Servings of onions represented the equivalent of 1.5 servings/day/NZperson, followed then by servings of carrots (1.1 servings/day/NZperson) and squash (0.6 servings/day/NZperson) (Tables 1 and 2). Collectively, these four vegetable types equated to a total of 7.7 servings/day/NZperson. If potatoes, onions, carrots, and squash are excluded, the production of remaining vegetable types would only provide the equivalent of 2.9 servings/day/NZperson.

Price for one serving of vegetable ranged from 8 cents for pumpkin to $1.12 for tomatoes (Table 2), with an average cost for one 75 g serving of 40 cents equating to $2 per person/day to meet five servings a day of vegetables. This is $4 a day for a household of 2, which equates to 0.75 kg a day. A week’s supply of vegetables for two people would be 5 kg in weight.

Over the year June 2020 to June 2021 (Figure 2), relatively high prices and seasonal variation in price were seen for courgettes, capsicums, beans, and fresh tomatoes. The lowest prices and least seasonal variation were observed for canned tomatoes, potatoes, frozen peas, pumpkin, and mixed frozen vegetables [25].

When individual vegetable types were categorized by dietary diversity group, “white roots-and-tubers” were amply sufficient but exclusively potatoes. Vitamin-A vegetables were also produced in sufficient quantity (Table 3). Of the vegetable types within the “vitamin-A” dietary group, half the servings were from carrots. Additionally, 44% of the “other vegetable” dietary group was contributed by the production of onions, of which around 85% gets exported [18]. In contrast, the production of “legumes” and “dark-green-leafy vegetables” fell wholly short of being sufficient of meeting the diversity of the population’s dietary need (Table 3). If one serving of vegetables from each of the five vegetable dietary diversity groups were to be available for each NZ person each day then the area used for legumes and dark-green-leafy vegetables would need to be increased by 76% and 3811% respectively (Table 3), based on current conditions and not considering the potential for diversification by crop rotation.
Figure 2. Seasonal variation in price of one kilogram of 19 vegetables from June 2020 to June 2021. Source statistics NZ consumer price index [25].

Table 3. Vegetables grown in New Zealand by dietary diversity group and servings/day/NZperson in the population, area of land used, and imports and exports of vegetables [19–22].

| Diversity Group                  | Servings/Day/NZperson | Hectares | Hectares/Serving | Import Servings/Day/NZperson | Export Servings/Day/NZperson |
|----------------------------------|------------------------|----------|------------------|-------------------------------|------------------------------|
| 3 White roots-and-tubers         | 4.465                  | 10,417   | 2333             | 0.13                          | 0.5                          |
| Vitamin-A                        | 2.233                  | 8952     | 4009             |                               |                              |
| Other vegetables                 | 4.373                  | 17,259   | 3947             | 1.4 (onions)                  | 0.6 (squash)                 |
| Legumes                          | 0.567                  | 4875     | 8598             | 4                             |                              |
| Dark-green-leafy vegetables      | 0.026                  | 100      | 3911             |                               |                              |

1 Hectares quoted in fresh facts [19–22] are not exclusive for all vegetables based on rotation of crops. 2 Import and export data extracted from Rush and Obolonkin (2020) [18]. 3 Exclusively potatoes. 4 Imported legumes are mainly dried—one serving 55 g. 5 Personal communication Vegetables New Zealand.

4. Discussion

This report, a snapshot in time, has examined the volume and variety of vegetables grown for the domestic market in NZ. The main finding is that domestic production, within each of the five vegetable diversity groups, is not adequate for two groups—namely legumes and dark-green-leafy vegetables. Potatoes and onions were produced in ample quantities after accounting for exports.

This does match the pattern of consumption reported in dietary surveys. The NZ adult nutrition survey in 2008/2009 [26] defined vegetables as all fresh, frozen, canned including mixes, coleslaw, tomatoes, green salads, legumes and pulses, legume products and dishes (baked beans, hummus, tofu), and vegetable dishes but did not report dietary intake by specific vegetables. Potatoes, kumara, and taro including fries were in a separate food group and, after bread and grains, this group was the third highest source of energy in the NZ diet at 6.8%. Vegetables contributed 3.8% of the total energy intake that was reported for the adult NZ diet. From the 2002 NZ child nutrition survey [27] of children aged 5–14 y, it is known that potato, potato fries, kumara (sweet potato), carrots, broccoli, peas, lettuce, cauliflower, cabbage, tomatoes, and corn in descending order were the most frequently consumed vegetables which also matches with the ranking of vegetables reported in this
analysis. However, what is consumed does not necessarily match the diversity that is required for optimal nutrition.

In our recent research, skin carotenoids, a validated biomarker of vitamin-A status, were measured by reflection spectroscopy in 571 adults aged 16 to 85 years [28]. Carotenoid status was negatively related to body size and positively to the intake of dark-green-leafy vegetables, carrots, and pumpkins. Based on the carotenoid measures, eight out of ten adults in this NZ study were at moderate risk, or more, of negative health outcomes [29] related to low vegetable intake including cancers, metabolic syndrome, and diabetes.

It is known that vegetable intake of NZ people is low [10] with 46% of adults reporting that they eat 2 or less servings a day. This measure also includes potato as a vegetable. Overall, men report consuming less vegetables than women and those living in higher deprivation, Pacific and Asian people also eat less vegetables. It is also known that in NZ one in five children are living in food-insecure households [30]. Food-insecure households are more likely to reside in deprived neighborhoods, and to have three of more children in the household. Food insecure children are more likely not to meet vegetable consumption guidelines. These children are also more likely to be classified as overweight or obese. Such issues are associated with accessibility, a food security-related term encompassing both not having enough money or physical access to healthy food.

The price of vegetables produced in larger quantities could arguably be considered modest in the current study (Table 2), notwithstanding out-of-season prices (Figure 2). Research modelling from NZ reported that a healthy diet sufficient in vegetables would cost between 18 and 25% of total expenditure of food, while for the current, less healthy diet vegetable cost was between 10 and 13% of food spend [31]. Food spend for households on minimum income required 27% to 34% of household income. Their modelling examined vegetables as one food group. Vegetable selection was based on ethnicity-specific expert panel recommendations in addition to identification of commonly consumed vegetables by Statistics New Zealand. Diversity within vegetables was not addressed. If the 15% goods and services tax (GST) was removed from healthy foods, including vegetables, demand for healthier food including vegetables could change. Improvements to NZ’s food environments also need to be made to help encourage consumer behavior with regard to promoting healthy eating as little, if any, progress has been made in recent years with the implementation of associated policies, especially for those that concern children [32].

It is also known that a proportion of what is currently being produced is lost or wasted and this accumulates across the supply chain, which means that not all food produced or sold to retailers is available to be consumed at household level [33]. Food waste is a huge issue both globally and nationally [34], with figures highest for more affluent countries [35]. In 2018 in NZ, by weight 25% of food wasted by households was fresh vegetables with one-third of that amount in a condition where it could have been eaten [36]. The top 20 foods wasted in a form that could have been eaten included the vegetables potatoes, broccoli, carrots, lettuce, onions, and sweetcorn. Such waste has implications for landfills where vegetables contribute to the release of methane. Vegetable waste also means that the farmed land and soils are unnecessarily pressurized, that water withdrawal used to produce the food was avoidable, and that the energy in the form of fossil fuel to produce food was unnecessary—collectively avoidable issues that all need to be better acknowledged via increasing existing efforts that educate consumers on food waste.

4.1. Tensions Associated with Expanding Outdoor Vegetable Production Land Use

In 2020, around 45,000 ha (or 0.2%) of NZ’s total land area was used for vegetable production [22]. According to Statistics NZ, the proportion of land used for sheep farming is 15.3%, beef 10.1%, dairy 8.3%, grain 1.8%, other livestock 1.3% and horticulture 0.5%—with the latter encompassing land used for growing fruit, including grapes for wine, kiwifruit, berries, and vegetables [37]. While the area of land currently used for growing outdoor vegetables technically has the potential to increase, a large proportion of versatile land, which generates optimal amounts of pasture growth [12], will be currently occupied by land
used for dairy farming. Dairy, a $20 bn industry, generates over 40% of NZ’s food and fiber export revenue [38] notwithstanding the large proportion of the country’s greenhouse gas emissions it produces [39], as well being responsible for widespread nutrient pollution [40]. If expanding outdoor vegetable production land use this and other factors such as proximity to city markets, access to freshwater for irrigation, seasonal labor supply, distribution of the food to the whole of NZ, a changing climate and environmental concerns also need to be considered as part of a transformation of the food system.

Intensive conventional outdoor vegetable production practices have been associated with high environmental nutrient footprints. For example, continuously working up the soil via rotary hoeing, harvesting, and deep ripping can negatively impact soil carbon levels and biodiversity, and coupled with excessively high fertilizer application rates, can render the soil more vulnerable to contaminant losses, such nitrogen leaching [41–45]. These practices, and expansion of land use for conventional outdoor vegetable production, would be at odds with sustainability and national policy intentions that set to maintain or improve freshwater health [46].

Sustainable strategies relevant to vegetable production such as the use of cover crops to restore the carbon content of the soil, minimal tillage practices, application of green manures, reduction of synthetic fertilizers, and/or soil testing to ensure optimum rates and the avoidance of excessive applications could assist with ameliorating and reducing these detrimental impacts [41,47,48]. The total quantity of fertilizers applied on farm can also have a relatively large effect on total greenhouse gas emissions hence the dual benefit of a reduced carbon footprint with the avoidance of unnecessary excessive application rates [49]. Such emissions can be substantial because between 1991 and 2019 in NZ, sales of synthetic nitrogen fertilizer for application onto land increased over 600% [50]. The uptake of the sustainable management practices described have not yet, however, shown measurable effects [43,50]. Regenerative agriculture [51], which takes into account the diversity and context of farms, aligns with best management practice and is gaining scientific momentum in New Zealand. It encourages a mindset of continuous farm improvement and increasing evidence on its benefits may encourage further uptake of its practice.

Encroaching urbanization and continuous rural fragmentation of the best food-producing land [52], particularly in locations that have traditionally grown outdoor vegetables in NZ, can also make it problematic to expand, or de-intensify this rural land use activity. An example is the Pukekohe area which is a renowned outdoor vegetable growing area situated about 50 km from the downtown area of New Zealand’s largest city, Auckland which is home to 1.6 million, 32%, of the country’s population. Pukekohe’s unique soils and climate provide more than 25% of the nation’s vegetables [53]. While too experiencing long-standing issues with deteriorating soil quality and elevated nitrate concentrations in surface and groundwater as a result of continuous vegetable production all-year-round in Pukekohe [41,54,55]; it is also seen by some as desirable for residential and commercial development [53]. Disturbance of soil for built purposes is irreversible. Once topsoil, typically the upper 30–40 cm, is removed for development preparations it is regarded as a man-made, or Anthropic soil [56], and utility of that soil becomes uncertain. It has been estimated that by 2043, there will be a decrease in the volume of vegetable production of between 46 and 55% in Pukekohe due to challenges such as urban encroachment, availability of skilled labor, and water access issues [57]. While the bulk of current prices per/kilogram and per/serving could arguably be considered modest (Table 2), prices have been estimated to rise between 43% and 58% by 2043 as a result of such described challenges. The New Zealand Government has recently recognized the unique land and soil characteristics associated with versatile land as a national asset and has proposed a National Policy Statement for Highly Productive Land to prevent the loss of more of our productive land and promote its sustainable management. Decisions on the proposed policy are expected in the first half of 2022.
4.2. Limitations and Strengths

Vegetable production in this analysis does not take account of the vegetables grown in the community, by schools and home-grown vegetables. In addition, annual averages are used and no account of seasonal variation in production is taken. Preservation processes such as canning, freezing, and drying could reduce shortfalls but this may not be equitable or reliable. As the intention was to undertake a macro/rudimentary analysis on the diversity of vegetables produced in NZ, a further limitation of this study is that values have been rounded to reflect uncertainties of measurement so the order of magnitude is indicative.

Other limitations are that production is subject to crop rotation and the ability to harvest with a need for seasonal workers. Some values of production of vegetables, for example, corn are also not clear. It is not known if the weight of raw product includes the cob or is the weight of the kernels as is assumed with processed corn and peas. Full effects of the ongoing trade and seasonal worker disruption by the COVID-19 pandemic are also not accounted for.

The main strength of this analysis is the combination of expertise and understanding of environmental land and soil needs, the sustainable development goals, and in-depth understanding of the need for dietary diversity which is fundamental to public health.

4.3. Implications and Future Research

While New Zealand is a net exporter of food, enough to feed a population of 35 or 40 million according to some reports [58]—figures that are indeed only accurate for dairy products [10]—results from this study indicate the importance of considering the diversity both across and within food categories. The shortfall of two vegetable dietary diversity groups in the current study is consistent with other research that describe, more generally, that the current and projected supply of both fruit and vegetable are already insufficient in achieving recommended dietary needs in many countries [16]. This can exacerbate the risk of relying on overseas imports to pick up such shortfalls, especially for both legumes and dark-green-leafy vegetables as per findings in the current study (Table 3). Relying on imports of dark-green-leafy vegetables that have a short shelf life can be even more problematic. Both legumes and dark-green-leafy vegetables are good sources of the vitamin folate, with one serving of either providing more than 50% of the recommended daily intake. Among women of child-bearing age, 31% had concentrations of red blood cell folate associated with some risk of neural tube defects [26].

Future research could focus on scenario and feasibility analysis of either expanding the area of land used for outdoor vegetable production or alternative means of production. Not only could this be explored for the shortfall of legume and dark-green-leafy production, but also other vegetable types, whereby detrimental intensive conventional practices have been a long-standing issue to the environment. Such scenario and feasibility analysis should focus specifically on sustainable land management practices to ensure positive environmental outcomes. These could include regenerative agriculture practices and principles to help build the scientific evidence base which could encourage its uptake. This is important as land and soils are becoming increasingly stressed [46] via intensification and, particularly relevant, as the population continues to grow that will require provision of foods for a nutritionally diverse diet to ensure national food security and equitable and sustainable access to healthy diets.

5. Conclusions

The production of vegetables appears to be adequate to feed the NZ population 5+ servings a day. Yet, reports that New Zealanders do not consume enough vegetables, and current findings that we do not produce enough legumes and dark-green-leafy vegetables to meet diversity guidelines, adds to the evidence that the domestic food system should focus on needs for healthy diets. While consumption of vegetables is lacking in NZ, it should not be considered as a justification that demand for vegetables should be consumer...
led. There is a responsibility within all sections of the food system to ensure equitable access to the foods that have been shown to be beneficial to public health and also the health of the planet. While land area used for vegetable production for domestic consumption in NZ is, and could continue to be, far less than that used by pastoral land use activities, the need for more sustainable diets that include high amounts of whole plant-based food, including vegetables [14], must be balanced with the finite quantity of land available and land use practices that lessen environmental impact. New Zealand’s population continues to grow, and this coincides with increasing uncertainties surrounding our natural resources, a changing climate, as well as current and future pandemics. Vegetables are an ultimate whole food. An environmentally sustainable supply of diverse vegetables for domestic use needs to be strategically and actively protected.

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