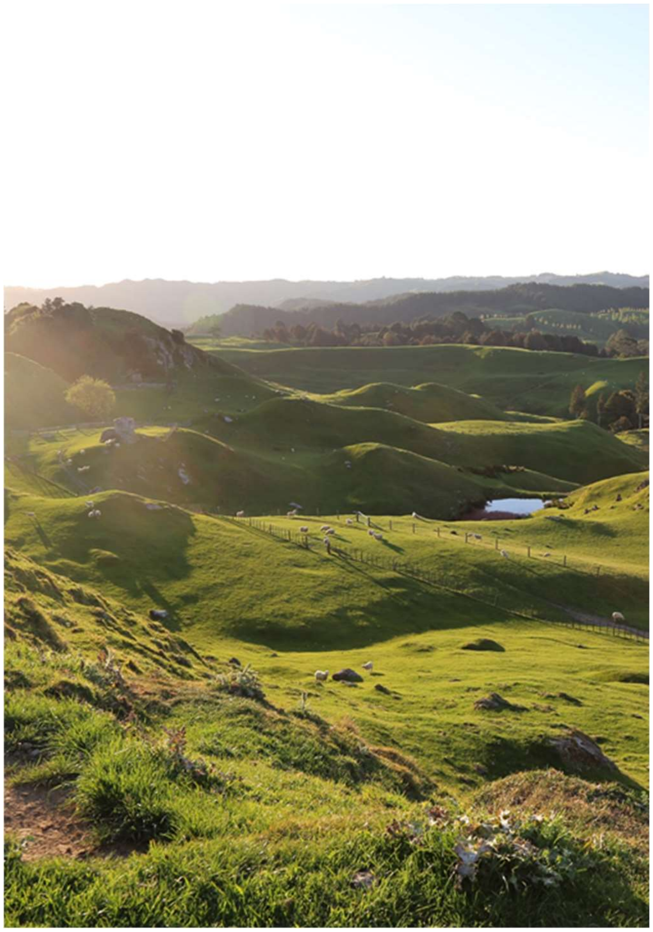

INTEGRATING HORTICULTURAL AND ARABLE LAND USE OPTIONS INTO HILL COUNTRY FARM SYSTEMS:

SITE-SPECIFIC CROP OPTIONS AND VALUE CHAIN-BASED BUSINESS CASE

Report for Our Land and Water National Science Challenge Rural Professionals Fund

G&D CONSULTING THOUGHT STRATEGY MASSEY UNIVERSITY TE KUNENGA KI PŪREHUROA UNIVERSITY OF NEW ZEALAND perrin ag NEW ZEALAND AGRI-BUSINESS ADVISORS

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Research Report for Our Land and Water National Science Challenge Rural Professionals Fund

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Toitū te Whenua, Toiora te Wai - Our Land and Water National Science Challenge envisage a future in which landscapes contain mosaics of land uses that are more resilient, healthy and prosperous than today. Essentially, 'the right enterprises in the right places for the right outcomes'.

Selection of potential crops suited to a given geographic location could assist a landowner/user in land use diversification options. Publicly available tools for selection of site-specific crop options could be more accessible for landowners/users and their network of rural professionals than proprietary tools.

The 'Integrating Horticultural and Arable Land Use Options into Hill Country Farm Systems' research project developed a process for crop identification and assessment to help landowners/users select potential crops for hill country land. This report addressed the first and third project phases: selected site-specific crop options, and the application of value chain-based business case assessment of these options.

The first project phase combined three open-source software tools to select potential crops suitable to a given geographic site. Here, a United Nations Food and Agriculture Organisation tool, EcoCrop, provided climatic suitability parameters for 1,669 crop plants alongside global climate data. EcoCrop was combined with a geographic information system, QGIS, and RStudio to enable statistical analysis.

An initial list of options, selected in phase one, was reduced three-fold by methods in the second project phase, based on multi-criteria decision-making tools, and in the third project phase, value chain-based business case assessment. The shorter list of options warrants more in-depth analysis and consideration.

To evaluate the software used to select the site-specific crop options, geographic coordinates for three hill country locations in the Taihape region were chosen. This process identified options using scenarios with and without access to irrigation. Based on a crop suitability ranking for a given site, a total of 49 crop plant species were identified over the three geographic locations. This selected list of crops was then provided for the second project phase; the multicriteria decision making process. Here, the landowner or model user reduced this list of crop options to a smaller set that suited their preferences. In some cases, the landowner/user suggested additional crops not identified by the initial EcoCrop-based analysis applied prior to the multi-criteria analysis. The multi-criteria decision-making process, reported separately, provided a shorter list of crop options for a business case assessment in the third project phase.

The value chain-based business case assessment provided landowners/users and their network of rural professionals with a framework to develop a business case. Publicly available information was used to identify crop options that warranted more in-depth analysis and consideration. The business case was based on generalised elements that included strategic context, economic assessment, and commercial options. For strategic context, Porter's competitive advantage and five forces analysis were used, alongside a "strengths, weakness, opportunities, threats" (SWOT) analysis. For the economic analysis, where publicly available gross margin data can be limited, open global databases for export Freight on Board (FOB) prices and yield data were used to estimate farmgate return. Value chain mapping identified, in most cases, two potential commercial options per crop. This mapping also identified where governance influence could lie within a given value chain option. Across each of these elements, publicly available open-access publications were also used to inform the assessments.

From the earlier two phases of this project, four fruit, two grain, five medicinal, two nut and two vegetable crops were shortlisted. Of these crops, apricot, quinoa, arnica, hazelnut and garlic were selected to provide case studies from each of the five product groupings. These crop species, or any of the other crop species discussed, do not indicate that any of these species are recommended or are endorsed as crop options for a landowner/user and should not be considered as such without appropriate professional advice. These five selected crops were chosen to illustrate the process of applying a generalised value chain-based business case assessment, using open-access information, to assist in determining next steps.

Assessment of the strategic context found that each of the example crops would need a commercialisation orientation that is based on a differentiation rather than cost leadership strategy. Factors such as a lack of scale, high dependency on manual labour, scarcity of previous commercial experience with a given crop or limited access to germplasm with known productivity advantages contributed to this outcome.

For a high proportion of the crop examples assessed, value chain mapping identified import substitution as a potential commercial option. This could occur by either the producer providing a raw product or partially processed product to a manufacturer for subsequent distribution to consumers, or the producer providing the product in a form suitable for direct distribution to consumers. Other commercial options included products for export in a fresh, semi-processed or final form.

The work highlighted that open-source software tools can enable a landowner/user and their network of rural professionals to identify a set of site-specific crop options for further assessment. This list of crop options can be reduced further by using multi-criteria decision-making tools to consider local knowledge on the site as well as understanding an owners' values and business itself. The work has also highlighted that additional publicly available information can be assembled into a value chain-based business assessment tool to further shorten the list of site-specific crop options. This list may then warrant more in-depth analysis using less easily accessible and possibly more costly proprietary sources of information.

Recommendations

- Landowner/user-centric tools to identify potential climate suitable crop options should be considered as part of the transitional process needed to achieve "a future in which landscapes contain mosaics of land uses that are more resilient, healthy and prosperous than today".
- Availability of tools are essential. The landowner/user-centric tools need to be open-source, open-access and easy to use under a range of rural internet connectivity.
- Access to relevant data is crucial. There is a role for central and local government to build on existing open-data initiatives to improve access and content of New Zealand-specific spatial datasets that strengthen the landowner/user-centric tools for the identification of site-specific crop options.
- Better information and analysis are needed to support the landowner/user decision-making processes. A role exists for collaboration between the public, non-government organisations and the private sector to consider the application of advances in text mining to replace manual extraction and synthesis of information relating to options for land use diversification.
- Effectiveness of tools will depend on awareness and capability. Utilisation of existing industry, training and rural professional networks should be considered as part of the process to improve access and uptake of landowner/user-centric tools for site-specific crop option identification.
- Joined-up initiatives are needed to support land use transitional processes. The bottom-up approach used in the landowner/user-centric tools should be seen as complimentary and not a substitute to the top-down national, regional and industry-based programmes.
- Value-chain development for new or existing crops in new localities is a long-term undertaking. Policy work is needed between government, non-government organisations and private sector on how to better facilitate land-use transition towards viable, resilient and sustainable crop-based value chains.

Photo by authors of hill country farm in Taihape region.

INTRODUCTION

Toitū te Whenua, Toiora te Wai - Our Land and Water National Science Challenge envisage a future in which landscapes contain mosaics of land uses that are more resilient, healthy and prosperous than today (Our Land and Water, 2018). The transformation of our landscapes to that envisaged by the Our Land and Water National Science Challenge could be assisted by supporting landowners/users in the gathering of information that could be used in land use planning. Incorporating new high value low intensity niche systems, including crops, into the landscape and development of these niches to achieve scale is one of the transitional pathways that has been highlighted (Bayne and Renwick, 2021).

Hill country livestock production occupies about 20% of NZ land and is characterised by a diverse range of abiotic and biotic factors (Dodd *et al.*, 2016). Māori also have considerable land-based assets, much of which is hill country with potential for development (PWC, 2014). Raising the productivity of the Māori freehold land resource associated with hill country was estimated to have the potential to increase GDP between 2013 – 2025 by up to NZ$270m in present value at a discount rate of 8%.

Mapping an improved indicator of the productive potential (PP) of New Zealand land shows much of the area associated with hill country farming has a significantly lower PP score than areas dominated by horticulture, viticulture and dairy (Harris *et al*., 2021). For example, a crop suitability map for wine grapes, a crop that can be grown as far South as Central Otago, showed little overlap with most of the hill country areas in the Central North Island and the South Island of New Zealand (Anderson *et al*., 2012). Previous research programmes have investigated crops that could be grown over wider parts of New Zealand, including a range of medicinal as well as novel vegetable and fruit crops (Douglas, 1997, Henderson and Hutchinson, 1997). Introduction of new crops can play a significant role in maintaining diversity in the agricultural economy. Particularly as a range of previous economic crops in New Zealand have experienced a life cycle of development through to decline (Halloy, 1991). Eleven of the twenty major crop species in New Zealand today have had to be developed from 'new' crops within the last 100 years.

Climate change could also have significant effects on the succession or decline of crops at both at the national and regional scales in New Zealand (Atkins *et al*., 1989; Kenny *et al*., 1995; Pyke *et al*., 1998; Kenny *et al*., 2000; Teixeira *et al*., 2015; Tait *et al.,* 2018). As well as the direct impacts of climate change on crops, land use change could also occur in response to climate change-related mitigation policy or from climate-related effects on crop pests and diseases (Dorner *et al*., 2018; Gerard *et al*., 2013; Wakelin *et al*., 2018). Learnings from what has helped Māori adapt to weather and climate variability in the past could also enhance current understanding of local weather and climate in relation to crop suitability within New Zealand (King *et al*., 2008).

To support regional economic development, crop suitability mapping has previously been used in parts of New Zealand to identify opportunities for new crop-based land use options (Wratt *et al*., 2006; NIWA, 2010; Saunders *et al.,* 2011; Rau, T., 2018; Ward and Clothier, 2020; NIWA, 2020). For a given landowner/user thinking about land use change, they need to consider a range of factors. For example, factors that can act as both drivers and barriers to land use change include the following groupings: biophysical, economic, technological, societal pressure and personal factors (Journeaux *et al*., 2017). For the individual landowner/users these barriers can be significant when considering crop-based land use change (The Catalyst Group, 2014). More specifically, these barriers can include knowledge on growing a given crop and its postharvest requirements, as well as market access.

Identifying crop-based land use options can be approached by starting with either a market-led or geographic-led process. For example, a set of six filters, starting with market insights and ending with the production requirements and environmental impacts, were applied to a range of speciality grains and pulse crops (Leftfield Innovation Ltd., 2019). In another example, new medicinal crop development was based on market insights, followed by a trial plot assessment process and the determination of commercialisation requirements (Douglas, 1997). Agro-climatic zone mapping is a well-established method that can be used to characterise areas of land suitable for specific groups of land users or individual crops. It has been applied to a range of horticultural crops in New Zealand, including kiwifruit (Kerr *et al.,* 1981; Salinger and Kenney, 1995). A more integrated approach, based on preparing high-resolution regional maps and geographic information system (GIS) surfaces of agriculturally relevant climate parameters, alongside soil data and information about the physical requirements of crops has been used to identify areas within New Zealand that are most likely to be suitable for high value crops (Wratt *et. al.,* 2006). Examples include detailed maps on suitability indices for Kaipara and the Far North District, as well as maps on the frost-free period for parts of Otago.

To assist landowners/users in selecting potential crop options for integration into hill country land, the 'Integrating Horticultural and Arable Land Use Options into Hill Country Farm Systems' research project aimed to develop a process for site-specific crop identification and assessment. Essentially, combining elements of both the geographic-led and market-led processes. As much as possible, this process incorporates publicly available open-source tools into a crop selection process alongside landowner/user input. There are three stages: firstly, the selection of crops suited to a particular location; next, an objective process using a decision support tool to identify the preferred crop(s), taking in to account individual farmer's crop performance assessments, goals and preferences; and finally, value chain-based tools to support the development of business cases for the most preferred crops. As the first and third stage of the project are based on publicly available databases, information and tools, this report addresses those two stages: site-specific crop options and value chain-based business case assessment.

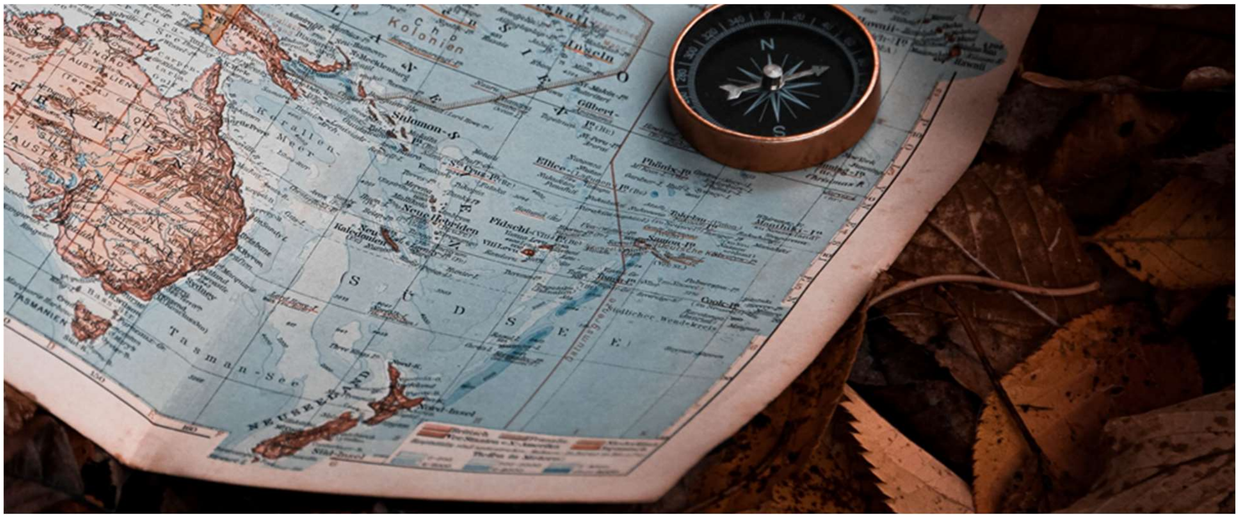
Within the literature, a range of tools have previously been applied to site-specific selection (Adornado *et al*., 2008; Kumar *et al*., 2010; Confalonieri *et al.,* 2013; Elnashar *et al*., 2021, Parthasarathy *et al*., 2016). These tools vary in both the amount of information they use in the selection process and their applicability geographically as well as their accessibility and ease of use. The Crop Ecological Requirements Database (EcoCrop) was selected as it is an open-source database containing many crop species, could be applied globally within open-source GIS, and provided simple empirical models for crops where more detailed agronomic data may not be available for complex models (Mugiyo *et al*., 2021).

For crop options identified in the two earlier parts of this project, a general business case was developed using a process that could enable a farmer and/or their rural professional to utilise. This process used accessible and publicly available open-access data in a framework that could provide sufficient information to determine if a given site specific crop option was feasible and warranted a more detailed analysis. This more detailed analysis was beyond the scope of the current project as, generally, it is enterprise specific, more cost intensive, and is best led by the landowner/user and their network of rural professions.

A general business case can be defined as a set of reasoned arguments, backed by quantitative evidence to justify a particular investment (Schipmann-Schwarze *et al*., 2020). For the current study, the following elements of a business case have been generalised: 1. strategic context; 2. economic assessment; 3. commercial options.

For strategic context, Porter's competitive advantage framework can be used to determine if the focus of a crop option should be on cost-leadership or product/service differentiation (Porter, 1985). Publicly available data on international Freight on Board (FOB) export prices and global yield data can be used to generate a potential farmgate price and return for use in an economic assessment (Yangyuyu *et al*., 2018, Monfreda *et al.,* 2008). For the evaluation of commercial options, value chain mapping can be used to identify potential options (Kaplinsky and Morris, 2000). Determining where the governance power occurs within a potential value chain could help inform landowners/users on their management approach within the chain (McIntyre, 2018). A financial case that considers the business affordability of making a change was considered out of scope for the current study as much of the information required would be specific to a given farming business and would be better addressed directly by the landowner/user.

This report used the example crops identified by the two earlier stages of this project to demonstrate the application of a value chain-based business case assessment for selected site-specific crop options. Work undertaken in this project was aligned to the three major science themes under Toitū te Whenua, Toiora te Wai - Our Land and Water National Science Challenge: Future Landscapes, Incentives for Change and Pathways to Transition.



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METHOD

Site-Specific Crop Options

In the first stage of the project, using a process based on EcoCrop and the open-source geographic information system software (QGIS), including RStudio, a subset of higher ranked crop alternatives suited to the locations of farms within the case study was identified (Valjarevic *et al*., 2020). The protocol for using EcoCrop in combination with QGIS and RStudio is provided in Appendix I of this report. RStudio enable the R-based statistical analysis of the crop and spatial data to be integrated with QGIS.

EcoCrop is a software tool that identifies up to 2,568 plant species for a given environment (FAO, 2016). It also contains a library of crop environmental requirements. EcoCrop was designed with a relatively basic requirement for crop environmental information. This design was chosen because the primary object of the EcoCrop project was to include many species as well as include species less well known and for which it was not possible to obtain detailed information. A potential drawback of this inclusive approach was that for a lot of species, the requirements used are limited as they are based on little available literature.

EcoCrop defines the suitable growing conditions *a priori* and generates a suitability index for each crop as an output. The EcoCrop model uses geospatial monthly precipitation and temperature data to assess suitability. For each crop, the model retrieves from the EcoCrop database the parameters that correspond to the crops acceptable temperature range, its acceptable range of total rainfall, and the length of the crop cycle (Ramirez-Villegas *et al.*, 2013). When the precipitation and temperature values exceed their absolute threshold, the model will give a suitability score of zero. On the contrary, if these values are within the optimum and absolute thresholds, the model will give a suitability score ranging from 0 to 1. EcoCrop does not know (or assume) the best planting date for a given crop in each place. Instead, the model simulates different possible growing seasons and selects the most suitable. From this series, EcoCrop takes the highest value as crop suitability. This assumes that a landowner/user would plant during the most ideal season.

Each simulated season starts on the first day of the month, one for each of the 12 months of the year. Each simulated season has the same length, determined by the corresponding crop-specific parameter in the EcoCrop database. Then, for each of the 12 simulated seasons, the model assesses whether the total rainfall and monthly temperature conditions during this period fall within the acceptable temperature and rainfall range. This produces 12 suitability values, one for each possible planting date. Using the EcoCrop database, two sets of crop suitability maps were generated in this project, one with irrigation and one without. Crop suitability values ≥ 0.5 are considered suitable to a site based on the parameters used by EcoCrop pertaining to the geographic location evaluated (Egbebiyi *et al*., 2019).

The EcoCrop modelling analysis was applied to three geographic locations near Taihape where several landowners/users had been identified as potential case study participants. The three locations were: 1. Taihape Napier Road and Makokomiko Road, Moawhango (Lat.-39.5528459, Long. 175.882981); 2. Koeke Road and Ngaurukehu Road, Mataroa (Lat. -39.6619067, Long. 175.6562823); 3. Mangaweka (Lat. -39.792538, Long. 175.8486793).

Multi-Criteria Decision-Making Process

At the start of the second stage of the project, case study landowners/users were surveyed to select those crops from the initial shortlist which were of interest to them. In addition, they were able to propose any other crop options they wanted to include in a subsequent workshop. This phase of the project, and the associated multi-criteria decision-making process methodology is covered in a separate report (McCarthy et al., 2021).

It should be noted that crop and yield data was provided for the landowner/user evaluation in the Multi-Criteria Decision-Making (MCDM) workshops as part of this second stage of the project. This information set included five selected crop groups containing ten fruit, fifteen grain, nine medicinal, five nut and ten vegetable crops. Five additional crops were added to the initial crop model selection, with three requested by questionnaire respondents and a further two novel crops of interest in New Zealand that were absent from the EcoCrop database. Where obtainable, publicly available, and accessible, crop resources on cultivation and marketing, such as those located under Crops for Southland at Great South (https://greatsouth.nz/), New Zealand Tree Crops Association (https://treecrops.org.nz/) as well as published literature, were made available to the workshop participants.

Value Chain-Based Business Case

Using the shortlist of crops identified by the first stage of this project, publicly available data on the global crop yield and FOB export price by crop and country was accessed from online databases at EarthStat (https://earthstat.org) and UN Comtrade (https://comtrade.un.org), respectively (Monfreda *et al.,* 2008; Ray *et al*., 2012; Yangyuyu *et al*., 2018). Although the data from these databases were sufficient for providing median values for yield and price, it was acknowledged that limitations can exist in the availability and accuracy of the underlying information reported by nations, (Brewer *et al*., 2020). Published literature and an online database at Tridge (https://tridge.com) were also used to resolve any gaps in yield and price data, respectively.

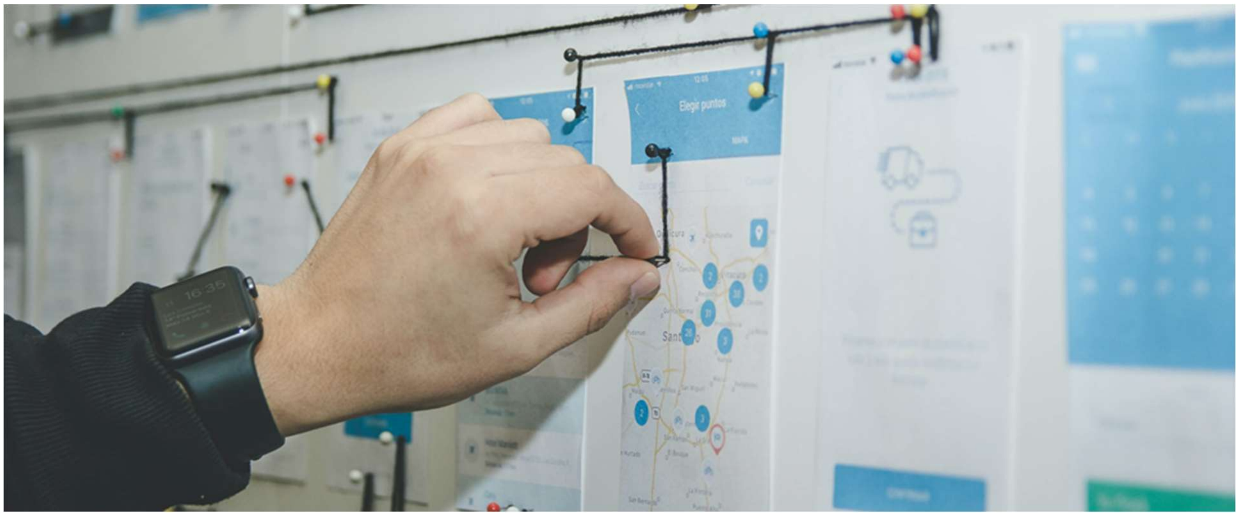
Collated global yield and price data were combined to give an indicative conservative FOB export price per hectare for a given crop. In New Zealand, limited publicly available data exists at an industry scale to calculate farmgate returns for many of the crops shortlisted in this project. In part this may be due to commercial sensitivity. Conversion of farmgate returns was estimated using industry scale data for fresh kiwifruit exports from New Zealand (Zespri, 2020, MPI, 2021). The published orchard gate returns, weighted by cultivar and tray weights, as well as orchard and packing reject rates, were combined with FOB export prices. The ratio of orchard gate price to FOB export price for kiwifruit was 0.6. Compared to the shortlisted crops in this project, kiwifruit has a well-established and integrated value chain based on a long storage life fresh fruit with proprietary genetics and branding (McIntyre et al., 2019). Therefore, a more conservative ratio of 0.4 was used to relate an FOB export price to a farmgate price for the purposes of the case study where value chain development of many of the crop options could be limited. These sources provided the crop and yield data for the landowner/user evaluation during the MCDM workshops that were part of the second stage of this project (McCarthy *et al*., 2021) and are shown in Appendix II.

Outputs from the MCDM workshop process resulted in a final shortlist of fruit (4), nut (2), grain (2), medicinal (5) and vegetable (2) crops that were identified for subsequent value chain assessment (McCarthy *et al.,* 2021). Of these crops, apricot, quinoa, arnica, hazelnut and garlic were selected to provide an example from each of the product grouping. These five selected crops illustrated the process of applying a value chain-based business case assessment. For each of the selected crops, a general assessment of the value chain was used to capture the main summary points using open access published literature that was publicly accessible.

Value chain mapping is a method that can be used to characterise the range of activities required to bring a product or service from conception, through the different phases of production to delivery to final consumers and final disposal after use (Kaplinsky and Morris, 2000). For the current study, value chain activities were plotted against the location of value chain activities. In this case, the value chain activities included production, primary processing, secondary processing, air/sea freight, manufacture, wholesale, retail and consumption/use. The location of these activities included on-farm, local, national, in-transit, in-country and re-export. Here, “in-transit” is associated with the export/import interface and “in-country” refers to the importing country. Usually, two main options were plotted for each crop, with option “A” being indicative of a higher priority than option “B”, with both options based on the salient themes in the available literature.

When considering the crop options identified by the first two stages of this project, it was important to determine how specific crops could contribute to the competitive advantage of a land-based business. Given the scale of individual land holdings, relative to an industry, competitive advantage strategies are likely to be either cost or differentiation focused (Porter, 1985). Here, the competitive strategies are based on whether the land-based enterprise could produce a given crop-based product at either a significantly lower cost or with a significantly higher value than the industry average. Porter’s five forces model was assessed using available literature (Grundy, 2006). Previously this model has been applied to crops, including chestnut and elderberry (Golban, 2015; Gold *et al*., 2006; Joublan *et al*., 2005; Cernusca *et al.*, 2012). The five forces were: barriers to entry; threat of substitutes; bargaining power of suppliers; bargaining power of buyers; rivalry among existing firms (competition). Porter’s five forces model has previously been integrated with SWOT analysis to develop competitive strategy in the food sector (Oneren *et al*., 2017).

Publicly available research reports and scientific publications were accessed using Google Scholar (https://scholar.google.com/). This can provide easy access for a landowner/user or rural profession to view the abstracts of publications and where open-access versions exist, links to enable access to the original publication in a portable document format (PDF). In addition, a general search using Google (https://google.co.nz) provided access to additional technical publications and reports of relevance.



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RESULTS AND DISCUSSION

Site-Specific Crop Options

A summary of the EcoCrop analysis is shown in Table 1. Comparison of the analysis, across the three geographic locations showed 15.9% - 18.6% of the total number of evaluated plant species were potentially suitable under a no irrigation scenario. For the same sites, under an irrigation scenario, this percentage ranged from 28.2 – 30.3%. In comparison to no irrigation, the irrigation scenario contained about 1.7 times the number of potentially suitable plant species. Under the same irrigation scenario, the crop suitability scores for a given species were similar across these sites (Appendix II). This may reflect the granularity of the site-specific climate data underpinning the modelling process.

Table 1. Number of plant species with a crop suitability index value ≥ 0.5 that was identified by EcoCrop for three geographic locations near Taihape, New Zealand in scenarios with or without irrigation. The total number of plant species assessed at each site with a crop suitability index value ≥ 0 was 1,669.

Water Infra-structure	Taihape Napier Road Site Lat. -39.5528459, Long. 175.882981		Koeke Road Site Lat. -39.6619067, Long. 175.6562823		Mangaweka Site Lat. -39.792538, Long. 175.8486793	
	Species with a Crop Suitability Index ≥ 0.5		Species with a Crop Suitability Index ≥ 0.5		Species with a Crop Suitability Index ≥ 0.5	
	(n)	*(%)*	*(n)*	*(%)*	*(n)*	*(%)*
No Irrigation	266	15.9	310	18.6	294	17.6
Irrigation	470	28.2	506	29.8	506	30.3

Across the three sites and two irrigation scenarios, the suitable crop species that were identified comprised a diverse range of economic crop groups including animal fodder, forestry, fruit, grains, medicinal, oilseeds, nuts, and vegetables. For the current study, plant species from the following five crop groups were considered: 1. fruit, 2. grain, 3. medicinal, 4. nuts, and 5. vegetables.

Using the combined EcoCrop and QGIS-based modelling approach, alongside survey results from the farmer respondents, an initial list of 49 crops were identified. These crop species were selected as potentially suitable for the final two case study sites: Napier-Taihape Road, Moawhango, Latitude -39.5528459, Longitude 175.882981; Koeke Road and Ngaurukehu Road, Mataroa Latitude -39.6619067, Longitude 175.6562823. Crop species were selected based on the ranking of their suitability scores (≥ 0.5) for these sites. To provide examples of potentially unsuitable crop species, for each crop grouping, the list of species that were potentially suitable to a given site also included the next plant species in the crop suitability ranking (i.e., a score <0.5). For example, at the Koeke Road and Ngaurukehu Road location, in the fruit category, the crop suitability score for apricot was 0.51 whereas the next closest fruit crop, cherry, had a score of 0.38 (Appendix II). In parts of New Zealand, both apricot and cherry can be successfully cultivated commercially in the same geographic locations, and on the same land blocks.

Multi-Criteria Decision-Making Process

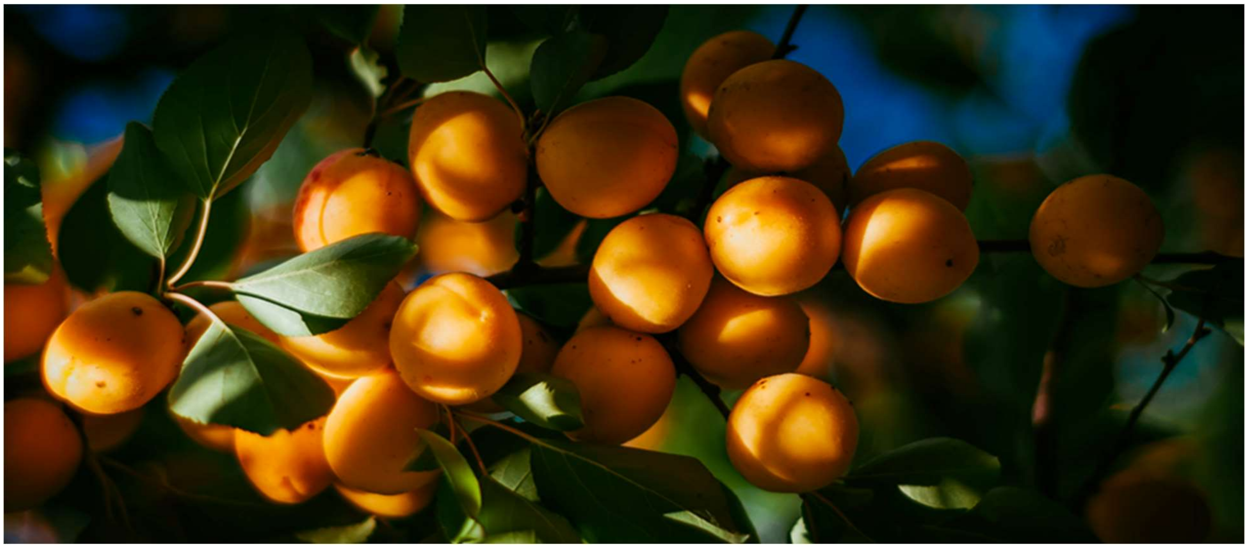
Appendix II contains the list of crops selected by the site-specific crop option process for the two geographic locations, and subsequently used in the multi-criteria decision-making process.

An initial survey with landowners/users highlighted three potential crop options not included in the EcoCrop database. The first two were the medicinal crops, Arnica (*Arnica species*) and Echinacea (Echinacea species). As EcoCrop did not contain data relating to either of these two crops, a USDA hardiness score was obtained for each crop species (https://pfaf.org/). Next, each USDA hardiness score was compared to the USDA hardiness score at both New Zealand-based study sites (https://plantmaps.com/). Both sites were within the suitable hardiness score for these two medicinal crops. The third potential crop option not included in the EcoCrop database was Manuka (*Leptospermum scoparium*), a plant species endemic to New Zealand and a traditional medicinal crop used by Māori. For New Zealand landowners/users, manuka, in both cultivated and naturally occurring plantings, is becoming an important crop for producing honey and essential oil (McPherson, 2016).

Global yield and export price data was able to be collated for the fruit (10), grain (10), medicinal (6), nut (2) and vegetable (10) crops (Appendix II). This data was provided as part of the multi-criteria decision-making process workshops with landowner/user participants The findings from this multi-criteria decision-making process are reported separately (McCarthy *et al*., 2021).

Value Chain-Based Business Case

Following the multi-criteria decision-making process workshops, analysis of the landowner/user participant responses enabled compilation of a shortlist of crops. This final shortlist, totalling thirteen crops, was comprised of fruit (apricot, blackcurrent, 'blueberry, cranberry), grain (hemp, quinoa), medicinal (arnica, echinacea, elderberry, licorice, manuka), nut (chestnut, hazelnut) and vegetable (horseradish, garlic). To illustrate the process of applying a value chain-based business case assessment, five crop species (apricot, quinoa, arnica, hazelnut and garlic) were selected to provide case study examples from each of the product grouping. These crop species, or any of the other crop species discussed, does not indicate that any of these species are recommended or are endorsed as crop options for a landowner/user and should not be considered as such without appropriate professional advice.



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Apricot (*Prunus armeniaca*)

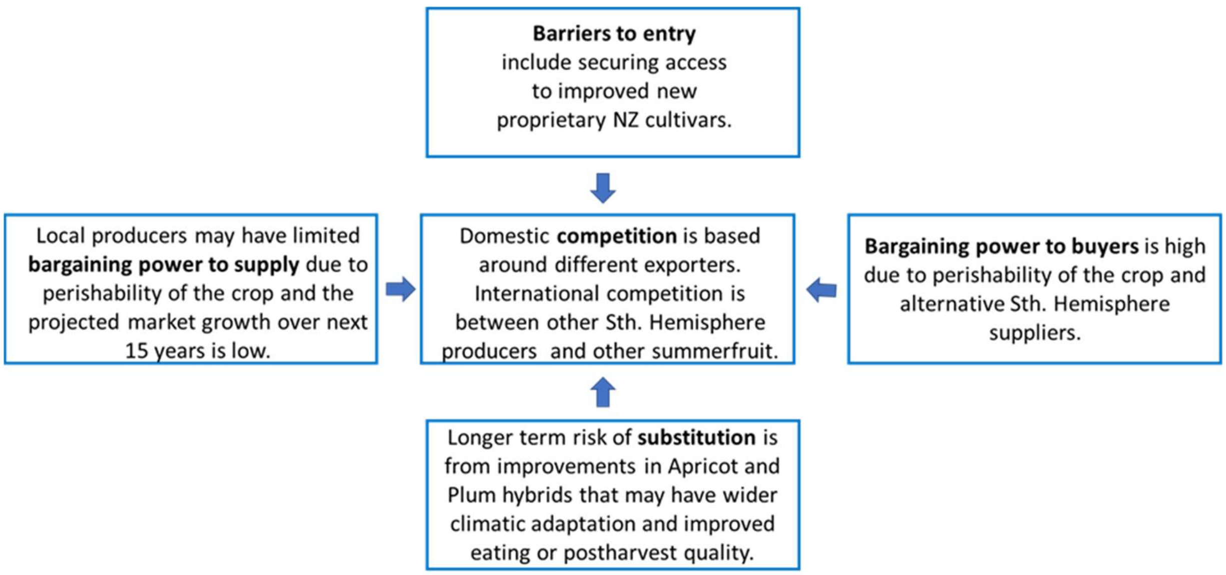
Strategic Context: Developing a differentiation strategy would be more feasible than a cost leadership strategy when cultivating this crop outside the main areas of production areas of Central Otago and Hawkes Bay (Figure 1). Differentiation is most likely to occur around the quality of the fresh product, timing of product availability, health benefits and credence attributes associated with integrated-pest management, or low environmental impact. Consumer feedback emphasizes the need to have high soluble solids at harvest and an absence of postharvest chilling related mealiness (Stanley *et al*., 2013). Australia is the main market for fresh apricot exports, taking two thirds of the export crop by value (NZHEA, 2021). New Zealand compliments Australian production through a later season supply window.

Economic Assessment: Domestic fresh apricots sales are worth NZ$6m y^{-1} and export sales NZ$3.7m y^{-1} (NZHEA, 2021). In 2015, a sample of Hawkes Bay summerfuit (apricots, cherries, nectarines, peaches and plums) orchards had a gross revenue of NZ$25,040 ha^{-1} and a gross margin of NZ7,512 ha^{-1} (Sinner and Newton, 2016.). Between 2011 – 2015, estimated apricot gross revenues were NZ$50,000 ha^{-1}, and 15 - 35% higher than nectarines, peaches and plums (NZIER, 2016). The national planted area is ~375 ha. A economic analysis is given in Figure 2, based on global average yield and median global FOB export price.

Commercial Options: For a fresh apricot crop, two domestic market options were considered (Figure. 2). The first was based on an export market supply, while the second, on domestic direct sales to consumers or end-users. For the first option, access to accredited packing facilities, either locally or nationally close by will be crucial. Recent phytosanitary changes required to access the Australian market are considered a trade risk (NZHEA, 2021). Governance of this value chain is based around export marketer's working under New Zealand Horticultural Export Authority coordination. In the second option, the landowner could govern the value chain through direct marketing of the fresh fruit to local retailers or consumers. The highly perishable nature of the fresh product requires well planned coordination of the harvest and postharvest parts with the distribution and sales parts of the chain. New Zealand has a national breeding programme focused on producing cultivars adapted to the prevailing environment and disease pressure, as well as the requirements of consumers and markets (Stanley *et al*., 2013). New Zealand's combined domestic and export sales of apricot are projected to grow from NZ$12.3m in 2015 to NZ$16.9m in 2035 (NZIER, 2016). Domestic sales are expected to dominate.

Fruit Crop: Apricot (*P. armeniaca)*	
(a). Porter's Competitive Advantage Strategies	
Cost Leadership Strategy	*Differentiation Strategy*
Challenging, as local producers would be dependent on seasonal labour for crop management and harvesting. Mechanical harvesting systems are more suited to processed crop. The short maturity season and postharvest life limited opportunities to access large scale packhouse facilities outside of the main production areas in New Zealand.	Possible to develop a differentiation strategy, but this would depend heavily on the use of proprietary cultivars that have sensory properties highly sought by the consumer, available over a longer period and can be shipped by air or sea with good out-turn to Australia, Europe, North America, Middle East and Asia.

(b). Porter's Five Forces Analysis

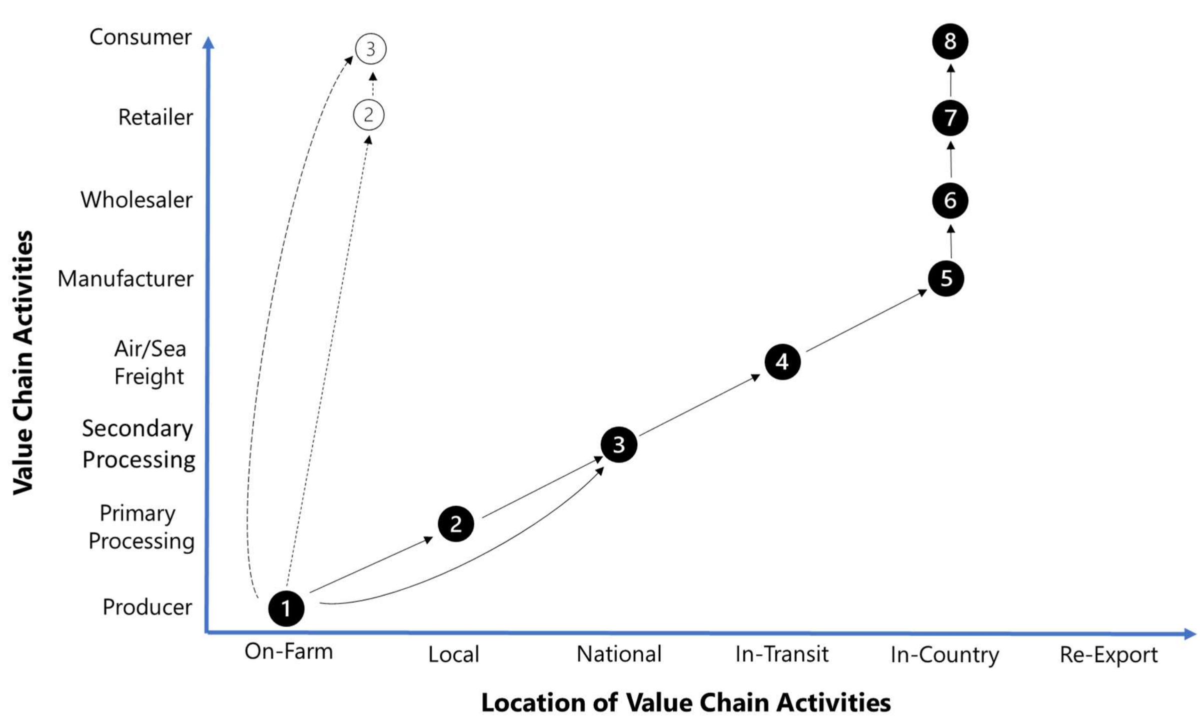


(c). SWOT Analysis

Strength: Proprietary cultivars suited to cooler parts of NZ, with consumer preferred attributes and extended shelf life.	**Weakness:** Very perishable product dependent on seasonal labour for crop management and harvest.
Opportunity: Sea freight of fresh apricots to markets in Europe and Asia could enable larger scale market development.	**Threat:** Adverse changes to market access in key export markets.

Key References: Stanley *et al*., 2013; Chidgzey, 2020, NZIER, 2016; NZHEA, 2021.

Figure 1. General assessment of (a). competitive advantage strategies, (b). Porter's Five Forces Model and (c). SWOT analysis on domestic supply of apricot (*P. armeniaca)* fruit for a fresh produce value chain using publicly available information.

<table>
<tr><td colspan="2">Fruit Crop: Apricot (P. armeniaca)</td></tr>
<tr><td colspan="2">(a). Economic Assessment</td></tr>
<tr><td colspan="2">$Conservative\ Farmgate\ Return = 30{,}000\ kg\ fruit\ ha^{-1} * NZ\$2.55 * 0.4 = NZ\$30{,}600\ ha^{-1}$</td></tr>
<tr><td colspan="2">(b). Commercial Options</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Scenario A (●) – Export of Primary Product</td><td>Scenario B (○) – Local Domestic Market Supply</td></tr>
<tr><td>❶ On-farm production of fresh produce.

❷ Produce would need to be packed at an export certified packhouse locally or ❸ nationally.
❸ Bulk of the packed produce would be air freighted to fresh export markets in Australia, Europe and USA. Sea-freight under trial.

❹ In-country, the imported apricots distributed fresh through ❺ import brokers, ❻ wholesalers, ❼ retailers to ❽ consumers.</td><td>① Is equivalent to Scenario A.

② Produce is delivered to local retailers.

③ Produce is sold fresh by retailers to local consumers, consumers passing through locality, or from farm direct to consumers through local “Farmers Markets”.</td></tr>
<tr><td colspan="2">Key References: Stanley et al., 2013; Chidgzey, 2020, NZIER, 2016; NZHEA, 2021.</td></tr>
</table>

Figure 2. General assessment of (a). a conservative economic assessment, and (b). commercial options for value chain activities and location of these activities for apricot (*P. armeniaca),* a fruit crop, using publicly available information.

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Quinoa (*Chenopodium quinoa*)

Strategic Context: Developing a differentiation strategy would be more feasible than a cost leadership strategy given the small local production and the availability of imported product that could be grown at scale. (Figure 3). Differentiation is most likely to occur around the quality of the grain product, health benefits and credence attributes associated with integrated-pest management, or low environmental impact. In South America, the genetic centre of diversity for quinoa, five ecotypes have been classified based on geographic adaptation (Hinojosa et al., 2018). Depending on ecotype, quinoa is adapted to a wide range of marginal soil conditions, including drought prone soils. Quinoa breeding is relatively recent and only commenced in the 1970's outside of the Andes (Zurita-Silva *et al.,* 2014). In New Zealand, there is a lack of locally developed cultivars. Quinoa grains provide potential benefits to human health, including phytochemicals that have antioxidant and anti-inflammatory activities (Tang and Tsao, 2017). Within New Zealand, growing grain crops outside the main regions of arable production could create issues in accessing postharvest infrastructure, including firms that dry, clean and pack the crop (Leftfield innovation Limited, 2020). Overseas, lifecycle analysis has shown 354 kg CO_{2eq} was emitted to produce 1 t of quinoa (Dehkordi and Forootan, 2020). This was similar to wheat, but lower than maize, rice, barley and rapeseed.

Economic Assessment: Based on import prices, quinoa is a relatively high value grain crop at about $4,000 t^{-1} in 2018 (Leftfield Innovation Limited, 2019). It was estimated that about 100 ha of a local quinoa crop would be sufficient to replace the current import volume of about 400 t y^{-1}. The report by Leftfield Innovation for Our Land and Water, provides more details on the economic opportunities for this grain crop. A conservative economic analysis is given in Figure 4, based on the global average yield and median FOB export price.

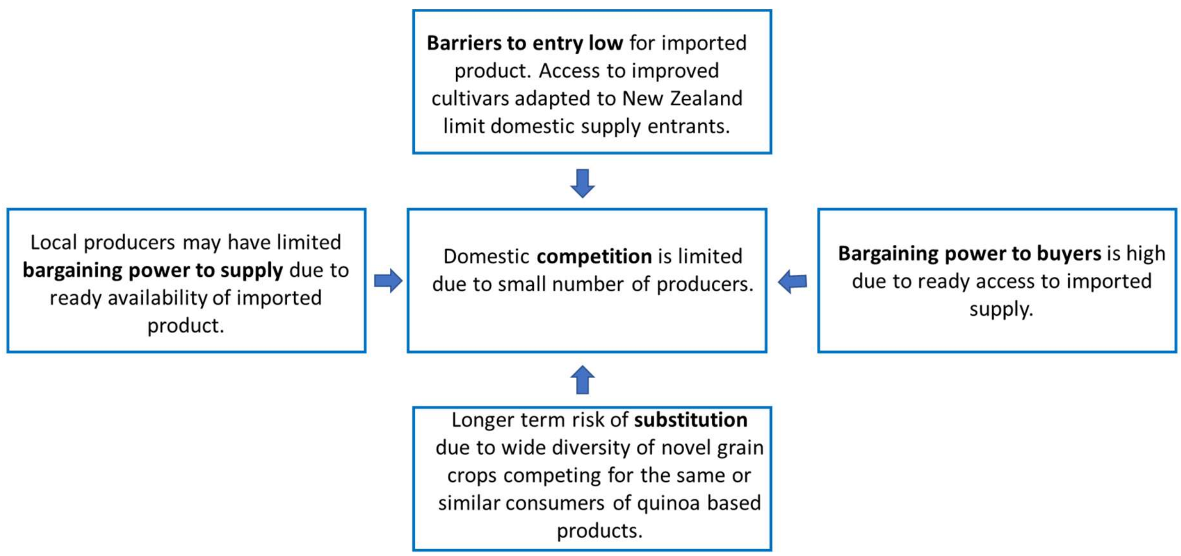
Commercial Options: For a quinoa crop, one domestic market option was considered (Figure. 4). This was based on import substitution using local processing facilities, where possible, to clean and dry the grain The dried product would then go to a national manufacturer for packing or further processing, such as producing flour, to then be supplied through domestic wholesale networks for distribution to retail and consumers.

Grain Crop: Quinoa (*C. quinoa*)

(a). Porter's Competitive Advantage Strategies

Cost Leadership Strategy	*Differentiation Strategy*
Challenging, as local producers would need scale in the production, drying and packing of product. Imported product is readily available.	Possible to develop a differentiation strategy, but this would depend heavily on access to locally adapted cultivars that have sensory properties highly sought by the consumer and can be grown sustainably under low chemical input or organic growing systems.

(b). Porter's Five Forces Analysis

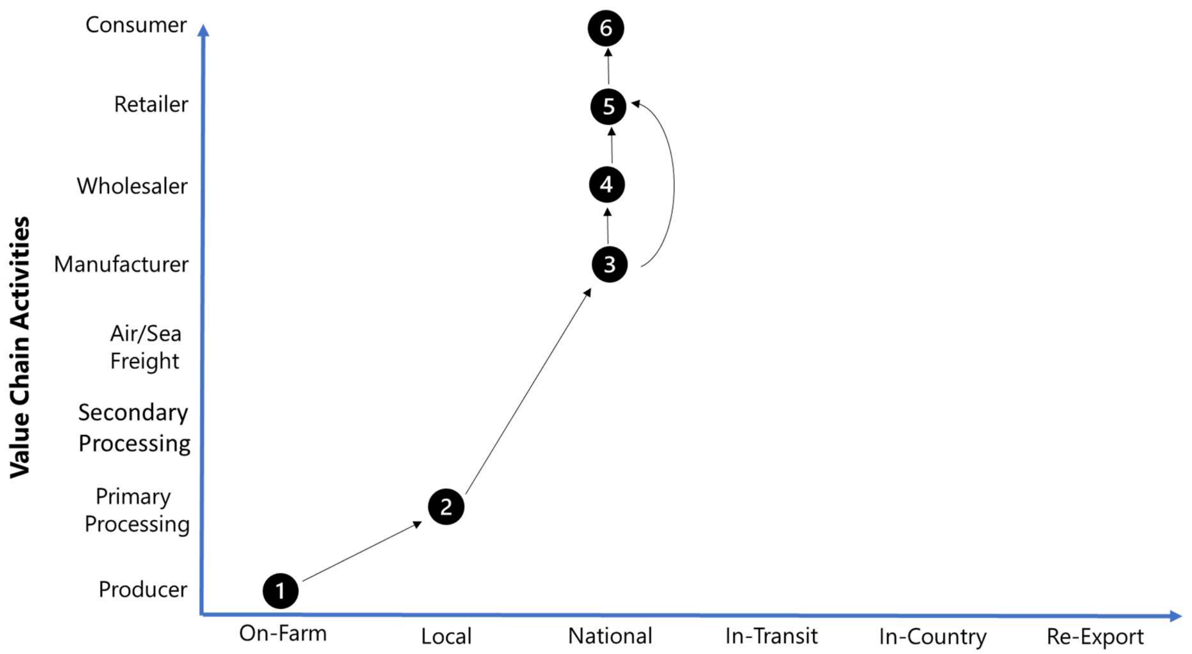


(c). SWOT Analysis

Strength: Quinoa is crop that is well suited to cooler parts of NZ and the grain has growing consumer appeal.	**Weakness:** Limited range of locally adapted high yielding cultivars with the diversity of quality attributes needed for the market requirements.
Opportunity: Substitution of imports with locally produced product, particularly with sustainable or organic growing systems.	**Threat:** Cost competitiveness of local product against imports from major global producers achieving significant productivity gains.

Key References: Hinojosa *et al*., 2018; Leftfield Innovation Limited, 2019; Zurita-Silva *et al.,* 2014

Figure 3. General assessment of (a). competitive advantage strategies, (b). Porter's Five Forces Model and (c). SWOT analysis on domestic supply of quinoa (*C. quinoa*) grain for a food product value chain using publicly available information.

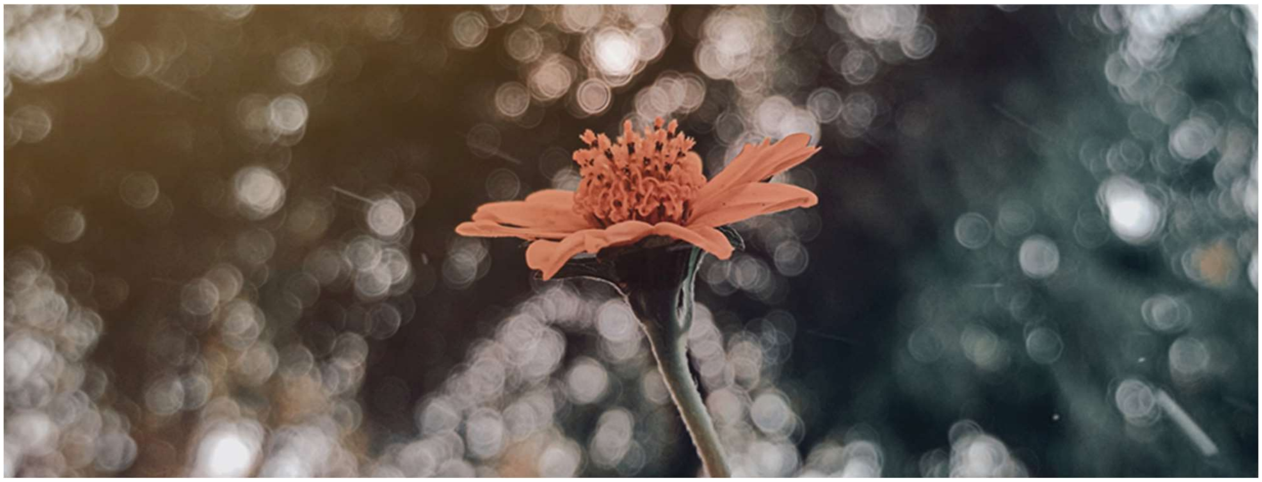
<table>
<tr><td colspan="2">Grain Crop: Quinoa (C. quinoa)</td></tr>
<tr><td colspan="2">(a). Economic Assessment</td></tr>
<tr><td colspan="2">Conservative Farmgate Return = 3,000 kg grain ha^{-1} * NZ$5.50 * 0.4 = NZ$6,600 ha^{-1}</td></tr>
<tr><td colspan="2">(b). Commercial Options</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Scenario A (●) – Domestic Market Supply</td><td>Scenario B (○) – n/a</td></tr>
<tr><td>❶ On-farm production of an annual grain crop that is harvest mechanically.

❷ Harvest grain is dried locally.

❸ Dried grain is supplied to a manufacturer for cleaning and packing, as well as further processing if required.

❹ Packed product is supplied to wholesalers for distribution to ❺ retailers, though to ❻ consumers.</td><td></td></tr>
<tr><td colspan="2">Key References: Hinojosa et al., 2018; Leftfield Innovation Limited, 2019; Zurita-Silva et al., 2014</td></tr>
</table>

Figure 4. General assessment of (a). a conservative economic assessment, and (b). a commercial option for value chain activities and location of these activities on one scenario for quinoa (*C. quinoa*), a grain crop option, using publicly available information.



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Arnica (*Arnica montana L., A. chamissonis*)

Strategic Context: In the short to medium term, it would be unlikely that a prospective local grower would pursue a cost leadership strategy (Figure 5). Particularly, given the limited scale and local experience with the crop, as well as a lack of germplasm with known performance by environment and management. Also, local producers would be dependent on high-cost hand harvesting until specialised mechanical harvesting systems has been developed or made available. The small scale of an industry to meet local supply may limit the development of mechanised solutions beyond on-farm innovation. Developing a differentiation strategy would be more feasible, but this would depend heavily on local manufacturers identifying significant advantage in substituting imported dried flowerheads and extracts with local supply. For example, would local product offer credence attributes that would be valued by the manufacturer and/or consumer. Such as locally grown, organic certification, low biodiversity impact, a superior bioactive phytochemical profile or free of adulterants. Adulteration of internationally traded *A. montana* with "false arnica" *Heterotheca inuloides* are a significant issue for buyers of dried flowerheads (Walker and Applequist, 2012). Disruptive technology, such as the production of the bioactive phytochemicals by induced suspension cell cultures for mass culture in a bioreactor, could be a future risk to the supply of these compounds from more traditional cultivation methods (Stefanache *et al*., 2013; Petrova *et al*., 2014).

Economic Assessment: Little publicly available published information exists regarding economic returns beyond that derived from global export prices (Appendix 1). The most accessible, provides data from a survey in the United States of America and Germany over 4 years prior to 2016 (Grafner and Applequist, 2016). Here, after drying, wild harvest flowerheads are sold to wholesale manufacturers for NZ$16.90 kg^{-1}, reaching up to NZ$47.30 kg^{-1} when exported. In New Zealand, the local market is currently based on the manufacture and distribution of therapeutant products produced from raw, extract or finished products. Annual demand in New Zealand could be up to 3 t y^{-1} of dried flowerheads at a price up to NZ$100 kg^{-1} (Smallfield and Douglas, 2008). Limited existing domestic supply makes it difficult to observe the competitive advantage of a domestic supply of *Arnica* species flowerheads over imported supply. A local producer considering this option would need to undertake more detailed due diligence with potential value chain partners, particularly commercial manufacturers, and suppliers of therapeutant products. The estimated farmgate costs are conservative and assume flowerhead drying occurs on-farm.

Due to labour requirements, on-farm costs are expected to be high for harvesting, as well as nursery production for planting stock. A conservative economic analysis is given in Figure 6, based on the global average yield and median FOB export price.

Commercial Options: For an arnica crop, two domestic market options were considered (Figure 6). The first was based on domestic market supply to substitute for imports, while the second was based on domestic direct sales to consumers or end-users. For the first option, the manufacturer is likely to play a significant role in the governance of the value chain given their role in determining the source of raw material, processing of that material, product formulation, labelling and branding. In the second option, the landowner could govern the value chain through direct marketing of the dried flowerheads to consumers.

From a producer perspective, *A. montana* plants have successfully been grown in New Zealand research plots, including the piloting of mechanical harvesting of flowers and rapid analytical measurement of the bioactive phytochemicals of interest, namely sesquiterpene lactones (Douglas *et al*., 2004). Research learnings have been translated into a grower handbook (Smallfield and Douglas, 2008). The main on-farm product from a planting of *A. montana* is fresh fully opened flowerheads. After 2-3 years from planting, flowerhead yield can vary two-fold, reaching 260 kg ha^{-1}, depending on propagation method, planting time and fertilizer regime (Pijevljakusic *et al*., 2014). Selected cultivars could reach up to 1 t of dried flowerheads (Smallfield and Douglas, 2008). A cooler micro-climate and higher exposure to ultraviolet – B radiation can increase the flowerhead content of active phytochemicals, such as sesquiterpene lactones (Spitaler *et al*., 2008). Once harvested at the right maturity, flowers could also be processed on-farm to retain the active phytochemical content by using a shaded shed with adequate circulation of air or dehydrator ovens operating at 40 °C (Asadi *et al*., 2020). Once dried, flowerheads could be supplied to a national manufacturer who could extract active phytochemicals and then use these extracts to manufacture various therapeutant formulations, such as tinctures, dried extracts, oils and salves (Kriplani et al., 2017). The *A. montana* roots and rhizomes can also provide a source of bioactive phytochemicals (Sutovski *et al.,* 2014).

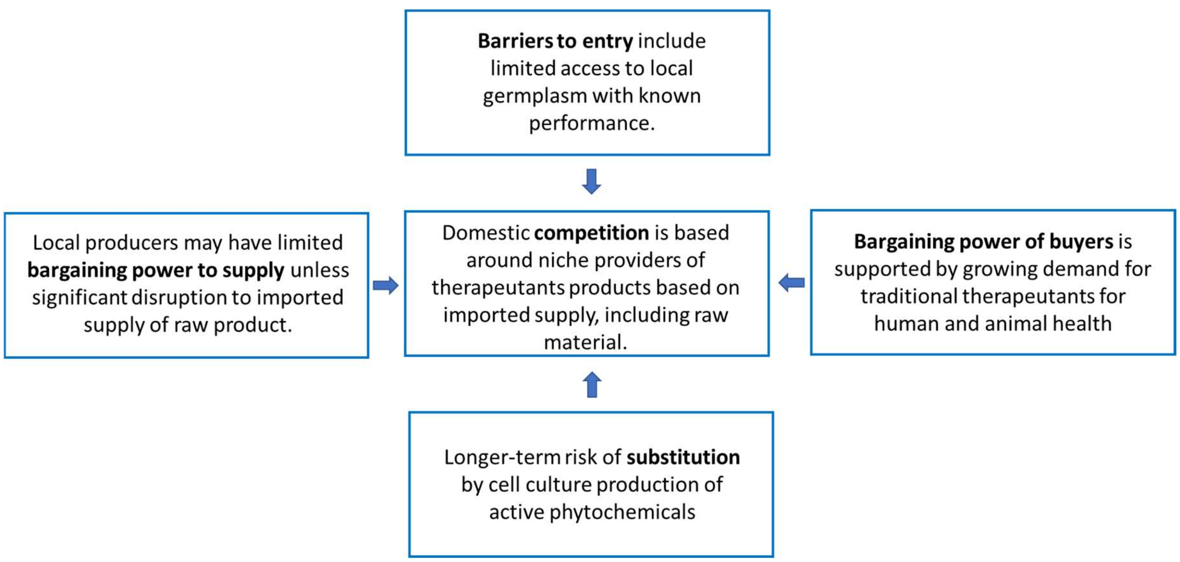
During manufacturing, the chemical composition of the raw dried flowerheads would need to be tested, as would the extracts used to formulate the therapeutant products. These therapeutant formulations could then be distributed through wholesale and retail to reach the consumer or end-user. Alternatively, once the flower crop is dried on-farm, the dried product could be marketed directly to consumers and end-users. However, there could be risks in this approach. Therapeutant products derived from *Arnica* species are recognised as traditional plant medicines, however, questions remain regarding their efficacy, particularly at higher doses while ensuring that treatments remain safe (Brito *et al*., 2012). Within New Zealand, such therapeutants are not incorporated into a contemporary regulatory framework which is both evidence-based and appropriate for such a longstanding therapeutant product (Clair, 2019). Without regulatory guidelines, there is a risk that adverse effects such as contact sensitisation (Reider *et al*., 2002), could be more prevalent when consumer prepared formulations or dose rates are not standardised to account for variation in the active phytochemicals within the dried flowerheads of *Arnica* species. Particularly as it is known that these active compounds can vary in relation to genotype, micro-climate, cultivation management, harvest timing and drying protocol (Aiello *et al*., 2012; Asadi *et al*., 2020; Pijevljakusic *et al*., 2014; Spitaler *et al*., 2008).

Medicinal Crop: Arnica (*A. montana* L.*, A. chamissonis*)

(a). Porter's Competitive Advantage Strategies

Cost Leadership Strategy	*Differentiation Strategy*
Challenging given the nascent experience with the crop in New Zealand and its productivity, as well as limited germplasm with known performance by environment and management. Also, local producers would be dependent on high-cost hand harvesting until specialised commercially available mechanical harvesting systems has been developed or made available. The small scale of an industry to meet local supply (equivalent to <10ha) could limit the development of mechanised solutions beyond on-farm innovation.	Possible to develop a differentiation strategy, but this would depend heavily on local manufacturers identifying significant advantage in substituting imported dried flowerheads and extracts with local supply. For example, would the local product offer credence attributes such as locally grown, organic certification, superior bioactive phytochemical profile or unadulterated raw material that would be valued by the manufacturer and/or consumer.

(b). Porter's Five Forces Analysis

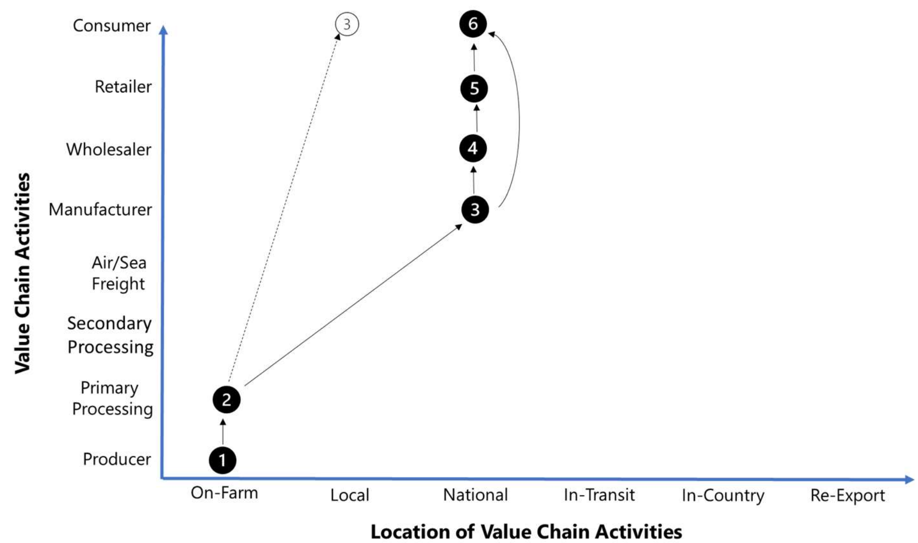


(c). SWOT Analysis

Strength: Crop climatically suited to cooler or higher elevation parts of NZ and commercial quality has been produced in local trial sites.	**Weakness:** Labour intensive harvesting of flowerheads and limited availability of germplasm with known productivity and quality under NZ conditions.
Opportunity: Sustainable production of cultivated product that reduces dependency on wild harvested Northern Hemisphere supply that can impact on biodiversity loss.	**Threat:** Regulatory changes that require more efficacy evidence for traditional medicines, and risk of substitution by cell culture production

Key References: Asadi *et al.,* 2020; Camelia, 2015; Kriplani *et al*., 2017; Sugier, 2007; Petrova *et al*., 2014; Pljevljakusic *et al*., 2012.

Figure 5. General assessment of (a). competitive advantage strategies, (b). Porter's Five Forces Model and (c). SWOT analysis on domestic supply of arnica (*A. montana* L., *A. chamissonis*) flowerheads for a therapeutant-based product value chain using publicly available information.

<table>
<tr><td colspan="2" align="center">Medicinal Crop: Arnica (A. montana L., A. chamissonis)</td></tr>
<tr><td colspan="2" align="center">(a). Economic Assessment</td></tr>
<tr><td colspan="2" align="center">Conservative Farmgate Return = 500 kg dried flower head ha^{-1} * NZ$20 * 0.4 = NZ$4,000 ha^{-1}</td></tr>
<tr><td colspan="2" align="center">(b). Commercial Options</td></tr>
<tr><td colspan="2">


</td></tr>
<tr><td>Scenario A (●) – Domestic Market Supply</td><td>Scenario B (○) – Domestic Direct Sales</td></tr>
<tr><td>❶ On-farm production of a flower crop that is hand or mechanically harvested December – January in New Zealand. Roots could have potential for essential oil production in the future.

❷ Fresh flowerheads are harvested and dried on-farm using a shaded drying shed with air circulation or dehydration at 40 °C.

❸ Dried flowerheads are supplied to a domestic manufacturer for extraction in ethanol, dried and formulation into therapeutic preparations.

Manufactured products are supplied to ❹wholesalers for: ❺distribution and ❻ marketing to consumers and/or end-users.</td><td>①- ② Equivalent to Scenario A.

③ Dried flowerheads are provided direct to consumers and/or end-users for homemade therapeutic preparations.</td></tr>
<tr><td colspan="2">Key References: Asadi et al., 2020; Camelia, 2015; Kriplani et al., 2017; Sugier, 2007; Pljevljakusic et al, 2012</td></tr>
</table>

Figure 6. Summary of (a). a conservative economic assessment, and (b). commercial options for the domestic supply of arnica (*A. montana* L., *A. chamissonis*) flowerheads for a therapeutant-based product value chain using publicly available information.

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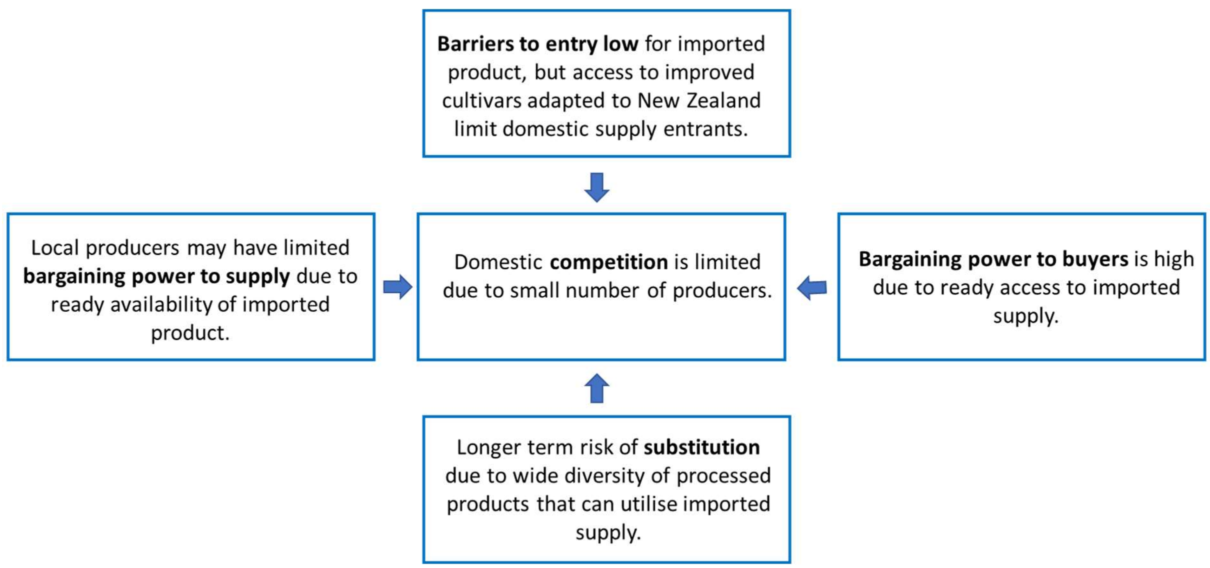
Hazelnut (*Corylus avellana)*

Strategic Context: Developing a differentiation strategy would be more feasible than a cost leadership strategy given the small scale of production and the availability of imported product from Turkey, Europe and the United States. (Figure 7). Differentiation is most likely to occur around the freshness and quality of the local nuts as the globally traded product can be stored for several years. A growing body of research is showing evidence of the health benefits of hazelnut consumption (Pema *et al*., 2016). The composition of the hazelnut kernel can vary by cultivar and geographic origin, including compositional attributes associated with health benefits (Krol and Ganter, 2020). In Australia, Ferrero, a large global confectionary branded value chain, has invested in the development of a 2,000-ha planting of hazelnut trees to secure supply (Holt and Murphy, 2017). In Europe, outbreaks of hazelnut bacterial blight have been on the increase, causing up to 10% of young trees (1 – 4 years old) to be killed (Lamichane and Vavaro, 2013). Modern hazelnut cultivation methods can significantly improve productivity (Silvestri *et al*., 2021).

Economic Assessment: In 2017, the domestic plantings of hazelnut was 278 ha, of which 90% was in the South Island (StatsNZ). With a shelled hazelnut weight that is 33% of the in-shell weight and an in-shell yield of 2.5 t ha^{-1}, domestic production could be about 230 t. This is similar to import volumes that are estimated at 250 t, assuming the bulk was shelled product. In-shell hazelnut prices range from NZ$3.0 – NZ$4.50 kg^{-1} to the local grower (www.hazelnutnurseries.co.nz/). A recent business case integrating hazelnut into an existing arable farm estimated a capital investment of NZ$12,000 ha^{-1} to establish and in real terms, requiring a payback of 12 years (Lilley, 2021). A local cultivation guide is available (https://treecrops.org.nz/). A conservative economic analysis is given in Figure 8, based on the global average yield and median FOB export price.

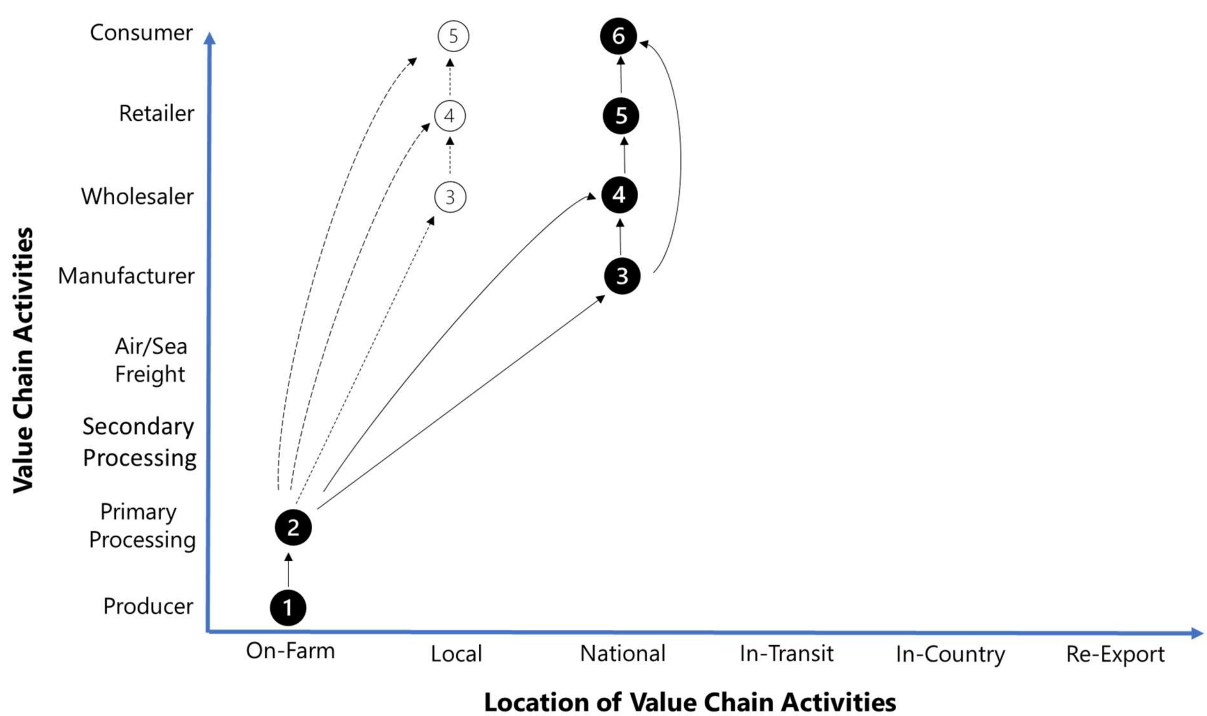
Commercial Options: For hazelnut, two domestic market options were considered (Figure. 8). The first, a domestic market supply, while the second, domestic direct sales to consumers. For the first option, access to national processing and packing facility would be required. However, for North Island producers, the bulk of processing capacity could be in the South Island, unless other facilities are accessed. For direct sales, on-farm grown product could be sold direct in-shell or shelled via local distribution networks or through mail-order and 'farmer markets'.

Nut Crop: Hazelnut (*C. avellana*)	
(a). Porter's Competitive Advantage Strategies	
Cost Leadership Strategy	*Differentiation Strategy*
Challenging, as local producers lack scale and proven productivity compared to imported product.	Possible to develop a differentiation strategy, but this would depend on marketing the fresh and local aspects, as well as incorporation into high value functional foods or culinary and confectionary products.
(b). Porter's Five Forces Analysis	



(c). SWOT Analysis	
Strength: High quality local product, that can be marked fresh (<1 year old).	**Weakness:** Limited range of locally adapted high yielding cultivars with the diversity of quality attributes required for the market requirements.
Opportunity: Increasing body of scientific literature on health benefits.	**Threat:** Biosecurity risk of bacterial blight introduction
Key References: Krol and Ganter, 2020; Lamichane and Vavaro, 2013; Silvestri *et al*., 2021,	

Figure 7. General assessment of the focus of (a). competitive advantage strategies, (b). Porter's Five Forces Model and (c). SWOT analysis on domestic supply of hazelnut (*C. avellana*) for a food-based product value chain using publicly available information.

<table>
<tr><td colspan="2">Nut Crop: Hazelnut (C. avellana)</td></tr>
<tr><td colspan="2">(a). Economic Assessment</td></tr>
<tr><td colspan="2">Conservative Farmgate Return = 2,000 kg dried in-shell nuts ha^{-1} * NZ$5.65 * 0.4 = NZ$4,520 ha^{-1}</td></tr>
<tr><td colspan="2">(b). Commercial Options</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Scenario A (●) – Domestic Market Supply</td><td>Scenario B (○) – Domestic Direct Sales</td></tr>
<tr><td>1 On-farm production of a nut crop.

2 Fresh nuts are mechanically harvested and dried on-farm.

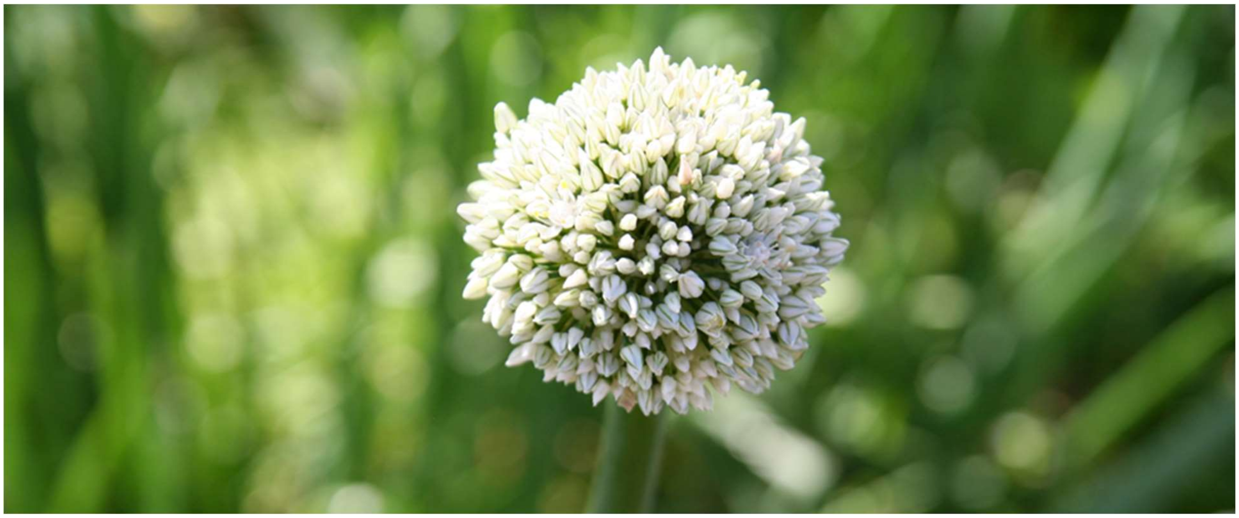
3 Dried whole nuts are supplied to a national manufacturer for processing into arrange of products, including the raw whole nut through to highly processed products.

4 Nationally, the processed product is distributed to wholesalers for distribution through a range of 5 retail outlets to 6 consumers.</td><td>1- 2 are equivalent to Scenario A.

3 Dried whole nuts or cracked raw nuts are supplied to local wholesale for distribution to 4 retailers, to 5 consumers.

Whole nuts on farm could be provided in-shell or cracked for supply direct to retail or through ‘farmer markets’ and direct sales to consumers.</td></tr>
<tr><td colspan="2">Key References: Krol and Ganter, 2020; Lamichane and Vavaro, 2013; Silvestri et al., 2021,</td></tr>
</table>

Figure 8. General assessment of (a). a conservative economic assessment, and (b). commercial options for value chain activities and location of these activities for hazelnut (*C. avellana*), a nut crop, using publicly available information.



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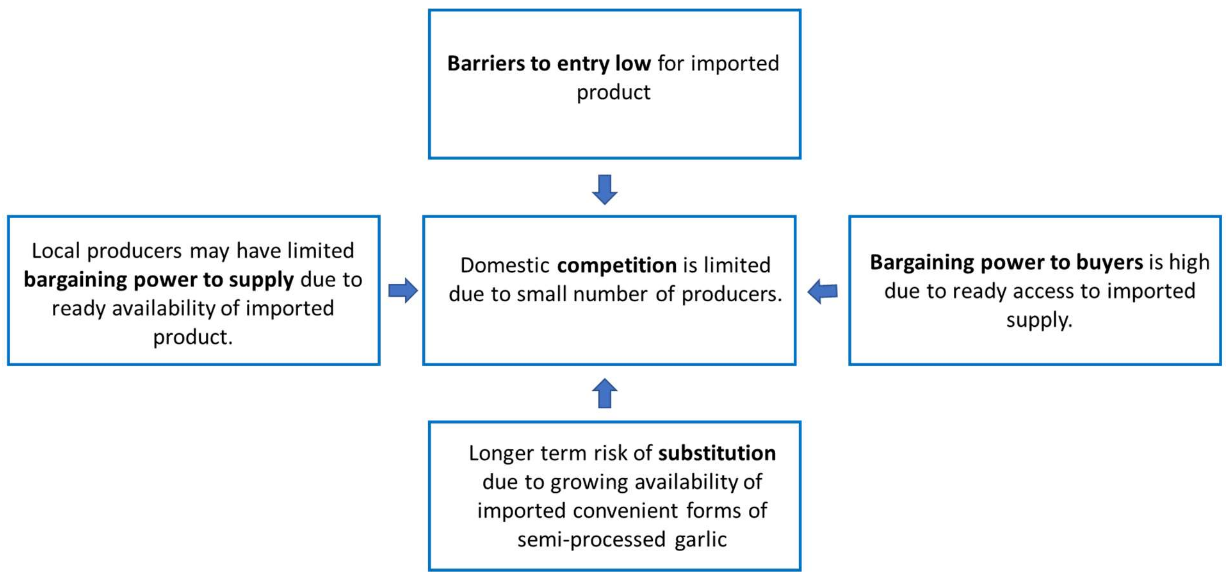
Garlic (Allium sativum)

Strategic Context: Developing a differentiation strategy would be more feasible than a cost leadership strategy when cultivating this crop outside the main onion producing regions due to the need for access to specialised cultivation and harvesting equipment, as well as postharvest facilities. (Figure 9). Differentiation is most likely to occur around the quality of the fresh dried product, timing of product availability, local supply, health benefits and credence attributes associated with integrated-pest management, or organic production. Higher value products, such as black garlic, can be produced by treating fresh bulbs under controlled high temperature and high relative humidity (Rios-Rios, et al., 2019). This process can improve the biological activity and health benefits associated with garlic (Ryu and Kang, 2017). Black garlic needs to be tested after processing under standardised conditions to ensure bioactive properties are enhanced (Kimura *et al*., 2017). Garlic rust is a significant pathogen on New Zealand crops and a risk to productivity (Negash *et al*., 2018).

Economic Assessment: About NZ$10.7m of onions, shallots and garlic were imported into New Zealand in 2019 (StatsNZ). Locally, 178 ha of garlic was cultivated, producing a crop of 1, 200 t with a market value of NZ$5.5m. (Aitken and Warrington, 2020). These figures indicate an average yield of 6.7 t ha^{-1}, at a farmgate value of NZ$4.60 kg^{-1}. Bulb yields of 16 -17 t ha^{-1} have been achieved in experimental plots in Central Otago and Southland (McIntosh *et al*. 1992). A conservative economic analysis is given in Figure 10, based on the global average yield and median FOB export price.

Commercial Options: For a garlic crop, two domestic market options were considered (Figure. 10). The first was based on a domestic market supply, while the second, on domestic direct sales to consumers or end-users. For the first option, access to national wholesalers with domestic distribution networks would be needed. For direct sales, on-farm grown product could be sold direct as dried bulbs to local distribution networks or through mail-order and 'farmer markets'.

Vegetable Crop: Garlic (*A. sativum*)	
(a). Porter's Competitive Advantage Strategies	
Cost Leadership Strategy	*Differentiation Strategy*
Challenging, as local producers would be dependent on mechanical cultivation and harvesting, as without that the crop can be very labour intensive. Most of the current domestic growers are large scale vegetable growers.	Possible to develop a differentiation strategy, but this would depend heavily on creating a clear point of difference in quality, flavour or credence attributes between imported products. Opportunities exist to develop higher value functional ingredients.
(b). Porter's Five Forces Analysis	

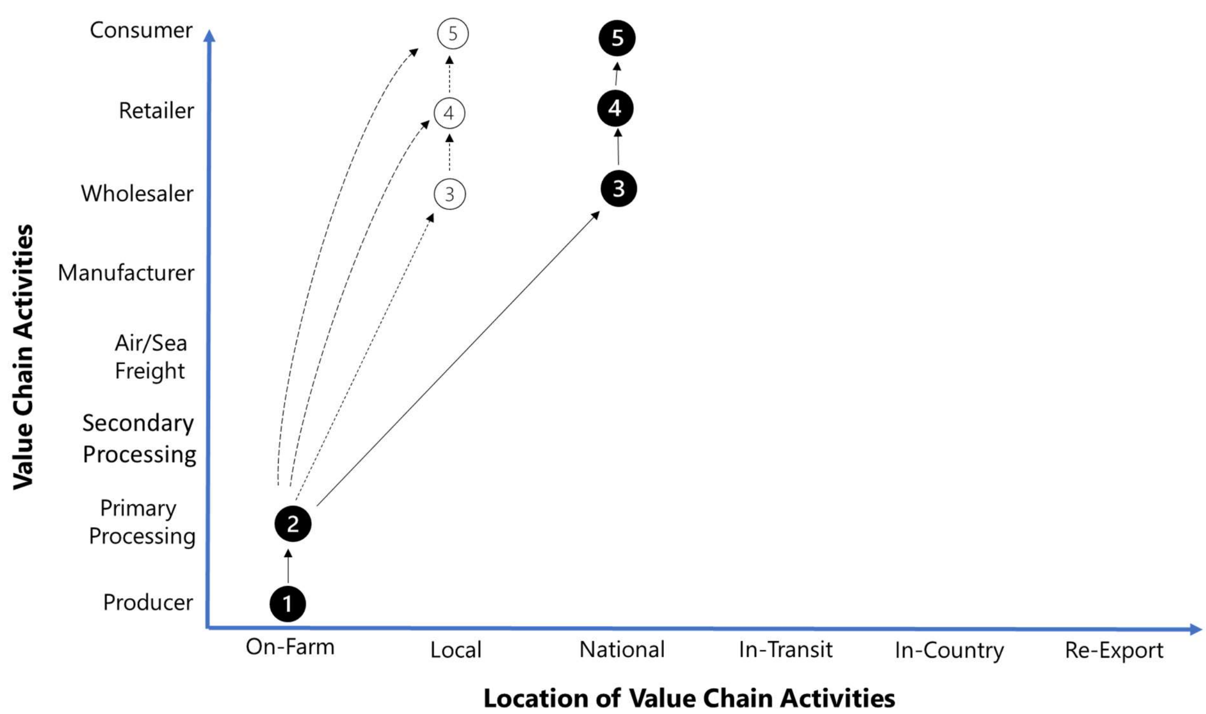


(c). SWOT Analysis	
Strength: Local product can be high quality and benefit from locally grown credence attributes.	**Weakness:** Dependent on seasonal labour for crop management and harvest, as without scale, more difficult to access mechanisation.
Opportunity: Local farmers markets, direct supply to consumers and low chemical input production systems.	**Threat:** Maintaining access to effective control of rust diseases for local product and growing demand for imported semi-processed garlic products.

Key References: Aitken and Warrington, 2020; McIntosh *et al*. 1992; Negash *et al*., 2018

Figure 9. General assessment of (a). competitive advantage strategies, (b). Porter's Five Forces Model and (c). SWOT analysis on domestic supply of garlic (*A. sativum*.) bulb for a vegetable-based product value chain using publicly available information.

Vegetable Crop: Garlic (*A. sativum*)
(a). Economic Assessment
*Conservative Farmgate Return = 6,000 kg dried bulbs ha^{-1} * NZ$3.65 * 0.4 = NZ$8,760 ha^{-1}*
(b). Commercial Options



Scenario A (●) – Domestic Market Supply	**Scenario B** (○) – Domestic Direct Sales
❶ On-farm production of a bulb crop. ❷ Fresh bulbs are mechanically harvested or by hand and dried on-farm. ❸ Dried whole bulbs are supplied to a national Wholesaler for distribution through a range of ❹retail outlets to ❺ consumers.	①- ② are equivalent to Scenario A. ③ Dried whole bulbs are supplied to local wholesale for distribution to ④ retailers, to ⑤ consumers.

Key References: Aitken and Warrington, 2020; McIntosh *et al*. 1992; Negash *et al*., 2018

Figure 10. General assessment of (a). a conservative economic assessment, and (b). commercial options for value chain activities and location of these activities on two scenarios for garlic (A. sativum), a vegetable crop option, using publicly available information.

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Other Crops

Opportunities for Blueberry (*Vaccinium spp.)* in New Zealand have recently been reviewed under the Food and Beverage Information Project (Coriolis, 2020). Key findings included opportunities to grow the blueberry product category, but there is also a need to improve the efficiency of the supply chain and the marketing of New Zealand blueberries. Supply chain integration within the New Zealand blueberry industry has also recently been reviewed (Bezuidenhout, *et al*., 2020). Māori agribusiness engagement in the blueberry industry is increasing, and bringing Māori values such as wairuatanga, aroha, whakapapa, manaaki and kotahitanga into the partnerships across the supply chain to improve social, cultural and environmental values alongside the economic activity. Other research on collectively owned Māori businesses and enterprises, has also highlighted the benefits of applying Māori cultural principles to value chains (Saunders *et al*., 2016; McIntyre *et al.*, 2019).

The main endemic species of mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) harvested commercially can occur naturally in the three Taihape locations used in the current study (McCathy, *et al*., 2019). Both medicinal crops can be grown as a source of honey or essential oils (Saunders and Lay, 2017; Hikurangi Bioactives Ltd. Partnership, 2020). Market development is more advanced for mānuka than kānuka. Oil composition of both species, and associated therapeutic properties, can vary significantly with the geographic location of the harvested plants (Maddocks-Jennings *et al*., 2005). Information on the oil composition of mānuka growing naturally near Taihape has been collated alongside other New Zealand geographic locations (Douglas *et al*., 2001). Mānuka oil composition can also vary between juvenile and mature plants, as well as between seasons (Porter *et al*., 1997).

Māori and non- Māori landowners are establishing mānuka and kānuka on their land blocks to provide riparian plantings as well as accessible stands for oil production. Cultivated mānuka can produce up to 5 tonnes per hectare of foliage. Depending on foliage quality, landowners/users can sell the foliage direct to distillers for NZ$500 - NZ$600 per tonne, equating to a farmgate return of up to NZ$30,000 per hectare. Depending on locality and access to oil distillery facilities, landowners/users may need to consider forming value chain-oriented cooperatives to process foliage and market essential oils for mānuka and/or kānuka. Our Land and Water National Science Challenge has funded several publications on New Zealand value chains with examples on different models and how value can be better shared to incentivise more sustainable land use practices (Saunders *et al*., 2016; McIntyre *et al.*, 2019).

Other endemic species, such as ti kouka (*Cordyline australis*) and horopito (*Pseudowintera colorata*), adapted to much of New Zealand's hill country, could also be developed in the future as niche crop options (Harris and Mann, 1994; Barillot *et al*., 2017).

For hemp (*Cannabis spp*.), as well as quinoa and other specialty grains and pulse crops, Our Land and Water National Science Challenge has funded work on identifying opportunities based on the application of 'six' filters spanning consumer insights through to the knowledge on how to grow the crops and their environmental impact (Leftfield Innovation Limited, 2019.). For hemp, limited local data was available on seed production yield and price as legalisation of hemp seed foods had only recently passed. Callaghan Innovation have produced a 'Hemp Seed Capability Roadmap' to provide information and guidance from seed production through to marketing (https://www.callaghaninnovation.govt.nz/). The Ministry for Primary Industries also provides guidance on working within the regulatory requirements for hemp seed as a food (MPI, 2020). In Australia, commercial seed yields range from 0.5 – 1 t ha^{-1} (PIRSA, 2019). A fibre crop can also be produced from hemp plants.

Chestnut was identified as a nut crop that was potentially suited to the Taihape trial sites. This crop is still a minor crop in New Zealand, with about 85 ha planted in 2017 (StatsNZ). Chestnut has recently been identified as an emerging crop opportunity in Australia (Coriolis, 2017). In 2016, Australia had over 1,300 ha planted, producing 1,200 t of in-shell nuts estimated to be worth A$7.30 kg^{-1}. A United States study applying Porter's five forces analysis found demand often exceed supply, production was dominated by part-time or hobbyist producers who manually harvest the crop from the ground (Gold *et al*., 2006). Barriers include a lack of information across the value chain, long payback, a shortage of commercial nursery stock and concerns about pest and disease control. Porter's competitive advantage methodology was also applied to the Chilean chestnut industry (Joublan *et al*., 2005). The analysis identified a competitive advantage for Chile as a Southern Hemisphere exporter of fresh nuts to the European and North American markets but found no competitive advantage in processed chestnuts. The pollination requirements of New Zealand and introduced chestnut cultivars is available (Klinac, *et al.*, 1995). The incidence of nut rot can be a significant postharvest issue and can vary between regions within New Zealand (Osmonalieva *et al*., 2001).

Cultivated elderberry species include the black elderberry (*Sambucus nigra*) and eastern elderberry (S. *canadensis*). *S. nigra* plants have successfully naturalised in the cooler parts of New Zealand through bird dispersal to the extent that they are considered an invasive weed speed species (Williams, 2006). This could pose a danger to biodiversity if the risk from bird dispersal is unable to be mitigated under commercial cultivation. Both species can have a higher total antioxidant capacity when compared to strawberry, raspberry and blueberry (Charlebois, 2007). *S. nigra* is a natural remedy against upper respiratory disorders and has recently been shown to have anti-influenza activity (Torabian *et al*., 2019). In the United States, a significant constraint on industry growth is a lack of regionally adapted cultivars, high labour costs and an absence of suitable mechanical harvesting equipment (*Cernusa et al*., 2012).

Echinacea (*Echinacea spp.)* is a medicinal crop that has been evaluated in New Zealand (Parmenter *et al*., 1992; Parmenter *et al*., 1997). Second year plant yields can range from 150 – 260 g m^{-2}, depending on plant density and site. In Canterbury, dry root yield can reach 0.5 t ha^{-1} in the first year, 1.9 t ha^{-1} in the second year, and 4.0 t ha^{-1} in the third year (Martin and Deo, 1997). A Canadian production guide provides details on the commercial requirements and gives an example of cash flow for 5 hectares of echinacea produced over 10 years, including 5 years of rotation (Alberta Agriculture, Food and Rural Development, 2005). Although the bulk of the crop is grown in-field, the guide also covers newer hydroponic production of roots that can have significant benefits on productivity and reduce the need for washing soil from roots.

Licorice (*Glycyrrhiza glabra*) is also a medicinal root crop that has been evaluated in New Zealand (Douglas *et al*., 2004). Maximum yield was obtained at a density of 24,000 plants ha^{-1}, producing 17 -28 t ha^{-1} in the second and third year, with a glycyrrhizin content exceeding the minimum international standard. The dried root is about 20% by weight of the fresh root weight. Weed control needs to be managed up to canopy closure (Hartley, 1996). About 1,377 t of dried roots worth NZ$5.3m was imported from China, Afghanistan and Australia into Japan in 2007 for processing to extract glycyrrhizin (Hayashi and Sudo, 2009). This quantity is lower than in previous decades as the major producing countries have increased domestic processing of the root to export glycyrrhizin extracts to Japanese pharmaceutical companies. For New Zealand, the bulk of the dried root product could be exported to a country like Australia or China (depending on phytosanitary requirements) for extraction of glycyrrhizin and then the extract re-exported to Japan (Figure 11). Depending on scale, extraction could also occur in New Zealand.

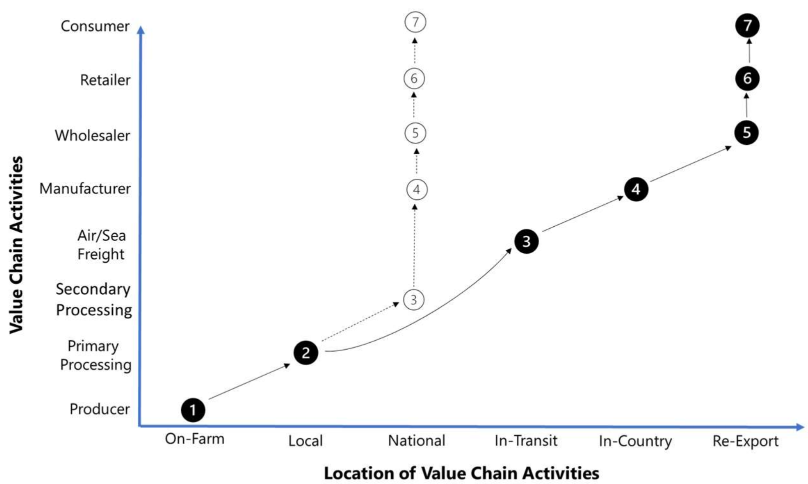

Figure 11. Example of value chain activities and location of these activities on two scenarios for licorice (*G. glabra*), a medicinal crop option, using publicly available information.

The EcoCrop analysis also identified a range of woody forage and forest tree species that were excluded from the current project. A recent study considered vegetation options for increasing resilience in New Zealand pastoral hill country (Tozer *et al*., 2021). This work has highlighted the option of introducing woody forage shrubs into hill country pasture systems as a way of increasing farm profitability and resilience to economic and climate-related vulnerabilities. A site specific EcoCrop analysis also could be applied to identify crop suitability for each of the exotic woody forage species identified in that study.

Local trial sites can provide good information to help ground-truth suitable crop options identified by the EcoCrop model. For example, in the Taihape case study area, landowners had been piloting a small commercial garlic planting to evaluate productivity and test marketing. On another land block, commercial plantings of quinoa are being evaluated in sufficient volume to provide product for market development. Given EcoCrop is based on globally available climate data for a given site, rather than factors such as local micro-climatic, pest and pathogen pressure and soil quality, these local trial sites can assist in the screening of potential crop options by providing exposure of the crop to these site-specific factors, as well as providing product for the evaluation of quality and commercial value chain options.

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Additional Tools

A significant proportion of the hill country land in the study area is Whenua Māori, primarily Māori customary and freehold land. Manaaki Whenua – Landcare Research has developed a Whenua Māori visualisation tool in conjunction with data from Māori Land Online provided by Te Tāhū o te Ture - Ministry of Justice at https://whenuaviz.landcareresearch.co.nz/. For a given Māori land block, this tool can provide site specific information on land use capability, land cover, climate and soil properties. This information can be used to ground truth the suitability of crops identified using the methodologies outlined earlier in this report.

Access to site-specific information on land use capability, land cover, climate and soil properties for any location in New Zealand is available using the online mapping tool located at the LRIS portal (https://lris.scinfo.org.nz/). Data layers for the production potential indicator for New Zealand land is also available in association with the original research published on the indicator (Harris *et al*., 2021). Spatial land use data and environmental data is also available from the Ministry for the Environment data portal (https://data.mfe.govt.nz/). S-map, has been integrated into the LRIS portal, and is based on combining traditional and digital soil mapping techniques that enable end-users to access highly customised spatial data, maps and factsheets for New Zealand soils (Lilburne *et al*., 2012). This data is important for further assessing site suitability for crop species identified by the EcoCrop-based analysis.

Taihoro Nukurangi National Institute of Water and Atmospheric Research has produced a series of maps that provide the spatial distribution of growing potential for selected crop and tree species using climate, soil and topography data at https://niwa.co.nz/gallery/crop-and-tree-species-growing-potential (Tait, 2010). The underlying GIS data raster files can be purchased at https://niwa.co.nz/climate/research-projects/national-and-regional-climate-maps (Wratt *et al*., 2006). An online interactive simulation of climate change related production variability of kiwifruit in New Zealand between 1971 and 2100 is available at https://well-shny-vp.shinyapps.io/CCII/ (Tait *et al*.,2018).

Web-based tools, supported by cloud-based data analytics, are also becoming more available to undertake crop climate suitability mapping for specific geographic locations (Peter *et al.,* 2020). For example, twenty-one crops, including quinoa, are currently available for near instantaneous climate suitability mapping using an experimental online interface at https://cropniche.cartoscience.com/ .

To identify site suitability for crops not included in the EcoCrop database, another set of open sources of tools can be used. These tools are DIVA-GIS software (https://www.diva-gis.org/) and the online Global Biodiversity Information Facility (GBIF) database located at https://www.gbif.org/ (Ward, 2007; Telenius, 2011). For example, Szechuan pepper tree (*Zanthoxylum simulans* Hance) was a crop species suggested by a landowner/user respondent during the MCDM workshop in the second phase of this project (McCarthy *et al*., 2021). Although this crop was not included in the EcoCrop database, it was possible to use the GBIF database to view a map and access data on geographic locations where this species had been reported to occur around the world. In this case, the database held 844 occurrences of the Szechuan pepper tree, including two occurrences in New Zealand, Bay of Plenty and Gisborne. By retrieving the geographic locations of these 844 occurrences from the GBIF database, the DIVA-GIS software could be used to import the occurrence data, and then predict sites with climatic conditions that could be suitable for Szechuan pepper tree, including locations within New Zealand. A landowner/user can then geolocate their own land block in the software to determine the crop suitability for that site.

While EcoCrop can be described as tool is based on ecological suitability of crops, Maxent, a machine learning tool, is based on socioeconomic suitability of crops (Moller *et al*., 2021). Here, existing spatial locations on where farmers have registered specific crops under European Union Policy are mapped on to existing soil maps and used to extract 30 soil-related attributes that can then be used to train a machine learning algorithm. Next, the trained model predicts the suitability for a given crop on locations not under cultivation by that same crop. When compared against EcoCrop, the Maxnet spatial suitability for a given crop could differ. This work highlights opportunities for further development of these types of models under the New Zealand S-Map and LRIS portals. These portals could provide more accessibility for landowners/users and rural professions to such socioeconomic suitability models for crops.

EcoPort (www.ecoport.org) is a knowledge management system that facilitates access to information about plant and insect species, including links to over 550 medicinal and aromatic plant species (Griffee, 2006). The sites also include photo records of species and location of where and when photos of species are collected. Te Mana Rāhui Taiao Environmental Protection Authority (https://www.epa.govt.nz/) provides The Plants Biosecurity Index that contains the list of plants legally allowed in New Zealand.

A portal to access free data relating to New Zealand, including the existing planted area of specific crops, as well as exports or imports is available through the figure.nz (https://figure.nz/) website. Much of the data relating to crops is sourced through Tatauranga Aoetearoa Statistics New Zealand (https://www.stats.govt.nz/) .

To support the Māori agribusiness sector and Māori landowners/users, a growing range of Kaitiakitanga tools have or are being developed (Hutchings *et al*., 2017). These tools have the potential to add value to the Māori agribusiness sector through the translation of existing knowledge as well as the development of Māori knowledge and science tools. Application of Kaitiakitanga tools to all three parts of the current project could significantly enrich both the process and outcomes of identifying site specific crop options for integration into hill country land. Particularly important for Māori landowners/users, there are also likely to be benefits for non- Māori landowners/users as well.

Ministry for Primary Industries has been working with Māori landowners/users to develop tools to assist the development of Māori land into production options (KPMG, 2015). This includes frameworks for planning, collaboration, access to investment, value chain development and the building of required skills, knowledge and networks at the governance and operational levels.

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SUMMARY AND RECOMMENDATIONS

Site-Specific Crop Options Process Effectiveness

In the first project phase, by combining three open-source software tools, the selection of potential crops suitable to the three Taihape-based geographic sites were able to be identified. This crop selection was based under two scenarios, with and without irrigation, using a suitability index value ≥ 0.5, as calculated from the EcoCrop model running under three open-source software tools. Initial landowner/user feedback had indicated five main crop groupings of interest: fruit, grains, medicinal, nuts and vegetables. Across the five crop groupings, 49 potential plant species were selected. Based on landowner/user group feedback, this list included three additional crops of interest not already in the EcoCrop database.

The three open-source software tools need to run the site-specific crop options process were readily available. A protocol to install and run this suite of software was collated so that the process could be replicated by landowners/users and rural professions (Appendix I) on their own personal computers. Ongoing global development of online and cloud-based tools could make this process even easier for landowners/users and rural professions (https://cropniche.cartoscience.com/).

Multi-Criteria Decision-Making Process Effectiveness

The selected list of crops was then provided for the second project phase; the multicriteria decision making process. In this multi-criteria decision-making process, the landowner or model user reduced the list of crop options to a smaller set to suit their preferences. In some cases, the landowner/user added crops that were not identified by EcoCrop-based analysis that had been applied prior to the multi-criteria analysis. The multi-criteria decision-making process, reported separately, provided a shorter list of crop options for a business case assessment in the third project phase.

Publicly available yield and FOB trade prices, accessed through global databases or literature, could be obtained for most of the potential crop options identified by the site-specific crop options process (https://earthstat.org; https://comtrade.un.org). This allowed indicative farmgate returns to be calculated and provided at the multi-criteria decision-making workshops. Similarly, where available, crop fact sheets were also provided at the workshops.

Overall, from the purposes of ground-truthing the potential crop options identified by the site-specific process, landowner/user participants were able to screen out options that were unlikely to be suited to their own geographic locations due to factors such as soil type, out of season frosts or fit with other land-use activity. In addition, the workshop participants were able to identify three additional crops not already contained in the EcoCrop database that could be suited to the given geographic locations. This included an endemic species, mānuka, that is adapted to the locality, and is already an emerging export industry providing honey and essential oil.

The multi-criteria decision-making process was effective at reducing the initial potential list of crop options from 49 crop species to 15. This was approximately 30% of the initial list of crop options that had been identified in the site-specific crop options process. This reduced the number of crops that were needed to be considered using the value chain-based business case process.

Value Chain-Based Business Case Process Effectiveness

From the earlier two phases of this project, four fruit, two grain, five medicinal, two nut and two vegetable crops were shortlisted. Of these crops, apricot, quinoa, arnica, hazelnut and garlic were selected to provide case studies from each of the five product groupings. Typically, the multi-criteria decision-making process resulted in a shortlist of about five potential crop options per model user. These five selected crops in the current example are not intended to be recommendations and were provided to illustrate the process of applying a value chain-based business case assessment for the value chain-based business case assessment.

Value chain mapping was used, in most cases, to identify two potential commercial options per crop. This mapping also identified where governance influence could lie within a given value chain option. Across each of these elements, publicly available open-access publications were able to be used to inform these assessments. This analysis can be undertaken more easily now as global open-access initiatives have significantly improved the accessibility of scientific papers and reports for landowners/users and rural professionals.

The value chain mapping exercise was effective in identifying suitable locational requirements of processing options for a given crop once it had been grown and produced on a block of land. This is particularly important as the lack of access to suitable processing facilities is a major limitation that has been identified in previous regional economic development studies on crop diversification options (Leftfield Innovation Ltd., 2020; The Catalyst Group Limited, 2014). For examples such as arnica and hazelnut, the harvested flowerheads and nuts, respectively, can be naturally air-dried under shade on-site. In contrast, products such as mānuka, require specialised steam distillation equipment operated by skilled operators to process cut foliage (Saunders and Lay, 2017). To avoid high transport costs, such a process plant would need to be located close enough to the sources of biomass within a production area. To ensure sufficient crop volume to operate efficiently would also require coordination between groups of landowners/users within a region.

From the earlier two phases of this project, four fruit, two grain, five medicinal, two nut and two vegetable crops were shortlisted. Of these crops, apricot, quinoa, arnica, hazelnut and garlic were selected to provide examples from each of the five product groupings for the value chain-based business case analysis. The selection of these crop species, or any of the other crop species discussed in this report are not intended to indicate that any of these species are recommended or are endorsed as crop options for any landowner/user and should not be considered as such without being analysed in more detail in conjunction with appropriate professional advice.

The strategic context assessment found that each of the crops would need to be orientated towards commercialisation based on a differentiation rather than cost leadership strategy. This result was due to factors such as a lack of scale, high dependency on manual labour, scarcity of previous commercial experience with a given crop or limited access to germplasm with known productivity advantages. For many of the medicinal crops, New Zealand product would compete with products produced in developing nations, often from the harvest of natural populations (Hishe, *et al*., 2016). Also, these supply chains can be long, with many intermediaries, but also well developed and specialised.

Value chain mapping identified import substitution as a potential commercial option for a high proportion of the crops assessed. Previously, under Our land and Water, work on grain and pulses has highlighted this as an option for the establishment of a local market to enable land use diversification (Leftfield Innovation Ltd., 2019). This could occur by the producer providing either a raw product or partially processed product to a manufacturer for subsequent distribution to consumers, or the producer providing the product in a form suitable for direct distribution to consumers. Other commercial options included products for export in a fresh, semi-processed or final form.

This work has highlighted that open-source software tools can enable a landowner/user and/or their network of rural professionals to identify a set of site-specific crop options for further assessment. By applying multi-criteria decision-making tools in collaboration with the landowner/user this list of crop options can further be reduced by considering local knowledge regarding the site as well as understanding of the owners' values and business itself. The work has also highlighted that additional publicly available information can be assembled into a generalised value chain-based business assessment tool to shorten the list of site-specific crop options that may warrant more in-depth analysis using less easily accessible and possibly more costly proprietary sources of information.

Regional economic development initiatives can assist the next stages of this process. In the case of the endemic species of mānuka and kānuka, funding of detailed handbooks on crop establishment, harvesting and processing requirements, as well as recent costs and returns can provide information for a landowner/user or rural professional to undertake a more detailed business case assessment (Saunders and Lay, 2017; Hikurangi Bioactives Ltd. Partnership, 2020). Funding of a series of reports on the wider food value chain are also another example of resources that are available for assisting in the development of a more detailed business case (www.coriolisresearch.com).

Learnings from the multi-criteria decision-making process have highlighted that process could benefit from having prior access to some or all of the information summarised by the value chain-based business case process. As the site-specific crop options process identified 49 potential crop options, it would be a significant undertaking to manually collate, annotate and summarise the information that the multi-criteria decision-making process could require prior to that process commencing. The value chain-based business case process, using manually sourced publicly available information, benefited from the multi-criteria decision-making process reducing the initial list of 49 potential crops down to a shortlist of 15 potential crops (or 5 potential crops per land block).

Advances in text mining for evidence-based medicine can enable automated annotation and summarisation of portable document formats of scientific papers and reports by using machine learning methods (Kuiper *et al*., 2014). Essentially, these are the same types of documents that have been reviewed in the current value chain-based business case process. At a national level, there could be a case for the application of text mining to replace manual extraction and synthesis of information relating to options for land use diversification. A common pool of up-to-date automated and summarised information on land use diversification options relevant to New Zealand could be used for the multi-criteria decision-making process. This would then allow more resources to be focused on detailed business case development and, where applicable, implementation.

There is a role for the integration or application of New Zealand-centric databases, such as those provided by the LRIS, S-Map and MFE data portals to assist in customising crop suitability selection to local soils and land use capability.

Landowners/users were able to identify potentially suitable plant species that were absent from the EcoCrop database. These included three medicinal crops, including mānuka, a species endemic to New Zealand. Improved accessibility of Geo-Tiff data layers from previous crop suitability studies in New Zealand, would allow some of these data sets to be applied within open-source tools used in the current study. For example, the work on crop and tree species growing potential based on climate, soil and topographic information (Tait, 2010).

As many of the crop suitability models use globally derived data, there could be biosecurity risks to New Zealand where some of the plant species identified as potentially suitable to a given local geographic location could naturalise. The modelling approach would benefit from integration with local biosecurity and environmental weed risk databases.

Recommendations

- Landowner/user-centric tools that enable site-specific identification of potential climate suitable crop options should be considered part of the transitional process needed to achieve "a future in which landscapes contain mosaics of land uses that are more resilient, healthy and prosperous than today".
- Availability of tools are essential for transitional processes. The landowner/user-centric tools need to be open-source, open-access and easy to use under a range of rural internet connectivity.
- Access to relevant data is crucial. There is a role for central and local government to build on existing open-data initiatives to improve access and content of New Zealand specific spatial datasets that strengthen the landowner/user-centric tools for site-specific crop option identification.
- Better information and analysis are needed to support landowner/user decision-making processes. A role exists for collaboration between the public, non-government organisations and the private sector to consider the application of advances in text mining to replace manual extraction and synthesis of information relating to options for land use diversification.
- Effectiveness of tools will depend on awareness and capability. Utilisation of existing industry, training and rural professional networks should be considered as part of the process to improve access and uptake of landowner/user-centric tools for site-specific crop option identification.
- Joined-up initiatives are needed to support land use transitional processes. The bottom-up approach used in the landowner/user-centric tools should be seen as complimentary and not a substitute to the top-down national, regional and industry programmes.
- Development of value-chains for new crops or existing crops in new localities is a long-term undertaking. Additional, policy work is needed between government, non-government organisations and the private sector on how to better facilitate land-use transition based on viable and sustainable crop-based value chains.

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https://www.researchgate.net/profile/Aleksandar_Valjarevic2/publication/346679525_The_future_of_edible_crops_in_Europe_and_their_maximum_point_of_resistance_in_temperature_increase/links/5fce4ba092851c00f8597f22/The-future-of-edible-crops-in-Europe-and-their-maximum-point-of-resistance-in-temperature-increase.pdf accessed 20/6/2021.

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APPENDIX I: PROTOTCOL FOR DETERMINING CROP SUITABILITY USING GPS CO-ORDINATES

Using the EcoCrop Model in combination with QGIS and RStudio Software.

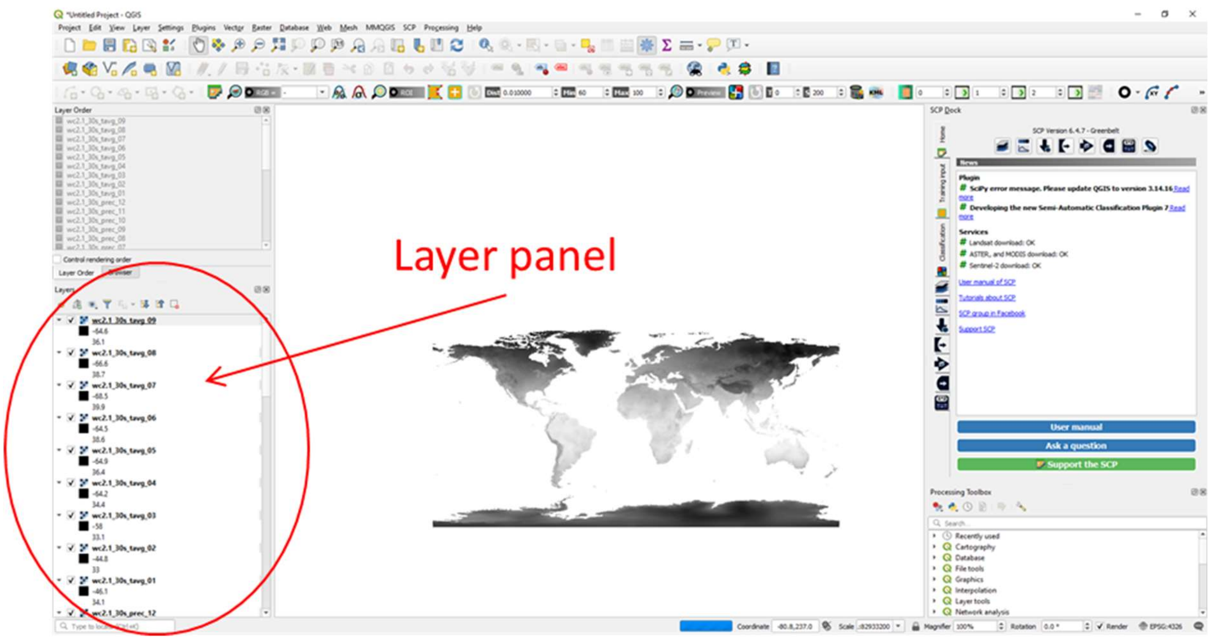
1. **Install QGIS**
   1.1. Download QGIS: Go to the QGIS download website (https://qgis.org/en/site/forusers/download.html) and download QGIS Standalone Installer Version 3.10 (64 bit) or (32 bit) If you are using a Windows PC either 64 or 32 bit system. Or the same version installer for Mac and Linux.
   1.2. Install QGIS: Execute the Installer and follow recommended options.
   1.3. Install plugins: Open QGIS, go to **plugins** -> **manage and install plugins**… and type *point sampling tool* in the search bar, select the **point sampling tool** plugin and click on **install plugin**. Once the first plugin is installed, then search and install the **NumericalDigitize** plugin. Then search and install the MMQGIS plugin.

2. **Install RStudio**

Proper installation of RStudio requires prior installation of R software.

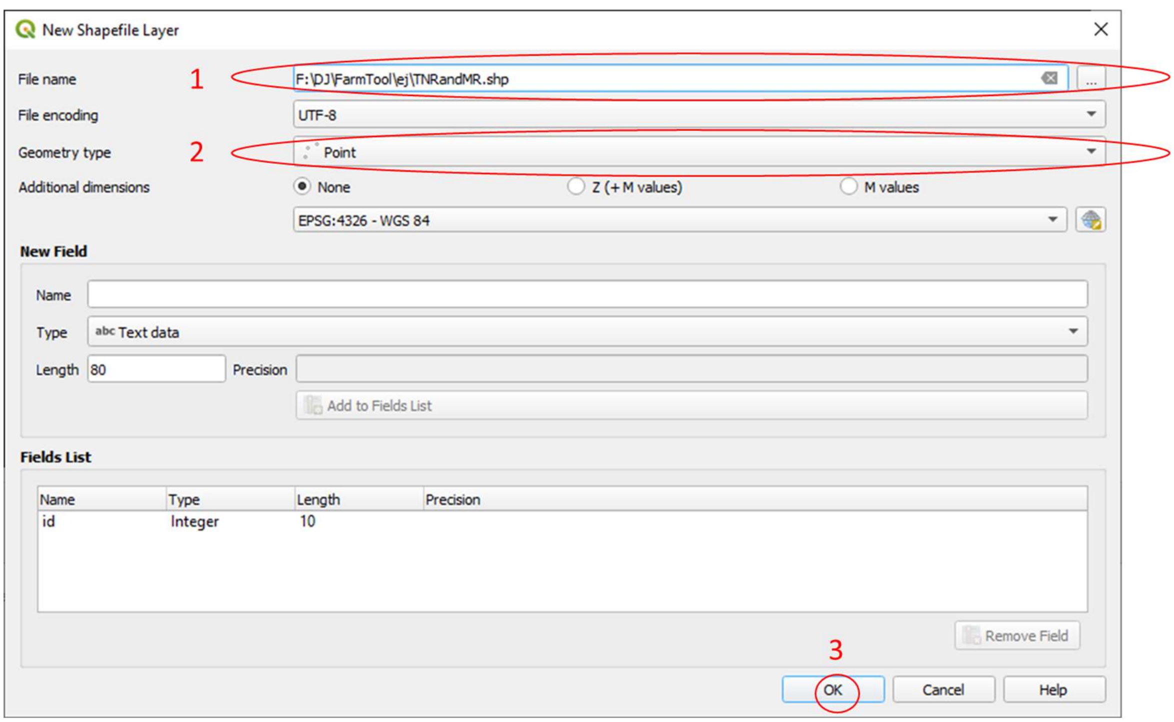
   2.1. Download R: If using Windows, download R installer by clicking here Download R for Windows. Mac or Linux installers can be found at https://cran.stat.auckland.ac.nz/.
   2.2. Install R: Execute the R installer and follow instructions by accepting recommended settings.
   2.3. Download RStudio: Go to R Studio download website (https://rstudio.com/products/rstudio/download/) and download the recommended free RStudio Desktop for windows installer (the website will automatically identify the version that bests suits your system). Mac or Linux installers can be found in the same website.
   2.4. Install RStudio: Execute the RStudio desktop installer and follow instructions by accepting recommended settings.

3. **Download and prepare climate data**
   3.1. Download data: go to WorldClim website (https://www.worldclim.org/data/index.html) and download historical climate data on minimum temperature, average temperature, and precipitation at 30 seconds (highest spatial resolution available ~1 km2). Each download contains a compressed file (.ZIP) with monthly world climate data in 12 separate raster (.TIF) images. Each image corresponds to a month of the year with the name ending in 01 being January and the name ending in 12 December.
   3.2. Decompress data: Extract the .ZIP compressed file into a folder.
   3.3. Start a New Empty Project in QGIS: Open QGIS (version 3.10: A Coruna) and double click on **New Empty Project**.
   3.4. Load climate data into QGIS: Open the folder where the climate data is stored, select all the 36 .TIF files and drag them into the **Layers** panel in QGIS.

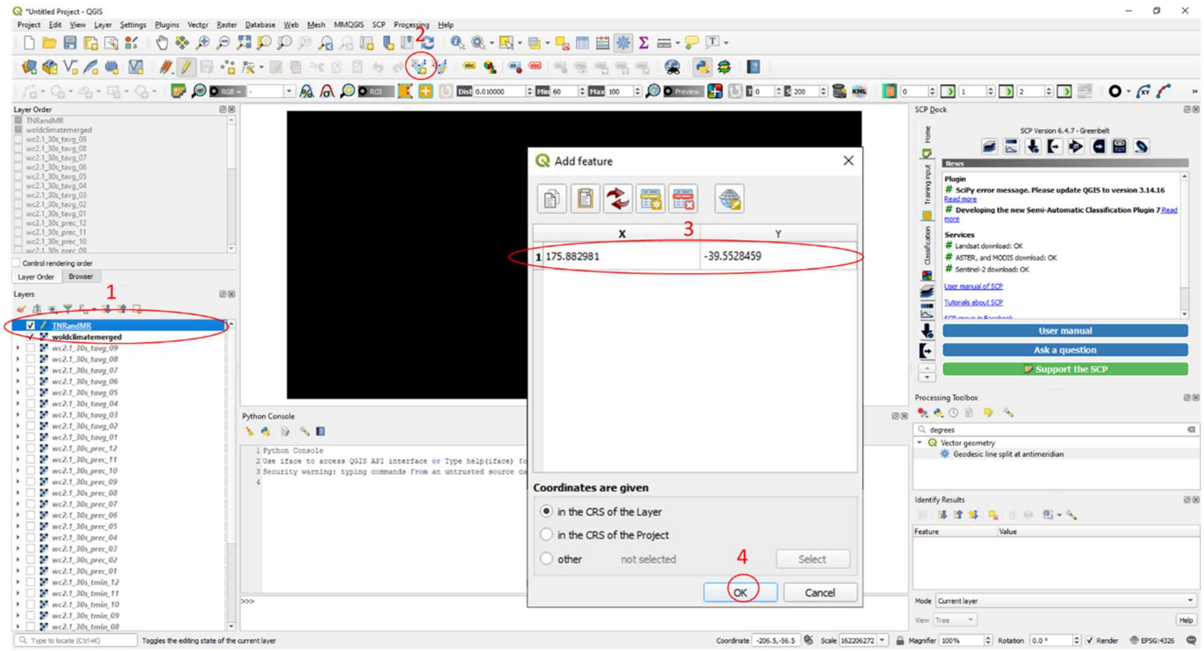


3.5. Obtain climate data for farm coordinates:

3.5.1. Create empty shapefile: go to **Layer** -> **Create Layer** -> **New Shapefile Layer**. Choose a folder to save the shapefile (.SHP) by clicking **…** and name the new shapefile layer (1), make sure the file is a point geometry type (2) and click OK (3).



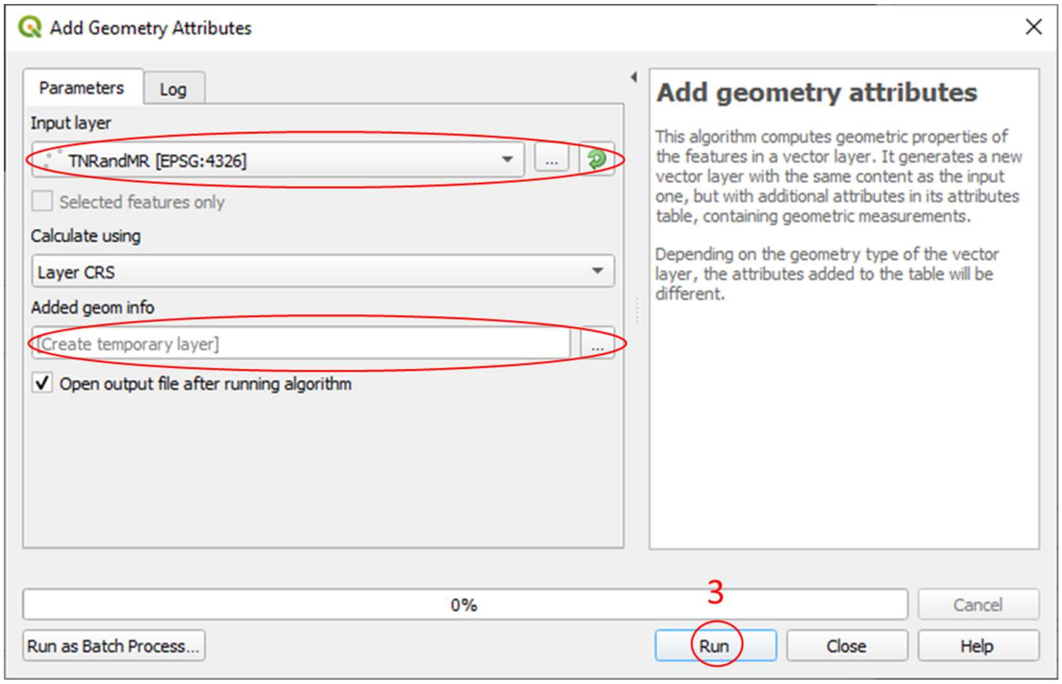
3.5.2.Locate shapepoint: **left click** on the file in the layers panel (1) and click **Toggle Editing** (2). Click on the numerical digitize icon (3) then write farm coordinates[1] in the Add feature window and click OK (4). Click OK on the emerging Feature Attributes window that will pop-up with ID set to null to accept changes.



3.5.3.Add coordinates to shapepoint: go to **Vector**-> **Geometry Tools**-> **Add Geometry Attributes**. Select the shapefile containing farm location data as input layer (1), choose a folder to save a new shapefile (.gpkg) by clicking **…** , then Save to File, name the new shapefile[2] layer (2). Then click Run (3).

[1] Coordinates must be in decimal degrees format. X correspond to Longitude and Y to Latitude.

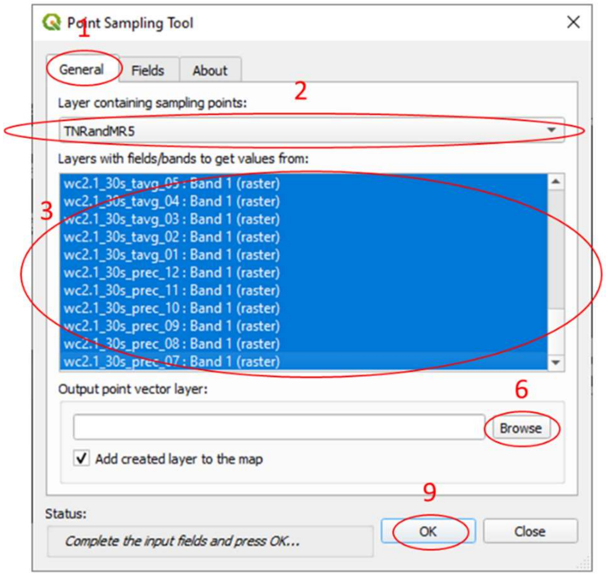
[2] File name must be different than the original (you can't overwrite the original file). If you have coordinates in Degree Minutes Seconds (DMS) you can use a web tool to convert the data to decimal degrees (e.g. https://www.fcc.gov/media/radio/dms-decimal)

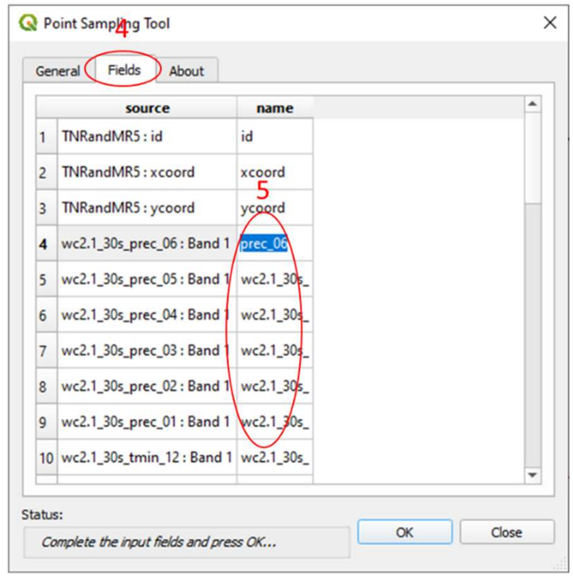


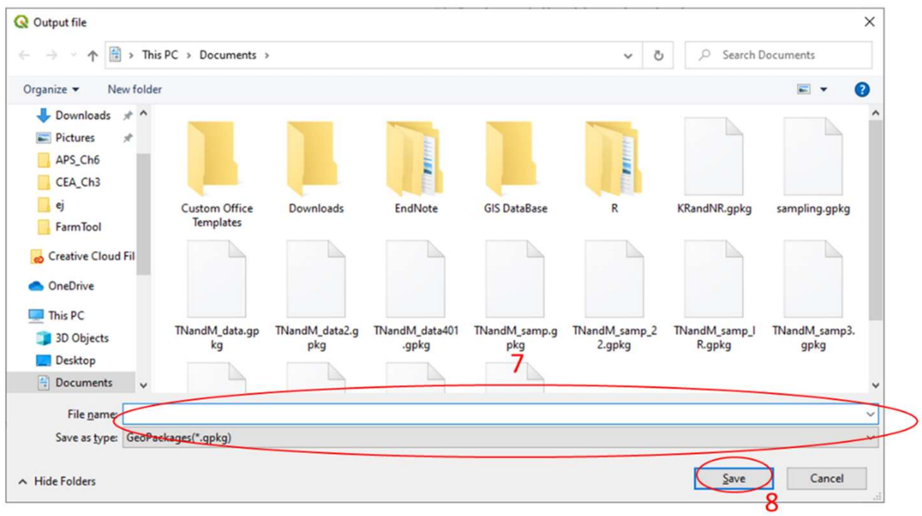
At this point take a quick look at the map and check to ensure the spot (red dot) on the map aligns with the coordinates of interest.

Next, in the layers section, right click on the .gpkg file (should have a red dot next to it and also the top-most file). Open the attributes table. Check to ensure there are 4 parameters, fid (set to 1), id (set to null) and the X and Y co-ordinates that you entered. Close the attributes table window.

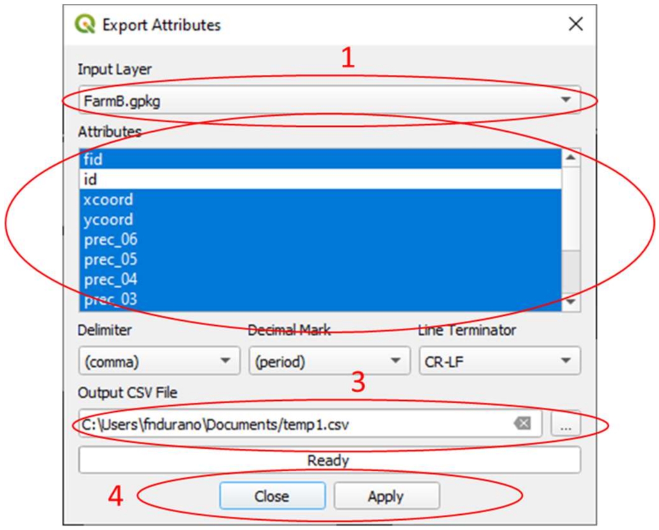
3.6. Add climate data to shapepoint: go to **plugins** -> **Analyses** -> **Point Sampling Tool**. In the General tab (1) select the gpkg that was created in point 3.5.3 as input layer (2) and select all climate raster files as layers with bands/fields to get values from (3).
Go to the Fields tab (4) and simplify world climate raster names by naming layer with the type of data (either prec, tmin, tavg) and month number corresponding to the layer preceded by _ as shown in (5) (eg. *Original name: wc2.1_30s_prec_01: Band 1 (raster)*, new name: *prec_01*).
Go back to the General tab (1), choose a folder (7) to save a new file containing farm location and climate data. Save the file (8). Click OK (9). Click Close (10).





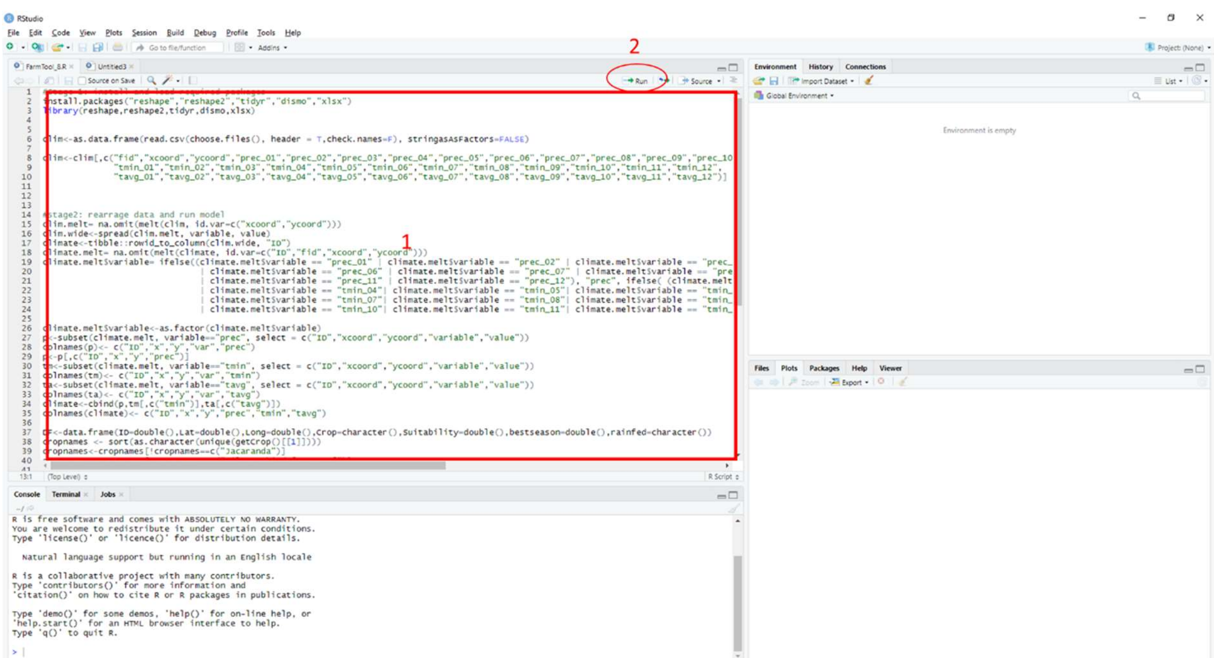


3.7. Export data to .CSV: go to **MMQGIS** -> **Import/Export** -> **Attributes Export to CSV file**. Select the file created in 3.6 as Input Layer (1). Select all attributes but id (2). Choose a folder and name .CSV file (3). Apply changes and then close window (4).



4. Run EcoCrop

4.1. Open RStudio and create new script: Go to File -> New File -> R Script. Copy and paste the code below in point 4.3 into the new script window (1). The Run button (2) is used to run the script one row at a time. However, there is the possibility of running more than 1 row at a time by selecting the group of rows to run and then hit the run button.

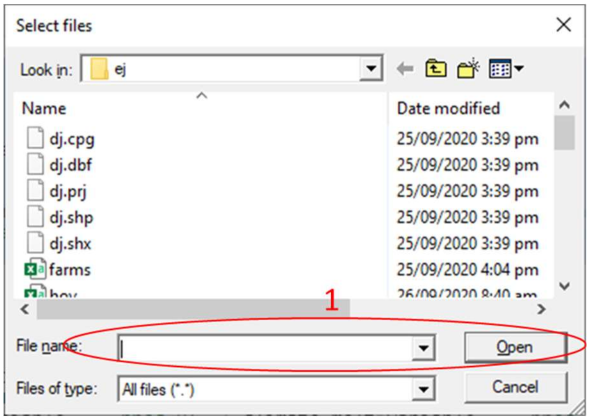


4.2. Run the code in three steps:

To make sure the system works properly, first time users are recommended to run the script in three steps.

The first run will install the packages required to manipulate data and run the EcoCrop model.

The second run will open a window to select the file with the farm data rearrage it and run the EcoCrop model. To load the data, simply browse to select the .CSV file created in point 3.7 and open it (1).



The algorithm will calculate suitability of every crop in the EcoCrop database considering irrigation is available or not. It will also deliver information on the best growing season with 1 being January and 12 December. If there is more than one best growing season, results will show the firs best growing season starting from January.

The third run will save data on farm #id, location coordinates, crop name, crop suitability, best season, and irrigation to a .CSV file. However, the path to the folder and name of the file must be specified by the user by replacing "mydata.csv" for the desired path[3] and file (e.g. “c:/farm/suitability.csv”).

4.3. R script

```
##########################################################################################

#Step 1: install and load required packages

install.packages("reshape")
install.packages("reshape2")
install.packages("tidyr")
install.packages("dismo")


library(reshape)

library(reshape2)

library(tidyr)

library(dismo)


#Step 2: load, rearrage data and run model

clim<-as.data.frame(read.csv(choose.files(), header = T,check.names=F), stringasAsFactors=FALSE)
```

[3] Note the use of /

```
clim<-
```

Hit Run. A window should “pop-up”. Select the .csv file from 3.7.2.

```
clim[,c("fid","xcoord","ycoord","prec_01","prec_02","prec_03","prec_04","prec_05","prec_06","prec_07","prec_08","prec_09","prec_10","prec_11","prec_12",

"tmin_01","tmin_02","tmin_03","tmin_04","tmin_05","tmin_06","tmin_07","tmin_08","tmin_09","tmin_10","tmin_11","tmin_12",

"tavg_01","tavg_02","tavg_03","tavg_04","tavg_05","tavg_06","tavg_07","tavg_08","tavg_09","tavg_10","tavg_11","tavg_12")]


clim.melt= na.omit(melt(clim, id.var=c("xcoord","ycoord")))

clim.wide<-spread(clim.melt, variable, value)

climate<-tibble::rowid_to_column(clim.wide, "ID")

climate.melt= na.omit(melt(climate, id.var=c("ID","fid","xcoord","ycoord")))

climate.melt$variable= ifelse((climate.melt$variable == "prec_01" | climate.melt$variable == "prec_02" | climate.melt$variable == "prec_03" | climate.melt$variable == "prec_04" | climate.melt$variable == "prec_05"
            | climate.melt$variable == "prec_06" | climate.melt$variable == "prec_07" | climate.melt$variable == "prec_08" | climate.melt$variable == "prec_09" | climate.melt$variable == "prec_10"
            | climate.melt$variable == "prec_11" | climate.melt$variable == "prec_12"), "prec", ifelse((climate.melt$variable == "tmin_01" | climate.melt$variable == "tmin_02"| climate.melt$variable == "tmin_03"
            | climate.melt$variable == "tmin_04"| climate.melt$variable == "tmin_05"| climate.melt$variable == "tmin_06"
            | climate.melt$variable == "tmin_07"| climate.melt$variable == "tmin_08"| climate.melt$variable == "tmin_09"
            | climate.melt$variable == "tmin_10"| climate.melt$variable == "tmin_11"| climate.melt$variable == "tmin_12"), "tmin", "tavg"))


climate.melt$variable<-as.factor(climate.melt$variable)

p<-subset(climate.melt, variable=="prec", select = c("ID","xcoord","ycoord","variable","value"))

colnames(p)<- c("ID","x","y","var","prec")

p<-p[,c("ID","x","y","prec")]

tm<-subset(climate.melt, variable=="tmin", select = c("ID","xcoord","ycoord","variable","value"))

colnames(tm)<- c("ID","x","y","var","tmin")
```

```
ta<-subset(climate.melt, variable=="tavg", select = c("ID","xcoord","ycoord","variable","value"))

colnames(ta)<- c("ID","x","y","var","tavg")

climate<-cbind(p,tm[,c("tmin")],ta[,c("tavg")])

colnames(climate)<- c("ID","x","y","prec","tmin","tavg")


DF<-
data.frame(ID=double(),Lat=double(),Long=double(),Crop=character(),Suitability=double(),bestseason=double(),Irri
gation=character())

cropnames <- sort(as.character(unique(getCrop()[[1]])))

cropnames<-cropnames[!cropnames==c("Jacaranda")]

cropnames<-cropnames[!cropnames==c("Silvery birdsfoot tref")]


j <- 1


IDs<- unique(climate$ID)

Rain<-c(TRUE,FALSE)


for (crop_current in cropnames) {

 for (ID_current in IDs){

  for (Rain_current in Rain) {

       spp_per_ID <- climate[climate$ID == ID_current,]

       ecores<-ecocrop(crop_current, spp_per_ID$tmin, spp_per_ID$tavg,spp_per_ID$prec, rainfed=Rain_current)

       DF[j, ] <- c(as.double (ID_current),

                    as.double (unique(spp_per_ID$y)),

                    as.double (unique(spp_per_ID$x)),

                    as.character(crop_current),

                    as.double (ecores@maxsuit),

                    as.double (ecores@maxper[1]),

                    as.character(ifelse(Rain_current==TRUE, "No","Yes")))

  j <- j+1

  }

 }
```

```
}
```

```
#Step 3: save file
write.csv(DF, file = "mydata.csv")
```

Note: in the file path for step 3, the correct back-slash needs to be use. The correct one is “/”. Not “\”

##

APPENDIX II: CROP INFORMATION

Appendix Table 1: Crop Suitability Index, Napier-Taihape Road, Moawhango
Latitude -39.5528459, Longitude 175.882981

Crop Type	Crop ID	Crop Name	Crop Suitability Index + Irrigation	Crop Suitability Index - Irrigation	Need For Irrigation	Product	Published Yield (T/ha)	Median World Export Price 2020 (NZ$/kg)	Farm gate return /ha	Time to production
Fruit	4749	Red currant	1.00	0.65	Y	Fresh	16	$4.50	$28,800	2-3 years
Fruit	3509	Lowbush blueberry	0.93	0.89	N	Fresh	35	$8.75	$122,500	2-3 years
Fruit	2469	Goldenberry	0.75	0.00	Y	Fresh	20	$2.20	$17,600	2-3 years
Fruit	1805	Cranberry	0.70	0.70	N	Fresh	25	$8.75	$87,500	2-3 years
Fruit	2141	European gooseberry	0.70	0.49	Y	Fresh	6	$3.30	$7,260	2-3 years
Fruit	4797	Red raspberry	0.62	0.56	N	Fresh	15	$10.30	$61,800	2-3 years
Fruit	689	Black currant	0.53	0.53	N	Proc.	20	$3.30	$26,400	2-3 years
Fruit	1709	Common fig	0.53	0.53	N	Fresh	12	$6.25	$30,000	4-5 years
Fruit	325	Apricot	0.49	0.00	Y	Fresh	30	$2.55	$30,600	4-5 years
Fruit	1433	Cherry, Sweet	0.37	0.37	N	Fresh	30	$4.30	$51,600	4-5 years
Grain	721	Black mustard	1.00	0.93	N	Dried	2	$3.65	$2,190	
Grain	5525	Spelt	1.00	0.70	Y	Dried	3	$2.00	$2,400	
Grain	2701	Hemp	0.93	0.50	Y	Dried	3	$5.10	$6,120	
Grain	1461	Chick pea	0.92	0.57	Y	Dried	2	$1.40	$1,120	
Grain	1705	Common buckwheat	0.89	0.00	Y	Dried	2	$1.50	$1,200	
Grain	2957	Italian millet	0.86	0.49	Y	Dried	2	$1.50	$1,200	
Grain	3441	Linseed	0.85	0.85	N	Dried	1	$1.60	$640	
Grain	4645	Quinoa	0.78	0.78	N	Dried	3	$5.50	$6,600	
Grain	5729	Sunflower	0.78	0.57	Y	Dried	3	$1.50	$1,800	
Grain	3377	Lentil	0.74	0.74	N	Dried	1	$1.55	$620	
Grain	529	Barley	0.72	0.72	N	Dried	4	$0.70	$1,232	
Grain	5037	Rye	0.64	0.64	N	Dried	1	$0.85	$340	
Grain	6369	Wheat, common	0.64	0.64	N	Dried	4	$0.65	$1,040	
Grain	4065	Oats	0.58	0.58	N	Dried	3	$0.65	$780	
Grain	5225	Sesame seed	0.44	0.44	N	Dried	1	$3.35	$1,340	
Medicinal	3417	Licorice, Common	1.00	0.86	N	Proc.	4	$9.25	$14,800	
Medicinal	5053	Saffron	1.00	0.74	Y	Proc.	0.02	$252.50	$2,020	
Medicinal	5189	Sea buckthorn	1.00	0.88	N	Proc.	5	n/a		
Medicinal	2037	Eastern elderberry	0.94	0.58	Y	Proc.	9	$9.25	$33,300	
Medicinal	3653	Mashua	0.80	0.30	Y	Proc.	70	n/a		
Medicinal	1429	Cherry, Sour	0.58	0.58	N	Proc.	15	$1.95	$11,700	3-5 years
Medicinal	4269	Pepper tree	0.43	0.00	Y	Proc.	n/a	n/a		
Medicinal		Arnica	USDA Crop Hardiness Zones 5 - 9		n/a	Proc.	0.5	$20	$4,000	
Medicinal	4269	Echinacea	USDA Crop Hardiness Zones 5 - 8		n/a	Proc.	6	$6.00	$14,400	
Nut	2145	European hazelnut	1.00	0.32	Y	Dried	2	$5.65	$4,520	4-5 years
Nut	225	Almond	0.70	0.70	N	Dried	2	$9.40	$7,520	4-5 years
Nut	4261	Pecan nut	0.64	0.64	N	Dried	3	$15.00	$18,000	4-5 years
Nut	1449	Chestnut, European	0.55	0.49	N	Dried	9	$3.90	$14,040	4-5 years
Nut	2105	English walnut	0.55	0.55	N	Dried	4	$4.75	$7,600	4-5 years
Vegetable	993	Brussels sprouts	1.00	0.02	Y	Fresh	30	$2.20	$26,400	
Vegetable	1333	Cauliflower	1.00	0.24	Y	Fresh	40	$1.30	$20,800	
Vegetable	4109	Onion	1.00	1.00	N	Fresh	45	$0.70	$12,600	
Vegetable	1309	Carrot	0.96	0.08	Y	Fresh	25	~~$0.80~~	~~$8,000~~	
Vegetable	4221	Parsnip	~~0.04~~	~~0.86~~	~~N~~	~~Fresh~~	~~25~~	~~$0.80~~	~~$8,000~~	
Vegetable	1125	Cabbage	~~0.02~~	~~0.86~~	~~N~~	~~Fresh~~	~~50~~	~~$1.30~~	~~$26,000~~	
Vegetable	4505	Potato	~~0.02~~	~~0.88~~	~~N~~	~~Fresh~~	~~64~~	~~$0.57~~	~~$14,592~~	
Vegetable	6577	Yacon	~~0.01~~	~~0.48~~	~~Y~~	~~Fresh~~	~~25~~	~~$1.30~~	~~$13,000~~	
Vegetable	2805	Horseradish	~~0.67~~	~~0.67~~	~~N~~	~~Fresh~~	~~6~~	~~$1.30~~	~~$3,120~~	
Vegetable	2381	Garlic	~~0.67~~	~~0.03~~	~~Y~~	~~Fresh~~	~~6~~	~~$3.65~~	~~$8,760~~	

Appendix Table 2: Crop Suitability Index, Koeke Road and Ngaurukehu Road, Mataroa

Latitude -39.6619067, Longitude 175.6562823

Crop Type	Crop ID	Crop Name	Crop Suitability Index + Irrigation	Crop Suitability Index -Irrigation	Need For Irrigation	Product	Published Yield (T/ha)	Median World Export Price 2020 (NZ$/kg)	Farm gate return /ha	Time to production
Fruit	4749	Red currant	1.00	0.91	N	Fresh	16	$4.50	$28,800	2-3 years
Fruit	3509	Lowbush blueberry	0.96	0.96	N	Fresh	35	$8.75	$122,500	2-3 years
Fruit	2469	Goldenberry	0.78	0.00	Y	Fresh	20	$2.20	$17,600	2-3 years
Fruit	1809	Cranberry	0.72	0.72	N	Fresh	25	$8.75	$87,500	2-3 years
Fruit	2141	European gooseberry	0.72	0.68	N	Fresh	6	$3.30	$7,260	2-3 years
Fruit	4797	Red raspberry	0.63	0.63	N	Fresh	15	$10.30	$61,800	2-3 years
Fruit	689	Black currant	0.55	0.55	N	Proc.	20	$3.30	$26,400	2-3 years
Fruit	1709	Common fig	0.55	0.55	N	Fresh	12	$6.25	$30,000	4-5 years
Fruit	325	Apricot	0.51	0.51	N	Fresh	30	$2.55	$30,600	4-5 years
Fruit	1433	Cherry, Sweet	0.38	0.38	N	Fresh	30	$4.30	$51,600	4-5 years
Grain	721	Black mustard	1.00	1.00	N	Dried	2	$3.65	$2,190	
Grain	5529	Spelt	1.00	0.94	N	Dried	3	$2.00	$2,400	
Grain	2701	Hemp	0.96	0.83	N	Dried	3	$5.10	$6,120	
Grain	1461	Chick pea	0.95	0.86	N	Dried	2	$1.40	$1,120	
Grain	1709	Common buckwheat	0.91	0.00	Y	Dried	2	$1.50	$1,200	
Grain	2957	Italian millet	0.88	0.82	N	Dried	2	$1.50	$1,200	
Grain	3441	Linseed	0.87	0.87	N	Dried	1	$1.60	$640	
Grain	4649	Quinoa	0.80	0.80	N	Dried	3	$5.50	$6,600	
Grain	5729	Sunflower	0.80	0.80	N	Dried	3	$1.50	$1,800	
Grain	3377	Lentil	0.76	0.76	N	Dried	1	$1.55	$620	
Grain	529	Barley	0.74	0.74	N	Dried	4	$0.70	$1,232	
Grain	5037	Rye	0.66	0.66	N	Dried	1	$0.85	$340	
Grain	6369	Wheat, common	0.66	0.66	N	Dried	4	$0.65	$1,040	
Grain	4069	Oats	0.60	0.60	N	Dried	3	$0.65	$780	
Grain	5229	Sesame seed	0.46	0.46	N	Dried	1	$3.35	$1,340	
Medicinal	3417	Licorice, Common	1.00	1.00	N	Proc.	4	$9.25	$14,800	
Medicinal	5053	Saffron	1.00	0.93	N	Proc.	0.02	$252.50	$2,020	
Medicinal	5189	Sea buckthorn	1.00	0.59	Y	Proc.	5	n/a		
Medicinal	2037	Eastern elderberry	0.96	0.86	N	Proc.	9	$9.25	$33,300	
Medicinal	3653	Mashua	0.83	0.59	Y	Proc.	70	n/a		
Medicinal	1429	Cherry, Sour	0.60	0.60	N	Proc.	15	$1.95	$11,700	3-5 years
Medicinal	4269	Pepper tree	0.44	0.00	Y	Proc.	n/a	n/a		
Medicinal		Arnica	USDA Crop Hardiness Zones 5 - 9		n/a	Proc.	0.5	$20	$4,000	
Medicinal	4269	Echinacea	USDA Crop Hardiness Zones 5 - 8		n/a	Proc.	6	$6.00	$14,400	
Nut	2149	European hazelnut	1.00	0.57	Y	Dried	2	$5.65	$4,520	4-5 years
Nut	225	Almond	0.80	0.80	N	Dried	2	$9.40	$7,520	4-5 years
Nut	4261	Pecan nut	0.66	0.66	N	Dried	3	$15.00	$18,000	4-5 years
Nut	1449	Chestnut, European	0.58	0.58	N	Dried	9	$3.90	$14,040	4-5 years
Nut	2109	English walnut	0.58	0.58	N	Dried	4	$4.75	$7,600	4-5 years
Vegetable	993	Brussels sprouts	1.00	0.21	Y	Fresh	30	$2.20	$26,400	
Vegetable	1333	Cauliflower	1.00	0.31	Y	Fresh	40	$1.30	$20,800	
Vegetable	4109	Onion	1.00	1.00	N	Fresh	45	$0.70	$12,600	
Vegetable	1309	Carrot	0.97	0.41	Y	Fresh	25	$0.80	$8,000	
Vegetable	4221	Parsnip	0.96	0.96	N	Fresh	25	$0.80	$8,000	
Vegetable	1129	Cabbage	0.95	0.95	N	Fresh	50	$1.30	$26,000	
Vegetable	4509	Potato	0.95	0.95	N	Fresh	64	$0.57	$14,592	
Vegetable	6577	Yacon	0.94	0.86	N	Fresh	25	$1.30	$13,000	
Vegetable	2809	Horseradish	0.70	0.70	N	Fresh	6	$1.30	$3,120	
Vegetable	2381	Garlic	0.69	0.33	Y	Fresh	6	$3.65	$8,760	