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

***THE MULTI-CRITERIA DECISION-  
MAKING PROCESS***

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



# INTEGRATING HORTICULTURAL AND ARABLE LAND USE OPTIONS INTO HILL COUNTRY FARM SYSTEMS: THE MULTI-CRITERIA DECISION-MAKING PROCESS

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

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# EXECUTIVE SUMMARY

The 'Integrating Horticultural and Arable Land Use Options into Hill Country Farm Systems' research project aims to develop a process and tools for crop identification and assessment to help farmers select crops to integrate into hill country farms. This report addresses the second of the three project phases: crop assessment using an objective process with a multi-criteria decision-making (MCDM) support tool to help farmers identify preferred crop(s) taking goals (criteria) and crop performance into consideration.

MCDM approaches can help people make objective decisions where there are multiple, conflicting and incommensurate (measured in different units) criteria. MCDM can help people to select an alternative, explore a decision, learn about their own and others' perspectives and communicate a decision (Belton & Stewart, 2002; Dooley et al., 2009; Renwick et al., 2019). The researchers worked with a group of Taihape sheep and beef farmers interested in alternative enterprises who they had had previous discussions with.

Prior to the MCDM workshop, a questionnaire was sent to a few local farmers interested in alternative crops to identify crop selection criteria likely to be important. Nine responses were received. All were interested, or possibly interested, in horticultural or arable enterprises. Fruit or nut crops and medicinal crops were of greatest interest (to 8 and 7 people, out of out of 9, respectively). About half were interested in vegetables, or grain, seed and oil crops. Attributes considered of moderate or greater importance related to: value chain success (returns, marketability, processing required, risk), crop production (time, labour, support and information, risk), enterprise fit (fit with current business, lifestyle and crop rotation), and environmental and biodiversity impacts.

Eight farmers from five farming businesses attended MCDM workshops. While numbers were low, they were sufficient to assess workshop effectiveness and identify crops of interest for the business cases in the next phase of the project. Criteria and weightings provided insight into what decision criteria were important to this decision.

A set of crop alternatives suited to local farming areas identified in the first stage of the project was provided to farmers at the MCDM workshop, along with a list of the important criteria identified in the questionnaire. Farmers selected those crops and criteria of interest to them and could add any other crops or criteria of interest. They then used a MCDM approach to assess the performance of these crops against their selected decision-making criteria weighted according to their preference, with crops then scored on their performance against these criteria. The farm businesses selected between five to eleven crops each, including crops from two to four crop types (fruit and nuts, grains, medicinal, vegetables). All crop types were included in the same analysis, so were assessed using the same criteria and weightings.

Crops of greatest interest were those suited to small-scale horticulture or cropping for farms with limited flats with interest in enterprises which can provide high returns from a small area to complement sheep and beef farming. Workshop participants showed greatest interest in medicinal crops (15 crops evaluated across 5 farmers), and fruit trees, fruit bushes and nut trees (9 crops across 3 businesses). This could be expected since these crop types are more likely to be grown on a small-scale compared to vegetable and grain crops, and generally had higher returns than grain or vegetable crops. The only vegetables selected for evaluation were garlic and horseradish, and the only arable crops were quinoa and hemp.

Each business selected between five and eight criteria for the analysis. The criteria considered important in this crop selection decision primarily related to profitability (crop returns, price risk, establishment costs), factors affecting success in the supply chain (markets, processing facilities) and factors related to successful crop production (labour required, production risk, crop rotation, access to information). Fit with lifestyle and environmental impact were mentioned twice and fit with business once. All respondents identified labour as being important, and at least four of the five identified returns and market.

Most people found the MCDM process relatively easy and rated this positively. Feedback responses from the workshop fit into three categories: crop varieties; the MCDM process; and the information required for the process. The workshop raised awareness of the range and variety of crops suited to the area, with those from most businesses commenting on this as something that was new to them and/or that they had learned from. Comments suggest some participants found the process insightful in terms of their crop selection decisions. These included reference to: determining a basis for the initial elimination of crops; thinking about “reasoning for planting crops”; “thinking about a range of criteria”; applying weights; and “getting [their] head around scoring”.

The novelty of many of the crops, and their lack of production in New Zealand or even developed countries, meant that the information provided was often limited and non-specific, as was the participants’ knowledge of these more unusual crops. Hence, most of the workshop participants commented on the difficulty in assessing the crops because of their limited knowledge and the lack of information e.g. on returns, production, harvest, markets. And as one participant commented, “accuracy of [MCDM] results relies on accurate crop knowledge beforehand”. Having access to information prior to the workshop would also have been helpful.

Recommendations included the following.

- For hill country farms, higher-returning niche crops suited to smaller areas of flat land will be of greater interest e.g. fruits, nuts, medicinal crops.
- Concise, reliable and relevant information on crops is required to support decision-making, particularly where the alternatives being considered are not well understood. Information is best provided in advance to allow time for reading before working through the selection process.
- The crops identified were useful but, crop databases do not include all crops as yet, but more are added over time. Publicly available information and expertise is available in NZ for some crops e.g. natives. Databases on soils and markets are available in NZ and will be useful for crop decisions.
- The business cases in the next phase will be helpful, as would a template and questions to develop a business case, and information on collaborative business structures such as cooperatives.
- The MCDM process was helpful. A MCDM process and model that is straightforward, relatively quick to use, and freely available to farmers and advisors could be developed, possibly as an application for web-based use or tablets, and with good supporting documentation and examples.
- It could be beneficial for farmers and their advisors to work through a MCDM process together, particularly for novel or unfamiliar alternatives. This would help both parties understand the decision and rationale for the outcome which is objective and explicit. The consultant can provide expertise on alternatives to assist the client in evaluating alternatives (scoring), while identification and weighting of criteria by the client can help the consultant target their advice and suggested alternatives to the client’s interest. Outcomes are easily made transparent to others in the business.



## INTRODUCTION

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. This process incorporates publicly available open-source tools into a crop selection process with landowner input. There are three stages: first, the selection of crops suited to a particular location; second, an objective crop assessment process for individual farmers to identify their preferred crops taking their crop performance assessments, goals and preferences into consideration; and finally, a description of value chain-based tools to support the development of business cases for the preferred crops. This report addresses the second stage of the project which focuses on individual farmer selection of their preferred crops, making explicit the drivers for crop selection and the preferred crops. The first and third stages of the project, which focus on the crops *per se*, are described in Apparao et al. (2021).

A multi-criteria decision-making (MCDM) tool was used in this process to support the selection of the preferred crop. MCDM approaches (processes supported by a tool) help people make objective decisions where there are multiple, conflicting and incommensurate (measured in different units) criteria. MCDM can help people to select an alternative, explore a decision, learn about their own and others’ perspectives and communicate a decision (Belton & Stewart, 2002; Dooley et al., 2009; Renwick et al., 2019). The researchers worked with a group of Taihape sheep and beef farmers interested in alternative enterprises who some of the research team had had previous discussions with. Preliminary work with this group had provided some insights into their horticultural enterprises of interest that they had already identified including quinoa, garlic, echinacea, arnica, hazelnuts, camelia oil. This work will be extended to further explore and evaluate options using the selected tools and novel process.

# METHOD

A subset of higher ranked crop alternatives suited to the farming areas was identified in the first stage of the project and was provided for farmer evaluation in the MCDM crop selection component of the project. Farmers selected those crops which were of interest to them, along with any other crop options they wanted to include. They then assessed the performance of these crops in a multi-criteria decision framework populated with their decision-making criteria, with crops scored on their performance against these criteria. Criteria were weighted according to their preference.

Prior to the meeting with the farmers to work through the MCDM process, a questionnaire to identify crop selection criteria which were likely to be important to them was sent to the farmer group interested in alternative crops, thereby reducing the time required for the MCDM process i.e. less time required to establish criteria in the workshop. Those criteria considered important were pre-defined at the MCDM crop selection workshop, with farmers able to select the criteria of interest to them and to add other criteria if they wanted in their MCDM evaluation.

## Criteria Questionnaire

A questionnaire was designed to gauge interest in crop types and identify the relevance and importance of a pre-defined subset of criteria to these different crop types. A questionnaire was designed for this purpose using Survey Monkey software.

Crop types categories identified were as follows, with examples provided which were not necessarily relevant to their area to avoid influencing their views.

- Fruit trees/fruit bushes/nut trees e.g. plum, raspberry, almond
- Vegetable crops e.g. cabbage, kumara, spring onion
- Grain, seed or oil seed crops e.g. oats, rape
- Medicinal crops e.g. hemp, kawakawa

For each crop type, respondents were asked the following.

*'Please indicate your level of interest in growing [crop type]', with a 5-point likert scale to indicate level of interest (very low, low, moderate, high, very high).*

If they indicated a moderate to very high response, they were asked the following questions about that crop type.

*'When deciding which [crop type] to grow, how important would you consider each of the factors listed below to be in making your decision', with a 5-point likert scale to indicate importance (very low, low, moderate, high, very high, not applicable).*

These criteria were identified from previous New Zealand farmer decision-making studies (Dooley, 2005; Dooley et al., 2005a, 2005b, 2009; Holt et al., 2019; Renwick et al., 2017, 2019) and the researchers' knowledge of farm management decision-making and horticultural supply chains and were as follows.

- Net annual return
- Establishment cost
- Time to production
- Production risk
- Price risk
- Diversification
- Access to market
- Processing facilities
- Fit with livestock business
- Fit with lifestyle
- Labour required
- Timing of labour input
- Access to information and support
- Access to specialised equipment
- Environmental impacts
- Contribution to biodiversity

They were also asked to *'List any other criteria and indicate importance'* and *'If there are any [crop type] species that you are interested in, please specify.'*

At the end of the questionnaire, the respondents were asked about their interest in alternative crops and further involvement in the project as follows.

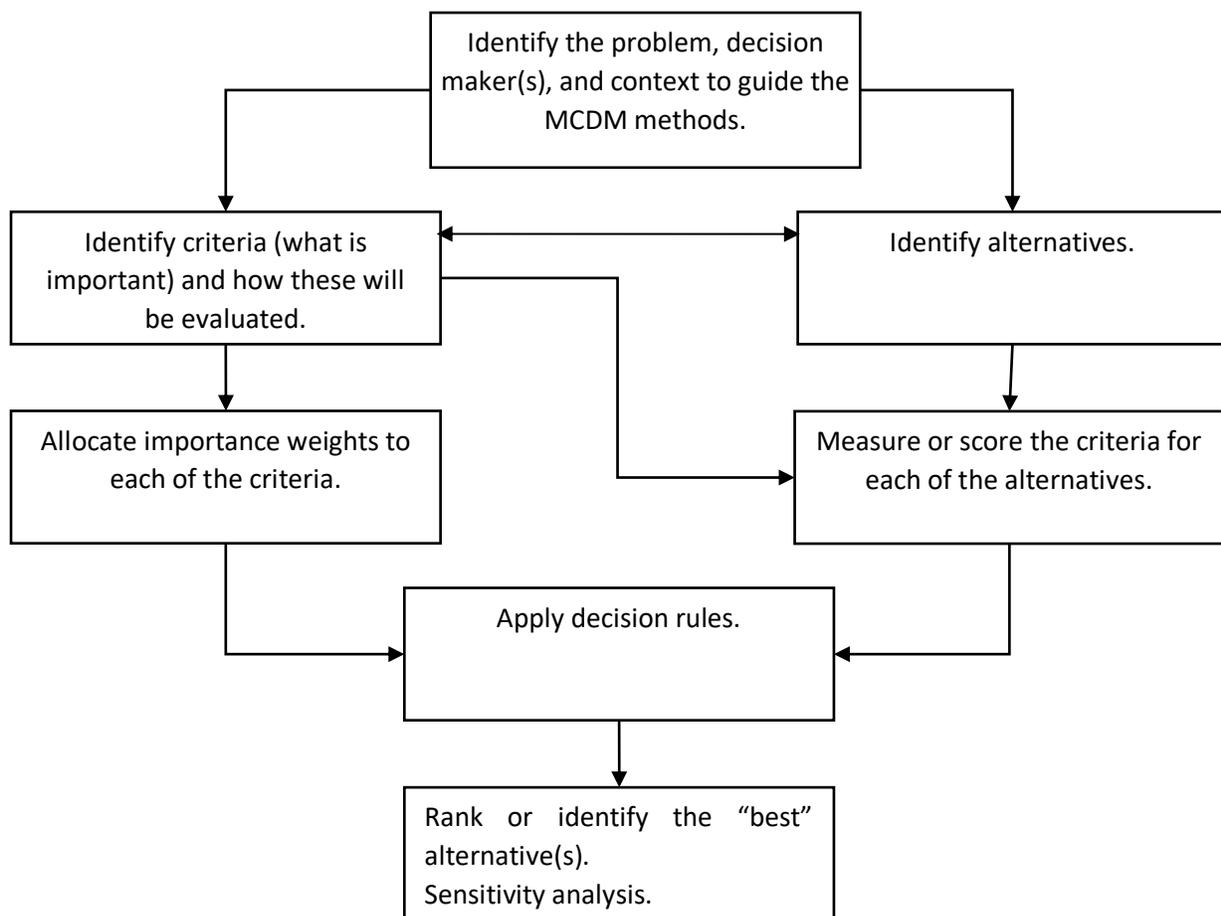
- *'Are you interested in considering horticultural/arable enterprises for your property?'*
- *'Are you interested in being involved in a process to select possible crop options? Note that this would require spending a half day workshop to explain the research outputs and work through the process.'* If yes, they were asked to provide contact details.
- *If you know of anyone else who might be interested in being involved, please let us know*

A covering letter and a link to the questionnaire in Survey Monkey was sent to 17 sheep and beef farmers in the interested farmer group on the 1<sup>st</sup> February 2021, with a reminder email sent on the 15<sup>th</sup> February 2021. The questionnaire results were closed early March and responses collated to inform the next stage of the process (MCDM workshop).

Criteria need to be relevant to the decision-makers, their situations and the decision under consideration. It should be noted that while questionnaire numbers were small, and as a survey, statistically insignificant, the purpose of this questionnaire was to determine interest in the different crop types and identify the importance of range of criteria with those farmers interested in alternative enterprises in this area, and who were therefore potential case study farmers to explore the process with as part of this research. That is, the information being sought was directly relevant to local farmers interested in horticultural enterprise, some of whom would be involved in the next step in the project. This questionnaire was not intended as a survey, *per se*.

## MCDM Process

There are numerous MCDM approaches, with the most appropriate MCDM approach for a particular problem depending on the problem, the decision-maker's requirements, and the requirements and limitations of the methods (Belton & Stewart, 2002; Dooley et al., 2009). A multi-attribute value theory (MAVT) method was chosen for the MCDM process. MAVT methods are suitable where there are discrete decision alternatives and subjective assessments. A utility value is calculated for each alternative, and alternatives can be ranked on this value. MAVT methods were selected because they: provide an objective approach to decision-making, can rank alternatives, can identify the contribution of the various criteria to the alternative ranking, and are quick and easy to facilitate and understand relative to other methods. The generic MCDM (MAVT method) process is shown in Figure 1. The MCDM process was supported by a MCDM spreadsheet tool developed by Dooley (Dooley, 2005; Dooley et al., 2005a, 2005b, 2009) to weight criteria, score alternatives against the criteria, and aggregate these values.



**Figure 1:** The MCDM process (from Dooley et al., 2005a).

Those farmers interested in participating in evaluating crops identified in the first phase, as indicated in the survey responses, were contacted early March with respect to a suitable date for a crop evaluation MCDM workshop in Taihape in April 2021. Other potentially interested farmers identified by locals were also contacted. The workshop date set was April 21<sup>st</sup> 2021.

The workshop was attended by a father and son, and two farming couples: that is, 3 farming businesses. There was greater interest, but unfortunately, the date clashed with a fertiliser company meeting in Taihape and a number of interested farmers were otherwise committed. One researcher met with two other farmers to work through the process on the 6<sup>th</sup> May.

The workshop went from 10 am to 2 pm, with a half hour lunch break. The workshop started with a brief presentation covering the background of the project, the crop selection process (first stage of the project) and an introduction to MCDM. The participants were then taken through an example of the process showing how to use the MCDM model for crop ranking/selection process. Following on from this, each farmer then worked on their own crop selection: if there were two participants from a farming business, they could do this together or separately. The farmers were provided with crop information and a list of the criteria from the questionnaire to help them with crop and criteria selection, and a blank MCDM spreadsheet template to populate with their own crop selections and criteria important to them. The spreadsheet has a non-existent 'Perfect' crop alternative that scored the top value on all criteria which was useful when making comparisons between alternatives.

A set of crop information was provided for two of the three geographical locations investigated in the first stage of the project (Koeke Road near Mataroa and Taihape-Napier Road near Moawhango). This information set included selected groups of fruit (10), nut (5), grain (15), vegetable (10) and medicinal (9) crops suited to their locality (number in brackets is the number of crops in that group). Five crops were added to the crop model selection, with three requested by questionnaire respondents and a further two novel crops of interest in New Zealand: crop suitability index scores were not available for these latter crops due to insufficient crop model information. The crops included for each location were the same (all crops suited to the region), but there were differences between locations in crop suitability indices and the need for irrigation. Participants used the dataset most applicable to where they lived. This crop information is provided in Appendix I. The crop selection tool is described in Apparao et al. (2021).

For each crop, information included: the crop suitability index with, and without (most likely), irrigation (index described in the first stage of the project); irrigation requirement; product type (fresh, processed, dried); the published median World yield and median World export price in 2020 (UN Comtrade Database, n.d.); estimated farm gate return per hectare (revenue); and estimated time to production where relevant e.g. trees. The estimated farm gate return per hectare was calculated as published yield/ha x world export price/yield units x 40%, assuming farmers would receive 40% of the median export price (A. Mowat, personal communication, April 19<sup>th</sup> 2021). While this was a crude estimate, it provided participants with a value suitable for making crop comparisons.

Quite a few of the crops were unusual and are not currently grown in NZ or only grown by a few specialist growers. Some of the crops, particularly the medicinal crops, are produced in developing countries under subsistence farming or with cheap labour, have potentially low yields under these conditions, and there is limited information availability. Nevertheless, some information is better than none and these crops could offer opportunities to those with an appetite for risk. Product type provided some indication of the likely complexity of the value chain required for that crop.

The farmers were also given a number of industry and academic papers with more detailed crop information on a number of key crops. This included information on Szechuan pepper tree, arnica, echinacea, mashua, blueberry, chestnuts, gooseberry, hemp, horseradish, saffron, sea buckthorn, soy, chickpeas, oats, buckwheat and quinoa. They focused on the crop suitability sheet when making their crop selections at the workshop but took the additional information away to refer to later.

Two researchers were available at the workshop to provide guidance and assist farmers in the use of the MCDM spreadsheet model. It was suggested five to seven criteria of importance be included in the analysis, but more could be included if required. Three laptops were available, allowing each business to work through their selection process simultaneously. Participants were asked to provide feedback on the process at the end of the workshop (Appendix II).



# RESULTS AND DISCUSSION

## Criteria Questionnaire

Nine responses were received, with 6 farmers indicating interest in the MCDM workshop. Seven were definitely interested in horticultural or arable enterprises (i.e. 'yes' response), with the other two farmers indicating 'maybe'. Table 1 summarises the questionnaire results. Fruit or nut crops and medicinal crops were of greatest interest as indicated by their average score and the number of respondents indicating interest in that crop type (8 and 7 out of 9, respectively). About half the respondents were interested in vegetables, or grain, seed and oil crops.

**Table 1:** Interest in crop type and importance of attributes (criteria) in selecting that crop type. (1=very low, 2=low, 3=moderate, 4=high, 5=very high). Values 4 and over are shaded. Importance rankings for the top attributes are shown in italicised brackets.

	Fruit trees, fruit bushes, nut trees <sup>1</sup>	Vegetable crops	Grain, seed or oilseed crops	Medicinal crops
<b>Interest in crop type</b>				
Number (moderate or high/total)	8/9	5/9	4/9	7/9
Average score	3.33	2.67	2.67	3.11
<b>Net annual return</b>	4.38 (8) (1)	4.40 (1)	4.75 (1)	4.43 (1)
<b>Establishment cost</b>	3.29 (7)			3.86
<b>Time to production</b>	3.50 (8)			3.71
<b>Production risk</b>	3.63 (8)	4.20 (2)	4.00 (2)	4.14 (4)
<b>Price risk</b>	3.71 (7)	3.80	4.00 (2)	4.14 (4)
<b>Diversification</b>	3.00 (7)	3.00	3.50	3.71
<b>Access to market</b>	4.29 (7) (2)	3.80	3.75	4.29 (2)
<b>Processing facilities</b>	4.00 (8) (4)	3.40	3.50	4.00 (6)
<b>Fit with livestock business</b>	3.88 (8)	3.40	3.25	3.57
<b>Crop rotation fit</b>		4.00 (4)		3.86
<b>Fit with lifestyle</b>	3.57 (7)	4.00 (4)	3.50	3.86
<b>Labour required</b>	4.13 (8) (3)	4.20 (2)	3.75	4.29 (2)
<b>Timing of labour input</b>	4.00 (8) (4)	3.80	3.50	4.00 (6)
<b>Access to information and support</b>	3.75 (8)	3.60	4.00 (2)	4.00 (6)
<b>Access to specialised equipment</b>	4.00 (7) (4)	3.20	3.75	3.86
<b>Environmental impacts</b>	3.71 (7)	3.80	3.75	4.00 (6)
<b>Contribution to biodiversity</b>	3.13 (8)	3.60	3.00	3.86

<sup>1</sup> First number in brackets for fruit and nuts is the number of farmers responding to that question. One person indicated 'Access to market' is not important in growing fruit trees. For other crop types, respondents answered all questions.

Respondents indicating moderate, high or very high interest in a crop type were asked to score the relative importance of a range of attributes on their decision on whether to grow that crop. Attributes included those important to: value chain success (returns, marketability, processing required, risk), crop production (time, labour, support and information, risk), enterprise fit (fit with current business, lifestyle and crop rotation), and environmental and biodiversity impacts. Criteria (attributes) that consistently scored high (average over 4 in Table 1) are shaded.

As can be seen in Table 1, about 40% of the attributes were important in deciding what, or whether, to plant (average score 4 or over), although there was some variation in scores allocated to these attributes (Appendix III). The number of attributes rated important varied: this was six for fruits and nuts, five for vegetables, four for grains, and nine for medicinal crops which is the crop type where there is probably the least information, few established markets and the greatest uncertainty. In terms of ranking, the most important attributes were net annual return, labour required and production risk.

All attributes averaged moderate to high importance (scoring 3 or over, Table 1) for all crop types, so were due some consideration. Net annual return was the highest returning score, with all respondents rating this as high or very high (score 4 or 5, Appendix Table III). Labour requirement and/or timing also scored highly for all crop types except grains which tends to be mechanised and has a lower labour requirement. In contrast, other crop types include crops with high labour requirements and seasonal labour demand (fruit and nuts, medicinal crops).

Production risk (vegetable, grain and medicinal crops) and price risk (grain and medicinal crops) were important attributes in making decisions (average over 4), possibly reflecting the more unusual or less well-known crops (especially medicinal) in these categories, the lack of established markets (e.g. medicinal crops, some fruit crops) and/or a need to access established markets especially with exported crops (e.g. some fruit). Support and information on grain and medicinal crops was identified as important, possibly because of the more unusual crops in these categories.

The need for specialised equipment was identified as important in the decision for fruit and nuts. Equipment required for picking and packing fruit and nuts can be expensive and would likely need to be purchased, whereas with other crop types some of the equipment needed will already be owned or may be comparatively inexpensive. Processing facilities for medicinal crops (processed), and fruit (fresh) and nuts (dried) was an important variable, ranking higher than for vegetables (fresh) and grains (dried). Similarly, access to market was more important, and second ranked, for these two categories (medicinal, fruit and nuts) than vegetables or grains. This suggests a greater importance on whole of supply chain implications for fruit and nuts, and medicinal crops than for vegetable and grains. Possibly vegetables would be more likely to be grown small-scale for local market or be crops that keep well and fit into established export chains (e.g. potatoes, onions), and grains can be easily stored for later distribution and sale if need be.

Environmental impacts did not rate among the most important attributes except for medicinal crops where this may also be important as an intrinsic attribute. However, this attribute was among the higher scoring attributes with an average score less than 4 (important) so was moderate to important in the decision. Biodiversity was lower ranked. However, the area likely to be used for horticultural enterprises is small and biodiversity is unlikely to be negatively impacted. Furthermore, this decision is about comparability between options, and biodiversity and possibly environmental differences between the crops may be small rather than being deciding factors in determining crop choice.

With respect to fruit and nut crops, one farmer with some experience in alternative crops suggested important attributes would be suitability for fodder/grazing (very high), suitability for two-tier farming (high), drought feed shortage management (high), general integration with farming systems, timing of production with respect to the fresh produce market in New Zealand (very high), and skilled seasonal labour and logistics (very high) which is uncertain in their location.

Other crops of interest identified by the farmers were echinacea and arnica (potential medicinal rotation crops for garlic which is a vegetable), quinoa (grain) which one local farming business already grows, and someone requested Szechuan pepper trees (medicinal crop) which was suggested by a Chinese visitor to their farm. One respondent made the point that access to scale is limited in their area, and fruit and nut crops for niche market opportunities are more likely to be of interest than crops suited to larger scale production systems. Similarly, for medicinal crops they also suggested there are so many unknowns that scale would be small i.e. preference for niche market crops.

## MCDM Process

Eight farmers from five farming businesses worked through the MCDM process: three at the workshop and two at a second meeting. Numbers were small, but sufficient to assess workshop effectiveness and identify general crops of interest for the business cases in the next phase of the project. Criteria and weightings provide insight into what decision criteria were important to this decision.

## Crop selection results

Table 2 summarises the workshop results for the five farm businesses. The farm businesses selected five to eleven crops each, from two to four of the crop types shown in Table 1. Since each business included all crop types in the same analysis, the crops would have been assessed using the same criteria and criteria weightings.

Of the grain crops, only quinoa and hemp were included, with three of the businesses including these in their assessments. In the information provided (Appendix I), these two crops had returns which were far higher than other crops on the list of crops suited to the area, so this is not surprising. Quinoa has also been grown in the region by one entrepreneurial farm business so is proven to be suited to the area with some information on this as a local crop available already. These two crops were among the highest-ranking crops for the second and fourth farm businesses (Table 2). These ranked poorly for the first farm business primarily because returns were lower than manuka oil and fruit crops which the first business was also interested in. In contrast, the second farm business are familiar with, and grow, grain crops on their flats already.

**Table 2:** Workshop results for the five farm businesses (MCDM evaluation crop rank in brackets).

Criteria	Weight	Crops evaluated	Score	Preferred crops
Return	20.0%	Manuka Oil	68.0%	Manuka oil (1)
Labour required	16.0%	Red raspberry	64.5%	Raspberry (2)
Market	16.0%	Low bush blueberry	62.0%	Blueberry (3)
Price Risk	14.0%	Apricot	61.0%	Apricot (4)
Production Risk	14.0%	Cranberry	57.0%	Cranberry (5)
Processing facilities	10.0%	Licorice	56.5%	
Establishment cost	10.0%	Pecan nut	50.0%	
		Echinacea	49.5%	
		Quinoa	48.5%	
		Garlic	48.0%	
		Hemp	22.5%	
Access to specialised information	22.7%	Quinoa	84.1%	Quinoa (1)
Processing facilities	18.2%	Hemp	62.5%	Hemp (2)
Labour required	15.9%	Licorice	61.4%	Licorice (3)
Environmental impact	15.9%	Eastern elderberry	44.3%	Eastern elderberry (4)
Production risk	13.6%	Chestnut	44.3%	Chestnut (5)
Establishment cost	13.6%	Pecan nuts	44.3%	
		Fig - common	40.9%	
Return	22.2%	Arnica	44.4%	Arnica (1)
Market	20.0%	Peony	44.4%	Echinacea (4)
Labour required	17.8%	Garlic	41.1%	Garlic (3)
Fit with lifestyle	15.6%	Echinacea	39.4%	Licorice (5)
Crop rotation fit	13.3%	Licorice	33.9%	Blackcurrant (6)
Environmental impacts & biodiversity	11.1%	Blackcurrant	30.0%	
Return	20.2%	Quinoa	75.0%	Horseradish (4)
Processing facilities	18.2%	Eastern elderberry	56.1%	Licorice (5)
Marketing	16.2%	Hemp	51.0%	Quinoa (1)
Price risk	15.2%	Horseradish	47.2%	Hemp (3)
Labour	15.2%	Licorice	33.1%	
Establishment cost	5.1%	Saffron	0.0%	
Production risk	5.1%			
Fit with other business	5.1%			
Market	23.8%	Arnica	63.7%	Arnica (1)
Crop rotation	21.4%	Licorice	63.1%	Echinacea (3)
Lifestyle	19.0%	Echinacea	59.5%	Licorice (2)
Labour	19.0%	Garlic	56.0%	Horseradish (5)
Return	16.7%	Horseradish	45.8%	Hazelnut (no MCDM)

Only garlic and horseradish were included as vegetable crops of interest for assessment, with three businesses evaluating garlic (two of which had trialled this), and two evaluating horseradish. These crops had lower returns per hectare than most of the crops on the list provided. However, garlic had the highest per kilogram return and possibly potential to add value (e.g. organic production, niche marketing opportunities), is perhaps better suited to a small scale vegetable production than some of the other crops on the list, keeps well, and is in short supply in New Zealand.

Horseradish was noted by those assessing this to 'grow like a weed' in the area so would be easy to grow. Had 'easy to grow' (important reason for selecting this crop) been included as a criterion in the MCDM assessment, this crop may have ranked higher in the MCDM evaluation. It was also observed horseradish could be used as stock feed, so could support the farm operation if need be or be fed to stock if or when the market price was low making this a dual-purpose crop.

Six (of 10) of the highest returning fruit trees and the two (of 5) highest returning nut trees were selected for evaluation, with most of these included in two farm business assessments (1<sup>st</sup> and 2<sup>nd</sup>). The returns for these crop types were the highest for all crops (Appendix I). The fruit tree crops ranked highest and were preferred crops for the first farm business (Table 2), but the pecan and chestnut trees and fig trees were outperformed by the grain and medicinal crops for the second farm business.

Selected medicinal crops included licorice for all 5 assessments and eastern elderberry (2 of 5 assessments) – both high-returning crops (Appendix I). Information on arnica and echinacea had been requested by the farmers, with two businesses assessing arnica and three businesses assessing echinacea. Two of these businesses were interested in these crops to include in a rotation with garlic: arnica had top score in both these assessments, and echinacea was their preferred second choice despite ranking lower in their MCDM assessments. In some situations, criteria can have a higher weighting than crop return, such as market and crop rotation fit in the fifth farm business. Saffron was evaluated by one business (high per kilogram return but low per hectare return) and scored very poorly in the assessment (very high labour requirement as well as comparatively low per hectare return).

Crops of interest not on the information sheet included manuka (for oil) and peony. The first farm business had planted manuka, so knowledge and pre-establishment would have contributed to this scoring well (top scoring crop). The fifth farmer added hazelnut to the preferred list after the MCDM evaluation but did not include this in their evaluation.

The MCDM rank order for the crops differed from the stated preferred order for the third, fourth and fifth businesses, although differences in ranks were minor. Dooley et al. (2009) found in their case studies that farmer decision-makers are not overly concerned when this occurs, and if there is time, will explore criteria scoring and weighting to re-evaluate the assessment. The fourth farm business ranked horseradish as their top preference despite this being fourth in the MCDM evaluation. Given that they were interested in this crop because it was easy to grow, it can be speculated that their criteria set was incomplete: if this had contained 'easy to grow' as a criterion, this crop ranking may have increased. It is also able to be used as a fodder crop so is dual purpose.

## Crop criteria and scoring

The criteria considered important in this crop selection decision primarily related to profitability (crop returns, price risk, establishment costs), factors affecting success in the supply chain (markets, processing facilities) and factors related to successful crop production (labour required, production risk, crop rotation, access to information). Fit with lifestyle and environmental impact were mentioned twice and fit with business once.

In selecting criteria, all respondents identified labour (required) as being important, and at least three of the five identified return (4), market (4), processing facilities (3), establishment cost (3) and production risk (3) as being important (shown as shaded in Table 1). Two of the five mentioned price risk, lifestyle fit, crop rotation fit and environment as being important. 'Access to specialised information' was top priority for one business and 'fit with other business' was a lower priority criterion for another business.

The criteria selected in the workshop confirmed the importance of those criteria scoring higher in the questionnaire results: all criteria scoring above four in the questionnaire, except timing of labour (which may be implicit in 'labour') and access to specialised equipment, were selected by at least one business at the workshop. Interestingly, 'establishment cost' was a lower ranked criteria in the questionnaire but was selected by three of the five businesses, two perhaps because they had included some fruit or nut crops in the selection.

It was suggested that workshop participants select five to seven criteria, so it was not surprising that the majority of these were factors that are essential to the success of a crop. Previous work, where farmers were able to select any number of criteria, criteria numbers exceeded this. However, the highest weighted top five to seven criteria determine the ranking of crops (Dooley et al., 2009), with lower weighted criteria after that having little impact on the final ranking. So it can be assumed that there were factors that were important but not necessarily included. Criteria may also not be included where differences in their performance on an attribute is similar and will not impact the final outcome.

Failure to include criteria does not mean they are low importance. Criteria important to a decision may not be included in the MCDM trade-off analysis. Some criteria are sufficiently important that an alternative will not be considered unless is above an acceptable cut-off value for an important criterion, above which trade-offs are not a major consideration e.g. environmental factors can be considered this way (Dooley et al., 2009).

In this workshop, returns were considered important in most crop selections. But for two farmers, these were less of a consideration. The second farm business likely included crop returns in selecting crops for evaluation but did not include this as a MCDM selection criterion, and this criterion was lower ranked by the fifth farm business. The latter business explained that the lower weighting on return was because the crop was to be part of a rotation with a primary crop, so crop rotation fit was more important for this secondary crop than returns.

In this MCDM approach, crops can be evaluated using measured values (e.g. \$/ha), or scores such as the 1 to 5 scores used in this workshop. Comparisons between scoring ranges are used to calculate the criteria weightings. Differences between farm business participants scores and criteria weights in this workshop cannot be compared directly. For a direct comparison to be able to be made, the best and worst scores need to be clearly defined so there is a shared understanding, as occurs in group workshops. However,

with individual decision-making this definition is not essential: decision-maker(s) intuitively know what their best and worst scores look like to them. This will also affect the relativity of weightings to each other. Therefore, with an MCDM process and tool to support individual decision-making, and do so in a time efficient manner, a clear understanding of individuals' maximum and minimum scores is unnecessary for anyone except the decision-maker.

However, some understanding of differences in individuals' decisions can be made by looking at criteria used, scores and weights. This is demonstrated by the table in Appendix IV which presents average scores for each attribute across all crops and ranked by average value, and scores for three crops on each criterion to demonstrate i.e. quinoa, licorice and echinacea. It is evident from this table, and from the crop utility scores in Table 2, that the range of scores and the score values differed between people e.g. the third farmer scored crops lower on average than others with a lower median and crop utility values.

Differences in knowledge, experience, circumstances, access to resources and perspectives will have affected scoring e.g. labour on average tended to be scored low, but for the fifth farmer this was the attribute they were most positive about on average, which may well reflect their circumstances and access to labour. It is also clear that perceptions of crops varied between people (Appendix IV). Quinoa tended to be viewed positively, although those in the first farm business had some reservations about returns, price risk and markets. Those already familiar with grain crops were more inclined to rate quinoa more positively e.g. second farm business. Comparative utility scores for the three crops (Table 2) differed reflecting score, criteria used and weightings e.g. quinoa outperformed licorice in two cases, but licorice outperformed quinoa in the first case. Similar observations can be made about other crop comparisons.



Garlic crop at Moawhango, near Taihape

Results were presented as utility values for each of the crops. These are an index value calculated by multiplying the scores for each attribute by the weight for that attribute. These results were also presented visually, in graph form, showing how the crop performs on each attribute which helps in understanding why that crop performed as it did e.g. how well did it score on each attribute, particularly the more highly weighted attributes which affect rank order (Figure 2).

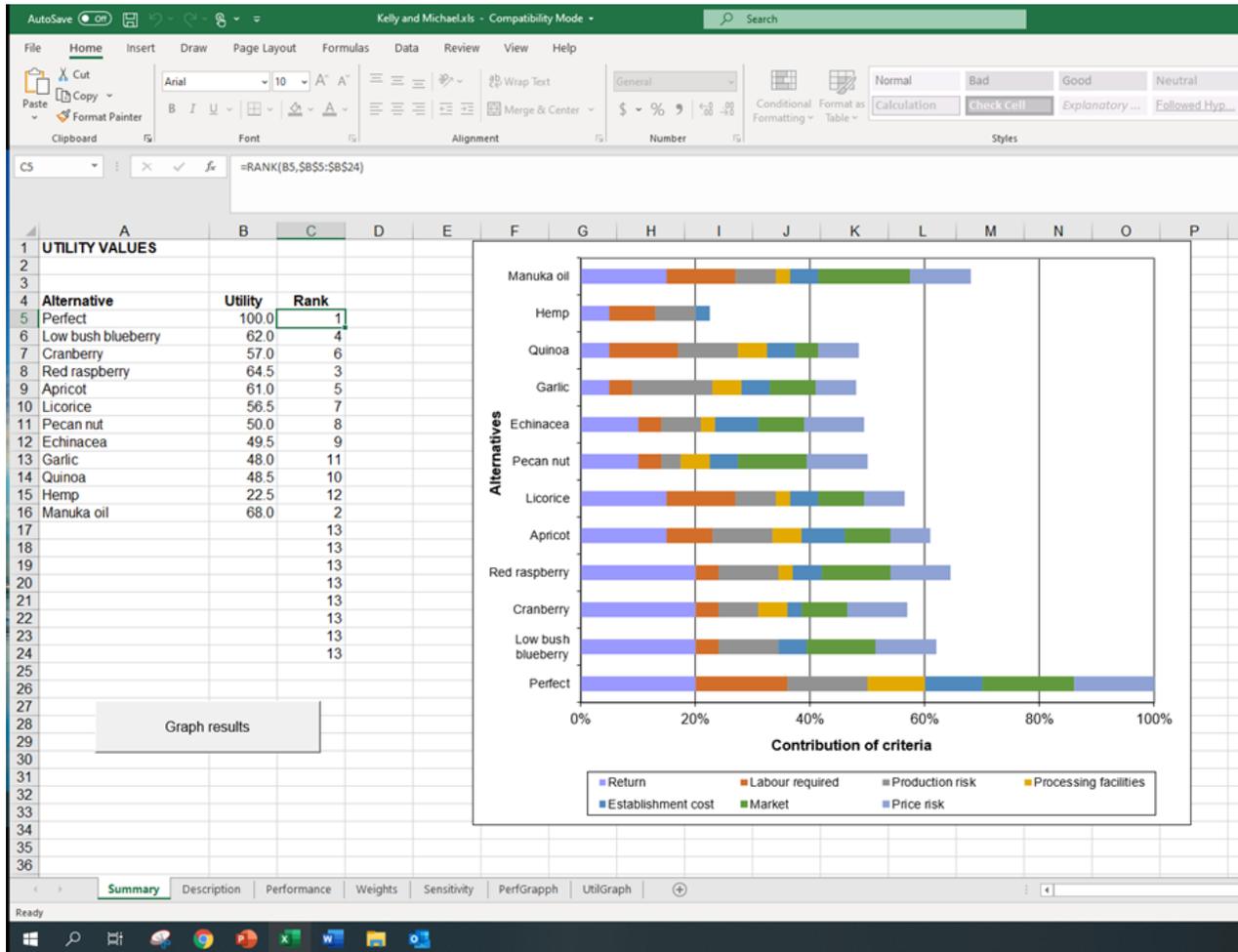


Figure 2: Utility value presentation and output: an example from the first farm business.

## Farmer feedback responses

The farmers all found the workshop reasonably easy (scale of difficult to easy) and it met their expectations (moderate response from one business, very high response from one business and the other responses high). There was a wider range of responses to the ease of using the MCDM process. On average, this was rated moderate to high. Three people from two farm businesses found using the process difficult, whereas six people from four farm businesses rated ease of use highly or very highly (note: in one business, one person rated this very high and one rated it low).

Their perception of the MCDM process per se varied: on average this was moderately to highly rated on a score from 'not great' to 'fantastic'. Owners of one farm business rated this lower than average: these people also found the process more difficult. Technology challenges, in part related to equipment available, may have contributed to this perception. Those in the four other businesses rated the process moderate to high.

Comments to the open-ended questions are presented in Appendix II. Many of the comments relate to their lack of knowledge of many of the novel crops presented at the workshop, and consequently, the difficulty in scoring crop performance in the MCDM process. This lack of crop familiarity also coloured their perception of the process and its usefulness, and these perceptions need to be considered in the context of these circumstances. It was observed that "better understanding of crops and growing/harvest would make our MCDM more relevant and accurate" and the process was "very easy to use, but accuracy of results relies on accurate crop knowledge beforehand", with about half the farmers commenting on this difficulty in evaluating crops with limited knowledge.

With respect to what was new for them and what they learned, over half the farmers commented on finding out about new crops that can be grown in their region. Other farmers commented on MCDM and the use of the tool, and thinking about reasons for planting crops, the range of criteria, and applying weights to criteria. The information provided raised awareness of the crops available which are suited to their area with observations on the "new opportunities", "all sorts of cropping options" and "very good global information". One person suggested that they needed to be aware of their own current returns to provide a basis for crop selection, and another commented on the need for more crop information and crop returns relevant to New Zealand.

Further information was specifically requested on: manuka oil production, requirements for licorice and peony production, and markets available in New Zealand for arnica and echinacea.



Echinacea, raspberries and blueberries, and horseradish.

# SUMMARY AND RECOMMENDATIONS

The MCDM component of this research project aimed to assess crop performance in a multi-criteria decision framework to identify crops of general interest for the business cases in the next phase of the project, and to assess the effectiveness of the MCDM process and tool used for the crop evaluation.

Farmer decision-making, which is influenced by multiple criteria, is an area of increasing research interest to inform policy and innovation. This component of the research can also provide insight into farmers' crop selection decisions and the criteria that influence these decisions to add to this body of knowledge.

## Crops of Interest to Hill-Country Farmers

The crops of interest to farmers in this area tend to be those suited to small-scale horticulture or cropping in an area where most farms have limited flats and are looking for enterprises which can provide high returns from a small area to complement sheep and beef farming. In other areas (e.g. Hawkes Bay, Canterbury), crop selection could be quite different although it can be surmised that many of the selection criteria will be the same.

Fruit trees, fruit bushes and nut trees, and medicinal crops were the two crop types of greatest interest to farmers responding to the questionnaire (Table 1) and to the five farm businesses attending the MCDM workshop (Table 2). Workshop participants showed greatest interest in medicinal crops (15 crops evaluated across 5 farmers) and fruit trees, fruit bushes and nut trees (9 crops across 3 businesses). This could be expected since these crop types are more likely to be grown on a small-scale compared to vegetable and grain crops, and generally had higher returns than grain or vegetable crops.

Medicinal crops were of greatest interest, with all farmers evaluating the highest returning crop, licorice, and three of the five farmers evaluating Eastern elderberry (high returns), both of which were on the suitability list. Echinacea and arnica had been requested and were also popular selections. One farmer evaluated saffron but this performed poorly. The first business added manuka (for oil), having recently planted this and identifying oil production as an opportunity. Information was also requested on Szechuan pepper trees and peonies. Crops with missing financial information were not evaluated.

The first farm business was particularly interested in fruit trees and bushes suited to the area, evaluating red raspberry, low bush blueberry, cranberry and apricot as well as pecan nuts. Fruit evaluated by others were common fig, and blackcurrant. The only fruits not evaluated were red currant (well suited but relatively low return), goldenberry (relatively low return, unsuited without irrigation), European gooseberry (low return) and sweet cherry (relatively low suitability index, longer time to production). The two highest returning nut species identified as being suited to the area (pecans, chestnuts) were also evaluated by two of the MCDM workshop farmers.

There was no interest in the workshop in evaluating conventional grain crops, but the high-returning novel grain crops, quinoa and hemp were evaluated by three of the five businesses in the MCDM analysis. Quinoa is already being grown by an entrepreneurial business in the area and hemp is a novel crop currently of interest in New Zealand.

Similarly, there was no interest in evaluating conventional vegetables suited to the area, which other areas can grow better. However, garlic, which was already being trialled and tends to be a niche vegetable crop, was evaluated by three of the five businesses. Horseradish which has comparatively low returns but grows easily and could be used as a fodder crop was evaluated by two businesses.

Therefore, niche-value, high returning crops that can be grown in a small-scale operation, which preferably do not require irrigation, are likely to be of interest to farmers as diversification options in this hill country farming area. Fruits and nuts, and medicinal crops will be of most interest. The following sections describe information required to support crop selection decisions.

## MCDM Process Effectiveness

Most people found the MCDM process relatively easy and rated this positively: only those from one business who found the process challenging were not positive. Feedback responses from the workshop fit into three categories: crop varieties; the MCDM process; and the information required for the process.

The list of crop varieties suited to the area provided at the MCDM workshops raised awareness of the range and variety of crops suited to the area, with those from most businesses commenting on this as something that was new to them and/or that they had learned from. The tone of the comments suggested they were unaware of “the range of crops we can try to grow in this area” (Appendix II) which one person observed “opened up new opportunities”. This suggests that the output from the first phase of the project is useful and expands thinking in considering possibilities.

Most found the MCDM process relatively easy, and it was suggested that this is a useful process with one respondent expressing appreciation of the opportunity to try the process in their comments. MCDM is an objective, stepwise, decision-making process, unlike the intuitive process people generally use. Self-learning about and understanding one’s own decisions is one of the identified benefits of the process (Belton & Stewart, 2002; Dooley et al., 2009) which results from working through the explicit stages of this objective decision-making process. Workshop comments were made regarding the challenges and new experiences from working through the various stages of the process included: determining a basis for the initial elimination of crops; thinking about “reasoning for planting crops”; “thinking about a range of criteria”; applying weights; and “getting [their] head around scoring”. This suggests some participants found the process insightful in terms of their crop selection decisions.

The novelty of many of the crops, and their lack of production in New Zealand or even developed countries, meant that the information provided was limited and non-specific, as was the participants’ knowledge of these more unusual crops. Hence, most of the workshop participants commented on the difficulty in assessing the crops because of their limited knowledge and the lack of information e.g. on returns, production, harvest, markets. The generic information on returns provided was also identified as inaccurate compared to what they knew had been received for one or two crops locally grown. However, finding information on regional or business specific returns is difficult, so where this information is known locally, general values should be replaced by local values. Furthermore, crops without financial information were not evaluated, probably due to the lack of sufficient information to assess these crops rather than a lack of interest *per se*, and since returns are a key criterion in decisions, some knowledge of these are likely to be required to evaluate a crop or even include it in the crops selected for evaluation.

“Accuracy of [MCDM] results relies on accurate crop knowledge beforehand” as one participant pointed out, with another suggesting that it was necessary to do research on the crops beforehand. Therefore, the list of crops suited to an area, and broad crop information or information on where these resources can be found, needs to be provided in advance of a workshop or a crop evaluation with sufficient time for participants to research the material so they can identify in advance those crops of interest to focus on at the workshop or when making the decision (with or without an MCDM process). However, information is not readily available on some of the more unusual crops, such as those primarily collected in the wild rather than commercially grown, so require a more investigative business case and a higher risk assessment before any decision was made to proceed with these.

Information provided at the workshop included the lists of suitable crops for the two areas, and a number of papers and reports on different crops so finding information on particular crops was not straightforward. Given the limited workshop time, the lists were consulted but few participants consulted the detailed information to any extent. Even if information had been sent to participants in advance, it is questionable whether many of the participants would have had time to read it all.

Furthermore, a primary purpose of this workshop was to help identify likely crops of interest to develop business cases for in the third phase of the project, creating somewhat of a chicken and egg situation. Hence, the crops identified in this phase are useful in informing this next phase. The business cases developed for these crop types will define the process required to develop a business case and provide information on the crops of interest. This information will then be available for others working through crop selection decisions in future. Once the business case information is available, this will be provided to the workshop participants and should they wish, they can re-evaluate the MCDM assessment model altering scores and weights and adding further criteria.

In this workshop, despite the limited information which reduced accuracy of outputs, the MCDM process was still positively received. In previous MCDM work using the process and model (Dooley, 2005; Dooley et al., 2005a, 2005b, 2009) to evaluate farm systems options which users were familiar with, the majority of model users were positive about the model and interested in exploring their decisions further i.e. sensitivity analysis with weights and scores. However, in this workshop, lack of time, and the uncertainty of the scores given limited information and knowledge meant that utility values relative to expected preference outcomes were not challenged or explored. Revisiting the MCDM analyses with information available from the business cases developed in the next phase of the project would result in more accurate, informative and useful outcomes for the participants, and likely some interest in exploring the assessments and weightings in sensitivity analysis.

For uncertain decisions or decisions with limited information, the MCDM process may be better undertaken working with an advisor (consultant, technical expert) to assist with technical information. Sensitivity analysis looking at the relative impacts of score changes on utility values can also be conducted. Risk criteria can also be included to incorporate some of the uncertainty in calculating utility scores for comparison. If decision-makers use the MCDM process individually, where time is not constrained, they would have the time to explore information or consult with experts in the process. If the process is used at a workshop, the presence of an expert to assist with technical questions on options could be useful.

## Decision Criteria in Crop Selection

The MCDM process criteria considered important in the crop selection decision, confirmed in both the questionnaire and the workshop, primarily related to profitability (crop returns, price risk, establishment costs especially for those with high establishment costs such as fruit and nuts), factors affecting success in the supply chain (markets, processing facilities) and factors related to successful crop production (labour required and possibly timing, production risk, crop rotation fit, access to specialised information, and possibly access to specialised equipment if required). Other factors such as fit with lifestyle and fit with business, and environmental also got a mention.

Failure to score these criteria highly does not mean they are of low importance. Criteria important to a decision may not be included in the MCDM trade-off analysis. Some criteria are sufficiently important that an alternative will not be considered unless it is above an acceptable cut-off value for an important criterion, above which trade-offs may not be a major consideration. It has been observed that environmental factors are sometimes considered this way (Dooley et al., 2005a, 2005b, 2009). Double-counting should also be avoided, so if two criteria are closely related, only one of these should be included and weighted accordingly. Criteria may also not be included where differences in alternatives performance on an attribute is similar (no differentiation between options), and therefore will not impact the final outcome.

Initial selection of alternatives for consideration on some criteria, with trade-offs considered between the final selection of alternatives meeting these cut-off criteria is logical and is also the approach taken in more intuitive decision making. In the workshop, crop returns were a consideration for most in selecting crops to evaluate, with lower performing crops excluded from the analysis. This will have had the impact of reducing the range between best and worst crop return scores in the MCDM trade-offs and affected the criteria weightings in the trade-offs with returns having less weight in the MCDM trade-off analysis than would have occurred if all crops had been included. Two of the workshop farm businesses either excluded returns from the MCDM analysis or rated this lower because alternatives selected already largely met their expectations in this context. Where MCDM outputs are to be shared, for example, for transparency and to explain a decision, making the criteria for selecting the alternatives for MCDM analysis explicit may be worthwhile, particularly where there could be criticism when it appears criteria others consider important have been excluded from the MCDM analysis.

Similarly, crops can be excluded at the selection for analysis stage for other reasons e.g. do not fit crop rotation, could potentially become invasive, personal dislike, do not meet acceptable environmental standards (Dooley et al., 2005a, 2005b, 2009). Some information pertaining to important criteria is likely to be needed for a crop to be considered in the list of alternatives to be evaluated: crops with no information on returns were not included in the MCDM analysis in the workshop.

Differences in knowledge, experience, circumstances, access to resources and perspectives will have affected scoring of alternatives and criteria weightings. It was expected crop type might influence criteria selection and weightings, however, all farm businesses at the workshop included mixed crop types in their list of crops for evaluation and were not conflicted by having the same criteria and weightings for evaluation all crops. At previous MCDM workshops using the model (Dooley et al., 2005a, 2005b, 2009) participants showed interest rather than concern when alternative rankings did not exactly match their intuitive ranking preferences, and spent time exploring their weights and score values and questioning some of these, to better understand their decision i.e. form of sensitivity analysis.

## Recommendations

- For hill country farms, higher-returning niche crops suited to smaller areas of flat land will be of greater interest e.g. fruits, nuts, medicinal crops for the domestic market or processors for further processing such as manuka provided for oil extraction.
- Concise, reliable and relevant information on crops is required to support decision-making, particularly where the alternatives being considered are not well understood e.g. novel crops.
  - Information on crop returns, production, processing and markets is required for crop selection decisions.
  - Information is best provided in advance with time allowed for reading before working through the selection process. If available, it would be useful to provide more comprehensive information on crop, or information sources, for further investigation if required.
  - Not all crops are included in the databases used to identify suitable crops. More crops will be added over time. Information on other crops of interest will need to be sourced elsewhere.
  - Information can be scarce for some of the more unusual crops which may not be commercially grown (e.g. collected from wild) or where there is little information. Further investigation or consultation of experts may be required to source this information.
  - There is NZ publicly available information or knowledge for some NZ crops e.g. natives such as kawakawa for medicinals.
  - There are also publicly available NZ databases on soil information for production (i.e. to identify if local soils are suited to a crop) and markets.
  - Success factors outside the farm gate need to be understood, which requires understanding of worldwide supply and demand e.g. for niche, value-value products.
- A list of the areas to explore and questions to ask for a business case, with a supporting template, would be useful, particularly for farmers exploring novel crops where information and markets are more limited.
- Similarly, information on collaborative business structures, such as cooperatives, which could be an effective way for a small group of farmers to work together to produce, process and market a niche crop could also be useful along with advice on how to set these up.
- The crop model was effective at helping farmers realise the range of crops potentially suited to their area, many of which they were not aware of and/or had not considered, and they were interested in exploring some options further. The process to explore crop databases needs to be readily available and understood by farmers and their advisors.

- When working through the MCDM process, consideration needs to be given to the following.
  - The process needs to be clearly explained or good supporting documentation or instructions provided, and if possible, an example provided to clarify considerations in criteria selection (e.g. avoiding double counting), weighting and scoring. MCDM processes can differ in scoring and weighting so instructions need to be tailored. Farmers found the scoring and weighting (swing weighting which requires fewer comparisons than some other methods) used in this research relatively easy.
  - Encourage farmers to include alternative(s) they are familiar with to provide a benchmark for scoring. A non-existent 'perfect' alternative that scores the highest value on all criteria can provide a useful comparison in visual output (contributions to utility scores).
  - Not all criteria are included in the MCDM trade-off. It may be useful to make explicit those criteria used to identify alternatives to be evaluated such as criteria that need to be met to be included e.g. minimum expectations e.g. environmental or minimum level of return required to be viable. This could be important where a decision needs to be transparent i.e. the MCDM outputs are shared with others. For personal decisions by, and for, individuals this is not essential.
- In this, and previous, research with farmers, the MCDM process (with swing weightings) resulted in self-learning, prompting thinking about what was important in their decision (criteria), and objective assessment of the various options based on performance. The transparency of the decision is also useful in sharing e.g. with others in the business.
- Software available for MCDM<sup>1</sup> can be expensive, with AHP software often being used in research applications. This suggests a MCDM tool and process that is straightforward, relatively quick to use, and freely available to farmers and their advisors be developed, possibly as an application suitable for web-based use or tablets for ease of use by farmers and advisors.
- Working through the MCDM process with a readily available tool with consultants or advisors with expert knowledge, could be beneficial particularly for novel or unfamiliar alternatives where performance can be uncertain. Working through the process together could benefit both parties, helping both parties understanding of the decision and rationale for the outcome which is explicit and transparent. The consultant can provide the client with expertise on alternatives to aid scoring and sensitivity analysis, especially where the client is less familiar with these. The identification and weighting of criteria by the client defines what is important to them which can help consultant target their advice and suggestion of alternatives to those likely to be of interest to the client. The decision outcomes can easily be made transparent to others in the business who need to be informed.

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<sup>1</sup> The "Decision-making software" (2021) reference shows a list of MCDM software. Software using AHP (Saaty, 2008) is a MAVT approach but requires a considerable number of comparisons between alternatives to determine weightings and can be expensive. This appears to be the most common MCDM approach for multi-criteria research in NZ. 1000 minds (1000 minds, n.d.) is another MAVT software developed in NZ for academia and business in NZ (appears to be used by corporate business at a cost) which also uses a different weighting and scoring approach to the MCDM used in this research. They now offer a basic free version (meenymo.com) which could be trialled but will require more time for data inputs and analysis than the method used in this research. The 1000 minds website (1000 minds, n.d.) has a useful general introduction to MCDM for those who are interested.

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# APPENDIX I: 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	0.94	0.86	N	Fresh	25	\$0.80	\$8,000	
Vegetable	1125	Cabbage	0.92	0.86	N	Fresh	50	\$1.30	\$26,000	
Vegetable	4505	Potato	0.92	0.88	N	Fresh	64	\$0.57	\$14,802	
Vegetable	6577	Yacon	0.91	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	4745	Red currant	1.00	0.91	N	Fresh	16	\$4.50	\$28,800	2-3 years
Fruit	3505	Lowbush blueberry	0.96	0.96	N	Fresh	35	\$8.75	\$122,500	2-3 years
Fruit	2465	Goldenberry	0.78	0.00	Y	Fresh	20	\$2.20	\$17,600	2-3 years
Fruit	1805	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	1705	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	5525	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	1705	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	4645	Quinoa	0.80	0.80	N	Dried	3	\$5.50	\$6,600	
Grain	5725	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	6365	Wheat, common	0.66	0.66	N	Dried	4	\$0.65	\$1,040	
Grain	4065	Oats	0.60	0.60	N	Dried	3	\$0.65	\$780	
Grain	5225	Sesame seed	0.46	0.46	N	Dried	1	\$3.35	\$1,340	
Medicina	3417	Licorice, Common	1.00	1.00	N	Proc.	4	\$9.25	\$14,800	
Medicina	5053	Saffron	1.00	0.93	N	Proc.	0.02	\$252.50	\$2,020	
Medicina	5185	Sea buckthorn	1.00	0.59	Y	Proc.	5	n/a		
Medicina	2037	Eastern elderberry	0.96	0.86	N	Proc.	9	\$9.25	\$33,300	
Medicina	3653	Mashua	0.83	0.59	Y	Proc.	70	n/a		
Medicina	1425	Cherry, Sour	0.60	0.60	N	Proc.	15	\$1.95	\$11,700	3-5 years
Medicina	4265	Pepper tree	0.44	0.00	Y	Proc.	n/a	n/a		
Medicina		Arnica	USDA Crop Hardiness Zones 5 - 9		n/a	Proc.	0.5	\$20	\$4,000	
Medicina	4265	Echinacea	USDA Crop Hardiness Zones 5 - 8		n/a	Proc.	6	\$6.00	\$14,400	
Nut	2145	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	1445	Chestnut, European	0.58	0.58	N	Dried	9	\$3.90	\$14,040	4-5 years
Nut	2105	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	4105	Onion	1.00	1.00	N	Fresh	45	\$0.70	\$12,600	
Vegetable	1305	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	1125	Cabbage	0.95	0.95	N	Fresh	50	\$1.30	\$26,000	
Vegetable	4505	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	2805	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	

# APPENDIX II: MCDM WORKSHOP FEEDBACK

## Diversification on Taihape Hill Country – Workshop

Wednesday April 21, 2021

### Feedback Sheet

Thank you for attending today's farm diversification workshop. We would appreciate if you could take a few minutes to share your opinion with us to help us serve you better.

*Please mark in the scale your experience*

How did you find the workshop?	Difficult ----- Easy
Did the workshop meet your expectations?	No ----- Yes
How did you find using the MCDM process?	Difficult ----- Easy
How did you find the MCDM process?	Not great ----- Fantastic
What did you find challenging?	
What was new for you?	
What did you learn?	
Do you have any further questions?	
Please list your preferred crop/s	
Any other comments	

Thank you for your time today.

Please leave this sheet with Iona or Carol

**Workshop comments received are shown below.**

<p>What did you find challenging?</p>	<p>Getting head around scoring. Limited knowledge of some crops (1)  Initial consideration of all the crop types and on what basis to eliminate so many (2a)  Giving values for weights and performance when had little info on crop requirements (3a)  Need to already know about crop to be able to rank (3b)  Limited knowledge of crops – need to do research first (5)</p>
<p>What was new for you?</p>	<p>The different varieties of cash crops (1)  Having all sorts of cropping options. Thoughts on reasoning for planting crops (2b)  Using MCDM, applying weights (3a)  Different crops available (3b)  The range of crops we can try to grow in this area (4)  Using the assessment tool on the computer (5)</p>
<p>What did you learn?</p>	<p>Open up to new opportunities (1)  Some v. good global information (2a)  New crops. Suitability of crops to our region (2b)  There are <u>so</u> many options. Need more info on crops to maximise benefit of modelling (3a)  Model relatively easy to use (3b)  That I have a lot to learn (4)  Thinking about a range of criteria (5)</p>
<p>Do you have any further questions?</p>	<p>More info on manuka oil production (1)  Requirements for licorice and peony production. Markets available in NZ for arnica, echinacea (3a).  Lots (4)</p>
<p>Any other comments</p>	<p>Need more relevant domestic returns for NZ. Some figures are too far out. One should be v. aware of their own returns as a basis? (2a)  Better understanding of crops and growing/harvest would make our MCDM more relevant and accurate (2b)  Very easy to use, <u>but</u> accuracy of results relies on accurate crop knowledge beforehand (3a)  Thank you for the opportunity to give it a try (5)</p>

## APPENDIX III: QUESTIONNAIRE RESULTS

**Appendix Table 3:** Number of farmers indicating each importance score for the specified crop type. (1=very low, 2=low, 3=moderate, 4=high, 5=very high).

<b>Importance Score</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
	<b>v. low</b>	<b>low</b>	<b>mod</b>	<b>high</b>	<b>v. high</b>
<b>Fruit &amp; nut trees or bushes (n=8)</b>					
Net annual return	0	0	0	5	3
Establishment cost	0	0	5	2	0
Time to production	0	0	4	4	0
Production risk	0	1	1	6	0
Price risk	0	1	1	4	1
Diversification	0	1	5	1	0
Access to market	0	0	0	5	2
Processing facilities	0	0	2	4	2
Fit with livestock business	0	1	1	4	2
Fit with lifestyle	0	1	2	3	1
Labour required	0	0	1	5	2
Timing of labour input	0	0	1	6	1
Access to information and support	0	0	3	4	1
Access to specialised equipment	0	0	1	5	1
Environmental impacts	0	0	2	5	0
Contribution to biodiversity	0	3	2	2	1
<b>Vegetable crops (n=5)</b>					
Net annual return	0	0	0	3	2
Production risk	0	0	0	4	1
Price risk	0	0	1	4	0
Diversification	0	2	1	2	0
Access to market	0	0	1	4	0
Processing facilities	0	0	3	2	0
Fit with livestock business	0	1	1	3	0
Crop rotation fit	0	0	2	1	2
Fit with lifestyle	0	0	2	1	2
Labour required	0	0	0	4	1
Timing of labour input	0	0	1	4	0
Access to information and support	0	0	3	1	1
Access to specialised equipment	0	1	2	2	0
Environmental impacts	0	0	2	2	1
Contribution to biodiversity	0	1	1	2	1

<b>Importance Score</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
	<b>v. low</b>	<b>low</b>	<b>mod</b>	<b>high</b>	<b>v. high</b>
<b>Grain, seed or oilseed crops (n=4)</b>					
Net annual return	0	0	0	1	3
Production risk	0	0	0	4	0
Price risk	0	0	0	4	0
Diversification	0	1	0	3	0
Access to market	0	0	1	3	0
Processing facilities	0	0	2	2	0
Fit with livestock business	0	1	1	2	0
Fit with lifestyle	0	1	1	1	1
Labour required	0	0	1	3	0
Timing of labour input	0	0	2	2	0
Access to information and support	0	0	1	2	1
Access to specialised equipment	0	0	1	3	0
Environmental impacts	0	0	1	3	0
Contribution to biodiversity	0	1	2	1	0

<b>Medicinal crops (n=7)</b>					
Net annual return	0	0	0	4	3
Establishment cost	0	0	1	6	0
Time to production	0	0	2	5	0
Production risk	0	0	0	6	1
Price risk	0	0	0	6	1
Diversification	0	1	1	4	1
Access to market	0	0	1	3	3
Processing facilities	0	0	1	5	1
Fit with livestock business	0	1	1	5	0
Crop rotation fit	0	0	2	4	1
Fit with lifestyle	0	1	1	3	2
Labour required	0	0	0	5	2
Timing of labour input	0	0	1	5	1
Access to information and support	0	0	1	5	1
Access to specialised equipment	0	0	1	6	0
Environmental impacts	0	0	1	5	1
Contribution to biodiversity	0	1	0	5	1

## APPENDIX IV: MCDM SCORING AT THE WORKSHOPS

**Appendix Table 4:** Crop scoring on criteria attributes: average and rank for all crops, and scores for licorice, quinoa and echinacea. Highlighted cells are equal or above crop average.

Criteria	Average	Rank	Licorice	Quinoa	Echinacea
Return	3.55	1	4	2	3
Labour required	2.73	6	4	4	2
Market	3.18	4	3	2	3
Price Risk	3.36	3	3	3	4
Production Risk	3.45	2	3	4	3
Processing facilities	2.27	7	2	3	2
Establishment cost	3.00	5	3	3	4
Access to specialised information	2.86	5	3	5	
Processing facilities	2.57	6	3	4	
Labour required	3.71	2	4	4	
Environmental impact	4.00	1	4	4	
Production risk	3.00	4	3	4	
Establishment cost	3.14	3	4	5	
Return	3.33	1	3		4
Market	2.50	3	2		2
Labour required	2.00	5	2		2
Fit with lifestyle	2.00	5	2		2
Crop rotation fit	2.50	3	3		3
Environment impacts & biodiversity	2.83	2	2		2
Return	3.33	1	4	4	
Processing facilities	2.50	5	3	4	
Marketing	2.17	8	1	4	
Price risk	3.17	2	2	4	
Labour	2.33	6	1	4	
Establishment cost	3.17	2	3	4	
Production risk	3.17	2	2	4	
Fit with other business	2.33	6	2	4	
Market	3.20	3	3		3
Crop rotation	3.00	5	3		3
Lifestyle	3.20	3	3		4
Labour	3.80	1	4		4
Return	3.40	2	5		3