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Farmer Identification of Valuable Traits in Agricultural Crops and Pastures: case studies in adoption and decision-making

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The Place To Be

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Executive summary

Desirable characteristics of farm inputs (and outputs) can be expected to change as a result of adapting to climatic variability or market pressures. This may lead to circumstances where producers require variants of inputs with entirely novel traits, or new combinations of traits.

Valuable traits are identified by producers based on two factors. The relevant characteristics of the trait within the farm production system (production context traits) and the relevant preferences of the distribution, processing and marketing systems (product bundle traits). Production context traits are valuable traits that correspond to the characteristics within the farm system which influence the benefit the technology or trait has to offer. Product bundle traits are traits identified by the producer that correspond to a market preference of the end user.

In order to examine farmer decision making and adoption of valuable traits in crops and pastures, we proposed a two-stage model of trait selection. In the first stage, valuable traits are identified on the basis of the congruence of the traits of an input with relevant characteristics of the agricultural production system (production-context traits), and relevant preferences of the distribution, processing and marketing systems (product-bundle traits).

Decision rules, or heuristics, are used by agricultural producers when they make choices about technologies and practices, including the purchase of farm inputs. Payne et al (1993) notes that there are two types of decision rules, compensatory and non-compensatory, that are used when people make choices. Decision rules have been studied widely in the field of marketing, specifically for understanding how people make choices between near alternatives such as among alternative products within a product class, or among variants of a particular product.

The second stage of trait choice occurs when decision rules are applied to make a variety selection. It is unlikely that cultivars combine all valuable traits. Instead, traits can be uncorrelated, or even negatively correlated. This means higher values of one or more desirable traits only occur at the expense of lower values of one or more other, desirable traits. Consequently, producers must use a decision making process to arrive at a compromise on the ideal mix of valuable traits. The decision-rules or heuristics that producers may use to making choices that involve compromising among traits can be classified into two types; compensatory and non-compensatory.

In studying valuable traits we chose four case study plants: wheat, canola, lucerne and white clover. These crops and pastures were deemed to be of considerable economic value in Victoria. To understand trait choices, and decision-making around this, we employed a qualitative approach based on semi-structured interviews across four case study crop and pasture types. The research was conducted in three geographical areas and included: the Rutherglen district, Corowa district; and the Shepparton Irrigation Region (SIR). Total interview numbers for canola was ten, twelve interviews for wheat, ten for lucerne and nine for white clover. In all, interviews were conducted with 27 landholders.

Valuable traits identified for wheat included, protein levels and yield for end use of feed wheat up to hard wheat standards. These were identified as product bundle traits. Canola valuable traits differ depending on the particular biophysical conditions on the farm. These

conditions relate to specific weed problems or level of herbicide resistance, managing disease or being able to grow a crop without it falling over and shattering (production context traits). Oil content and yield were also identified for canola as product bundle traits. Lucerne valuable traits include winter activity/dormancy for end use of hay or seed production (product bundle) or grazing (production context). White clover valuable trait was identified as nutrition levels for end use of grazing in pasture mix (production context).

There are several trade-offs in choosing wheat varieties. Growers can be strongly wedded to high-performing wheat varieties (affect referral heuristic). The Satisficing heuristic is used for 'must have' production context and product bundle traits of wheat. Production context traits are the strongest driver for canola varieties. Satisficing and lexicographic rules apply in the first instance (non-compensatory), and then compensatory decisions are often left to the agronomist due to too many 'near alternatives'. Winter dormancy/activity was the dominant trait considered in the first instance for lucerne (non-compensatory). End use for lucerne drives varietal decisions using the lexicographic heuristic which was the dominant decision-making approach. Selecting particular white clover varieties based on valuable traits seems to be absent. Any variety is considered to be suitable provided it is in the correct proportion in the pasture mix. Decision making seems to be comparing valuable traits of white clover with new perennial ryegrass cultivars.

These results are useful for informing farmer's ability to adapt to changing climate and market conditions. By applying the two-stage model of trait selection, it would provide an industry with the benefits of understanding the decision making of the producer, assist with extension, and provide insight to the development of agricultural inputs with novel traits.

1. Introduction

Challenging climatic conditions and shifting market preferences create a decision-making environment for farmers that is forever changing. Desirable characteristics of farm inputs (and outputs) can be expected to alter as a result of adapting to these changing climatic or market conditions. For example, selecting a wheat variety with a suitable flowering time that does not coincide with frosts. This may lead to circumstances where producers require variants of inputs with entirely novel traits, or new combinations of traits. Understanding how producers value traits, and how they make decisions about choosing between alternative combinations of traits, may guide research into the development of variants of crops and pastures that possess new, valuable traits. Such an understanding would also assist extension in efficiently promoting variants of crops and pastures, novel and otherwise, to primary producers.

The Productivity Commission Draft Report 'Barriers to Effective Climate Change Adaptation' (released 27th April 2012) recommends policy reforms to help deal with uncertainty around the frequency, intensity, location and timing of extreme weather. Such reforms would be applied to overcome barriers such as market failures, regulatory barriers, institutional barriers and behavioural barriers (including agricultural producers). Understanding how producers make decisions in regard to their crop selection can lead to an increase in the adaptive capacity and resilience to climate and market uncertainty in the future.

Valuable traits of crops and pastures are identified by producers based on two factors; 1) the relevant characteristics of the trait within the farm production system (production context traits); and 2) the relevant preferences of the distribution, processing and marketing systems (product bundle traits). Production context traits are valuable traits that correspond to the characteristics within the farm system which influence the benefit the technology or trait has to offer. For example, selecting herbicide tolerant varieties of canola for producers with wild radish or herbicide resistant ryegrass problems. Product bundle traits are traits identified by the producer that correspond to a market preference of the end user. For example, a producer would select an Australian Hard wheat variety if the end use requires high protein with good milling quality. The combination of the production context and product bundle traits are known as the 'consideration set' in the first instance.

To make choices about crop and pasture selection, producers must formulate criteria, more or less, to evaluate variants against. In other words, they must identify a set of characteristics or traits they regard as valuable and which the variety or cultivar must possess, in greater or lesser degree. For example, a crop grower may choose a cultivar on the basis of characteristics or traits such as disease resistance, time to maturity, and vigour.

Decision rules, or heuristics, are used by agricultural producers when they make choices about technologies and practices, including the purchase of farm inputs. There are two types of decision rules, compensatory and non-compensatory, that are used when people make choices (Payne et al. 1993). Decision rules have been studied widely in the field of marketing, specifically for understanding how people make choices between near alternatives such as among alternative products within a product class, or among variants of a particular product.

Ash et al. (2008) discuss the challenges of adaptation within Australian agriculture. The report highlights incremental and transformational change options applied as a result of changes in climatic conditions. One of these options includes breeding and selecting varieties that are adapted to higher CO^2 levels, change in temperatures and moisture availability. The report also highlights the impact of constant change in international market forces. It acknowledges current adaptation options build on existing management or technological approaches however the barriers to adaptation may involve attitudinal, social, behavioural, institutional or environmental barriers. Easterling et al (2003) provides research outcomes of modelling adaptation to climate change. Selection of cultivar trait is used as a variable to represent a countermeasure of farmers to overcome the negative impacts of climate variables.

The research presented in this report makes a valuable contribution to the body of knowledge around the challenges of adaptation in Australian agriculture. Understanding the factors that influence producers valuation of traits, and their use of compensatory and non-compensatory decision rules to choose among different trait combinations, is likely to provide a useful basis for understanding how farmers adapt to changing environmental conditions and changing market demands.

2. Objectives

This study was part of a broader research project aimed at understanding the human dimensions of adaptation to variability (farmer adaptation to both changes in climate and markets). This component of the project focussed on farmer decision-making processes regarding their selection of crop and pasture varieties (based on their perceptions of valuable traits).

The study aimed to:

1. Examine farmer perspectives regarding the valuable traits of crops and pastures in terms of ‘production context’ and ‘product bundle’ traits,
2. Identify the decision rules (non-compensatory and compensatory) likely being used by farmers to make choices regarding crop and pasture selection; and
3. Discuss the implications of these findings for development of new traits or variants of traits in response to changing market and climate conditions.

3. Background

In this section we review the literature across a number of agricultural industries to identify the valued traits, and efforts to improve traits, in crops and pastures. We propose that traits that are considered valuable by producers can be classified into two classes: 1) those that are valuable because of their fit with the farm production system, which we term 'production context' traits; and 2) those that are valuable because of their fit with processor and market preferences which we term 'product bundle' traits.

We then describe a series of decision-rules or heuristics that producers may use where choosing a crop or pasture variety. Taken together the identification of valuable traits and the heuristics used to make a variety selection form a two-stage model of trait choice.

3.1 Valuable traits of crops and pastures: insights from the literature

The research focussed on four crops/pastures: wheat, canola, lucerne and white clover. The industry context for valued traits is discussed for each in turn.

3.1.1 Valuable traits of wheat

Around 46% of Victorian crop production comprises wheat. In the 2009/2010 season 2.97 million tonnes of wheat was grown in the state, predominantly in Western and Northern Victoria. There are many varieties of wheat which suit particular environments and aim to meet particular end uses in terms of protein content and hardness. Wheat varieties are continually changing as new varieties with improved traits are released and older varieties are phased out (DPI 2011b).

There are numerous production-context and product-bundle traits of wheat varieties. Production-context traits are critical as these determine which varieties will perform the best given the particular biophysical conditions on farms. These biophysical conditions will govern which varieties can be grown, particularly if the farmer is constrained by an underlying soil condition such as soil acidity or is limited by lower rainfall. The maturity of the crop is also vital to ensure that flowering time does not coincide with frosts. Given that every season is different, and paddock conditions differ, the choice of variety based on production context traits is best described as decision making under uncertainty (Detlefsen & Jensen 2004). It is recommended that several varieties be grown to spread the climatic and disease risks by growing varieties with different maturity and disease resistance classifications (Wheeler 2011).

The product-bundle traits likely to be considered by farmers relate to end-uses. Wheat varieties are described in terms of end-use classes which reflect traits relating to target protein range, hardness and milling quality. 'Australian Hard 1' and 'Australian Hard 2' have a target protein range of 13 and 11.5% respectively. The APW (Australian Premium White) classification is also a hard grain with good milling quality but has a protein of 10.5%. General Purpose (APW) is general purpose milling wheat. The 2011 Victorian Winter Crop Summary (DPI 2011b) describes 48 wheat varieties suitable for particular parts of Victoria and market end uses. In Northern Victoria, 30 varieties are recommended including ASW, APW, AH and feed wheats.

The high protein wheats (i.e. AH1) are mostly grown in the Mallee and Wimmera. Feed wheat, not generally suitable for milling, often yields higher than other wheat classes and is grown in 600–800 mm rainfall areas. Several wheat varieties are suitable for 'dual purpose' meaning they can be grazed early in the season for a short time and then go on to produce a grain crop. Wheeler (2011) suggests that grain growers spread risk by sowing several varieties with different end-uses.

Genotype-by-environment (G x E) interactions are an important consideration for crop traits and are defined as the 'change in the relative performance of genotypes when they are evaluated in different environments' (Cooper et al. 1995: 492). According to Murphy et al. (2007) grain yield is the best indicator of the interaction between different genetic and environmental factors, so can be used as a measure of genotypic response to farm system-specific conditions.

Grain crop variety trials are an important information source for farmers and allow them to compare yields of different varieties under environmental conditions similar to their own. The National Variety Trials (NVT) website provides farmers with performance information for a range of recently-released grains across many regions throughout Australia. Additionally, state agricultural agencies provide summary information for grain growers in different areas of each state.

The CSIRO is conducting 'pre-breeding' research into a range of wheat traits including seedling emergence, high early vigour, tillering, salinity tolerance and aluminium tolerance, rust and virus resistance. There is also research relating to starch content to develop varieties that better suit different end product requirements such as low gluten foods, dough, and noodles (CSIRO n.d.).

3.1.2 Valuable traits of canola

Canola is the third most important winter grain crop in Australia (after wheat and barley) and is an important part of the cropping rotation for disease and weed control. Canola breeding has made major advances in recent years resulting in several new varieties each year. The canola grower has a wide range of variety choices across four major types of canola – conventional canola (with no herbicide tolerant traits) and three groups of canola with tolerance to particular herbicide groups.

Triazine tolerant varieties (known as 'TT' canola) were released in 1993. This was followed by the Imidazolinone tolerant (Clearfield) varieties in 1999 and Roundup Ready Canola (GM) grown commercially in Victoria and NSW since 2008 (McCaffrey et al. 2009). Herbicide tolerant varieties are very useful for growers who have significant problems with wild radish and herbicide resistant ryegrass. Also, growing different varieties, and thereby rotating herbicide group use, is an important strategy for managing herbicide resistance.

Of the 52 currently recommended varieties for Victoria (DPI 2011a) there are 5 conventional varieties, 9 Clearfield varieties (Imidazolinone tolerant), 23 Triazine tolerant, and 15 Roundup Ready cultivars. It is important to note that there are open pollinated and hybrid varieties within all the canola groups. For example, four of the conventional canolas are hybrids, 5 Clearfield hybrids, 9 RR hybrids, whereas many of the TT are open pollinated (10 varieties) (DPI 2011a). Hybrids are plants bred with improved traits such as increased yield, oil, disease resistance and early vigour. The seed of hybrid varieties costs twice as much than open-pollinated but there are substantial yield benefits (estimated to be 11% better). The disadvantage of hybrid varieties is that the seed cannot be saved and used again. In 2010 it was estimated that 40% of canola seed sales were for hybrid varieties (GRDC 2010).

Bonuses are paid to growers who can produce a crop with high oil content. The industry has a benchmark oil content of 42% with a bonus of 1.5% paid for every percentage point above this and a penalty for levels below this standard (McCaffrey et al. 2009). Oil content varies between cultivars and is also influenced by the environment and the season.

The most serious canola disease is Blackleg (a fungus) and choosing a variety with good resistance to the disease is said to be the best defence (Marcroft & Hind-Lanoiselet 2009). Cultivars are rated for Blackleg resistance each year across sites in several states.

Another trait that is critical to growing canola is flowering time. Canola varieties should be selected with a view to avoid frosts at flowering time as well as ensuring seed development before high temperatures. According to Robertson et al. (2001) both cultivar and environment determine time of flowering in canola.

3.1.3 Valuable traits of lucerne

The ability of lucerne to grow throughout Victoria on a wide range of soil types and climatic conditions makes lucerne a very attractive crop for growers. It is an adaptable crop that is drought tolerant and can produce useful amounts of high quality feed from minimal rainfall. It also responds well to irrigation and can produce up to 15 to 25t/ha each year (DPI 1998). Lucerne is considered to improve the sustainability of Australian broadacre agriculture by adding nitrogen to soil, mitigating salinity risks by lowering the watertable and improving soil water penetration (Irwin et al. 2001).

Lucerne has several end-uses. It can be utilised as a pasture for year-round grazing, hay production or seed production. A grower's aim is to have a greater leaf to stem ratio if it is intended for grazing or hay production (J.Bouchier pers.comm. 2011). It is also beneficial in crop rotations due to its ability to supply fodder when other pasture species are low in protein, as well as improving nitrogen levels in the soil (a good lucerne stand can potentially add 140 kg N/ha to the soil in one year). Its long taproot enables it to draw on deep soil moisture making it ideal to grow in dryland areas or can be irrigated to boost production (NSW Agriculture 2003). In moist conditions it can be susceptible to water logging (Lolicato & Lattimore 1998).

The feed value of legumes in ruminant nutrition has been acknowledged as greater than that of grasses. This is because of its rapid particle breakdown, faster rumen fermentation, lower rumen mean retention time and therefore greater voluntary feed intake (Ramirez-Restrepo & Barry 2005). However, Ramirez-Restrepo and Barry (2005) state that legumes have failed to live up to their true potential due to three disadvantages. Firstly, less feed in winter is generally grown from legumes compared to grasses. Secondly, the rapid solubilisation of protein causes frothy bloat in cattle; and some legumes have oestrogenic compounds that affect reproductive performance of ewes when grazed during mating.

Although lucerne is a perennial plant, its winter growth dormancy varies between varieties. Winter active varieties continue to grow throughout the winter period while winter dormant varieties have little growth. The trade off between the two is winter dormant varieties persist longer (>4 years) than winter active (3-4 year crop) (NSW Government 2009). This varietal difference is sometimes utilised by hay producers who would normally select a winter dormant variety, but may choose a winter active variety to get quick production and improve the business cash flow (J.Bouchier pers.comm, 2011).

Up to the late 1970's, 'Hunter River' was the predominant cultivar grown in Australia, until winter active cultivars of Peruvian and African origins showed greater yield, though less persistence than 'Hunter River'. In the 1960s the CSIRO breeding programs aimed to develop new lucerne varieties that were both productive and persistent. In ongoing Australian breeding programs, varieties grown for hay production under irrigation have been bred for aphid resistance, while grazing varieties have been selected for tolerance to continuous grazing pressures (Irwin et al. 2001).

There are currently many varieties of lucerne on offer to growers that vary in their growth habit and resistance to aphids and disease. A rating is given to varieties on the following traits: winter activity from very highly winter active (dormancy 10) to winter dormant (dormancy 3), resistance level of *Collectotrichum* Crown Rot and *Phytophthera* Root Rot, Stem nematode tolerance and, Blue-green aphid and Spotted alphalpha aphid resistance (NSW Government 2009). The critical factors for growers to consider when choosing a lucerne variety is the level of winter activity, and its aphid and disease resistance. Desirable improvements in lucerne include Roundup Ready traits (to combat couch and summer grasses), water logging traits (to help overcome *Phytophera* disease), insect resistance and tolerance to acid soils (J.Bouchier pers.comm, 2011).

3.1.4 Valuable traits of white clover

White Clover is an important pasture crop due to its high quality feed and ability to fix atmospheric nitrogen (Lane et al. 1997; Lane et al. 2000). However it has several limitations including unreliable yield, insufficient growth in winter months, lack of persistence under low soil moisture and hot conditions. An Australian Government (2004) report estimates that white clover is worth $267 million to the dairy industry in Victoria.

White clover is used for grazing, pasture hay and seed production. It is an important plant in mixed pastures due to its high nutrition value, high voluntary intake by grazing animals, adaptability across soil types and environmental conditions, ability to grow well with perennial grasses; and its regenerative capabilities via stolons and seed bank. It is also capable of fixing atmospheric nitrogen via a symbiotic relationship with *Rhizobium* bacteria (Australian Government 2004).

To grow good white clover, good summer rainfall or irrigation is required. Soils with medium to high fertility are needed to supply phosphorus and sulphur for good yields. White clover can be affected by fungal and viral diseases or insect and other invertebrates. It can also be toxic to grazing animals due to its anti-nutritional compounds that can be a catalyst for bloat in ruminants, or cyanogenesis which can initiate muscle wastage. Additionally, phytoestrogens can interfere with reproduction of livestock in grazing animals (Australian Government 2004).

White clover is capable of regeneration by seedling recruitment or survival through the stolon system. There is a trade off between traits for stolon branching and flowering vigour in white clover plants. Abundantly-flowering white clover tends to have less stolons and the potential to produce large amounts of seed, but less stolons. Bees are an important pollinator of white clover as the plant requires cross-pollination for seed set because the pollen is not easily dispersed by wind. In general, seed set declines with decreasing temperatures (Australian Government 2004).

Smith et al. (2007) describes the use of molecular marker technologies to identify the genomic location of particular key agronomic traits in white clover, to develop white clover plants that are immune to the Alfalfa mosaic virus. This virus has been estimated to cause losses of A$800 million/year to Australian rural industries.

Insect and invertebrate pests vary depending if the white clover plant, is used for grazing or seed production. The red-legged mite, blue-oat mite and lucerne flea affect establishment of the white clover plant while the native budworm, clover casebearer and bluegreen aphid affect white clover seed crops. Viral diseases include the white clover mosaic virus, alfalfa mosaic virus and yellow vein virus, all of which affect white clover productivity (Australian Government 2004).

3.2 Decision rules: compensatory and non-compensatory

The previous section outlined the main valuable traits of the four case study crops. It is very rare, if not impossible, that a cultivar would possess all valuable traits in the desired proportions. Indeed, there are trade-offs between traits where some valuable traits might be negatively correlated. For example a higher-yielding hybrid canola variety might not have good standability and could be more difficult to harvest. So, producers must compromise between traits to find the variety that best fits their production-context and end-use (product-bundle) requirements. To do so, producers employ decision rules, otherwise known as heuristics. In this section we outline these decision rules of which there are two major categories: non-compensatory and compensatory.

3.2.1 Non-compensatory decision rules

Individuals, in our case producers, use decision rules when making choices between different variants of products. In an agricultural context, some product traits are far more important, or dominant, than others. A positive evaluation on one trait does not compensate for a negative evaluation on another trait. In other words, the two traits are not commensurable. Consequently, non-compensatory decision rules apply when evaluating the variants of an input that differ in their traits. There are several non-compensatory decision rules which can be applied, as described by Kaine and Niall (2001). These are described in Table 1.

Table 1 Types of non-compensatory decision rules (based on Payne et al. 1993; Kaine & Niall 2001)

Decision rule (heuristic)	Description	Example
Elimination-by-aspects heuristic	This rule applies when one attribute is considered to be the most important, with a minimum threshold score set and variants not meeting this threshold are rejected.	A wool producer decides to cull ewes below a certain weight with a second criteria being to cull ewes that haven't lambed.
Lexicographic heuristic	This rule applies when one trait is considered dominant. The variant is selected that has the highest valuation on that trait.	A wheat grower who selects varieties simply based on potential for the highest yield.
Satisficing heuristic	This rule is applied when traits are given a minimum threshold score and are considered in sequence. Variants that don't meet the threshold on any of the relevant traits are discarded.	A wool producer culls a good-sized ewe with fine wool because it did not meet the standard for foot conformation.
Affect referral heuristic	Applies to repeated choices where a person uses a previously formed alternative (from memory or experience) and then picks most highly valued variant.	A wheat producer grows the same variety of wheat each year because it has a reliable high yield and can be grazed.

Generally, non-compensatory decision rules are more likely to be used if the decision is complex (because of the number of alternatives and range of features to be evaluated) and if time pressures are involved (Hauser et al. 2009). However, if a particular trait is deemed to be very important (e.g. high yield in wheat) then a non-compensatory decision rule may be used even though there is sufficient time and information to apply a compensatory decision rule.

The application of non-compensatory decision rules to non-commensurate traits excludes variants of inputs that fail to meet the rule from the 'consideration set' (Eliaz and Spiegler 2011). The consideration set is the term used to describe the group of alternatives, or variants of an input, that possess at least the minimum combination of traits that the producer regards as valuable. Variants that fail to make the consideration set because they do not possess the minimum acceptable threshold on one or more valued traits are excluded from contemplation as possibilities for purchase.

3.2.2 Compensatory decision rules

A compensatory decision rule is more likely to be used where product traits are commensurable. This means that a higher score on one attribute can compensate for a lower score on another (Kaine & Niall 2001). When a farmer considers compensatory traits they are making trade-offs between 'near alternatives'. According to Arana and Leon (2009: 2316), 'individual attributes are weighted by their contribution to overall utility in order to evaluate the relative utility of each profile'.

Kaine and Niall (2001) provided the use of a breeding index in ram selection as an example of a compensatory decision rule. With a breeding index rams are evaluated according to their aggregate score on a number of measurable traits that the producer regards as commensurable (e.g. fleece weight and fibre diameter). Higher scores on one or more traits compensate for lower scores on other traits. The different traits can be weighted to reflect the objectives of the wool producer. A farmer who uses a spreadsheet from a local crop variety trial might also follow a similar process. Table 2 summarises the types of compensatory decision rules which can be applied.

Table 2 Types of compensatory decision rules (based on Payne et al. 1993; Kaine & Niall 2001)

Decision rule (heuristic)	Description	Example
Weighted additive rule	Traits are weighted according to importance. The weighted sum of scores is evaluated with the highest-scoring alternative selected. A good score on one trait can offset a bad score on another.	Using an Index Selection for selecting a ram (e.g. LambPlan).
Equal weight heuristic	All traits are weighted equally and the highest-scoring alternative is selected.	Difficult to apply to an agricultural context when traits are not always commensurable.
Frequency of good and bad heuristic	Traits are evaluated as being above or below set threshold scores. The alternative with the most good features and least bad features is selected.	Choosing a wheat variety that has a good disease resistance rating and yield, while avoiding poor weathering and harvesting traits.

Logically, the application of compensatory decision rules to commensurate traits should only occur with near-alternative traits that are members of the consideration set. In other words, the application of compensatory decision rules to compensatory traits should follow the application of non-compensatory rules to non-compensatory traits. To do otherwise is inefficient.

3.3 Two-stage model of trait choice

In order to examine farmer decision making and adoption of valuable traits in crops and pastures, we proposed a two-stage model of trait selection (Kaine et al. 2011).

In the first stage, valuable traits are identified on the basis of the congruence of the traits of an input with relevant characteristics of the agricultural production system (production-context traits), and relevant preferences of the distribution, processing and marketing systems (product-bundle traits). The relevant characteristics of the production system correspond with the factors in the farm system that influence the benefits of acquiring a technology or trait. Following Kaine et al. (2011) we have termed these production context traits. The relevant characteristics in relation to the distribution, processing and marketing system correspond with Lancaster's (1966) description of products as bundles of characteristics so we have termed these product bundle traits. The valuable traits chosen by farmers in the first instance are called the 'consideration set'.

The second stage of trait choice occurs when decision rules are applied to make a variety selection. As stated earlier, a cultivar that combines all valuable traits is unlikely. Instead, traits can be uncorrelated, or even negatively correlated. This means higher values of one or more desirable traits only occur at the expense of lower values of one or more other, desirable traits. Consequently, producers must use a decision making process to arrive at a compromise on the ideal mix of valuable traits. The decision-rules or heuristics that producers may use to making choices that involve compromising among traits can be classified into two types; compensatory and non-compensatory.

Non-compensatory traits can be described as 'must-haves'. In other words, they must be present in the crop/pasture variety for it to have any value at all to the producer. So it seems that non-compensatory traits should define the characteristics of a variety to be an eligible member of the consideration set at the outset. For example, if a wheat variety scored very low for potential for high yields it may not be in the producer's consideration set in the first place. Both production context traits and product bundle traits may be non-compensatory.

Compensatory traits are those that are valuable to the producer but their presence or extent may be traded-off against the presence or extent of other valued traits. In other words, commensurate traits are those on which the producer is prepared to compromise.

The final selection of a crop or pasture variety from the group under consideration (the consideration set) will be made based on the producer making trade-offs among commensurate traits using compensatory decision rules. For example, when choosing pasture species to meet the nutritional requirements of sheep there can be a trade-off between digestibility and herbage mass (Bell et al. 2007). Both production context traits and product bundle traits may be compensatory.

4. Methods

4.1 Case study selection and background

In studying valuable traits we chose four case study plants: wheat, canola, lucerne and white clover. These crops and pastures were deemed to be of considerable economic value to Victoria. Canola, wheat and lucerne are commonly grown in both dryland and irrigated cropping enterprises in northern Victoria, while white clover is common in irrigated pastures.

As a pre-cursor to the field studies, we conducted an extensive literature review regarding valuable traits of the four case study crops and pastures: wheat, canola, lucerne and white clover (Kaine et al. 2011). To further understand the valuable traits of each crop and pasture, we spoke to industry experts. This also ensured we had a thorough understanding of the local context for variety choice (i.e. climatic conditions and the markets for the products).

To understand trait choices, and decision-making around this, we employed a qualitative approach based on semi-structured interviews across the four case study crop and pasture types.

4.2 Study area

The research was conducted in three geographical areas and included: the Rutherglen district, Corowa district and the Shepparton Irrigation Region (SIR). The Rutherglen district was deemed to be representative of medium-sized mixed cropping and grazing enterprises (dryland) and included properties within a 20 km radius of Rutherglen. The Corowa district included properties within 20 km from the Victorian/NSW border and included large dryland cropping enterprises. Finally, the SIR is an important area for irrigated lucerne with a variety of end-uses.

4.3 Participant selection

Given the privacy legislation, the research team did not have access to a database of producer names from which to draw a random sample. Instead, a mixture of techniques was employed to recruit interviewees. By working in three study areas we were able to obtain a mixture of property sizes and enterprise types.

For the canola and wheat interviews we focused on the Corowa and Rutherglen districts. Interviewees were drawn from a mixture of convenience sampling and using a technique called 'snowballing'. A convenience sample was drawn from producers previously involved in DPI-run farmer groups in the North East. We also used the telephone directory to identify contact details of people who identified themselves as farmers in the Yellow Pages. In some cases the interviewees nominated other people who might be interested in participating (i.e. snowballing technique). The same process was taken to recruit irrigated cropping, lucerne and white clover growers in the Shepparton Irrigation Region.

All people who were approached consented to be interviewed and were provided with information describing the research. Interviews were then arranged at convenient locations and times. Interviews were conducted between October 2011 and April 2012 to enable avoidance of peak activity times on the farm (i.e. hay making and grain harvest).

In several cases, interviewees were able to discuss two of the case study plant-types. The total number of 'cases' of data was 41. Ten interviews were conducted on canola, twelve on wheat, ten on lucerne and nine on white clover. In total, interviews were conducted with 27 landholders.

4.4 Qualitative approach: semi-structured interviewing

Farmers were personally interviewed in-person by two researchers to enable accurate manual recording of notes. Semi-structured interviews involve a set of questions which can be asked in any order and often includes extra probing (Walter 2006). This technique is particularly useful for the exploration of perceptions and opinions because they allow the interviewee to respond to broad questions or statements with limited direction and provide opportunities for the interviewer to probe for further information (Bryman 2004).

Interviews were semi-structured and comprised of several themes:

- Understanding the farm context: this included property size, enterprise description, proportion of farm sown to crops, pastures.
- Understanding what types of crops (or pastures) are currently grown and their markets.
- Varietal changes and frequency. What motivates farmers to change or to try a new variety?
- Preferred crop or pasture traits and how these are prioritised. These traits were discussed in order of importance with further questions regarding why these traits are important and to understand decision-making rules used.
- Understanding where the farmers get information from to guide their trait/varietal decisions.

There was extensive probing around each question. The duration of the interviews was between 40 to 60 minutes.

4.5 Data analysis

The 41 interview transcripts were sorted into each case study crop/pasture. Farm context data was summarised in tables for each case study and provided a basis for understanding why certain traits were important. Valuable traits, in order of importance, were compiled in a table to allow interpretation of relative importance of production-context versus product bundle traits. Valuable trait 'themes' were identified and described through open coding. Quotes were used to support the data and provide context for the decision-making. We then estimated the likely non-compensatory and compensatory decision rules (as described by Kaine & Niall 2001) being employed in each of the 41 interview transcripts. Decision rules were summarised in a table for each case study industry.

5. Results

5.1 Participant description

The majority of interview participants (n=15) came from the SIR and represented irrigated cropping, lucerne and dairy (permanent irrigated pastures) [Table 3]. Properties in the SIR were smaller with a median size of 180 ha. Six farmers from the Rutherglen district were interviewed, they were dryland croppers and growing lucerne. Median property size was 1,000 ha for the Rutherglen study area. Eight farmers with dryland cropping properties in the Southern Riverina (n=8) were also interviewed, with properties having a median size of 2,100 ha.

Table 3 Participant description across the four case studies

ID # and location	Prop size	Crop and/or pasture varieties described in interview [and end-use]
W#1/C#1/L#4 SIR	223 ha	Two varieties of wheat (AH & ASW) including a dual purpose wheat [protein and feed market], triazine-tolerant canola, irrigated lucerne.
W#2/L#5 SIR	273 ha	Two dual purpose wheat varieties [feed wheat market], lucerne hay.
W#3 SIR	470 ha	Three varieties of wheat (AH, APH and feed) [feed wheat market].
W#4/C#5 R'glen	1,800 ha	Two varieties of wheat (feed and AH) [feed wheat market], triazine tolerant and RoundUp Ready canola.
W#5 R'glen	860 ha	One dual purpose wheat variety [feed wheat market].
W#6 R'glen	1,000 ha	Two wheat varieties used as dual purpose (AH and ASW) [protein and feed wheat market].
W#7 R'glen	1,000 ha	Three wheat varieties (ASW, AH) and dual purpose [protein and feed wheat market].
W#8/C#6 S. Riverina	1,000 ha	Three wheat varieties (AH, APW) and dual purpose [protein and feed wheat market], triazine-tolerant and RoundUp Ready canola.
W#9/C#7 S. Riverina	2,000 ha	Four wheat varieties (ASW,AH) some dual purpose [protein and feed wheat market], conventional and RoundUp Ready canola.
W#10/C#10 S. Riverina	2,200 ha	Six wheat varieties (AH, APW) [high quality milling market], triazine tolerant canola varieties.
W#11/C#8 S. Riverina	5,200 ha	Four wheat varieties (AH) [high quality milling market], triazine-tolerant and RoundUp Ready canola varieties.
W#12/C#9 S. Riverina	2,600 ha	Four wheat varieties [high protein market], Triazine Tolerant, Round Up Ready and Clearfield canola varieties.
C#2/L#6 SIR	800 ha	Triazine tolerant canola varieties, high quality lucerne hay [horse industry].
C#3 R'glen	1,000 ha	Conventional canola varieties.
C#4 R'glen	1,000 ha	Conventional and Round Up Ready canola varieties.
L#1/WC#3 SIR	142 ha	High quality lucerne hay [horse industry], white clover in permanent dairy pasture.
L#2 / SIR	180 ha	High quality lucerne hay [horse industry].
L#3 / SIR	190 ha	Lucerne hay [sold off-farm].
L#7 S. Riv	1,000 ha	Lucerne hay [sold off-farm].
L#8 S. Riv	1,012 ha	Lucerne [seed production].
L#10 S. Riv	2,630 ha	Lucerne [seed production].
WC#1 SIR	97 ha	White clover in permanent dairy pasture.

WC#2 SIR	130 ha	“
WC#4 SIR	151 ha	“
WC#5 SIR	160 ha	“
WC#6 SIR	160 ha	“
WC#7 SIR	180 ha	“
WC#8 SIR	300 ha	“
WC#9 SIR	400 ha	“

W# indicates a wheat interview, C# a canola interview, L# a lucerne interview and WC# white clover.

5.2 Results: farmer perspectives on valuable traits of crops and pastures

Interviewees were asked to identify the most valuable ‘must have’ traits for wheat, canola, lucerne and white clover. The results for each are described in turn.

5.2.1 Valuable traits of wheat: results

Growers in the SIR were growing dual purpose and feed-grade wheat with two growers also trying for a higher protein premium with AH [see Table 3]. Around Rutherglen the emphasis was on mainly dual purpose wheats with the majority of grain sold as feed wheat. The Southern Riverina properties are generally much larger, growing more varieties, and aiming for the protein market but then selling downgraded wheat as feed.

Table 4 summarises the valuable traits according to each wheat grower interviewed, in order of importance. The grey-shaded boxes show ‘production context’ traits - those traits that are considered valuable because of their fit with the production system on that farm (‘production context’). Boxes with yellow shading show ‘product bundle’ traits, or wheat traits that are valuable because of their fit with processor and market preferences.

Table 4 shows that while there are many important traits that farmers are selecting for related to their farm context, product bundle traits are given much higher importance, particularly by growers on larger properties. The desire to grow wheat that has the potential for higher yields was identified in the top two traits of all but two interviewees. Interestingly, the classification of the wheat was only in the top two traits of four growers, even though all growers spoke about the end-purpose of their wheat varieties being important.

Of the production-context traits, the ability for the crop to be grazed (dual purpose) was most important by the Rutherglen-based farmers. The ability of the variety to fit into the farms’ sowing window was a trait highlighted as 2nd or 3rd most important for seven growers. This trait is particularly important for large properties where sowing occurs over a number of weeks. The tolerance of the wheat variety to stripe rust was another important consideration as it was mentioned by all but one grower, most often as the 3rd or 4th trait of most importance. Weathering at harvest was a concern for several growers, particularly those who had bad experiences with this in their AH wheats, particularly growers of ‘Lincoln’. Potential for lodging was also mentioned. Finally several farms had acid soils which limited the farmers to acid tolerant wheat varieties.

Table 4 Valuable traits of wheat identified by growers (in order of importance) (grey shading 'production context traits, yellow shading 'product bundle' traits)

Grower #	1st	2nd	3rd	4th	5th	6th
W#1	Classification (protein)	High yield	Lodging susceptibility			
W#2	Dual purpose	Ability to save own seed	Maturity time	Stripe rust resistance	Weathering at harvest	
W#3	Dual purpose	Suits sowing time	Stripe rust resistance	Protein content	Wet soil tolerance	Lodging susceptibility
W#4	Dual purpose	High yield	Stripe rust resistance	Other diseases resistance		
W#5	Acid soil tolerance	Classification	Flowering time/frost	Stripe rust resistance	Stem rust resistance	Dual purpose
W#6	High yield	Dual purpose	Stripe rust resistance	Acid soil tolerance	Flowering time (frost)	Other disease resistance
W#7	High yield	Suits sowing time	Weathering at harvest	Stripe rust resistance	Ability to save own seed	
W#8	High yield	Stripe rust resistance	Classification (protein)	Dual purpose (sometimes)	Weathering at harvest	
W#9	High yield and protein	Suits sowing time / maturity	Stripe rust resistance	Dual purpose (sometimes)		
W#10	Classification (hard wheat)	High yield	Suits sowing time	Stripe rust resistance	Acid soil tolerance	Weathering at harvest
W#11	High yield	Suits sowing time	Weathering at harvest	Disease tolerance	Lodging susceptibility	Acid soil tolerance
W#12	Classification	High yield	Suits sowing time	Stripe rust resistance	Lodging susceptibility	

High yield and quality were the most important trait that most growers were aiming for. Several interviewees had said they only selected high-yielding varieties. While some growers were aiming at the 'quality' market, one of the major end-points for grain in the study area was the intensive animal industries (who don't pay protein premiums). Therefore, many growers sold feed-quality or down-graded wheat where their aim was higher yield rather than quality:

> *'For this area our philosophy is always go for yield'* [W#8].

The larger enterprises grew several different varieties, among these was usually an AH variety aimed at the premium milling market. These growers tended to aim for the best quality but settled for selling their wheat locally for feed if it was downgraded:

> *'To get a premium you need to get a better protein profile and use harder varieties…if you get low protein then you take it to x [a large local feed mill], they don't care about mixing varieties'* [W#8].

Freight/transport considerations also influenced end-use. If a grower had to transport the grain further to get a protein premium they were sometimes better off to target the local feed wheat market:

> *'It costs a lot more to take it to Melbourne – you might be better off just to sell it for feed wheat at Corowa'* [W#5].

While some growers felt they could achieve higher yields by growing feed-quality grain, others thought it was better to go for the protein market:

> *'We stay away from feed-quality grain. Instead, we grow the highest quality product we can grow. There are far better premiums to be had in the protein market'* [W#10].

Achieving a protein premium was thought to require a mixture of wheat traits and fertiliser management.

It would seem that any new traits bred into wheat varieties (in response to changing climates and markets) should not compromise the potential for high yield and particular end-uses. Local variety trials are very important for farmers to see how well a particular variety is performing in their area under local climate conditions.

Table 4 shows that flowering time and fit within the farmer's sowing window is an important consideration. Early-maturing varieties provide drought tolerance whereas later maturing varieties struggle when the weather heats up at the end of the growing season. On the other hand, early varieties can get frosted. Most often, the growers we interviewed sowed several varieties with different maturity times as a risk management approach:

> *'We try to get variance in sowing time – we sow over 6 weeks. So growth cycle or maturity time is a trait we pick for'* [W#8].

Other growers, particularly on large properties, had to grow a range of different maturity times to allow them to sow across a long sowing window:

> *'We need to sow through a 10 week window. We need varieties to sow in April, mid-May and early June. It's about risk management, frosting is a major factor. Also, if it's a very dry April/May we can hold off and sow into June'* [W#10].

'Flowering time is crucial – it can't flower in the middle of September to October. Over the drought we lost a lot of crops during the mid-October period' [W#5].

It seems that by using a range of varieties with a spread of maturity farmers are already adapting and managing risk due to climatic conditions.

Disease resistance (specifically stripe rust resistance) was another important trait. However, there seemed to be different perspectives regarding this trait. Firstly, there were farmers who refused to grow wheat with poor stripe rust resistance:

'I just won't have it [Whistler wheat variety]. *For the last 2 months you've got to keep spraying it. It's much easier to grow the rust-resistant varieties'* [W#9]; and

'We won't grow highly susceptible varieties. If something came along with high rust resistance, with other qualities we liked, we'd go for it straight away' [W#10].

The second perspective were those farmers putting up with stripe rust because they believed the variety had other benefits which out-weighed this problem. Additionally, fungicides are said to be cheaper now:

'*We hit it* [stripe rust] *with fungicide and it's OK. It's a high yielding variety so we would rather keep it'* [W#7]; and

'Most stripe rust is religiously sprayed around here anyway' [W#2].

The ability of wheat to be grazed and then go on to produce grain was seen as a highly valuable trait for mixed cropping/grazing enterprises. Varieties such as Whistler, Wrangler and Wedgetail were popular choices:

'We like it [Whistler] *because it's good for grazing. Last year we grazed it 6 times and it still went 4 t/ha when we harvested it'* [W#6].

Grazing dual purpose crops also seem to provide a drought strategy during dry years:

'In drier years the crops that are grazed do best. This is because the biomass goes down in winter and they don't use as much water. This leaves more water available for the grain-fill period' [W#9].

Another important trait, particularly in terms of climate, is that of weathering at harvest. Some of the newer varieties are highly susceptible to weathering damage. This occurs when there are significant rainfall events during harvest. The grain becomes 'shot and sprung' and can be heavily downgraded. It seems the newer varieties are more susceptible to sprouting after only one or two weather events at harvest. However, because of other attractive traits (such as mid season maturity, higher protein classification, moderate strip rust resistance) some growers had persisted in growing these varieties:

'Lincoln is very prone to weathering at harvest – it can get heavily downgraded. Even one rain can cause a downgrade. It is AH quality so you can get premiums for it' [W#9]; and

'*They need to find a replacement for Lincoln. You only need a leak in the corner of the paddock and it's gone!'* [C#12].

5.2.2 Valuable traits of canola: results

Table 5 summarises farmer perspectives (n=10) of the traits they consider to be most important when choosing a canola variety. The majority of traits, with the exception of oil content and yield, are production context traits. The emphasis placed on the various traits highlights the range of farm contexts in which canola is likely to be grown. The production context traits seem to be critical as these determine which varieties will perform best given the particular biophysical conditions on farms. These conditions relate to specific weed problems or level of herbicide resistance on the farm, managing disease (particularly black leg) and being able to grow a crop without it falling over and shattering. The two 'product bundle' traits identified by interviewees were oil and yield.

Table 5 Valuable traits identified by canola growers (in order of importance) (grey shading 'production context traits, yellow shading 'product bundle' traits)

Grower #	**1st**	**2nd**	**3rd**	**4th**
C#1	Standability	Herbicide traits	Black leg resistance	–
C#2	Standability	Yield	Herbicide traits	–
C#3	Flowering time / maturity	Black leg resistance	Oil content	–
C#4	Herbicide traits	Black leg resistance	Standability	–
C#5	Herbicide traits	Yield	Oil	Black leg resistance
C#6	Black leg resistance	Yield	Herbicide traits	–
C#7	Yield	Flowering time / maturity	Herbicide traits	Oil content
C#8	Oil and yield	Black leg resistance	Standability	–
C#9	Black leg resistance	Sclerotinea resistance	High yield and oil	Standability
C#10	Oil and yield	Black leg resistance	Sclerotinea resistance	Flowering time / maturity

Herbicide-related traits are one of the most important traits influencing variety selection by farmers. Growing different varieties of canola (with different herbicide tolerances) is known to be an effective way to rotate herbicide groups and thus manage herbicide resistance (Parker 2009). All types of canola were grown in the study area including triazine-tolerant (TT) on seven out of ten properties, Round-Up Ready (RR) on five properties, conventional canola on three properties and Clearield on only one property. Often a mixture of canola types were grown with several varieties grown within the canola groups.

The TT varieties include both open-pollinated and hybrid varieties and are tolerant to triazine-based herbicides such as Simizine and Atrazine. TT canola is grown not only as a way to rotate different chemical groups but is the chosen variety for growers with wild radish problems: *'TT canola is a robust chemical system – it is a very good tool to manage resistance'* [C#2]. TT canola varieties are also said to be '*good all rounders'* where *'you don't need many spray applications. Conventional canola needs too much spraying – you might only have to do TT once'* [C#10]. In some cases Round-Up Ready varieties were being grown in combination with TT canola. While RR canola enables growers with herbicide resistant ryegrass to effectively grow canola, RR was thought to be not as effective on wild radish. Six out of 10 interviewees were already growing RR canola while several others were keeping it as an option if herbicide resistance became a problem:

> *'We are interested in GM canola and we know we'll eventually have to use it. We will eventually get herbicide resistant ryegrass issues, but we don't need to go down that path yet. At the moment we manage ryegrass by putting in a forage crop and manage the weeds that way'* [C#10]; and
>
> *'We are holding back on GM canola until we need it'* [C#5].

Another grower didn't want to use RR because they didn't want to over-do the use of RoundUp on their ryegrass, thinking it might lead to a resistance problem.

While growers were generally satisfied with RR canola from an agronomic perspective, there were several constraints:

> *'It's harder to deal with RoundUp Ready canola. We've got a paddock in this year to learn about it more. Last year it was difficult to sell – there is a limited market when it is of poor quality. Also, there's a $100 discount per tonne compared with conventional canola'* [C#7]; and
>
> *'To grow Round Up Ready you need to be accredited. The seeds are highly priced. You also have to pay a royalty when you deliver your grain'* [C#4].

Black leg is the most serious disease of canola and one of the most important considerations when choosing a canola variety. Canola breeding focuses strongly on black leg resistance with resistance in existing varieties breaking down over several years. Growers tend to change their varieties according to black leg ratings and often consult with the agronomist to do this. Black leg can spread as spores from neighbouring crops and risk can increase if canola is grown too often in the rotation. Some farms are likely to be more at risk than others, particularly those growing a lot of canola each year. These farms are likely to have black leg rating as the most important trait:

> *'If black leg resistance is low then we won't use that variety – there is so much canola around us. We've tried low black leg resistant varieties before and we copped a hiding'* [C#6].

Several interviewees reported growing several varieties of canola as a risk minimisation strategy if one crop failed to black leg or another disease.

Yield was in the top two traits of six out of ten of the interviewees. Often yield and oil were considered to be the main parameters when selecting a variety. Several farmers used NVT trial data to select varieties which were consistently performing well for yield:

> *'We select [varieties] from years of data. It must have a record of performing well over 3 to 4 years. We also look for how it went in other parts of the State'* [C#10].

Several farmers preferred to grow hybrids because of their high yield. One farmer reported that hybrid canola yields 10-15% better than conventional varieties, while another claimed that conventional canola performed better than hybrids in a weed-free situation. However, there seems to be trade-off with standability and difficulties in windrowing and harvest as bigger plants tend to fall over.

Some growers said yield was more important than oil with statements such as '*As long as it yields well you'll make money'* [C#7]; and '*If it's got good yield then everything else will fall into line'* [C#9]; and '*Yield beats oil hands down'* [C#6]. This seems to often lead to growers choosing yield above other considerations.

There appeared to be different beliefs about oil content and how much of an influence the variety, seasonal conditions and fertiliser management have on this. Firstly, there were growers who believed there was not much varietal difference regarding oil. Mostly, growers acknowledged that oil content was a combination of variety, season and management:

> *'Management has a lot to do with oil content, but it's 50/50 really. The better variety goes a lot better but you need good management'* [C#8]; and
>
> *'Newer varieties are being bred for higher oil content. If you look at a variety in the NVT trials and notice lower oil content 3 years in a row then don't touch it – it's a variety thing'* [C#5].

Yield and standability seem to be traits which are negatively correlated. The higher yielding, often hybrid, varieties have a higher tendency to lodge or fall over. This was well recognised by interviewees: '*A few years ago we had trouble with lodging. But when they lodge you know it's a big crop…high yields'* [C9].

The final important trait in selecting canola is maturity time. Canola is susceptible to frosting. There are early, mid and late maturing varieties. People sow different varieties at different times during the sowing window. As was the case with wheat, growers on bigger properties require a larger sowing window. Often growers sow several varieties with different maturities as a risk management strategy.

Also related to maturity is that canola must be harvested before the weather gets too hot. Canola doesn't have good dry tolerance – this may be an area for future research. The interviews indicated that canola growers are growing a range of varieties specifically suited to their own farm context (herbicide needs, weed spectrum, disease levels etc). It seems they are quite happy to change varieties and try new ones as long as they meet these farm context conditions. They are not as strongly 'wedded' to varieties as is the story for wheat.

5.2.3 Valuable traits of lucerne: results

The valuable traits of lucerne, as identified by growers, consist of both production context and product bundle traits (Table 6). The interviews revealed several end-uses for lucerne: seed production, pasture for grazing livestock on the farm, hay production for use on-farm and hay production sold off farm. It is important to clarify that lucerne traits aimed at providing grazing pasture and hay on-farm are actually production context traits. Traits relating to end-use of lucerne off the farm (i.e. hay and seed production) are classified as product bundle traits. It seems that end-use is a particularly strong driver when considering traits to make variety selections.

Table 6 provides a summary of valuable traits of lucerne as identified by ten growers. Taken together these traits are known as the 'consideration set' from which varieties are selected by growers. The interviewees were asked to specify the 'must have' traits (in order of importance) when selecting a variety of lucerne to sow on their farm. The first trait for most was the level of growth activity in the winter period. In most cases this is defined by the attributes of the plant which suited the production system or a particular market preference. The remaining 'must have' traits vary and therefore highlight the range of farm contexts that lucerne is grown in. Some growers have several varieties to cover a number of end-uses.

Table 6 Valuable traits identified by lucerne growers (in order of importance) (grey shading 'production context traits, yellow shading 'product bundle' traits)

Grower # [end-use]	1st	2nd	3rd	4th
L#1 [high quality hay]	Winter dormant	Fine stem	Leafy	Vibrant colour
L#2 [on-farm grazing]	Winter dormant	Nutritional quality	–	–
L#3 [on-farm grazing and hay sold off farm]	Dormant (Hay & grazing) Active (Grazing)	Thin stem (dormant) Thick stem (active)	Nutritional quality	Water efficient
L#4 [high quality hay]	Dormant (Hay) Semi dormant (Hay & grazing)	Leafy (dormant) Nutritional quality (semi)	Fine stem (dormant) – (semi)	Quick production (dormant) – (semi)
L#5 [on-farm grazing and hay sold off farm]	Winter dormant	Persistent	Thin stem	Water efficient
L#6 [high quality hay]	Winter dormant	Colour	Yield	Nutritional value
L#7 [hay sold off farm]	Winter active	Quick production	Rye grass control	–
L#8 [seed production]	Winter dormant	Strong plant	Seed yield	–
L#9 [on-farm grazing]	Lower watertable	Nutritional quality	–	–
L#10 [on-farm grazing and seed production]	Winter active	Seed yield	Nutritional quality	–

In summary, those growing hay for the high-end hay market are selecting for winter dormancy, fine stems, leafiness and colour. The ability for the plant to produce yield quickly is also important. Seed yield is important for seed production, while nutritional traits are important for grazing on-farm.

The trait that growers look for in the first instance is the level of dormancy/activity in the plant. This trait seems to determine other traits in the variety. For example, the winter dormant varieties have a finer stem and more leaf, making it an ideal preference for the high end lucerne hay market. Due to dormant varieties not producing all year round, they are able to also persist longer in terms of years of production. L#2 noted that the dormant variety also responds to summer irrigation, giving it a good kick-start to the season.

The winter active varieties were grown by four of the ten interviewed. The general use for winter active lucerne varieties was winter grazing when other pastures are inactive. The winter active lucerne plant is a lot hardier in terms of its stem to leaf ratio, allowing it to withstand hard grazing without affecting its production.

Lucerne growers L#8 and L#10 produced lucerne seed as part of their product bundle yet one preferred a winter dormant variety and the other preferred a winter active variety. Both were also situated in the Southern Riverina on dryland farms. L#10 noted:

> '*the seed production company tell us what they want us to grow'.*

If a winter active variety is grown, the trade off is the persistence of the plant as it will not last as long as a winter dormant variety. The characteristic of the plant differs a lot between winter active and dormant varieties and therefore is suited to different market preferences. Winter dormant varieties were selected by those who were producing high quality hay (L# 1, 2, 3, 4, 5, 6 and 8):

> *'Haymaster 7 makes leafier hay than L55 which I had 10 years ago' (L#6).*

Winter active growers were looking for a source of winter feed for on farm grazing purposes (L# 3, 7, 9 and 10). However, the exception to this rule is L#7 who grows a winter active variety for hay production and selects for quick production which utilises winter rainfall due to being on a dryland farm:

> *'I chose Sali-7, a winter active variety for quick production. I got four cuts in the first summer' (L#7).*

Not surprising, those that highlighted nutritional value as one of the most valuable traits have livestock to graze the lucerne. However, grower L#6 rated nutritional value as one of the most valuable traits but has no livestock and produces high quality lucerne hay:

> *'my aim is to make the best quality, I set the price based on colour and a feed test to know the nutritional value*'.

A general observation from the interviews was the recognition by farmers of the value of lucerne as a plant. Lucerne is particularly valuable for its high production in response to summer rain. Given the trend of increasingly frequent summer rainfall events in recent years, the popularity of lucerne is expected to grow. On the other hand, some lucerne growers started growing lucerne on their property during the drought because it is viewed as a water efficient plant. It not only provided some grazing for on-farm stock but also provided quality hay production sold off farm to local dairy farmers with feed shortage problems. The demand from dairy farmers to seek off farm produced fodder has declined as a result of a return to wetter conditions during the 2010/11 season:

> *'because of the water shortage, I went away from permanent pasture to lucerne which also allowed me to supply local dairy farms with hay but because they are growing their own feed now, I can't sell my lucerne hay'* (L#4).

Current climate averages trigger the dormancy in lucerne varieties that posses this trait. A shift in the timing of lower temperatures or general change in temperatures would affect the performance of current lucerne varieties chosen for a particular end use. Those that choose winter active varieties make their selection based on providing feed when other fodder is unavailable. Winter dormant varieties are generally selected for hay production. The more general implication of a changing climate may mean very little recognition of winter dormancy/activity in the varieties, forcing the selection of lucerne varieties with plant characteristics such as leaf to stem ratio or waterlogging capabilities.

5.2.4 Valuable traits of white clover: results

The nine interviewees for white clover traits were all dairy farms and had white clover as part of their permanent pasture mix. It is important to note that there were no white clover seed or clover hay producers interviewed due to difficulties in obtaining a sample. Consequently, the traits identified by white clover growers [Table 7] were all production context traits because the clover was for on-farm grazing purposes relevant to milk production of the dairy herd.

Table 7 summarises the valuable traits of white clover as identified by nine growers. The interviewees were asked to specify the 'must have' traits (in order of importance) when selecting a variety of white clover to sow on their farm. The first trait that most growers identified was the nutritional value that white clover provides in the pasture mix for dairy cattle. Particular varieties were not highlighted as having more or less than any other variety. The next valuable trait was persistence. This was highlighted because throughout the drought, irrigated permanent pastures dried off on many properties. Since the return of wetter conditions, white clover has re-emerged in the pasture mix without re-sowing due to its hard-seededness. White clover's ability to withstand wet environments was also seen as valuable along with digestibility and palatability.

Table 7 Valuable traits identified by white clover growers (in order of importance) (grey shading 'production context traits, yellow shading 'product bundle' traits)

Grower #	1st	2nd	3rd	4th
WC#1	Nutritional value	Persistence	–	–
WC#2	NA	–	–	–
WC#3	Tough in wet	Protein	Digestibility	–
WC#4	Palatability	Low NDF*		
WC#5	Nutritional value	–	–	–
WC#6	Nutritional value	–	–	–
WC#7	Nutritional value	Persistence	Tough in wet	Broad leaf
WC#8	Nutritional value	–	–	–
WC#9	NA	–	–	–

* NDF – Non-digestible fibre

Many growers highlighted the nutritional value of white clover as an important trait. Its presence in a permanent pasture mix was important to these growers:

> *"Rye and white clover mix is the best for dairy production"* (WC#6); and
>
> *"I just want the nutritional value that the mix provides"* (WC# 5).

It was highlighted that white clover doesn't produce the high yields but rather high quality. Growers were also aware of the risks associated with having too much white clover in the mix as it can lead to bloat in cattle and ultimately production losses. One grower said *"spend money on bloat or add rye grass to balance the mix"* (WC#6), referring to feeding anti-bloat medication as the safe option. Another grower said, *"It increases milk production for sure"* (WC#4) but hadn't re-sown the paddocks with white clover because rye grasses are now 20% higher in protein and rye is much more convenient to irrigate.

White clover is known for its persistence. Growers were impressed by its survival through drought years that saw very little rainfall and variable availability of irrigation water. With the recent wetter conditions, white clover has been appearing in pasture paddocks after irrigation and has been assumed to come from a viable seed bank in the soil. One grower noted: *"white clover is a prolific setter of seed"* (WC#7). Its emergence now is as a result of recent rainfall at appropriate times. Another grower said *"I bought rye grass seed because I didn't want to spend money on white clover seed with no water but discovered it's coming up after rainfall"* (WC#1).

Digestibility and palatability were mentioned by two growers. One of the growers highlighted *"white clover had low Non-digestible fibre (NDF) at 30% compared to rye that has 40% and hay that's got around 60-70%"* (WC#4). This was important because it means the cow is not filling up on feed with little nutritional benefit.

The interviews revealed several unwelcome traits. Indeed, two growers were keen to eradicate white clover from their pasture mix. White clover was thought to be too competitive with rye grass in summer but did not have high enough production in autumn, winter and spring. Growers felt this left a feed gap in the farm system that could be improved by growing something available during that period as opposed to buying in feed.

The nutritional value of white clover comes at a cost in terms of tonnes of dry matter produced. Rye grass has a protein level of 18% (compared to 30% of white clover) but one grower noted, "*this is enough as dairy cows only require 18%*" [WC#9]. It was highlighted that the surplus protein levels in cows' digestive systems consumes energy to break down, consequently it is not utilised for milk production. Having white clover in the pasture mix was thought to be an unmanageable source of protein because the cows' consumption needed regulation.

Interestingly, the interviewees did not mention any specific varieties. Growers were generally unaware of what variety of white clover they were growing. There was no comparison between varieties of white clover amongst the interviewees.

5.2.5 Conclusion

There were a wide range of valuable traits across the four crops and pasture-types. The most valuable traits of wheat strongly related to end use/classification, yield and suitability to the sowing window. The valuable traits of canola differ depending on the farm context, particularly the weed burden and herbicide resistance status. Lucerne valuable traits centre on winter activity/dormancy according to particular end uses. Finally, white clover is normally considered as part of the pasture mix and takes animal nutrition needs into consideration.

There are many varieties of wheat and canola with new varieties added each year. While there are several lucerne varieties, lucerne is long-lived and not re-sown very often. White clover, while seen as an important part of the pasture mix, was being compared to the nutrition and agronomic benefits of the new varieties of perennial ryegrass. The main considerations in terms of adapting to challenging climate includes: changes in timing of growing season rainfall, variable irrigation water availability (affecting white clover emergence after drought), potential change in flowering time and how this might increase frost risk, heavy rainfall at harvest (weathering), increased incidence of summer rain (increased opportunity for lucerne growing).

5.3 Decision rules used in making trait choices

Interview data was analysed to determine the likely non-compensatory and compensatory decision rules (as described by Kaine & Niall 2001) being employed for wheat, canola, lucerne and white clover variety selection.

5.3.1 Wheat variety selection

In the first instance, the wheat growers were likely to select varieties by assessing valuable traits which met their own specific production context and product bundle requirements. The second stage of selecting a wheat variety consisted of using a variety of compensatory and non-compensatory decision rules to trade-off and compromise among traits when choosing among near alternatives.

There seem to be some interesting differences between canola and wheat variety selection. While there are quite a number of wheat varieties to choose from in each of the classifications, there do not seem to be as many 'near alternatives' as is the case with canola. Also it seems that positive or negative past experiences with a wheat variety can have a large influence on decision-making about which variety to grow (i.e. 'affect referral heuristic'). While several canola varieties may be grown to 'cover-off' on several traits, wheat growers are often growing several varieties to cover a range of variations on one trait – flowering time/maturity.

The interview data showed strong use of the affect referral heuristic (a non-compensatory rule) when selecting wheat varieties. In other words positive or negative experiences with a certain wheat variety they have used in the past influenced their decision-making. It was evident that growers are quite wedded to particular varieties because they can reliably achieve high yields as well as other benefits (e.g. dual purpose, suits sowing window). While growers had 'tried and true' varieties which they tended to sow each year, they also tried some newer varieties. It seems they phased out their older varieties slowly and only after a newer variety had demonstrated itself to be an adequate, if not better, replacement. Growers made comments such as:

> *'We just stick with our two old varieties. Why would we want to jump ship? If a new one came out we'd really want to see it perform in trials…have a good look for a few years'* [W#6].

The satisficing heuristic (also a non-compensatory heuristic) was also commonly used for wheat variety selection (n=6). In other words, varieties that don't meet a threshold on any particular 'must have' traits set by the grower, were discarded. Soil conditions, avoiding frosts and late season heat; and selecting varieties with particular end-uses were important traits. For example several growers had said they would consider any variety as long as it had a hard classification, good stripe rust resistance and suitable flowering time.

The data showed that once the non-compensatory rules had been applied, growers would use the compensatory rules to select and trade-off between varieties with similar traits. In one case, for example, the grower only considered varieties which were high yielding and then several other important traits were traded off (stripe rust resistance, weathering potential). This indicated the use of the 'frequency of good and bad' heuristic.

There were several trade-offs mentioned in wheat variety decisions. Firstly, several growers are willing to tolerate varieties with low stripe rust resistance because of the high yield benefits. Secondly, some growers wanted high yields but acknowledged that there was a greater risk that the crop would lodge. Finally, some growers had persisted with a high yielding, high protein variety, but which had very poor weathering tolerance.

It is interesting to note that very few growers mentioned speaking to agronomists when selecting wheat varieties. Instead it seems that NVT trial results, crop sowing information days; and speaking to other farmers was a more common source of information. Growers often wanted to see new varieties performing well in their district for several seasons before they tried them.

5.3.2 Canola variety selection

The interviews revealed a range of mainly production context traits which varieties needed to meet before they became part of their 'consideration set'. The second stage of selecting a canola variety consisted of using non-compensatory (mainly lexicographic and satisficing decision rules) and compensatory ('frequency of good and bad') decision rules. The interviews revealed that there are *many* 'near alternatives' in canola varieties to select from. It seems that several varieties might be grown to meet a variety of trait requirements. Another important finding was that farmers relied heavily on agronomists to help them choose between the many varieties within the particular canola groups.

The interviews revealed that the production context traits were dominant in variety selection. Each grower was quite different in how they viewed traits as 'must-haves' and those which they would choose between. The satisficing heuristic (non-compensatory) was used by several growers where for a variety to be deemed suitable it had to perform strongly on several traits. These traits related to the farm context and were issues that presented these growers with the most risk for producing the crop such as frost, disease and controlling herbicide-resistant weeds. Once these traits had been met it was then up to the agronomist to choose among similar varieties. In other words the agronomist is applying the compensatory decisions:

> *'We meet with the agronomist at the end of January and map out a plan, select varieties. Agronomists have good contacts with seed suppliers'* [C#7]; and

C#6 had said that once black leg resistance, yield and triazine tolerance had been considered he'd ask the agronomist '*which one to grow...it doesn't matter that much'*.

For three canola growers the lexicographic non-compensatory rule was applied. For these growers oil and yield were considered above everything else. However, trade-offs were made when choosing among the other traits. While growers often desire the higher yields achieved by hybrid plants they understood the trade-offs regarding the potential for the crop to lodge leading to pod shatter or harvesting problems.

5.3.3 Lucerne variety selection

Interviews revealed that by far the most important trait considered for lucerne growers was winter dormancy/activity. This then determines other traits in the plant. As a result, non-compensatory rules were applied, particularly the 'lexicographic heuristic'. This rule implies that a positive evaluation on one trait does not compensate for a negative evaluation on another trait.

'Lexicographic heuristic' is where one trait is considered dominant. The variant selected has the highest valuation on that trait then within that variant, other traits are evaluated (Kaine and Niall 2001). The traits that growers L# 1, 2, 3, 7, 8, 9 and 10 based their decision on originate from production context traits. For example L#1 preferred winter dormant varieties to create time for a holiday off the farm. Three growers highlighted varieties with product bundle traits (L# 4, 5 and 6). Grower L# 6 must have a winter dormant variety due to its plant characteristics that appeals to the high end of horse industry hay market.

Winter activity levels were the dominant valuable trait lucerne was selected on. For example growers L#1, 4, 5, and 6 selected a variety that had to be winter dormant, they choose varieties with fine or little stem, then more leaf, then vibrant colour characteristics.

5.3.4 White clover variety selection

Our approach to describe trait selection decisions with compensatory and non-compensatory decision rules did not fit well with white clover variety selection. In the case of the nine growers we interviewed, the story is quite different. While some growers had been growing 'Irrigation White' for many years, others were happy with any white clover variety that came in dairy pasture seed mixes. Also, it seemed that the growers we had interviewed were not choosing between traits of white clover varieties. Rather, they were comparing the valuable traits of white clover to that of the newer perennial rye grasses.

Also, white clover was mostly considered as part of the pasture mix so the decision-making was around the right proportion of clover to include.

> *'You just need the right pasture mix – not too much white clover or you get bloat. We over-sow the ryegrass every year to make sure we have reasonable feed with limited water'* [WC#3].

'Elimination-by-aspect' rule is applied when one attribute is considered to be the most important, with a minimum threshold score set and variants not meeting this threshold are rejected (Kaine and Niall 2001). Those that use this heuristic are growers WC# 2, 3, 4, 7 and 9. The traits that these growers based their decision on originate from production context traits.

The 'lexicographic heuristic' applies when one attribute is considered dominant. The alternative is selected according to the one with the highest score on that attribute. Growers WC# 1, 5, 6 and 8 used this heuristic as nutritional value was the most important reason for white clover to be in the pasture mix.

The 'Elimination-by-aspect' and 'Lexicographic heuristic' rules are non-compensatory decision rules. That is a positive evaluation on one trait does not compensate for a negative evaluation on another trait.

Often growers relied on the agronomist/seed seller to give them the most appropriate variety (and in the right proportion) when buying a mix to sow.

The White Clover seed bank can be very large and in the right conditions, clover germination can be substantial. One grower had mentioned the problems this leads to when sowing a new cultivar:

> *'To introduce a new clover it would have to compete with the existing clover'* [WC#2].

It should be noted that this data was from nine interviews only (and all in irrigated dairy enterprises) so we cannot assume that all white clover growers would respond similarly.

5.3.5 Conclusion

In summary, the decision making around variety selection differs between the four case study crop-types [Figure 1].

Wheat variety selection	Canola variety selection
❖Growers can be strongly wedded to high-performing wheat varieties (affect referral heuristic). ❖Satisficing heuristic used for 'must have' production context and product bundle traits. ❖There are several trade-offs in choosing wheat varieties.	❖Production context traits strongest driver for canola varieties (e.g. weed status, disease). ❖Satisficing and lexicographic rules apply first (non-compensatory). ❖Compensatory decisions often left to the agronomist due to too many 'near alternatives'.
Lucerne variety selection	**White Clover variety selection**
❖ Dormancy/activity was the dominant trait considered in the first instance (non-compensatory). ❖ End-use for the lucerne drives varietal decisions. ❖ Lexicographic heuristic (one dominant trait) was the dominant decision-making approach.	❖ Selecting particular varieties based on traits seems to be absent. Decisions were more around clover content in pasture mix. ❖ Lexicographic and elimination by aspect heuristics apply. ❖ Decision making seemed to be comparing valuable traits of white clover with new perennial ryegrass cultivars.

Figure 1 Summary of heuristics used for variety selection

6. Discussion

The findings presented in this report have provided useful insights into farmer decision-making processes regarding their selection of crop and pasture varieties based on their perceptions of valuable traits. Semi-structured interviews (n=41) were conducted with growers of wheat, canola, lucerne and white clover in three agricultural regions of Northern Victoria. The data collected was able to shed light on the traits that producers must have in order to fit with production-context and product-bundle requirements (known as non-compensatory traits) and the traits which are 'near alternatives' and able to be traded-off (compensatory traits). Secondly, we were able to observe the likely decision rules, or heuristics, being applied in each case. The major themes and implications of the study in terms of farmer decision-making, extension and the development of agricultural inputs with novel or different traits are discussed in turn.

- *Farmers' perceptions of valuable traits in crops and pastures as important considerations for the development and extension of novel or new combinations of traits*

Farmers' perception of valuable traits of crops and pastures seems to reflect a relationship between the physical characteristics of the farm, distribution, processing and marketing system. As such, farmers' trait valuation is highly specific to their own individual farm context. Nevertheless there seems to be some consistent themes. The valuable traits of wheat relate to both the market (yield and classification) but also to farm-specific environmental conditions such as flowering time. Valuable traits of canola are also highly dependent on the farm context relating to weed burden, herbicide resistance, disease status and maturity time. The most important lucerne trait is winter dormancy/activity and is driven by product end-use; while the production context is also important for white clover. For cultivars with new traits (or combinations of traits) they must possess the 'must have' traits from farmers' perspectives.

The differences in trait valuation depending on farm context aligns with the findings of Asrat et al. (2010) who found 'large heterogeneities of preferences' for crop traits across farms. Indeed, they found that growing newer more productive varieties would only occur in larger farm businesses that were less risk-averse. The study found that farmers placed great emphasis on adaptability and yield stability traits in crops compared to productivity-related (product bundle) traits. Asrat et al. (2010: 2397) suggested a lack of harmony between newer crop traits with farmer concerns about yield stability had been a 'major reason for precarious adoption of improved varieties'. Our results indicate farmer have concerns about the weathering problems with the newer varieties of wheat. Farmers seem to keep growing older varieties (or revert back to them) because they produce reliable yields and suit their production context needs. The newer varieties are grown because of attractive traits but are acknowledged as risky. Improving weathering traits would seem an important area for wheat breeding.

Important traits for wheat relate to end-use (protein, dual purpose), yield, sowing time suitability and disease resistance. Adaptation might be needed in terms of future changes to the sowing window (i.e. change timing of sowing because of frost and hot finishes) and increases in weathering damage at harvest time. Loch et al. (2012) state that if rainfall patterns were to change as a result of climate variability then the reliability of when rain falls would have implications for the autumn break.

Stokes and Howden (2010: 90) highlighted the importance of developing options for likely adaptation opportunities (amongst other things) which include developing 'climate ready' varieties using biotechnology and possibly develop new crops or pastures that are pre-adapted to future climate predictions. It was thought that in the wheat industry alone 'relatively straightforward adaptations to future climate change, such as the growing of new varieties, adjustment of planting times, and the practising of moisture conservation may be worth between AU$100 million to AU$500 million per annum at the farm gate' (Stokes & Howden 2010: 92).

Our results indicate that valued traits of canola identified were herbicide tolerant traits (TT, RR and Clearfield), disease resistance (black leg resistance), oil and yield. Growers seemed confident in their canola-group options relating to herbicide resistance. These different groups were effective weed management tools for farmers. It is important that in breeding newer varieties for adapting to climate and market conditions, these traits are developed in canolas across all herbicide groups.

It is important that extensive trials of both established and newer wheat and canola varieties (i.e. The National Variety Trials) continue throughout local grain growing areas across Victoria. This will ensure that information is available about which varieties are most suitable in response to changes in maturity times, flowering etc.

A 2011 study of pasture breeders identified traits relating to persistence and production in stressful environments as important priorities in grass and legume breeding (Smith & Fennessy 2011). This has been a change with past focus from a breeding perspective on forage quality traits. These findings align with our results indicating that water availability is an important consideration for being able to grow white clover. However, growers are still concerned about managing animal health risks in white clover. Enhancing persistence and production traits in lucerne across the various dormancy/activity classes is also important.

Knowing how producers value traits as compensatory or non-compensatory can assist research and extension professionals to understand how producers use quantitative information such as that provided in crop variety trial summaries. Also, understanding why producers regard traits as non-compensatory can assist research and extension professionals to identify ways for this to be reversed where it is inappropriate. Finally, trait information can enable extension staff to understand future inputs or variants of inputs that may become worthwhile for producers in a region to consider that previously were not.

- *The dominance of non-compensatory heuristics in crop and pasture varietal decisions*

Our results indicate that producers predominantly use non-compensatory heuristics in crop and pasture variety selection. Selection of wheat varieties was mostly based on the affect referral and satisficing heuristics. For canola the satisficing and lexicographic heuristic was used by the farmer and then agronomists were left to make recommendations from near alternatives. Finally, the lexicographic heuristic was dominant for lucerne and white clover. The literature indicates that non-compensatory rules often dominate because they are cognitively simpler. For example, in wheat selection the affect referral heuristic played a strong role in decisions about variety selection. It seems that positive or negative past experiences with a wheat variety can have a large influence on decision-making. Growers are quite wedded to particular varieties because they can reliably achieve high yields and also have other benefits (e.g. dual purpose, reliable flowering time). Older wheat varieties seem likely to be phased out slowly, and only after the newer variety has demonstrated higher yield and other qualities over several years. A study by Barkely and Porter (1996) of wheat growers in the US found that varietal decisions are strongly related to past production decisions and relative yields. Our results align with these findings.

The lexicographic strategy – used in canola, lucerne and white clover selection – means that a perceived poor performance on the most important trait ensures that variety will not be chosen, no matter how well the variety performs in other traits or attributes (Payne et al. 1993). In many cases growers have several non-compensatory traits so will grow several varieties to ensure these traits are covered-off. This has important implications for extension of varieties with novel traits in that non-compensatory traits need to be met in the first instance.

While non-compensatory traits are used in the outset for selecting viable canola varieties, the farmer is still left with a suite of near alternatives to choose from. They are then required to make trade-offs to select a variety to grow. For canola it seems that the agronomist is relied on to suggest a variety. This finding aligns with long-established findings in the marketing literature which suggest that people avoid compensatory decisions because they require significant cognitive effort, value trade-offs and can be emotionally uncomfortable (Hogarth 1987).

It was beyond the scope of this study to understand how agronomists choose from near-alternatives (i.e. employ compensatory decision rules). However, a local agronomist had indicated that she relied on local variety trial results to make her recommendations. The decision-making processes of agronomists would be an interesting area for further research.

- *The likelihood of farmers to adopt new varieties to adapt to changing climatic conditions and market preferences*

Payne et al. (1993) suggests that by using non-compensatory processes in multi-alternative choices, potentially good alternatives can be eliminated early in the decision process. This notion begs the question of does the reliance on non-compensatory rules have implications for capacity for growers to adopt new varieties in response to climate and market adaptations? We suggest this may not be the case. The wheat and canola growers we interviewed were open to using new varieties, as long as they had demonstrated good performance in their district. To spread risk they also grew a more reliable variety. Given that wheat and canola are annual crops, the farmer has more flexibility to change varieties. Lucerne is a more long-lived crop so variety selection might only occur every four years. The capacity to change white clover varieties is more difficult given the large seed bank and the longevity of the seed in the soil.

- *Usefulness of two-stage model of trait choice*

Our research proposed that the choices producers make about traits can be described by a two-stage model of trait choice. At the outset, producers identify valuable traits in crops and pastures on the basis of the congruence of traits with important characteristics of their agricultural production system (production context traits) and the preferences of the markets they are supplying (product bundle traits). The second stage of the model consists of a variety of decision-rules or heuristics that producers may use to trade-off traits when choosing among alternative, non-ideal variants of an input. Such choices involve compromises among the ideal set of traits because a variant that possesses an ideal mix of traits is not available, and often not possible.

The research applied theories from marketing. We found that marketing theories are particularly useful for understanding farmer decision making because when farmers are making variety selections they are essentially consumers. Using non-compensatory and compensatory heuristics as a lens to view farmers' varietal selection seems highly appropriate. Hauser et al. (2009) suggest that heuristics are likely to be used when: there are more products to choose from, more features to be evaluated, there is more time pressure; and when the consumer is more familiar with the category. Further to this, Hauser et al. (2009) proposes that the application of non-compensatory rules for consideration decisions are growing in relevance and that such research is likely to have increasing impact as researchers push further the limits of scalability and explore synergies with behavioural experiments.

The two-stage model of trait choice we proposed aligns well with psychological theories based on the logic of decision-making such as image theory (Beach & Mitchell 1987; Beach & Potter 1992; Beach & Connolly 2005). Such models are likely to be useful for examining decision processes that producers are likely to follow in response to changes in climate and markets. Crouch (1981) suggested that adoption of agricultural innovations or practices is often grounded in practical sense where choice is restricted by the mix of technologies and practices already in place, resource constraints, and current on-farm management strategies. Kaine et al. (2011) suggested that because the choice between variants of an input may be more apparent than real, the consideration set is likely to have few members and hence the purchasing decision is often a simple matter of elimination rather than finely balanced criteria.

It is likely that climate variability, by altering the environment within which a farm system must operate, forces producers implement new tactics in order to meet their goals. Such tactics will involve producers purchasing variants of agricultural inputs that have different characteristics which better suit their changed environment. The two-stage model offers a number of benefits in regard to agricultural adaptation to climate change and agricultural mitigation of greenhouse gases. First, the presence of a systematic and identifiable relationship between the characteristics of the farm, distribution, processing and marketing system and the traits that are desirable in an input means that the traits that are, or would be, valuable in an input may be discovered, or predicted, as the case may be (Kaine et al. 2011). Understanding the resulting changes to farming systems will enable predictions to be made about changes in the desirability of the traits of inputs. This may guide research into the development of inputs with new traits and assist extension in identifying inputs, or variants of inputs, that may become worthwhile for producers in a region to consider which previously were not.

The results reported in this working paper provide a solid basis regarding the usefulness of marketing theories for agricultural decision-making. It would be useful to test the two-stage model, with additional variables from image theory, in a larger quantitative sample.

7. Recommendations

To assist farmers to adapt to climate variables and changes in markets, the following is recommended:

1. Develop an understanding of farmer decision making processes for trait selection
   - Famers' perception of valuable traits of crops and pastures seems to reflect a relationship between the physical characteristics of the farm, distribution, processing and marketing system. As such, farmers' trait valuation is highly specific to their own individual farm context.
2. Use farmer decision making understanding to assist extension services to farmers.
   - Identifying inputs or variants of inputs that may become worthwhile for producers in a region to consider that previously were not. Why producers regard traits as non-compensatory can assist in finding ways for this to be reversed where it is inappropriate. Understanding how producers use quantitative data can also assist extension professionals.
3. Use farmer decision making understanding to provide insights to the development of agricultural inputs with novel traits.
   - Identifying how producers use quantitative information can assist research professionals understand how such things as crop variety trial summaries or other commensurable information is used. Also identifying why traits are viewed as non-compensatory through understanding the relationship between the characteristics of the farm, distribution, processing and marketing system, can assist with the development of new traits.
4. Use of two-stage model to identify valuable traits
   - Identifying the relationships between the characteristics of the farm, distribution, processing and marketing system and the traits that are desirable in an input means that the traits that are, or would be, valuable in an input may be discovered, or predicted. To the degree that changes in climate can be translated into changes in the relevant characteristics of farm systems, predictions may be made about changes in the desirability of the traits of inputs.

8. Conclusion

In this paper we have used a two-stage model of trait selection by primary producers to identify valuable traits and the decision rules used to select between varieties of crops and pastures. In the first stage valuable traits are identified on the basis of the congruence of the traits of an input with relevant characteristics of the agricultural production system, and relevant preferences of the distribution, processing and marketing systems. The second stage of the model consists of a variety of decision-rules or heuristics that producers may use to trade-off traits when choosing among alternatives.

We applied insights gained from interviewing 27 producers (resulting in 41 trait choice cases) in wheat, canola, lucerne and white clover; to the two-stage model. It should be noted that our sample size was relatively small and so to draw significant conclusions about the wider population, further research would require larger sample sizes for all four crops and pastures investigated.

The two-stage model provided a useful tool to identify valuable traits for many reasons. First, the presence of a systematic and identifiable relationship between the characteristics of the farm, distribution, processing and marketing system and the traits that are desirable in an input means that the traits that are, or would be, valuable in an input may be discovered, or predicted, as the case may be. To the degree that changes in climate can be translated into changes in the relevant characteristics of farm systems, predictions may be made about changes in the desirability of the traits of inputs. This may guide research into the development of inputs with new traits and assist extension in identifying inputs, or variants of inputs, that may become worthwhile for producers in a region to consider which previously were not.

Second, the model distinguishes between valuable traits that are compensatory and those that are not. Knowledge of non-compensatory traits may assist research into the development of new inputs by providing guidance on those traits that the product of new research must possess if it is to enter the consideration sets of producers, and so be a candidate for acquisition or purchase.

Third, knowledge of which traits producers treat as compensatory, and which non-compensatory, traits may assist researchers and extension professionals to understand the ways in which producers will use quantitative information on traits generally and index-based selection mechanisms in particular. This understanding can assist in the presentation of crop variety trials trait information and quantitative indexes on livestock traits to ensure maximum use is made of such information (Kaine et al. 2002).

Finally, knowledge of the reasons why producers regard traits as non-compensatory may assist researchers and extension professionals to identify ways in which this can be reversed, where such regard is inappropriate.

These results are useful for informing farmer's ability to adapt to changing climate and market conditions. By applying the two-stage model of trait selection, it would provide industry with the benefits of understanding the decision making of the producer, assist with extension, and provide insight to the development of agricultural inputs with novel traits.

Application of this to future work could include testing a quantitative model where socio-demographic variables are taken into account, along with other factors such as farmer consideration of risk in the farm context.

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