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A Model of Farmers' Identification of Valuable Traits and Trait Selection Decisions

Service Design Working Paper 04-11

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Victoria
The Place To Be

Published by the Victorian Government Department of Primary Industries

East Melbourne, July 2011.

ISBN 978-1-74264-862-0 (print)

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Acknowledgments:

The research was funded by the Department of Primary Industries under the "Innovation in Agriculture Program".

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Executive summary

Victorian agricultural producers have a wide range of choices available to them regarding plant cultivars, varieties and animal breeds - all with different traits to suit particular environments, end-uses and markets. Some traits are valuable because they fit well with the production system and the environment unique to that particular farm. These are ‘production context’ traits. An example is acid soil tolerant barley. There are also traits which fit with processor requirements and market preferences, such as malting quality barley. These are ‘product bundle’ traits.

In this paper we reviewed the literature on traits for several agriculture industries as a means of identifying valuable traits in pastures, grain crops, horticulture, sheep, beef and dairy cattle. Rarely, it seems, does a variant of a variety, cultivar or breed exist that combines all valuable traits in the desired proportions. Rather, it seems that valuable traits are often negatively correlated and so producers must compromise or make trade-offs regarding such traits. To do so, producers must employ decision rules, or heuristics. In this paper we provide an overview of these rules.

Non-compensatory rules apply when traits are not commensurable, in other words a positive evaluation on one trait doesn’t compensate for a negative evaluation on another trait. Often there is a minimum acceptable threshold on one or more traits and if these are not meet then the alternative under consideration is excluded from the producers’ consideration set. Compensatory decision rules are used where traits are commensurable - where a higher score on one trait can compensate for a lower score on another and so trade-offs can be made.

Bringing together the valuable traits identified in the literature, and using non-compensatory and compensatory decision rules, we propose a two-stage model of trait selection. In the first stage valuable traits are identified on the basis of congruence of the traits with production context and product bundle requirements. The second stage of the model consists of a variety of compensatory and non-compensatory decision rules that may be used to trade-off and compromise among traits when choosing among near alternatives. Finally, we discuss how our proposed model aligns with image theory, a psychological theories of decision-making (Beach & Mitchell 1987; Beach & Connolly 2005).

We plan to test the model in subsequent work using industry-based case studies. If supported, the model would provide important insights for research and extension in regards to what research products may assist farmers to adapt to changes in climate and markets.

1. Introduction

As climate change progresses the desirable characteristics of farm inputs (and outputs) can be expected to change. For example, heat tolerance may become a progressively more valuable characteristic or trait in livestock over time (Gaughan et al. 2010). 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 agricultural inputs that possess new, valuable traits. Such an understanding would also assist extension in efficiently promoting variants of agricultural inputs, novel and otherwise, to primary producers.

To make choices about which particular variant of an agricultural input to purchase, 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 input 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). Kaine and Niall (2001) for example, describe how both compensatory and non-compensatory decision rules can be used by wool producers to make choices about sourcing rams for sheep breeding. 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.

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. This should assist research and extension in supporting primary producers in reducing greenhouse gas emissions and adapting to climate change.

2. Objectives

In this paper we aim to:

1. Identify valuable traits from the agricultural literature, in terms of 'production context' and 'product bundle' traits across a range of agricultural industries
2. Describe non-compensatory and compensatory decision rules in the context of farmer decision making; and
3. Propose and describe a two-stage model of trait choice and input purchase.

In the next section we review the literature across a number of agricultural industries to identify valued traits for each industry and the factors that influence producers' identification of valuable traits in farm inputs. 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 an input involves compromising among traits. A model that describes producers' decision-making in regard to identifying and choosing between valuable traits is proposed. Finally, we illustrate how the model may operate using examples from grains, dairying, sheep and horticulture.

3. Literature review

In this section we review the agricultural literature regarding the factors that influence producers' identification of valuable traits in farm inputs. We propose that traits that are considered valuable by producers can be classified into those that are valuable because of their fit with the production system ('production context') and those that are valuable because of their fit with processor and market preferences ('product bundle').

3.1 Valuable traits in pasture varieties

In reviewing the literature on pasture traits we focussed on traits related to animal production systems. There are other important contexts in which pastures are used which lead to different combinations of valuable traits in pasture plants such as pasture for hay or silage production, pasture phases in cropping programs and commercial pasture seed production.

In livestock systems valuable pasture traits are predominantly related to the production context in because the pasture is an input into animal production or is part of the cropping program on the farm. The valuable traits of pasture species are 'product bundle' traits when the pasture is used for production of fodder, hay or silage that is sold or in the case of commercial pasture seed production.

There have been some very useful recent studies to identify valuable pasture traits from the perspective of pasture breeders and producers in Australia. While past studies highlighted the importance of forage quality traits, more recent research highlights the importance of abiotic stress traits related to herbage yield and stress tolerance. Traits deemed important for white clover are root growth, persistence, drought tolerance and tolerance of hostile soil conditions. Two important traits for lucerne are tolerance of hostile soils and persistence. Finally, traits to deal with water-related stress (too much or too little water) are seen as important for perennial ryegrass (Smith & Fennessy 2011).

Salam et al. (2010) used qualitative data to develop a pasture characteristics framework for Western Australia. Several traits relating to establishment and growth were the most desired characteristics of pastures by farmers. Also important was feed supply and quality, adaptability and insect tolerance. Salam et al. (2009) also studied the adoption of annual legumes in WA. The most important agronomic traits influencing adoption were found to be superiority in establishment and growth (re-generation/seeds buried in soil and on soil surface, seed-setting, persistence), strength in controlling weeds (herbicide tolerance, grazing ability to control weeds), ability to supply feed (potential dry matter) and pasture quality (palatability and nutritious) (Salam et al. 2009).

In Table 1 we have summarised the valuable traits of pastures (legumes and grasses) into categories. The first category of traits (adaptability to environmental conditions) refers to the plant's ability for increased dry matter production and persistence in environments where the plant would encounter abiotic stress. Recent literature suggests that there is increased emphasis on traits to cope with abiotic stress in pasture plant breeding (Smith & Fennessy 2011). Revell & Revell (2007) reported pasture improvement programs focussing on traits for deep root systems, grazing tolerance, water logging, and salt and acid soil tolerance. Predictions that climatic change will trigger changes in soil management because of increased acidity, salinity and reduced phosphorus reinforce the need to develop traits to cope with abiotic stress (Oram & Lodge 2003).

Several morphological traits of pasture plants were identified as potentially valuable. Such traits are important for silage or hay production. For example, erect and larger leafed white clover is more suitable for hay and silage production, as are the more upright varieties of perennial ryegrass (NSW Government 2011). Morphological traits also determine how a plant might respond to grazing and influence persistence. For example, clovers with a stoloniferous growth habit are better able to spread out and persist, while larger-leafed varieties of white clover will have higher yields (NSW Government 2011).

Table 1 Important traits for choosing pasture varieties

Trait categories	Trait choice consideration
Adaptability to environmental conditions	Drought tolerance, frost tolerant, waterlogging tolerant, acid/alkaline soil tolerant, rhizobial compatibility, ability to cope with false break.
Morphological traits	Ratio of leaf to stem*, annual or perennial, summer or winter activeness, erect/upright or prostrate, time of flowering, seed production*, dry matter production*, stoloniferous/rhizomatous growth.
Establishment and growth	Ease of establishment, hardseededness, persistence, regeneration, seed bank longevity, seed-setting, growth, early vigour, recovery ability after grazing, early/late feed supply, variety maturity (for hay)*, time of flowering.
Feed quality and supply*	Protein content, digestibility, palatability, fibre content, sugar content, potential for milk/meat tainting, lipid content, lignin content, leaf shear strength.
Avoidance of animal health issues	Avoidance of endophytes (ryegrass) and oestrogen (sub-clover), seed/burr characteristics.
Pest and disease tolerance	Insect tolerance, resistance to disease, virus resistance.
Weed control	Herbicide tolerance, competitive against weeds

See text for sources
Traits that might be considered as ‘product-bundle’ are marked with an asterisk

There are several potentially valuable traits relating to establishment and growth. An important trait for clovers is hardseededness which is associated with the permeability of the seed coat. Hardseededness enables seeds to survive for long periods in the ground over dry weather, while lack of hardseededness can mean the pasture is more prone to false breaks. Persistence is also an important trait as pasture plants need to survive droughts, grazing and maintain longer term productivity (Evans 1996).

Feed quality and quantity traits are those which influence the pasture's nutritive value. Digestibility, the proportion of feed an animal can consume to satisfy nutritional requirements, is the most important measure of the feed value of pasture (Bell et al. 2007). Protein content and several other nutritive traits are particularly important for producing milk solids in dairy cows.

Some pasture species carry toxins and high levels of oestrogens which affect animal health and may be referred to as 'anti-quality' traits. Ryegrass and Tall Fescue contain alkaloids, known as endophytes, which are toxic to stock in high levels (NSW Government 2011). Also, some older varieties of sub-clover contain high levels of oestrogen which can cause infertility in stock.

Finally, pest and disease resistance may be highly valuable traits. For example, rust resistance is important for fescue and ryegrass varieties in high rainfall and humid areas, while resistance to root rot may be important for clover.

Genotype-environment interactions are critical to pastures. While there are correlated traits across production environments, growth rates will be quite different in different environments (Smith & Fennessy 2011). There are notable genotype-environment interactions involving plant yields and the effects of nitrogen fertiliser application on the expression of yield traits. In a review of future prospects for pasture plant breeding, Parsons et al. (2011) discuss the complex ecological interactions that must be accounted for when attempting to introduce specific traits for persistence.

Revell and Revell (2007) propose a set of minimum standard traits that new pasture cultivars should meet. These include: herbage production from multiple sites and years, nutritive value, seed production, regeneration/hardseededness, burr/pod characteristics, herbicide tolerance, rhizobial compatibility and susceptibility to pests and disease.

3.2 Valuable traits in grain crops

Farmers are faced with choosing from among a large array of grain crops and varieties that are adapted to suit a range of environmental conditions and market uses. Grain varieties are continually changing as new varieties with improved traits are released and older varieties are phased out.

Grain crop varieties are grouped into varietal classifications according to genetic characteristics, physical traits and end-use or quality attributes. In Table 2 a range of traits that are valuable in a selection of grain crops (wheat, oats and barley) are grouped in categories. There are numerous traits which we have classified as morphological, pest and disease susceptibility, environmental condition traits and end-purpose traits. Importantly, many of these traits have important production context implications (morphological, pest and disease susceptibility and environmental conditions). Additionally there are product bundle or market traits which include the range of 'end-purpose' traits which are required by certain customers or markets.

The production context traits are critical as these determine which varieties will perform the best given the particular biophysical conditions on farms. Environmental 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 the end-uses of the various varieties. This is particularly important for wheat where several traits are used to describe wheat classes such as target protein range, hardness and milling quality. For example Australian Soft wheat which is used for biscuits has a soft grain, good milling quality and a protein level between 7.5 to 9.5 per cent. Australian Prime Hard wheat which is used for bread has a hard grain, good milling quality and dough strength with a protein range of 13-15 per cent (AWBI 2008).

Wheeler (2011) suggests that grain growers also spread their quality risks by sowing several varieties with different end-uses. A Productivity Commission report (PC 2010) suggested that growers may find narrower market-driven specifications difficult to achieve, also meaning farmers have less flexibility in crop management.

Barkley and Porter (1996) found that if there were not sufficient financial incentives for wheat with high milling and baking traits (product bundle traits), farmers were more likely to select wheats based on production traits. Average yield was a prominent trait that farmers selected for, with yield stability also playing an important role. Additionally, varietal decisions were strongly tied to past production decisions and economic considerations often led farmers to plant varieties with higher-yielding traits rather than end-use traits (Barkley & Porter 1996).

Table 2 Important traits for choosing grain crop varieties

Trait categories	Trait choice consideration
Morphological traits	Growth habit, stature, straw strength, awns, head density, high early vigour, early, mid or late maturing, tillering
Pest and disease susceptibility	Rust resistance Resistance to fungus (fusarium) and nematodes (e.g. cereal cyst nematode)
Environmental conditions	Waterlogging tolerance Acidic/alkaline soil tolerance Boron tolerance Salt tolerance Drought tolerance
End-purpose traits	Grain yield, yield stability, grain size*, grain weight*, grain colour*, grain hardness*, protein content*, export malting quality (barley)*
Other traits	Potential for dual purpose (oats: recovery after grazing)
Trait categories	Trait choice consideration (farm context or product-bundle)

See text for sources
Traits that might be considered as 'product-bundle' are marked with an asterisk

Brennan and Bialowas (2001) examined the changes in wheat traits and varieties grown on NSW farms from 1965 to 1997 and found that traits relating to yield and grain quality had changed greatly over the years with wheat varieties becoming shorter with stronger straw, lighter in colour and more focus on mid-maturity. Interestingly, they found that eight to ten different varieties were grown in each shire each year, with generally three varieties grown in most of the area, together with a few new varieties and some older varieties in the process of being replaced.

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. Farmers have access to descriptions of each variety, yield, growth information and disease-related characteristics.

The CSIRO is conducting 'pre-breeding' research into a range of wheat traits to enhance both production context and product bundle traits (see: http://www.csiro.edu.au/science/wheattraits.html). These include numerous abiotic traits related seedling emergence, high early vigour, tillering, salinity tolerance and aluminium tolerance as well as biotic traits such as resistance to rust, nematodes, fusarium and particular viruses. There is also research into traits relating to the starch level of grains to develop varieties that better suit different end product requirements such as low gluten foods, dough, and noodles (CSIRO 2011).

3.3 Valuable traits in horticultural crops

The horticulture industry produces a diverse range of crops. The broad crop categories include pome (apples, pears), stone (nectarines, peaches, plums), berries (strawberries, raspberries), nuts (almonds, walnuts), vines (melons, grapes) and citrus (lemons, oranges). These can then be categorised into fresh produce, preserved or dried.

Horticulture varieties can be categorised by traits that reflect their appearance, quality or how they react to certain environmental conditions. In Table 3 a range of traits that are valuable in horticultural crops are grouped into categories. Many traits in the table are identified as product bundle traits because they reflect market preferences.

The production context traits are critical for growers to consider when choosing a variety that is best suited to their environmental conditions. Environmental conditions can affect the flowering times varieties. Some varieties may require a certain number or intensity of frosts.

Choice of variety is also influenced by soil type since this determines the availability of water, depth of water penetration, nutrients availability and mechanical impedance to root growth. Cockroft and Wallbrink (1966) investigated the importance of the physical properties of soils that may affect tree performance in the Goulburn Valley and they concluded that irrigated fruit trees are greatly influenced by soil variation. Other production context traits are the pest and disease tolerance of different varieties. In some cases growers may choose a new variety to overcome plant disease with the expectation that it will be resistant to a new pathogen (Pink 2002).

There are tactics, such as the use of rootstocks, to create flexibility with respect to varietal choice. For instance, a Valencia orange rootstock study on soil types with high lime content provided growers with appropriate rootstocks in these soil situations (Mikhail & El-Zeftawi 1979).

The product bundle traits are different for the domestic or export markets as there are significant differences in the appearance or sensory characteristics different markets preferred. There are many studies and reviews associated with characteristics influencing consumer choice of fruit and vegetables (Austin & Hall, 2001; Lorden et al. 2007; Daillant-Spinnler et al. 1996; Wismer et al. 2005). For example, Daillant-Spinnler et al. (1996) related sensory properties of apples from the southern hemisphere to the UK market. Wismer et al. (2005) found that consumers primarily decide to purchase a particular type of fruit on the basis of sensory characteristics. Wismer et al. (2005) highlight that cultivars are now released using science techniques to identify the more highly preferred product to inform breeding programs. Similarly, Lorden et al. (2007) recommends strategies that are associated with becoming competitive in the overseas market by producing fruit with desirable qualities from the Victorian perspective.

Table 3 Important traits for choosing horticulture varieties

Trait categories	Trait choice consideration
Fruit appearance	Size*, Shape*, Colour*
Environmental conditions	Flowering times, Suitability of soil, Maturation*, Vigour*
Sensory characteristics	Acidity of fruit*, Sugar*, Texture*, Flesh characteristics*, Skin characteristics*, Odour*
Other	Pest/disease tolerance Storage time*

See text for sources
Traits that might be considered as 'product-bundle' are marked with an asterisk

Table 4 Important traits for choosing dairy cattle

Trait categories	Trait choice consideration
Production	Milk yield, cell count, fat content*, protein content*
Fertility	Daughter fertility, semen fertility, calving ease, survival
Workability	Milk speed, likeability, temperament
Type	Mammary system, feed conversion efficiency
Linear	Udder depth, pin set, foot angle, angularity, body depth, udder texture
Other	Registered or commercial herd

See text for sources
Traits that might be considered as 'product-bundle' are marked with an asterisk

3.4 Valuable traits in dairy breeds

Cows used to produce dairy milk in Victoria are generally Holstein-Friesian and Jersey. Milk products include milk, butter, butter milk, cream, custard, dairy desserts, cheese, yoghurt and milk powder.

Traits in dairy breeds are categorised into production, fertility, workability, type and linear traits. Most of the valued traits in dairy breeds relate to the production context, meaning farmers will select breeds with the expectation that they will perform better in their environment (see Table 4). There is a major emphasis on the quantity of milk produced per cow as this is the principal actor affecting profitability dairy farms. Consequently, much of the literature on dairy cattle selection is aimed at selecting cattle to increase milk production (Haile-Mariam et al. 2004; Haile-Mariam & Goddard, undated; Hoekstra et al. 1994; Visschert & Goddard 1995; Leitch 1994).

Haile-Mariam et al. (2004) assessed the genetic correlation between fertility and production traits of Holstein-Friesian cattle to test if selecting for increased milk yield had a negative affect on fertility traits. Similarly, Hoekstra et al. (1994) investigated the correlations between fertility and production of Dutch and Holstein Friesian breeds in Europe based on the belief that the fertility of the crossbred herds had deteriorated due to selecting for milk production. While milk yield may be the priority trait when making selection decisions mistakes in structural traits such as foot angle or body depth can take many years to breed out of a milking herd (Melissa Spain, pers. comm., 2011).

Milk composition is an important product bundle trait. Roche and Dalley (1996) estimate there to be 13 per cent solids in milk and it is these solids that determine the value of the milk due to the capacity to separating milk into various component solids. These components are used as ingredients in other foods or combined in novel ways to create new products. The composition of milk can be manipulated at the farm level by changing the nutrition of feed to cows and by trait selection. Leitch (1994) carried out a review on the comparison of selection indices for dairy cattle breeding in different countries and found that while breeding objectives can vary, protein had the highest emphasis in all selection indices that were considered.

Genotype-environment interactions were investigated by Haile-Mariam and Goddard (undated) to identify Holstein-Friesian sires that were consistently superior across all environments for economic traits (production, survival and fertility). This was important to establish the credibility of performance evaluation systems based on consideration of the registry status of the animal. Visschert and Goddard (1995) used genetic analysis to estimate profit in Holstein-Friesian and Jersey dairy herds in Australia. They define profit as a function of milk production, herd life, food consumption, costs associated with health, reproduction and housing.

Herd recording provides one source of information for farmers when making selection decisions. The Australian Dairy Herd Improvement Scheme (ADHIS) provides estimates on the genetic merit of bulls and cows based on their production performance. These estimates are known as Australian Breeding Values and these are an example of a selection index (Short et al. 1997).

3.5 Valuable traits in beef breeds

Beef breeders generally have one objective which is to increase live weight through efficient use of inputs. Dominant breeds in Australia include Hereford, Angus, Shorthorn, Murray Grey and, in the northern areas, the Brahman. Each breed has differences in its meat characteristics and so breed choices are made at least partly on the basis of the target market. Trait categories include carcass, reproductive and growth traits.

Almost all the literature on beef breed selection refers to increasing productivity and feed efficiency (DeRouen et al. 1992; Robinson & Oddy 2004; Richardson et al. 1998; Archer et al. 1999; Koch et al. 1963). Robinson and Oddy (2004) studied the feed conversion efficiency of beef breeds in a feedlot situation and found that feed efficiency is heritable and genetic improvement for feedlot cattle is possible. Richardson et al. (1998) found that selecting for net feed efficiency should improve efficiency without having to increase inputs such as feed. Similarly, Koch et al. (1963) determined that selecting for feed efficiency would result in increased daily gain but feed consumption would not be affected.

Charteris (2006) observed that, apart from scrotal size, reproductive traits in beef cattle have been shown to have low heritability as opposed to most growth traits and carcass traits. Consequently, while genetic progress in a beef herd is generally achieved by selecting superior cattle for the breeding objective and culling inferior animals, culling for poor reproductive performance is mainly a herd management decision, not a genetic decision (Charteris 2006). Scrotal size, which is associated with days to calving in daughters, is included in Estimated Breeding Values contained in Breedplan).

Gaden and Parnell (undated) encourage beef producers to have a clear breeding plan that includes market suitability and low cost, efficient production. They argue that, while markets will keep changing, a good producer will have high yields of saleable meat with minimum fat, tender meat and a wide range of weight in the herd to supply the continual market for livestock.

Table 5 Important traits for choosing beef breeds

Trait categories	Trait choice consideration
Carcass	Heat tolerance, tick resistance, temperament, net feed efficiency, structure, eye muscle area*, bone-out retail beef yield*, fat depth*, intra-muscular fat*, live weight*, meat tenderness*
Reproductive	Scrotal size, gestation length, calving ease, age at first calving, heifer conception rate, cow conception rate, days to calving
Growth	Calf weaning weight, birth weight

See text for sources
Traits that might be considered as 'product-bundle' are marked with an asterisk

Table 6 Important traits for choosing sheepmeat and wool breeds

Trait categories	Trait choice consideration
Live weight	Maternal weaning weight, weight* (birth, weaning, post weaning, yearling, hogget, AWT)
Carcass	Conformation, fat depth*, eye muscle depth*
Reproduction	Number of lambs born/weaned, Scrotal circumference
Wool	Fleece rot susceptibility, fleece weight*, fibre diameter*, staple strength*, staple length, colour*, crimp frequency*, skin follicle size and density*
Worm resistance	Worm egg count
Other	Temperament

See text for sources
Traits that might be considered as 'product-bundle' are marked with an asterisk

Currently the Asian market for marbled beef, a meat characteristic only found in some breeds but may also be selected for in others, is growing. For example, Wagyu beef is very high in intra-muscular fat creating marbled meat. DeRouen et al. (1992) investigated crossbreeding and how this may affect carcass traits such as yield, composition, palatability and quality.

3.6 Valuable traits in sheep breeds

Breeds of sheep vary widely in terms of traits related to meat and wool production. For example, carpet wool sheep including Romney or Perendale are typically stronger wool types (staple strength the important factor) but can be used as dual purpose for both meat and wool (DPI 1994). Another dual purpose breed is the Merino which can produce lambs suitable for slaughter l at an early age as well as producing good quality wool of differing fibre diameter (DPI 2000a). The various traits that are sought in meat and wool sheep breeds are reported in Table 6.

White Suffolk sheep produce carcasses suited to the meat industry as traditional and boneless cuts (DPI 2000b). Dorper sheep are also meat producing sheep and are known to produce high quality lamb from low quality roughage as a result of them originating from the arid regions of South Africa (DPI 2000c). Finn sheep are known for their high lambing percentage and are therefore used as a maternal breed that may replace some first cross ewes (DPI 2000d).

The literature on breeding in sheep meat and wool focuses on wool production and, in particular, Merino wool production (Mortimer et al. 2010; Swan et al. 2009; Mayo et al. 1970; Butler et al. 1995; Cottle et al. undated; Ferguson & Watts undated; Banks & Brown 2009). Selection methods can be categorised into visual and objective methods. Butler et al. (1995) observed that many breeders placed more importance on traits assessed visually (handle, character and colour) as opposed to traits assessed using objective measurement (fibre diameter and fleece weight). Mortimer et al. (2010) also found support for this observation.

Kaine and Niall (2001) carried out a survey of sheep breeders in Victoria and, subsequently, nationally that investigated decision making and breeding. They discovered that the breeding strategies of woolgrowers depended on their beliefs about (Kaine & Niall 2001; Kaine et al. 2006):

- The impact of the environment on the ranking of bloodlines in terms of fibre diameter and fleece weight
- Genetic interactions between rams and ewes
- Differences in livestock management between the stud and the commercial woolgrower, and
- The likelihood that fleece characteristics such as crimp definition and frequency and staple structure are more reliable indicators of skin

traits such as wool follicle size and density than are objective measurements of fibre diameter and fleece weight

Banks and Brown (2009) argued that in different areas the structure of a flock was connected to the income mix of the farm. Hence, farm performance depended on matching the structure of a flock to the production context.

There has been significant investment in genetic evaluation systems in the sheep industry. Estimated Breeding Values have been available since 1989 for meat and dual purpose breeds while Central Test Sire Evaluation began in the early 1990s (Swan et al. 2009).

The use of index selection to make trait choices is debated in the wool industry. Welsman (2000) suggests that it is important for the Australian sheep industry to accept and adopt quantitative genetics to achieve faster genetic gain. However, Ferguson & Watts (undated) took the contrary view, arguing that productivity could be increased just as quickly using traditional selection methods as it could be using index selection to increase fleece weight and reduce fibre diameter.

3.7 Conclusion

In this section we have summarised the range of valuable traits in plant-based and animal-based agricultural industries and the factors that influence producers' identification of valuable traits in these farm inputs. We proposed that traits that were considered valuable by producers can be classified into those that were valuable because of their fit with the production system (production context) and those that were valuable because of their fit with processor and market preferences (product bundle traits).

A number of observations can be made from our review of the literature. First, production context traits are valuable in all industries because producers seek varieties, cultivars, or breeds that will perform best within the constraints of their environment. Product bundle traits are particularly important for grains, horticulture and the meat industries because the products in these industries are used in a range of end-uses and must meet the requirements of particular markets.

Rarely does a variant of an input exist that combines all valuable traits in the desired proportions. Often, it seems that valuable traits are negatively correlated. This means higher values of one or more traits of value only occur at the expense of lower values of one or more other, valuable traits. Consequently, producers must compromise on the presence or extent of traits. In grains, pastures and horticulture, in particular, producers are likely to ameliorate production and market risks by using more than one variety of crop, cultivar, etc.

The development of varieties with different or new traits seems to occur more frequently with pasture plants and grains than for livestock. New pasture and grain varieties are released, and old varieties phased out, almost continuously. The introduction of new traits into livestock, and the dissemination of these through national herds and flocks, takes considerable more time.

The influence of genotype-environment interactions on the expression of particular traits is noted in the literature in all agricultural industries. Predicting the effect of these interactions at a regional level is critical if climate changes. Breeding in the plant industries in particular is focussing on developing cultivars with higher tolerance to abiotic stress.

As suggested above, the producer is likely to make trade-offs when selecting cultivars, varieties or breeds for particular traits. In the next section we describe a series of decision-rules or heuristics that producers may use when choosing an input which involves compromising among traits.

4. Decision rules

4.1 Non-compensatory 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 must 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:

- The 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. Kaine and Niall (2001) use the example of a wool producer deciding to cull ewes below a certain weight with a second criteria being to cull ewes that haven't lambed.
- The lexicographic heuristic: this rule applies when one trait is considered dominant. The variant is selected that has the highest evaluation on that trait. For example, a wool producer may select rams simply on the basis of having the highest fleece weight.
- The satisficing heuristic: this rule is applied when traits are given a minimum threshold score and considered in sequence. Variants that do not meet the threshold on any of the relevant traits are discarded. Kaine and Niall (2001)

provide the example of a good-sized ewe with fine wool being culled because it did not meet the standard for foot conformation.

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 with time pressures involved, though this may not always be the case (Hauser et al. 2009). However, if a trait is deemed sufficiently important then a non-compensatory decision rule may be used even though there is sufficient time and information to apply, in principle, a compensatory decision rule.

Kaine and Niall (2001) provide evidence that non-compensatory decision rules are used by some wool producers when selecting rams for sheep breeding. For example, certain traits relating to lustre, feel, and crimp definition must be present for rams to be classified as soft rolling skins (Kaine & Niall 2001). Rams that do not possess these traits are excluded, by producers that value these traits, from consideration as candidates for purchase.

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.

4.2 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). Importantly, when an individual considers compensatory traits they are making trade-offs among traits across 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.

There are several compensatory decision rules that can be taken including (Kaine & Niall 2001):

- The ‘weighted additive’ rule: where traits are weighted according to importance, the weighted sum of scores is evaluated with the highest-scoring alternative selected.
- The ‘equal weight’ heuristic: where all traits are weighted equally and the highest-scoring alternative is selected.
- The ‘frequency of good and bad’ heuristic: traits are evaluated as being above or below set threshold scores, with the alternative or variant with the most good features and least bad features is selected.

Index selection for selecting a ram is an example of a weighted additive rule. However, in order to make an evaluation using this approach, attributes must be commensurate.

Logically, the application of compensatory decision rules to commensurate traits should only occur with variants of an input 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.

5. A two-stage model of trait choice

In this section we propose a two-stage model of trait selection by primary producers.

5.1 Trait valuation

We have proposed a two-stage model of trait selection by primary producers. 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 relevant characteristics of the production system correspond with the factors in the farm system that influence the benefits of acquiring a technology or practice so, 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.

5.2 Trait choice

Rarely is it the case that a variant of an input exists that combines all valuable traits in the desired proportions. Often, the values of traits are 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 purchase or acquire a variant of an input that is a compromise on the ideal mix of valuable traits. Producers may draw on a number of decision-rules or heuristics when making choices that involve compromising among traits. As we described earlier, 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-commensurate traits are those which must be present in the input for it to have value at all to the producer. It would seem that non-commensurate traits should define the variants of an input that are eligible members of the consideration set the producer has available to choose among because their absence excludes them from contemplation as possibilities for purchase or implementation. Producers may draw on a variety of non-compensatory heuristics, as described in the preceding section, when evaluating non-commensurate traits. Both production context traits and product bundle traits may be non-commensurate.

Commensurate 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 variant of an input from amongst those variants of the input that constitute the consideration set is based on 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 commensurate.

6. Discussion

We have reviewed the literature to identify valuable traits in plant and animal inputs for a number of agricultural industries, and the factors that make these traits valuable. We have also provided an overview of non-compensatory and compensatory decision rules that agricultural producers are likely employ when they evaluate farm inputs to meet production and market constraints. Understanding how producers make such decisions, knowing the factors which make traits non-compensatory, and the processes used to trade-off traits has much to contribute to our understanding of farmer decision-making.

We are proposing that the choices producers make about traits can be described by a two-stage model of trait choice. In the first stage we propose that, at the outset, producers identify valuable traits in crops, pastures, and animals 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 two-stage model of trait choice we are proposing seems consistent with general psychological theories of the fundamental logic of decision-making such as image theory (Beach & Mitchell 1987; Beach & Potter 1992; Beach & Connolly 2005). This is important as such models should describe the decision processes that producers are likely to follow in response to changes in climate and markets.

Image theory treats decisions as social acts and recognises that decision-makers come to a decision with a store of knowledge which influences their decisions and guides their behaviour (Beach & Potter 1992; Nelson 2004). This knowledge can be classified into three categories or images: the value image which consists of knowledge about what truly matters and is based on beliefs and values of the producer; the trajectory image which consists of knowledge about what constitutes a desirable future and is based on goals: and the strategic image which consists of knowledge about how to go about securing that future and is based on plans (Beach & Mitchell 1987; Beach & Strom 1989; Beach & Potter 1992; Beach & Connolly 2005). Changes in the producer's task environment, including changes in markets or climate, may precipitate a change in the strategic image and, if profound enough, in the trajectory image.

Plans in the strategic image have two aspects: tactics and forecasts. Tactics are concrete behaviours while forecasts focus on the outcomes of those behaviours. The various plans in the strategic image must be coordinated so that they do not interfere with each other and the decision-maker can pursue their goals in an orderly fashion (Beach & Connolly 2005).

There are two kinds of decisions in image theory: progress decisions and adoption decisions. Progress decisions are decisions about whether a plan is making progress towards achievement of its goal (Beach & Connolly 2005). These decisions rely on forecasts as to whether the anticipated outcome plausibly includes achievement of the goal or not. If the forecast does include goal achievement the plan is retained. If not, the plan is abandoned and a new or amended plan must be adopted (Beach & Connolly 2005). Hence, a change in markets or climate requires may mean that goal achievement is no longer forecast and thereby require the current plan to be abandoned and or amended.

Adoption decisions augment knowledge and concern adding new principles to the value image, new goals to the trajectory image or new plans to the strategic image (Beach & Connolly 2005). The criterion for adding a new goal or plan is whether it is compatible with existing principles and consistent with existing goals or plans of the decision-maker. If a goal or plan is sufficiently incompatible with existing principles or interferes with existing goals or plans then it is rejected. Importantly, adoption decisions are accomplished by screening options in the light of relevant principles, goals and plans (Beach & Mitchell 1987; Beach & Strom 1989; Beach & Potter1992).

The compatibility criteria in image theory are non-compensatory (Beach & Strom 1989). This limits the need for making a choice between options to those situations where two or more options survive screening. Crouch (1981) observed that the decision to adopt an agricultural technology or practice is often a matter of practical sense as the scope for choice is restricted by the mix of technologies and practices already in place, resource constraints, and the management strategies of the producer. This suggests that the choice between variants of an input may be more apparent than real, the consideration set has few members. The decision as to what to purchase is often a simple matter of elimination rather than a question of optimisation based on finely balanced criteria.

When two or more options pass screening the decision-maker may call on one or more of a repertoire of decision strategies to make a choice depending on the circumstances of the choice. These circumstances include characteristics such as unfamiliarity with, and complexity of, the choice, significance and irreversibility of the outcomes, and the decision-maker's motivation (Beach & Connolly 2005). Climate change, by altering the environment within which a farm system must operate, forces producers to abandon or amend their plans, and consequently change tactics, in order to secure their goals. Changing plans and implementing new tactics requires that producers purchase variants of agricultural inputs that have different characteristics which better suit their changed environment.

In terms of image theory, the purchase of a novel, to the producer, variant of an agricultural input is an adoption decision because it involves the incorporation of a new tactic, in the form of an input with novel traits and associated changes to the farm system, into relevant plans in the producer's strategic image. The novel variant is screened by considering the compatibility of the amended plans with the value image and the consistency of the amended plans with the trajectory image. If the amended plans fail the screening test then the change in tactics is rejected as is the new variant. If the amended plans pass the screening test then the change in tactics is implemented and the new variant is purchased.

The constituents of the value, trajectory and strategic images that are relevant to producers' screening of variants of agricultural an input are the elements in the farm system that influence the intensity of the technical improvement the variant offers, the relevance of the improvement to producers' objectives, and the compatibility of the improvement with their values, experiences and needs. These define the beneficial production context and product bundle traits the producer seeks in the agricultural input.

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. This may be done using techniques proposed by Kaine et al. (2011).

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. For example, Revell and Revell (2007) suggest certain traits must be retained in new pasture species. They describe researchers as having 'duty of care obligations' to retain such traits when developing new pasture species.

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, for example, quantitative information 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. For example, in the past wool producers have only purchased rams from studs in their own district, or studs from districts with climates similar to theirs (Kaine & Niall 2001; Kaine et al. 2006). This is because their particular beliefs about genotype-environment interactions with respect to fibre diameter and fleece weight meant that district of origin was a non-compensatory trait in rams. Such beliefs are argued to reduce the potential for genetic gain in sheep flocks (Pollard et al. 2002).

7. Conclusion

We have proposed a two-stage model of trait selection by primary producers in this paper. 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 relevant characteristics of the production system correspond with the factors in the farm system that influences the benefits of acquiring a technology or practice so we have termed these production context traits. The relevant characteristics in relation to the distribution, processing and marketing system we have termed these 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. We propose that producers apply non-compensatory heuristics to the evaluation of non-commensurate traits. This process narrows the range of alternatives under consideration by the producer to those that have relevant prerequisite traits. We propose that producers then apply compensatory heuristics to the evaluation of the commensurate traits to make a final choice among the alternatives in the consideration set.

We plan to test this model in the future by application to producers' decisions in regard to choosing pasture species, livestock breeds and bloodlines, plant varieties and tree crop cultivars.

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