ADOPT: a tool for predicting adoption of agricultural innovations

Kuehne, G[1]., Llewellyn, R[1]., Pannell, D[2]., Wilkinson, R[3]., Dolling, P[4].

[1]CSIRO – Ecosystem Sciences, [2]University of Western Australia, [3]VIC Department of Primary Industries, [4]Department of Agriculture and Food Western Australia.

Abstract

A wealth of evidence exists about the adoption of new practices and technologies in agriculture but there does not appear to have been any attempt to simplify this vast body of research knowledge into a model to make quantitative predictions across a broad range of contexts. This is despite increasing demand from research, development and extension agencies for estimates of likely extent of adoption and the likely timeframes for project impacts. This paper reports on the reasoning underpinning the development of ADOPT (Adoption and Diffusion Outcome Prediction Tool). The tool has been designed to: 1) predict an innovation's likely peak extent of adoption and likely time for reaching that peak; 2) encourage users to consider the influence of a structured set of factors affecting adoption; and 3) engage R, D & E managers and practitioners by making adoptability knowledge and considerations more transparent and understandable. The tool is structured around four aspects of adoption: 1) characteristics of the innovation, 2) characteristics of the population, 3) actual advantage of using the innovation, and 4) learning of the actual advantage of the innovation. The conceptual framework used for developing ADOPT is described.

Key words: Adoption, Diffusion, Prediction

1 Introduction

The adoption literature is strong on describing a range of factors that can influence adoption of new technologies and practices in agriculture (Feder & Umali, 1993; Knowler & Bradshaw, 2007; Pannell, et al., 2006; Rogers, 2003). However, it is weak at providing tools and recommendations that allow research, development and extension (R, D and E) project proponents to understand how to best take advantage of these factors when they are developing or extending particular innovations. There does not seem to have been any substantial attempt to simplify the extensive knowledge of adoption and diffusion of agricultural innovations into a form that would make it easily accessible and usable by research scientists, extension agents and administrators.

Many large investments in R, D and E are made intending to achieve high rates of adoption but with little consideration of a rationale or an informed strategy for encouraging the desired levels of adoption (Pannell & Roberts, 2010). Without considering the influences on adoption and diffusion R, D & E investment can result in poor investment returns and unsatisfactory or illusory on-ground benefits. There is demand from R, D & E funding agencies for ex-ante assessments of adoptability and proposed practice change resulting from potential R, D & E investments. Being able to better estimate likely peak adoption levels and the time to peak adoption, and the related ability to take actions to improve adoption strategies of innovations, will be valuable for researchers, research managers and research funders. The use of a tool based on established adoption and diffusion principles also offers a level of consistency when comparing forecasts of impacts across projects. In addition, a more complete understanding of the attributes of innovations and how they influence adoption and diffusion, could allow the attributes of the innovation or the extension strategy to be modified so that levels of adoption and diffusion can be improved.

Even though adoption and diffusion is very difficult to forecast— the issue is complex and crosses economic, social and psychological disciplinary boundaries—there is an ongoing need and demand for estimates to be made. There is a need for a tool that can predict adoption and diffusion outcomes, inform users about influences on those outcomes and engage in the process. In the next section we review previous efforts and discussion on ex-ante prediction of adoption and diffusion. We then describe the conceptual framework used in developing ADOPT and the aims of the tool.

1.1 Predicting Adoption and Diffusion Outcomes: The Literature

The existing adoption literature has described the adoption process in detail but, because of its complexity, only modest progress has been made toward presenting this knowledge in a form that is useful for applying it to prediction of adoption and diffusion of innovations. In this section we review a selection of the existing approaches used for predicting adoption and diffusion and discuss the strengths and weaknesses of those approaches.

Dearing and Meyer (1994) were among the first to examine adoption and diffusion from the viewpoint of prediction rather than just focus on the influences on the adoption process. Various approaches have been used in previous attempts at predicting adoption and diffusion. One was to measure the complex socio-economic attributes contributing to adoption and diffusion by seeking the "opinions from a panel of experts that will contribute to the development of heuristic models and rules for behaviour of people as part of the adoption process" (TAMU, 2000, Section 6.8).

A more qualitative approach was taken by Dearing and Meyer (1994, p. 45) who suggested that adoption and diffusion can be predicted by identifying the "(1) perceptions of the innovator, (2) how the innovator talks about the innovation, and (3) the perceptions of potential adopters … ". They suggest that this approach is especially useful when attempting to determine the likelihood of adoption of innovations with similar characteristics.

The innovation most commonly used for ex-ante evaluation of adoption has been the introduction of bovine somatropin (bST) into the U.S. dairy industry. It was an ideal innovation for this purpose because it was near to commercialisation and farmers already knew about it (Caswell, Fuglie, & Klotz, 1998; Lesser, Bernard, & Billah, 1999; Zepeda, 1990). Caswell et al. (1998) identified three approaches used to study the predicted adoption and diffusion of bST as, 1) a simple survey of producers intentions, 2) an expected profits approach which used farm-level financial and other data to determine which producers would find the innovation profitable and therefore adopt it, and 3) an historical market trends approach which predicted adoption by extrapolating the future market for the use of the innovation.

Each of these ex-ante approaches has inherent disadvantages. The survey of producers' intentions (Armstrong, 2001; Lesser, et al., 1999; Zepeda, 1990) is susceptible to survey bias, while the expected profit approach (Caswell, et al., 1998) suffers from a reliance on assumptions of producers' risk attitudes, the costs of the innovation and prices gained for the farm outputs. The historical trends approach has limited usefulness when innovations have no corresponding similar innovation with available trend information (Caswell, et al., 1998; Langley, Pals, & Ortt, 2005; Sporleder & Liu, 1992, cited in Caswell, et al.1998). Lesser et al. (1999) suggest that surveys are not precise; but with wholly new innovations where there is no pre-existing information about the innovation they are the only practical method to use. The survey of perceptions of not yet adopters and adopters (Dearing & Meyer, 1994), as already mentioned, is best suited to choosing between similar innovations. Dearing and Meyer (1994) suggest that qualitative information should be gathered along with quantitative data to “create a composite picture of comparable innovations” (p. 56). Using a survey of past adoption behaviour to predict farmers adoption of different innovation (Batz, Janssen, & Peters, 2002) is an approach that is suitable if the innovation that is studied is similar to the one used to build the initial adoption model. Expert analysis (Armstrong, 2001; Langley, et al., 2005; TAMU, 2000) is also troublesome because experts are subject to bias.

The development of the conceptual framework and ADOPT were necessary because previous attempts were time-consuming because of their data collection requirements, not wholly successful. In addition there is an apparent demand. Pannell et al. (2006) published an exhaustive list of adoption influences, not just related to the innovation but also to the adopter, or potential adopter, and have provided a sound basis for the development of the conceptual framework which underpins the tool.

The conceptual framework, and the variables that were used were determined, in part, by the aims of the tool. These were that:

- The tool should not have high data demands because the resources and ability to collect extensive data for ex-ante analysis of adoption is usually going to be very limited.
- The tool should be simple enough to be readily used and understood by project practitioners and not just specialist R&D impact assessors
- The tool needed to encourage a process of learning from participative ex-ante evaluation with local experts and non-specialist project proponents. This was done by guiding and explaining to the user the reasons why the questions were being asked and how they influenced adoption and diffusion.
- The tool was required to promote users’ engagement with adoptability issues by more clearly focusing their attention on them. This process of concentrating the user’s attention occurs as they respond to twenty-one questions and consider the effect of the question’s attribute on adoption and diffusion.

- The tool needed to encourage users to think more deeply about the definition and characterisation of both the innovation under consideration, and the target population of potential adopters. The tool asks the user to describe in words the nature of the innovation and the target population. All of the questions are then answered with either the target population or the innovation in mind.
- Because there are many variables that influence adoptability and have been discussed in the literature factors included in the tool needed to be based on principles strongly established in the adoption literature. To minimise complexity at the same time as providing an acceptable result the 'established' variables became the focus of the tool. Other variables which do not occur or are not prominent in the literature, but can be assumed to have mediating effects on the established variables were also added in to the conceptual framework.

2 The Conceptual Framework

In this section we describe why and how the conceptual framework (see Figure 1) was developed and we describe how each of the variables that we have chosen for the conceptual framework influences adoption and diffusion.

The challenge with designing the conceptual framework was to develop a model of adoption and diffusion that balanced complexity and usability and fitted with the aims of the tool. This meant that not all of the established influences were included in the framework. Those that were not included lacked consistency, were likely to be too closely associated with variables already included in the model, were inconsistent in the direction of their relationship, had onerous data gathering requirements, or not a strong influence on adoption. Variables that were not included include age and education. Age, although commonly appearing in adoption studies, has an inconsistent relationship, and education which, although having an influence on adoption, is too hard to gather data for, at least in a way that differentiates the targeted population from others.

Because the conceptual framework "explains either graphically, or in narrative form, the main things to be studied—the key factors, concepts or variables—and the presumed relationship among them" (Miles & Huberman, 1994, p. 18) it formed the basis of the tool.

The final conceptual framework hypothesises the interrelationships between the influences on adoption and diffusion that we have sought to develop for a targeted population and innovation; it is a way to think about and view the variables that interact to influence adoption and diffusion.

Presenting the conceptual framework as a diagram could be expected to increase the number of people who are easily able to understand the reasoning for the framework. It enables easier communication among experts, non-experts and has even enabled more effective communication among the economists, sociologists, extension professionals and farming systems specialists of the interdisciplinary development team.

We chose variables matching those identified by Pannell et al. (2006) related to: networks, profit expectations, property size, the short term costs of adoption, the innovation's impact on profits, impacts on riskiness of production, the complexity of the innovation, perceived environmental credibility of the practice, able to be trialled on a small scale, able to be observed and readily apparent effects. Other variables used by Pannell et al. (2006) were not included because they were not strong influences on adoption and diffusion or not able to be quantified with existing information.

The literature shows that influences on adoption can be conceptualised as either related to, 1) learning about relative advantage, or 2) the actual relative advantage (see Table 1). Similarly each influence can also be characterised as being related to the population or to the innovation. The influences on adoption can be described conceptually using a quadrant that includes:

Table 1: Adoption influences conceptualised as a quadrant

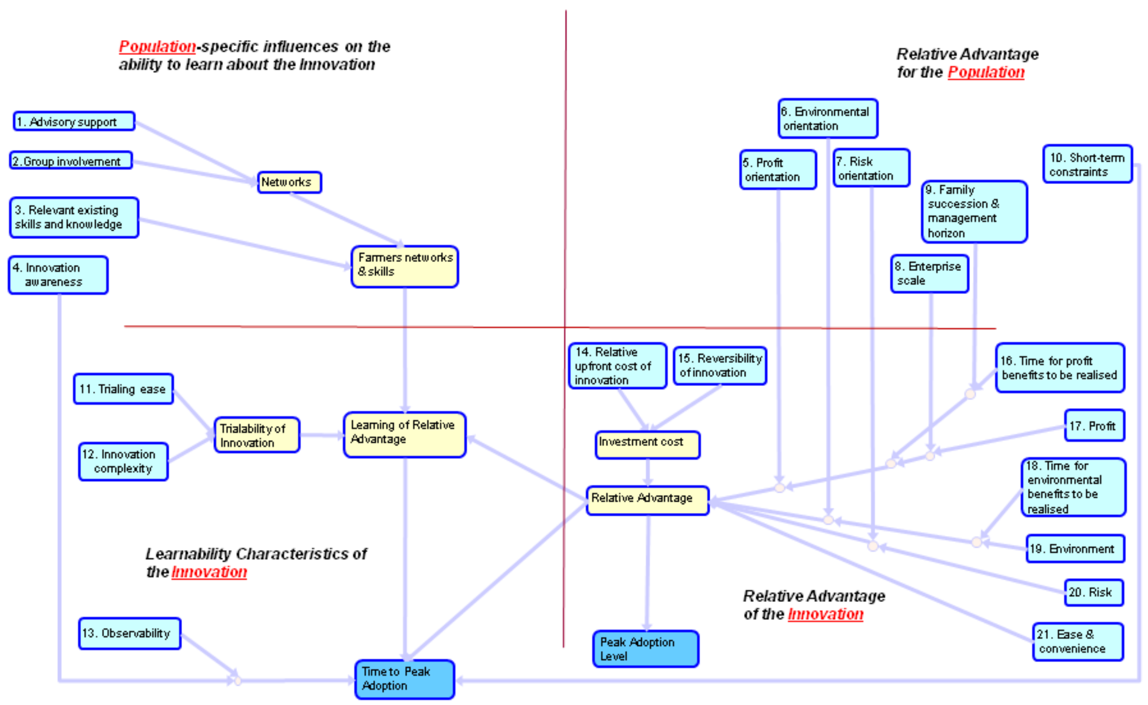
Population-specific influences on the ability to learn about the innovation	Relative advantage for the population
Learnability characteristics of the innovation	Relative advantage of the innovation

This quadrant is designed as a summary of how the conceptual framework works; it is a simple description of the ambiguity that is an adoption decision.

The conceptual framework (see Figure 1) shows that the two left-hand quadrants—*Population-specific influences on the ability to learn about the innovation* and the *Learnability characteristics of the innovation*—only influence the time taken to reach peak adoption; they do not influence the peak adoption level (Griliches, 1957).

The *Relative advantage for the population* and the *Relative advantage of the innovation* influence both the time taken to reach peak adoption and the peak adoption level. They influence the time taken to reach peak adoption in two ways (Griliches, 1957). Short-term constraints have a direct impact while the other variables have a more filtered effect in that *Relative Advantage* also affects the *Learning of Relative Advantage* node.

Figure 1: The Conceptual Framework



3 The Conceptual Framework Variables

This next section presents reasons for choosing the variables used in the conceptual framework. The variables in each of the four quadrants are dealt with in turn and followed by a general discussion of how the variables can influence adoption.

3.1 Learnability of Population Quadrant

The top left quadrant (Fig. 1) is about considering the population-specific influences on the ability to learn about the innovation. Adoption involves a learning process where farmers gather information, reassess their beliefs about the innovation under consideration and review their decision whether to adopt or not. Constraints to the learning process slow the time to peak adoption but they are not complete obstacles (Lindner, 1987). This quadrant is about learning of the benefits, or the relative advantage provided by the innovation. Learning has an important role to play because adoption is a decision that is made under uncertainty which is reduced through learning (Jensen, 1982). The four variables contributing to this quadrant are discussed in subsections 3.1.1 to 3.1.4.

3.1.1 Group Involvement: What proportion of the target population participates in farmer groups?

This variable is aimed at uncovering whether the target population are involved with at least one group that is relevant to the innovation. It is being used as an indication of the information networks that the targeted farmers use, as well as a de facto measure of their local learning and development capacity. It is related to participation in groups that are potentially related to the innovation; for example a local farming systems group involving crop-livestock farmers for a grazing-related innovation. As an example, a positive relationship has been found between farmers' membership of Landcare groups and their adoption of specific conservation practices (Cary, Webb, & Barr, 2002; Curtis & De Lacy, 1996) although the direction of causality is uncertain.

3.1.2 Advisory Support: What proportion of the target population uses paid advisors for advice relevant to the innovation?

More rapid adoption of some innovations, particularly those that are more information-intensive or complex, is associated with higher levels of on-farm advisory support and access to expertise (Llewellyn, 2007). This variable aims to uncover how much the target population uses advisors for advice relevant to the innovation. Advisory support and the previous variable Group involvement are combined to form the node labelled Networks. Networks are an important variable to consider because, at least initially, potential adopters have incomplete information and do not know everything that matters about the innovation (Hiebert, 1974).

3.1.3 Relevant Existing Skills & Knowledge: What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?

This variable is designed to capture whether potential adopters will need to spend time developing new skills and knowledge before they can gain the expected advantage from the innovation. The *Relevant Existing Skills and Knowledge* variable is aimed at establishing how adequate farmer's existing knowledge is for adopting the innovation. More complex innovations require users to undertake more training or skill development before they will be adopted (Rogers, 2003).

3.1.4 Awareness: What proportion of the target population would be aware of the use or the trialing of the innovation in their district?

This variable is intended to capture the target populations' existing awareness of the innovation and whether more time will be needed for the target population to become aware that the innovation exists and is suitable for their local environment. It is one of the types of knowledge of an innovation that is a prerequisite for adoption (Rogers, 2003).

3.2 Learnability Characteristics of Innovation Quadrant

This bottom left quadrant (Fig. 1) is not about considering the population but it is about considering the innovation-specific influences on the ability to learn about the innovation. Some innovations by their nature will be difficult to learn about while others will be easy to learn about.

3.2.1 Trialable: How easily can the innovation be trialled on a small scale before a decision is made to invest in full adoption?

Trialing has two components; skill development and the reduction of uncertainty (Feder & Umali, 1993). Skill development happens by practising the use of the innovation and accumulating experience. If small-scale trials are not possible or not enlightening, the chances of widespread adoption are greatly diminished. "Trialability is the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003, p. 258). If farmers cannot trial the innovation, so that they can easily and inexpensively gain knowledge and experience about the innovation under their farm conditions, the rate of adoption can be diminished (Abadi Ghadim, Pannell, & Burton, 2005; Pannell, et al., 2006).

3.2.2 Innovation Complexity: To what extent does adopting the innovation involve complex changes to the farming system?

Rogers (2003) defines complexity in an adoption context as "the degree to which an innovation is perceived as relatively difficult to understand and use" (p. 257). This means that greater complexity increases the difficulty, required effort and time to learn about the innovation's performance and how best to implement it.

Innovations that require complex changes make the farming system more difficult to understand and also can make it more difficult for the farmer to evaluate whether the innovation has been successful (Pannell, 1999; Vanclay, 1992).

3.2.3 Observability: To what extent would the innovation be observable to other farmers when it is used in a district?

Rogers (2003) suggests "observability is the degree to which the results of an innovation are visible to others" (p. 258). Innovations with characteristics that allow the target population to easily observe the benefits of the innovation and whether it has, or is, being used by those around them will result in higher rate of adoption than otherwise. This question focuses on observation of the use of an innovation which enables more rapid awareness of its existence and local use.

3.3 Relative Advantage for the Population Quadrant

The top right quadrant (Fig. 1) is about establishing whether the advantage, potentially, gained from adopting the innovation is a sufficient motivation to shift the population towards adoption of the innovation.

3.3.1 Enterprise Scale: On what proportion of the farms in the target population is there a major enterprise that could benefit from the innovation?

This variable aims to define the number of farms among the target population who could benefit from adopting the innovation. This is because a large enterprise scale will usually increase the overall attractiveness of adopting the innovation (Hoag, Ascough, & Frasier, 1999). During the intial stages of diffusion larger enterprises are likely to invest more in information gathering (Feder & Slade, 1984) which could be because they have greater access to financial and human capital.

3.3.2 Family succession/Management horizon: What proportion of the target population has a long-term (greater than ten years) management horizon for their farm?

Although it is common in adoption studies to include the age of the grower as an explanatory variable, in this conceptual framework *Family succession and Management horizon* has been used instead to identify the planning horizon of growers. It is probable that farmers (regardless of their age) who intend to manage the farm business for a longer period, or who have family members who wish to continue operating the business over the longer term, are more likely to consider innovations that require a longer period before benefits are fully realised, or a larger upfront investment of resources (and thereby a longer period for the investment to provide a return on costs) (Gasson & Errington, 1993). The response to this question is weighted more heavily for innovations that involve a longer period for benefits to be realised or higher upfront costs in the form of capital and learning.

3.3.3 Profit Orientation: What proportion of the target population has maximising profit as a primary motivation?

Achieving a profit is not the only motive of farm business decision-makers and sometimes not one of their primary motives. An instance where few landholders in a population have profit as a primary motivation are those areas with 'hobby'-sized farms that are supported by off-farm income. In most of Australia's commercial broadacre farming regions it could be assumed that profit maximisation is one of the farmers' primary motives. However, assuming that a farmer focuses on profit for its own sake can be a mistake because profit is often pursued for its role in enabling family goals such as family continuity (Pannell, et al., 2006). *Profit orientation* mediates the influence of other factors related to the expected profit to be gained from adopting the innovation.

3.3.4 Environmental Orientation: What proportion of the target population has caring for the natural environment as a primary motivation?

This variable is intended to measure the proportion of the population who are likely to pursue environmental payoffs as a primary goal of their management decisions. Although sustainable management of the natural resources of the farm are likely to be very important for a majority of farmers, some populations are likely to contain more people for whom care of the natural environment is an equally or more important motive than profit. In some regions with less commercially oriented farm production, some target populations have many land managers who own land primarily with the intention of interacting with or improving the natural environment. *Environmental Orientation* mediates the influence of the expected environmental impacts of the innovation, relative to other variables in the *Relative Advantage* quadrant such as *Profit* and *Ease and convenience*.

3.3.5 Risk Orientation: What proportion of the target population is highly averse to taking farm business management risks?

This variable seeks to uncover the target populations' attitude towards the type of farm business risk, both negative and positive, which is incurred to reach a particular economic goal in the future (Zaleskiewicz, 2001). Farmers vary widely in their tendency to take or avoid risks in their decision making. The more risk-averse a landholder is, the more likely they will be to adopt an innovation that is perceived to reduce risk or not to adopt an innovation that is perceived to increase risk. Most populations of farmers should have similar levels of risk aversion although it is commonly assumed that farmers tend toward slight risk aversion. This variable mediates the influence of the innovation characteristics associated with risk.

3.3.6 Short-term constraints: What proportion of the target population is under conditions of short-term resource constraints?

This variable is aimed at determining the proportion of the target population that may be less willing or able to make a capital investment in an innovation involving a substantial up-front investment because of their short-term capital constraints e.g. due to current drought. These constraints are considered transitory, but when they are active they are extremely important. This variable has its greatest influence on the likelihood of rapid adoption in the short-term by delaying adoption by several years.

3.4 Relative Advantage of the Innovation Quadrant

The bottom right quadrant (Fig. 1) is important because it deals with the advantages of the innovation. It deals with the part of *Relative Advantage* that is derived from the innovations' characteristics; it is not related to how the population perceives the innovations characteristics.

3.4.1 Relative upfront cost of innovation: What sized initial investment is required to adopt the innovation?

The initial costs of the innovation expressed relative to the ongoing cost of using the innovation may affect the rate of adoption (Rogers, 2003). Innovations requiring high upfront costs compared with their financial returns and with benefits occurring sometime after the investment is made are perceived as riskier and are less likely to be adopted quickly (Vanclay, 1992).

3.4.2 Reversibility of innovation: To what extent is the adoption of the innovation able to be reversed?

This variable is designed to uncover the *Reversibility* of an innovation; a factor that influences the potential cost of adoption by making it difficult to do something else at a later date. It is the degree to which, and the ease with which, the pre-adoption status quo can be reinstated. Irreversibility of an innovation can lead to slow rates of adoption (Baerenklau &

Knapp, 2007).

3.4.3 Profit Benefit: To what extent is the use of the innovation likely to affect the average profitability of the farm business?

This variable is designed to gauge the profit to the overall farm business from the adoption of the innovation rather than seeking a per hectare or a gross margin figure. It aims to capture the typical expected profit benefit of an innovation once its profit benefits are being fully realised. This question is aimed at identifying the typical level of profitability that would be expected for a normal season.

3.4.4 Time for Profit Benefit: How long would it take for most of the major profit benefits to be realised after the innovation is first adopted?

This variable aims to capture the expected time delay before the profit benefits measured by the previous variable are achieved. The longer it takes to receive profit benefits the lower the net present value of those profits. Landholders who need to focus on profits in the short-term are less likely to adopt innovations with long time to profit benefits. This variable mediates the profit benefit response.

3.4.5 Risk effect: To what extent would the use of the innovation expose the farm business to risk?

This variable is aimed at identifying whether the innovation reduces the possibility of the farm business experiencing years of poor performance. Adoption of anything new is likely to involve some level of risk; however, some innovations are more likely to expose the farm business to risk of financial failure than others.

3.4.6 Environmental Costs & Benefits: To what extent would the use of the innovation have on-farm environmental advantages or disadvantages?

This variable aims to uncover the environmental costs and benefits of adopting the innovation. Other variables in the conceptual framework focus on expected time to full environmental benefit (see Section 3.4.7), and are designed to capture the lengths of time involved from when adoption starts until the time that environmental advantages are fully realised.

3.4.7 Time to Environmental Benefit: How long would it take for most of the major environmental benefits to be realised after the innovation is first adopted?

This variable aims to capture the expected time delay before the anticipated environmental benefits identified in the previous question are achieved. If environmental payoffs are expected to occur too far into the future, no matter what those payoffs are they will have less current value. This variable mediates any environmental benefit identified by the previous variable.

3.4.8 Ease and Convenience: To what extent would the use of the innovation affect the ease and convenience of the management of the farm?

Some innovations do not aim to just increase production or financial gains but their value is in improving the ease with which some farming activities can be performed as well as potentially providing lifestyle benefits. This variable is aimed at identifying these non-pecuniary costs and benefits. An innovation that introduces more management demands, reduces ease and convenience and is therefore less likely to be adopted.

4 The Tool

ADOPT aims to operationalise a conceptual framework based on well established adoption theory and literature (Feder & Umali, 1993; Lindner, 1987; Pannell, et al., 2006; Rogers, 2003). The tool provides the interface for users to interact with the thinking and the concepts described in the framework. Based on an Excel spreadsheet the tool asks users to describe the innovation and the target population in words. Users are then asked to make a choice between five options (except for *Profit* which has eight) in response to questions for each of the twenty-one conceptual framework variables. The responses provided by users are represented by numerals from one to eight. These are used in equations and functions that have been constructed to model how we think the variables of the conceptual framework relate to each other, and the influence they have on adoption and diffusion. This was done by considering the strength, direction and the nature of the influence of the variables.

The outputs of the tool are values in years for the *Time to Peak Adoption* and a percentage value for the *Peak Adoption Level*. The expected characteristics of the innovation's diffusion is also graphically displayed using an S-shaped curve consistent with those found in diffusion literature (e.g. Griliches, 1957; Marsh, Pannell, & Lindner, 2000).

4.1 Testing and further development

As part of the development process for the tool it has been tested by eleven regional co-ordinators for the Grain & Graze 2 program who examined twenty-eight ex-ante projects overall (Kuehne, Nicholson, Robertson, & Llewellyn, 2011). After using the tool the co-ordinators were interviewed. One reported: "The rate of adoption calculated was often really slow—depressing! ... It shows good reasoning why it would be slow ... ". Even though they thought the *Time to Peak Adoption* was longer than what they wished for (bearing in mind that this figure affected the attractiveness of their projects for future funding) they felt that the tool provided plausible explanations for why this was the case. This early testing of the tool was reassuring in that it showed that the hoped for and important aim of predicting adoption was not illusive, but with further development and testing was likely to be achieved. They also said that: "The real value is that it makes you think why we do something—the constraints and leverages". This comment showed that the tool worked to inform users about the influences on adoption and diffusion which was another aim of the tool. Showing how the tool works to engage participants one said, "… responding to the questions made you think, especially about the audience, the social factors and the risk aspects". Early testing of the tool is encouraging with users cautiously suggesting that the tool appears to achieve each of its' aims. To ensure a more robust tool validation is also being conducted using diffusion data sets when the speed and extent of adoption and most of the twenty one variables used in the tool are already known. After testing, validation and any refinements to the tool are completed, the inner workings of the tool— the reasoning and the process by which the tool generates its outputs—will be described in a subsequent publication.

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