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ENCOURAGING USE OF SEASONAL CLIMATE FORECASTS BY FARMERS

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ABSTRACT

What encourages use of seasonal climate forecasts? Considerable effort is being applied in developing seasonal climate forecasts and demonstrating the potential benefits available to farmers from using seasonal climate forecasts. This study examines three factors underlying the use of seasonal climate forecasts by farmers: the level of forecast *understanding* by farmers, the *format* presentation of the forecasts, and the *attitude* of farmers towards the usefulness of forecasts as indicators of future rainfall. Using judgement analysis, the use of forecasts in cropping decisions was determined for 73 Australian farmers. Then a moderated regression analysis was used to predict forecast use from the three underlying factors. The study found that a good understanding of the forecast was more important than the forecast format in predicting its use. However, this main effect of good understanding on higher use was qualified by a three-way interaction, such that good understanding was only associated with higher use when farmers had a favourable attitude toward the usefulness of seasonal climate forecasts and the forecasts were presented in a frequency format. Thus, the study found all three factors were important in predicting the use of seasonal climate forecasts by farmers. However, relatively little is known about farmer attitudes toward the usefulness of seasonal climate forecasts and how these attitudes arise, and further research is recommended in these areas. Copyright © 2005 Royal Meteorological Society.

KEY WORDS: seasonal climate forecast use; understanding; format; attitude; judgement analysis; southern Queensland

1. INTRODUCTION

What factors encourage use of seasonal climate forecasts (SCFs)? There have been promising developments in seasonal climate forecasting since the late 1980s due to an increasing understanding of the relationship between rainfall and the southern oscillation index (SOI; Clewett *et al*., 2000; Meinke and Hammer, 2000; Meinke and Hochman, 2000), including the development of SCFs for relatively small local areas (Stone *et al*., 1996). There is also a growing body of evidence demonstrating that using SCFs in decisions can benefit farming operations and improve profitability (Hammer *et al*., 1996; Hammer and Nicholls, 1996; Meinke *et al*., 1996; Hammer, 2000; Meinke and Hammer, 2000; Meinke and Hochman, 2000). Despite this, a range of studies show that use of seasonal climate forecasts is relatively low (Changnon, 1992; Sonka *et al*., 1992; Hastings, 1993; Virtual Consulting Group Australia, 1999), though a more recent study of 2500 Australian farmers shows increasing use of seasonal climate forecasts (Climate Variability in Agriculture R&D Program, 2001). This paper investigates some psychological factors underlying SCF use.

Studies of SCF usefulness often assume that useful SCFs will be used (Schneider and Garbrecht, 2003). This is not a safe assumption, and the concepts of SCF usefulness and SCF use need to be distinguished from each other. Useful SCFs can be defined in terms of an ability to predict seasons that deviate from climatological norms (Schneider and Garbrecht, 2003) and can be measured relatively easily by comparing seasonal predictions with seasonal outcomes. In contrast, SCFs use refers to the extent to which decision makers incorporate SCF information into their decision-making processes. However, measuring SCF use is

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complex: not only are many sources of information involved in any one decision, but individual psychological factors are also involved in the decision-making process.

The approach taken in this study was to use a technique called judgement analysis to measure individual SCF use by farmers, which can then be related to other individual characteristics. Judgement analysis is a well-established technique for quantifying the use of different pieces of information in judgement and decision making (see Cooksey (1996) and Stewart (1988)), and involves randomly varying these pieces of information by presenting a wide range of scenarios to a decision maker. In this study, farmers made cropping decisions based on varying information about SCFs, on-farm prices for summer crops, debt/asset ratios, income flows over the past 12 months, nutrients available in the soil, and soil moisture. From these decisions, a measure of individual SCF use was calculated and then related to three psychological factors hypothesized to underlie SCF use; namely: SCF *format* (how farmers perceive different SCF formats), SCF *understanding* (how well farmers understand SCFs), and SCF *attitudes* (farmer attitudes toward the usefulness of SCFs).

1.1. Psychology and seasonal climate forecasts

SCFs are most commonly presented in terms of probabilities; for example, the probability of above-median rainfall, the probability of at least average rainfall, or the probability of rainfall in the top tercile. Thus, using SCFs also requires human abilities to reason with *probabilities*, which has been subject to considerable psychological research.

Kahneman and Tversky's *Heuristics and Biases* programme of research suggests that human minds do not possess the proper statistical algorithms to reason with probability theory (e.g. Tversky and Kahneman, 1974; Kahneman *et al*., 1982). According to this perspective, humans are regarded as poor intuitive statisticians, making reasoning errors such as base rate neglect, overconfidence and the conjunction fallacy (Cosmides and Tooby, 1996), and examples of these reasoning errors have been applied to using SCFs (Nicholls, 1999, 2000; White, 2000).

However, research by Gigerenzer (1991, 1994) has challenged this perspective by showing that many of the reasoning errors associated with probabilities can be overcome by presenting the information in a particular format: a frequency format. Gigerenzer (1991, 1994) argues that humans are not inherently poor statisticians, but that 'reasoning errors' occur because of confusion about what is meant by the word 'probability'. He suggests that this word has two meanings, and that presenting probabilistic information in a frequency format clarifies which meaning of the word 'probability' is being used.

The two different meanings of the word 'probability' arise from two different theories of probability: the frequency and subjective probability theories. According to the frequency probability theory, probabilities can only sensibly refer to frequencies of events that have occurred in the past within a specific reference class. An example of a frequency format applied to SCFs is: 'In the last 120 years there were 23 years when rainfall was in a rising SOI phase in April. In these 23 years there were 16 years (or 74%) when rainfall exceeded the long-term median in the three months that followed'. In essence, the frequency format emphasizes historical events and the notion of chance.

The subjective probability theory refers to the fact that probabilities can be used to express degrees of confidence about the occurrence of future events. Proponents of this approach argue that it makes sense to use probabilities in this way because it makes sense to express our confidence about a single event occurring in the future, and because we can sensibly refer to the probability of a single event occurring in the future (Gigerenzer, 1994). In this context, SCF probabilities may be seen by farmers as expressions of confidence in predictions about future events made from causal models under a range of assumptions, rather than representing the frequency of historical events. However, SCFs intending the word 'probability' to be interpreted using frequency probability theory often present the SCF in a *single-event probability* format, which can easily infer that 'probability' should be interpreted using subjective probability theory. An example of a single-event probability format for a SCF is: 'In the next 3 months there is a 30% probability of above-median rainfall'. In essence, this single-event probability format emphasises a future event and the notion of predictability.

A farmer reading an SCF including the words 'a 30% probability of above-median rainfall' may interpret the SCF in two ways, depending on whether they have a frequency or subjective perspective of the probability.

Under the frequency perspective, it implies a 70% chance of below-median rainfall; under the subjective perspective, it implies a prediction of above-median rainfall, though with a low level of confidence. Although SCFs are typically meant to be interpreted using the frequency conception of probability rather than the subjective conception of probability, the SCF formats often do not make it clear to farmers which conception is applicable. Gigerenzer would argue that presenting an SCF in a frequency format makes explicit which conception of probability is being used and, consequently, reduces the confusion that leads to reasoning errors. Reducing this confusion may also lead to higher SCF use.

Improving farmer understanding of SCFs often centres on educational initiatives such as media releases, short courses and extension activities. As alluded to, another way of improving understanding is through using frequency formats. Coventry (2001: Study 1) found that farmers reported a clearer understanding of SCFs when presented in a frequency format as opposed to a single-event probability format. Farmers also preferred the frequency format for conveying the forecast to other farmers compared with the single-event probability format, and perceived this format as less misleading when the season outcome was inconsistent with the SCF. However, Study 2 in Coventry (2001) also found that SCFs in frequency formats did not influence crop yield judgements as much as SCFs in a single-event probability format, which implies that farmers make less use of SCFs in a frequency format. This is surprising given that farmers preferred the frequency format, and suggests that something other than understanding and format may also influence the use of SCFs.

Attitudes among farmers toward the usefulness of SCFs for predicting seasonal rainfall outcomes were noticed to vary markedly during a pilot test of the survey instrument for this study. Social psychologists have previously shown that attitudes influence people's intentions and their behaviour, including the behaviour by farmers in adopting innovative farm practices (Lynne *et al*., 1995). Therefore, an additional question on the farmers' attitudes toward the usefulness of SCFs was added to the survey to see whether attitudes influenced SCF use. It seemed plausible that unfavourable attitudes could result in lower use of SCFs, regardless of SCF understanding or SCF format.

An attitude is a consistent tendency to respond toward an object in a favourable or unfavourable way (Allport, 1935; Katz, 1960; Fishbein, 1967). They are derived from both direct and indirect experiences (Campbell, 1963; Rajecki, 1990; Ajzen, 1993) and are relatively stable over time (Ajzen, 1993). Attitudes involve both cognitive beliefs about outcomes of adopting particular behaviours and emotional evaluations (Ajzen and Fishbein, 1980). The fact that attitudes also include emotional evaluations means that SCF use may not rely entirely on cognitive aspects such as SCF understanding and format. SCF use may also be influenced by emotional experiences, such as the negative emotional experience associated with experiencing losses after relying on a favourable SCF that was followed by an unfavourable seasonal outcome.

1.2. Hypotheses

The first hypothesis was that higher SCF use would be associated with greater SCF understanding (H1), based on the assumption that people are more likely to use information they understand well. The second hypothesis was that higher SCF use would be associated with a frequency format (H2), based on the assumption that people are more likely to use information that is less confusing. The third hypothesis was that higher SCF use would be associated with a more favourable attitude toward the usefulness of SCFs (H3), based on the assumption that more use is made of information perceived as useful. The interactions with attitude were also tested based on the assumption that farmers with unfavourable attitudes toward SCFs would not have higher SCF use, regardless of the level of their SCF understanding or the SCF format (H4).

2. METHOD

2.1. Participants

The participants were 73 male farmers (mean age: 45 years) from grain-growing regions in southern Queensland and northern New South Wales, Australia, who undertook dryland cropping operations and who had previous experience with opportunity cropping practices. Dryland cropping refers to cropping without the assistance of irrigation, and opportunity cropping refers to planting directly after another crop in the same paddock to capitalize on opportunities such as high market prices. These farmers were selected so they would be familiar with the decision scenarios presented to them.

The farmers were randomly selected from telephone directories and invited to participate in the study if they met the above criteria. Of the farmers contacted, approximately 30% participated in the study and all these farmers, except one, had seen SCFs before. In fact, most of the farmers (64%) were either familiar or very familiar with the SCFs used in the region (e.g. 'the probability of exceeding median rainfall in the next 3 months is _%') and only six farmers considered themselves unfamiliar with them. No incentives were provided to farmers to participate, other than giving them feedback on their decision-making characteristics and providing information on SCFs, both of which were done at the end of the session.

2.2. *Design*

A 2×2 mixed design was used, with SCF format (frequency and single-event probability formats) as a between-groups factor and with planting decision (before and after receiving the SCF) as a within-groups factor. Farmers were randomly allocated to one of two SCF format groups (for more detail on the formats, see climate information below). With the within-groups factor, farmers were asked to make planting decisions both before and after receiving an SCF. Although it was not possible to counterbalance the before and after conditions in this factor, any sequencing effects where statistically controlled in the measure of SCF use.

2.3. *Materials*

2.3.1. Information included in decision scenarios. Dryland opportunity cropping decisions (as opposed to cropping decisions more generally) were used for two reasons. First, opportunity cropping leads to reduced soil moisture, and this increases the salience of the SCF information being studied. Second, with opportunity cropping, scenarios could be constructed to increase the variability in the decision to crop, and this is desirable for statistical reasons.

As part of the judgement analysis, each scenario included a range of information relevant to cropping decisions, and this information was randomly varied in each of the scenarios. Important factors in dryland opportunity cropping decisions were identified by a content analysis of responses to an earlier pilot survey that asked farmers to identify such factors. The information varied in the scenarios is outlined below. However, the scenarios also included some standard information that did not vary in each scenario: the crop planted (sorghum in most cases); the season (summer); and the preceding crop in that paddock (wheat). Assumptions were also made about a range of factors to simplify the scenarios: no apparent weed or disease problems at planting; sorghum grown for grain rather than grazing; no storage available for the sorghum (i.e. sorghum sold at the on-farm price provided); no irrigation; and the farmer used their standard cultivation practices and fertilizer application rates.

Definitions for each of the six factors that were systematically varied are provided below. The first five factors are presented using bar graphs (e.g. see Figure 1) and the SCF is presented in written form.

On-farm price for summer crop. The ranges for on-farm prices of summer crops were determined after discussions with a number of grain merchants and local growers in Toowoomba, southeast Queensland.

Debt/asset ratio. This was defined as the ratio of total farm debt to total farm assets, expressed as a percentage. Values presented ranged from 0 to 60%, which was typical of farmers surveyed.

Income flow over the past 12 months. This referred to gross farm income for the 12 months prior to the opportunity cropping decision. This was a subjective measure, ranging from very poor to very good. Participants were asked to assume no off-farm income.

Nutrients available to the soil. This was an estimate of the soil quality for growing the summer crop without any fertilizer application. This factor was also a subjective measure, ranging from very poor to very good.

Soil moisture. The soil moisture depth was based on the notion of a 'full profile' which is the maximum depth of soil moisture measured for planting purposes in the paddocks the farmers had chosen for their decisions. This factor ranged from an empty profile to a full profile.

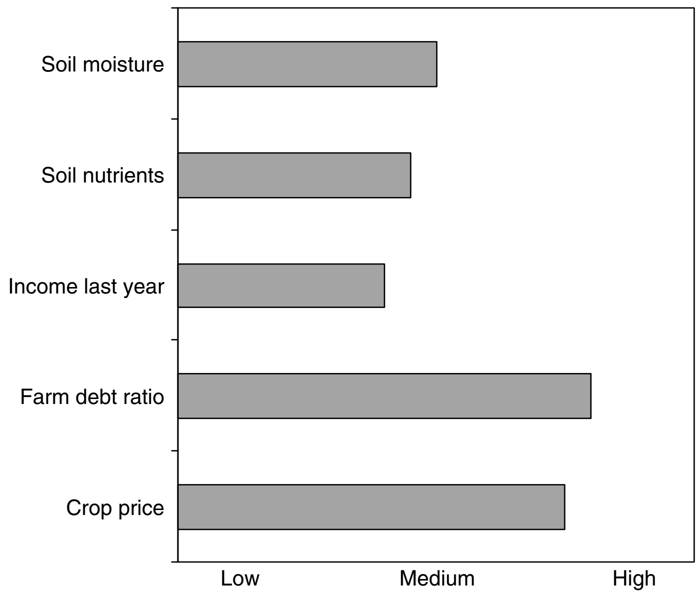

Figure 1. Bar graph presentation of factors systematically varied in the decision scenarios

Table I. The judgement scale for the strength of evidence for the decision to opportunity crop

Decision	No	No	No	Yes	Yes	Yes
Confidence	3	2	1	1	2	3
Judgement scale	1	2	3	4	5	6

SCF information. The SCFs presented the probability of above-median rainfall over a 3 month period using six different probability levels: 25%, 35%, 45%, 55%, 65% and 75%. The forecasts were presented in either a frequency or single-event probability format. The frequency format referred to multiple events in the past; for example, 'There have been 25 years with SOI phases like the current phase. In six of those 25 years (25%) rainfall was above the median in the 3 months that followed'. The single-event probability format was similar to that used in the local media and referred to a single event in the future. For example, 'Based on the SOI phase, the probability of getting above-median rainfall in the next 3 months is 25%'.

2.4. Measures

2.4.1. Planting decisions and judgement scales. Farmers were asked to make decisions about whether to opportunity crop after viewing the factors in each scenario. After each decision, they were asked to indicate their level of confidence in the decision: 1 = 'I am not completely certain that this is the right decision'; 2 = 'I am moderately comfortable with this decision'; and 3 = 'I am absolutely positive that the decision will be right'. This information was used to construct a six-point judgement scale, as shown in Table I. This judgement score is a measure of confidence or strength of evidence for a decision to opportunity crop (1 = very little strength of evidence; 6 = very strong evidence to plant).

2.4.2. SCF use. The measure of SCF use was based on the difference in judgement scores between cropping decisions made prior to and after receiving SCF information. For example, a farmer may decide to opportunity crop but not be completely certain that this was the right decision (a prior judgement score of 4). Then they may receive an unfavourable SCF and decide not to opportunity crop, and may feel moderately comfortable that this was the right decision (a post-judgement score of 2). In this case, the difference in judgement scores would be 2.

These difference scores vary with the different SCF levels (i.e. 25%, 35%, 45%, 55%, 65% and 75% chance of above-median rainfall). If a farmer makes little use of the SCF, then there will be little change in difference scores across each level of the SCF. However, if the farmer makes much use of the SCF, then there will be considerable change in difference scores across each level of the SCF. To capture the concept of SCF use as the variation in difference scores across levels of the SCF, an F statistic was calculated for *each* farmer using a one-way analysis of covariance (ANCOVA) on the difference scores across levels of the SCF.

Using an F statistic as a measure of SCF use has two advantages. First, no assumption is needed about a linear relationship between SCF levels and SCF use. Second, the ANCOVA method generating the F statistics can statistically control for any influence of the other judgement factors, as well as the prior judgement, by entering them as covariates. This statistical procedure minimizes any possible carryover or sequencing effects in the experiment. However, F statistics are positively skewed, so the square root of the F statistic was then taken to normalize this distribution. In summary, SCF use was measured as the square root of the F statistic from an ANCOVA using judgement difference scores across levels of the SCF, controlling for the other factors and the prior judgement.

2.4.3. SCF understanding. SCF understanding was measured using six multiple-choice questions. They tested the extent to which farmers held a frequency or single-event probability interpretation of the SCF and were based on characterisations of frequency and single-event (or outcome) orientations by Konold (1989). One mark was given for correct answers and one mark deducted for incorrect answers, and the SCF understandings scores ranged from $+7$ to -7.

The test was also given to 12 climate forecasters and agricultural extension officers to validate this measure of SCF understanding. As expected, these participants scored highly on the test (mean: 86%), far above the average score for farmers surveyed (mean: 39%). This provided evidence of the measure's validity, and also showed a relatively poor SCF understanding by farmers on average.

2.4.4. SCF attitude. SCF attitudes were measured using the question 'What is your attitude toward the usefulness of the climate forecast as an indicator of future rainfall?' An example was given of the SCFs used in the region, and the responses were recorded on a six-point scale, from 1 = extremely unfavourable to 6 = extremely favourable.

2.5. Procedures

Prior to undertaking the judgement and decision task, farmers completed a questionnaire. This covered farmer and farm characteristics, familiarity with and attitude toward SCFs, as well as testing their understanding of the SCF. Then the decision-making task was explained to farmers, including the opportunity cropping scenario, the assumptions, and the ranges for the information varied in the scenarios. After this, farmers had a practice session using seven scenarios designed specifically to elicit both yes and no decisions and a range of confidence levels in those decisions. After the practice session, farmers made opportunity cropping decisions for 100 different scenarios. For each scenario, farmers were asked to provide a decision and a confidence level based on information that did not include the SCF. Then they were given an SCF and asked to 'remake' the decision and provide another confidence level. At the end of the decision-making session, an information session was provided on the SCF to ensure that each farmer had a basic understanding of the SCF.

3. RESULTS

3.1. Descriptive statistics

Table II shows the frequency distribution for selected variables. Generally speaking, farmers were familiar with the SCF and had a positive attitude toward it. However, as mentioned, the average score for understanding the SCF was low. However, some of the farmers (18) had attended a 'Managing for Climate Risk Workshop' (MCRW) and this was *correlated* with more understanding and a more favourable attitude toward the

Table II. Frequency table for selected variables

	Frequency
Seen the seasonal climate forecast before?	
No (1)	1
Yes (2)	73
Familiarity with the forecast	
1 (familiar)	35
2	11
3	20
4	5
5 (unfamiliar)	1
Attended MCRW	
No (1)	55
Yes (2)	18

Table III. Correlation matrix between selected farmer attributes

	Workshop	Attitude	Understanding	Format	Use	Statistics
Attitude	0.30**					
Understanding	0.41**	0.22				
Format	0.08	0.05	0.14			
Use	0.10	0.10	0.29*	0.30*		
Statistics	0.29*	0.16	0.43**	0.06	0.29*	
Age	0.02	0.01	−0.24*	−0.08	−0.14	−0.01

* $p < 0.05$; ** $p < 0.01$.

usefulness of the SCF (see Table III). However, attending the workshop was not significantly correlated with higher use of the SCF.

As expected, SCF use was significantly correlated with both understanding and format. Those farmers with more understanding and those given a frequency format were likely to make more use of SCFs. However, SCF use was not significantly correlated with attitude toward the usefulness of SCFs. Also positively correlated with SCF use was 'statistics', which was a personal characteristic of farmers referring to whether a farmer had had any statistical training in their educational background (No = 1, Yes = 2). Those who had had statistical training also tended to be younger farmers. These last two variables (statistics and age) were entered as covariates in the regression analysis to control for any possible confounding effects of personal characteristics.

3.2. Regression analysis

A moderated regression analysis was conducted to predict SCF use from the independent variables SCF format, SCF understanding and SCF attitude, as well as interactions between these independent variables. This model explained a significant amount (28%) of the variation in SCF use, $R^2 = 0.28$, $F(7, 63) = 3.52$, $p < 0.01$. Supporting H1, a main effect was found for SCF understanding such that greater SCF understanding was associated with higher SCF use, and this explained 7% of SCF use, $sr^2 = 0.07$, $b = 0.27$, $t(67) = 2.23$, $p < 0.05$. However, no support was found for H2; no significant main effect was found for SCF format, $sr^2 = 0.02$, $b = 0.14$, $t(67) = 1.20$, $p = 0.23$. It seems that even though Table III showed a significant correlation between SCF format and SCF use, format was not a significant predictor of SCF use when also taking into account farmer SCF understanding and SCF attitude. Likewise, H3 was not supported; no significant main effect was found for SCF attitude, $sr^2 = 0.03$, $b = 0.18$, $t(67) = 1.53$, $p = 0.13$. However, SCF attitude was

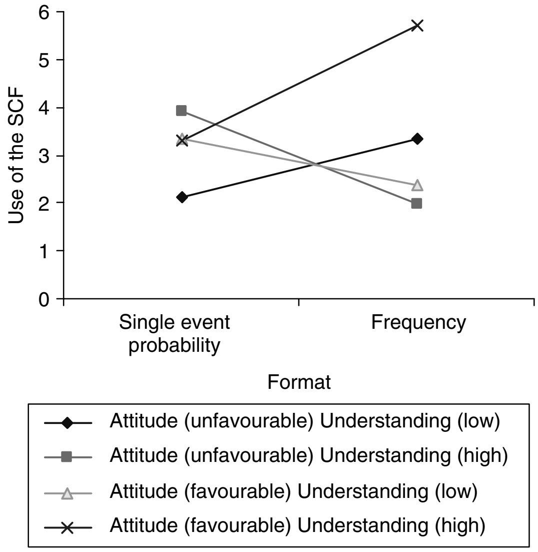

Figure 2. Three-way interaction of SCF format, SCF attitude and SCF understanding on SCF use

also hypothesized to moderate relationships between SCF format and SCF understanding on SCF use such that higher SCF use would not be found for those farmers with an unfavourable attitude, regardless of SCF understanding and SCF format (H4). Although no significant two-way interactions were found at the second step of the moderated regression analysis, an interpretable three-way interaction was found at the third step that explained an additional 9% of the variation in SCF use, R^2change $= 0.09$, $F(1, 63) = 7.45$, $p < 0.01$.

This three-way interaction is shown in Figure 2. It shows that significantly more SCF use only occurred when there was a combination of good SCF understanding, a frequency format and favourable SCF attitude. This highlights the importance of all three factors combining to promote higher SCF use. In other words, if a farmer had a poor SCF understanding, had received a single-event probability format, or had an unfavourable SCF attitude, then SCF use would not be high. This three-way interaction thus qualifies the main effect found for SCF understanding by showing that a good understanding of the SCF is not sufficient for higher SCF use. It is also important to have a frequency format and a favourable attitude toward the usefulness of SCFs.

4. DISCUSSION

4.1. *Summary of results*

As expected, both higher SCF understanding and frequency formats were associated with more SCF use in the correlation table. However, in the regression analysis, only SCF understanding had a main effect on SCF use. Thus, understanding of the SCF appears more important than SCF format, though both are conceptually related to each other. Perhaps more importantly, the main effect of SCF understanding on SCF use was qualified by a three-way interaction between SCF understanding, SCF format and SCF attitude. This interaction showed that higher SCF understanding was associated with higher SCF use, but only when farmers had a favourable attitude toward the usefulness of SCFs and they were presented in a frequency format. This outlines the conditions under which efforts to improve SCF understanding of farmers will lead to more use of SCFs.

4.2. *Implications and future research*

This study uses a task where farmers 'cognitively process' a range of information to arrive at a cropping decision. Anecdotal evidence from the survey suggests that this is a very common way for farmers to arrive at cropping decisions. However, farmers can also ‘electronically process’ information. They can use SCFs in conjunction with crop, pasture and other simulation systems as decision-support systems. Future research can examine whether SCF use differs when used simply as part of a cognitive decision process or when used in conjunction with decision-support systems.

With regard to cognitive processing, most efforts to promote SCFs use have been focused on cognitive aspects of SCF understanding. Extension efforts to promote SCF use have been primarily aimed at increasing SCF understanding by explaining how SCFs are derived, and more recent research into probability presentation formats has also focused on increasing understanding by encouraging the use of frequency formats, which are now being incorporated into SCFs by some agencies. By comparison, very little effort has been focused on the role of attitudes toward the usefulness of SCFs in predicting SCF use.

As mentioned, attitudes are composed of a belief component and an emotional or affective component; for example, a belief that using SCFs does not lead to better cropping outcomes and a negative feeling about using SCFs. Although this study did reveal the importance of SCF attitudes, future research is needed into the relative importance of the belief and affective components of SCF attitudes, as well as how these attitudes are formed.

The formation of attitudes toward something can arise from direct or personal experiences with that something. Anecdotal evidence from some farmers about their direct experiences of using SCFs suggests that some gain an unfavourable attitude toward SCFs after relying on an encouraging SCF of above-median rainfall that is then followed by a dry season. Some even expressed ill feeling toward SCFs and believed that SCFs had been ‘wrong’ in the past. From a frequency perspective of probability, an SCF is never ‘wrong’ because the probability of above-median rainfall in any one season also implies a corresponding probability of below-median rainfall. However, farmers may not have a frequency perspective owing to the prevalence of single-event probability formats in presenting SCFs. And even if they do have a frequency perspective, which is beneficial in counteracting the perception of SCFs being wrong (Coventry, 2001), it is still possible that unfavourable attitudes may still form to the extent that attitude formation is an emotional as well as a cognitive process.

Future research is needed into attitude formation, looking at answering a number of questions: Do previous experiences with using SCFs contribute to forming and changing attitudes toward the usefulness of an SCF? What is the effect of a series of ‘negative’ experiences with using SCFs (i.e. relying on SCFs of above-median rainfalls that are then followed by dry seasons)? Does this depend on their SCF understanding, the SCF format, or whether they have a frequency perspective of probability? To what extent do the attitudes of other farmers influence a farmer’s attitude toward SCFs?

4.3. Limitations

This study has some limitations arising from the fact that attitudes toward SCFs were identified at a late stage in the survey design process as a potential factor influencing SCF use; the study was initially focused on SCF format and understanding. This resulted in only a single-item measure of SCF attitude being used rather than a multiple-item measure, which may have been a more reliable measure. A multiple-item measure would also have been able to capture both the belief and affective components associated with these attitudes separately.

Another limitation in this study was that there were demand characteristics associated with the judgement and decision task, such that farmers may have felt that they were expected to adjust their initial cropping judgements in response to the SCFs provided shortly after. Thus, Figure 2 still shows some SCF use with unfavourable SCF attitudes, little SCF understanding and a single-event probability SCF format. In normal (non-experimental) circumstances it is unlikely that there would be any use of the SCF in such a situation.

Also, the experimental task automatically provided the SCF for each scenario, which means that the study did not take into account any difficulties that farmers may have accessing SCFs for their local area. Little use is made of SCFs that are difficult to access (Tarhule and Lamb, 2003). To access SCFs for their immediate *local* area, farmers in the present study would have needed a computer package called *Rainman,* a personal computer, and occasional Internet access to update historical local rainfall data.

On the other hand, access to various types of SCFs from various sources can complicate understanding SCFs and their use. A range of broader *regional* area SCFs can often be accessed by farmers from radio, television, and print media, as well as from various Internet sites. Farmers may even monitor SCFs for regions in other parts of the world via Internet sites, such as those maintained by the Australian Bureau of Meteorology, the International Research Institute for Climate Prediction and the European Centre for Medium-Range Weather Forecasts. Obtaining SCF information of various types, from various sources, at various geographic levels, and for other regions means that understanding how SCFs are used is more complex than is represented in this paper. However, the basic finding still holds, that more use of SCFs is expected when farmers have a good understanding and a favourable attitude toward the SCFs, and when agencies present SCFs in frequency formats.

It is also possible that the experimental task may have weakened the SCF format manipulation. Those who initially interpreted the probabilities in SCFs as subjective probabilities (i.e. as expressions of confidence in a predicted outcome) may have been coached into adopting a more frequentist interpretation in the course of making many decisions using a wide range of probabilities from 25 to 75%, all of which referred to above-median rainfall. In other words, the fact that there was no mention of below-median rainfall in any of the 100 scenarios may have provided a cue after a while that a subjective interpretation was not applicable. This may explain why there was no significant main effect for SCF format in the regression analysis.

Despite the limitations with this study, it brings to light the importance of favourable attitudes towards SCFs in promoting SCF use. However, although this study suggests that attending SCF workshops *may* lead to more favourable SCF attitudes, the evidence is only correlational thus far. It is equally plausible that farmers attended these workshops because they already had favourable attitudes toward the usefulness of SCFs. As mentioned, more research is needed into SCF attitude formation.

5. CONCLUSIONS

This study gives some insights into why SCFs are not used widely by farmers, despite a range of studies showing the potential benefits of using SCFs in farming decisions. In other words, it shows why simply providing useful SCFs does not mean they will be used; farmers also need good SCF understanding, a frequency format and a favourable SCF attitude.

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REFERENCES

Ajzen I. 1993. Attitude theory and the attitude–behaviour relation. In *New Directions in Attitude Measurement*, Krebs D, Schmidt P (eds). Walter de Gruyter: New York; 41–57.

Ajzen I, Fishbein M. 1980. *Understanding Attitudes and Predicting Social Behavior*. Prentice-Hall: Englewood Cliffs, NJ.

Allport GW. 1935. Attitudes. In *A Handbook of Social Psychology*, Murchison C (ed.). Clark University Press: 798–844.

Campbell DT. 1963. Social attitudes and other acquired behavioral dispositions. In *Psychology: A Study of a Science*, Koch S (ed.). McGraw-Hill: New York; 94–172.

Changnon SA. 1992. Contents of climate prediction desired by agricultural decision makers. *Journal of Applied Meteorology* **31**: 1488–1491.

Clewett JF, Cliff NO, Drosdowsky LM, George DA, O'Sullivan DB, Paull CJ, Partridge IJ, Saal RL. 2000. Building knowledge and skills to use seasonal climate forecasts in property management planning. In *Application of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems: The Australian Experience*, Hammer CL, Nicholls N, Mitchell C (eds). Kluwer Academic: The Netherlands; 291–307.

Climate Variability in Agriculture R&D Program. 2001. Survey shows forecast use up. CLIMAG: Newsletter of the Climate Variability in Agriculture R&D Program (CVAP), No. 5. http://www.cvap.gov.au/climag5.html#_Toc515690178 [11 December 2004].

Cooksey RW. 1996. *Judgment Analysis: Theory, Methods and Applications*. Academic Press: San Diego, CA.

Cosmides L, Tooby J. 1996. Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgment under uncertainty. *Cognition* **58**: 1–73.

Coventry W. 2001. Single-event versus frequency formats for presenting climate forecast probabilities: beyond reasoning abilities to judgment. Unpublished Honours thesis, University of Queensland, Brisbane.

Fishbein M. 1967. Attitude and the prediction of behavior. In *Readings in Attitude Theory and Measurement*. Fishbein M (ed.). Wiley: 477–492.

Gigerenzer G. 1991. How to make cognitive illusions disappear: beyond "heuristics and biases". *European Review of Social Psychology* **2**: 83–115.

Gigerenzer G. 1994. Why the distinction between single-event probabilities and frequencies is important for psychology (and vice versa). In *Subjective Probability*, Wright G, Ayton P (eds). John Wiley: New York; 129–161.

Hammer CL. 2000. A general systems approach to applying seasonal climate forecasts. In *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems: The Australian Experience*, Hammer CL, Nicholls N, Mitchell C (eds). Kluwer Academic: The Netherlands; 51–65.

Hammer CL, Nicholls N. 1996. Managing for climate variability: the role of season climate forecasting in improving agricultural systems. In *The Second Australian Conference on Agricultural Meteorology*, Brisbane, Bureau of Meteorology.

Hammer CL, Holzworth DP, Stone RC. 1996. The value of skill in seasonal climate forecasting to wheat crop management in a region with high climate variability. *Australian Journal of Agricultural Resources* **47**: 717–737.

Hastings PA. 1993. Seasonal climate forecasts: perceptions and responses of Queensland rural producers. PhD thesis, University of Queensland, Brisbane.

Kahneman D, Slovic P, Tversky A. 1982. *Judgment Under Uncertainty: Heuristics and Biases*. Cambridge University Press: Cambridge.

Katz D. 1960. The functional approach to the study of attitudes. *Public Opinion Quarterly* **24**: 168.

Konold C. 1989. Informal conceptions of probability. *Cognition and Instruction* **6**(1): 59–98.

Lynne GD, Casey CF, Hodges A, Rahmani M. 1995. Conservation technology adoption decisions and the theory of planned behavior. *Journal of Economic Psychology* **16**: 581–598.

Meinke H, Hammer GL. 2000. Experiences in agricultural applications of climate predictions: Australasia. In *International Forum on Climate Prediction, Agriculture and Development*, Palisades, NY.

Meinke H, Hochman Z. 2000. Using seasonal climate forecasts to manage dryland crops in northern Australia: experiences from the 1997–98 seasons. In *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems: The Australian Experience*, Hammer CL, Nicholls N, Mitchell C (eds). Kluwer Academic: The Netherlands; 149–165.

Meinke H, Stone RC, Hammer CL. 1996. SOI phases and climate risk to peanut production: a case study for northern Australia. *International Journal of Climatology* **16**: 783–789.

Nicholls N. 1999. Cognitive illusions, heuristics and climate prediction. *Bulletin of the American Meteorological Society* **80**(7): 1385–1397.

Nicholls N. 2000. Opportunities to improve the use of seasonal climate forecasts. In *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems: The Australian Experience*, Hammer CL, Nicholls N, Mitchell C (eds). Kluwer Academic: The Netherlands; 309–327.

Rajecki DW. 1990. *Attitudes*. Sinauer Associates: Sunderland, MA.

Schneider JM, Garbrecht JD. 2003. A measure of the usefulness of seasonal precipitation forecasts for agricultural applications. *Transactions of the ASAE* **46**(2): 257–267.

Sonka ST, Changnon SA, Hofing S. 1992. How agribusiness uses climate predictions: implications for climate research and provision of predictions. *Bulletin of the American Meteorological Society* **73**: 1999–2008.

Stewart TR. 1988. Judgment analysis: procedures. In *Human Judgment: The SJT View*, Brehmer B, Joyce CRB (eds). North Holland Elsevier: Amsterdam.

Stone RC, Hammer GL, Marcussen T. 1996. Prediction of global rainfall probabilities using phases of the southern oscillation index. *Nature* **384**: 252–256.

Tarhule A, Lamb PJ. 2003. Climate research and seasonal forecasting for West Africans — perceptions, dissemination, and use? *Bulletin of the American Meteorological Society* **84**(12): 1741–1759.

Tversky A, Kahneman D. 1974. Judgment under uncertainty: heuristics and biases. *Science* **185**: 1124–1131.

Virtual Consulting Group Australia. 1999. Improving the communication of climate information to dairy farmers. Canberra, Land and Water Resources Research & Development Corporation.

White BJ. 2000. The importance of climate variability and seasonal forecasting to the Australian economy. In *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems: The Australian Experience*, Hammer CL, Nicholls N, Mitchell C (eds). Kluwer Academic: The Netherlands; 1–22.

