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The acceptance of long-range weather forecasts: a question of perception?

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The perceptions of rural property managers of weather services and forecasts largely determines whether or not such services benefit the rural community. These perceptions were examined by a survey of property managers across Queensland who were involved in a wide variety of agricultural activities. Results from the survey, which was conducted prior to the release of ENSO-based long-range forecasts in Australia, reveal that the acceptance and subsequent use of these forecasts as an effective planning tool may be initially limited by a number of factors. Desired levels of forecast reliability, forecast presentation style, use of terminology in forecasts and perceptions with regard to weather information services are discussed.

Introduction: the problem

Recognition of teleconnections associated with the El Niño/Southern Oscillation (ENSO) phenomenon has led to renewed interest in the potential of long-range weather prediction (e.g. McBride and Nicholls 1983; Nicholls 1990). Reflecting this trend, individuals and institutions, including the Bureau of Meteorology (henceforth referred to as the Bureau) and the University of Queensland's Applied Climate Research Unit (UQACRU), have recently begun to produce ENSO-based long-range weather forecasts.

One aim of such services is to assist rural land management through the provision of improved information on seasonal weather patterns. The success of improved forecasts, however, will depend largely on the response of those people involved in land management decisions to new information sources, given the range of rural sector activities (Heathcote 1988).

Research using decision-analytic methods has clearly demonstrated advantage in using even limited skill long-range forecasts in numerous production situations (see Katz et al. 1987; Easterling and Mjelde 1987; Murphy 1985; Winkler et al. 1983). 'Real world' decision-making in any context, however, involves subjective attitudes, values and perceptions as well as objective factual information (Whyte 1985). Furthermore, the degree of acceptance by rural producers of new management information and techniques is clearly related to the level of compatibility of such innovations with the existing practices, perceptions and values of those producers (Rogers and Shoemaker 1971).

Hence, critical examination of responses to available weather services and forecasts and perceived needs of potential user groups is necessary when attempting to determine the most effective ways of processing and communicating the new ENSO-based information in order to maximise its potential benefits to rural industries. To date, the authors are unaware of any published studies of actual responses of decision-makers to specific long-range forecasts, although early work in natural hazards research (Heathcote 1969; White 1974) provides a conceptual basis for such research.

The present study discusses results derived from a survey of perceptions held by rural property managers of weather information services and weather forecasts. The survey was conducted prior to the release of both the Bureau and UQACRU ENSO-based long-range forecasts, and as such, contributes towards clarifying the nature of the social environment into which the new forecast products are now being disseminated. Importantly, the timing of the survey permits opportunities for comparative studies at a later date evaluating the impact of ENSO-based information on the perceptions and decision-making of rural producers.

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The survey

The research focused on the comprehension of climatic and weather-related terms, and on the perceptions held by a sample of Queensland property managers of established and publicly available (at the time of survey) weather information services including non ENSO-based long-range weather predictions*. The overall aims of the research were:

(a) to gauge the extent of utilisation and perceived reliability of available weather forecasts and services;
(b) to attempt an appraisal of the perceived accuracy requirements for practical application of a long-range forecast product;
(c) to identify factors within the forecast-response system which result in sub-optimal utilisation or misuse of weather information by this user group;
(d) to examine the possible implications of the above in determining the degree of acceptance and utilisation of the new ENSO-based forecasts with a view to optimising product design and extension.

Comprehension of basic ENSO-related concepts was also evaluated as an adjunct to the fourth aim.

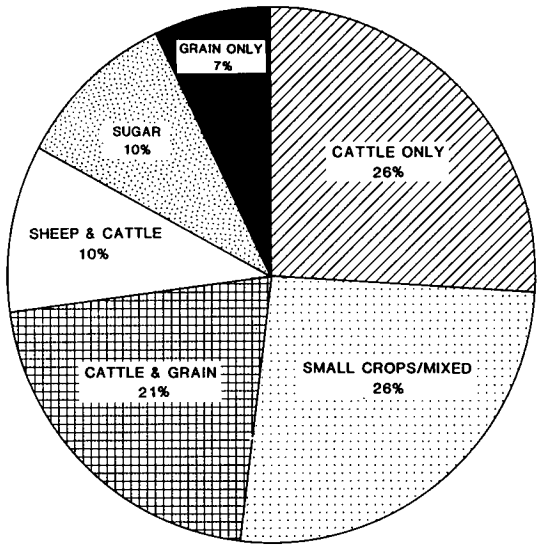
It was assumed that weather and climate information was highly significant for rural production. This assumption has been examined elsewhere (Maunder 1970, 1986) and has been well substantiated by the present study, where 98 per cent of respondents viewed climate and weather variability as making a significant difference to their productivity (see Q.5, Appendix).

The sample

Although the survey sample was small in terms of the total population of farm units/properties in the state of Queensland, the research was designed as a preliminary identification of common perceptions across a broad range of the rural sector. Ninety-one respondents were drawn from two sources. Firstly, the Queensland Country Women's Association (QCWA) distributed 150 questionnaires through its regional branches across the State in 1988 to members who, after being contacted by the Regional Presidents, had agreed to participate in the survey. A total of 65 were returned, representing a 43 per cent response rate. Secondly, a group of former students of the Rural Management Development Centre (RMDC) of the Queensland University of Technology were surveyed, also in 1988. Of the total of 46 questionnaires mailed out, 28 were returned representing a 60 per cent response rate. In the case of both groups, respondents returned completed questionnaires in the mail during the latter part of 1988 and during 1989.

*Non ENSO-based long-range weather predictions issued by private sources Lennox Walker and Leon Morandy have been publicly available in rural newspapers such as *Country Life* for some time. These are the private forecasting services referred to in the text. Bureau short-range forecasts were widely available.

Fig. 1 Property types represented in sample.



The sample represented a broad spectrum of primary industry ranging from beef, dairy and sheep to sugar cane, grains and small cropping. Cattle and mixed cattle/grain properties accounted for 73 per cent of the sample (Fig. 1). There was a bias in the sample in so far as respondents were either interested members, or spouses of members of the QCWA, or were former students of the RMDC. These groups might have been expected to have a higher level of awareness and motivation by virtue of their self-selection in the case of the QCWA members or, in the case of the RMDC students their enrolment in a management course. The sample was also biased in so far as perception of problems associated with climate and weather, and user needs in weather information varied according to the type of industry that respondents were engaged in.

The questionnaire

The questionnaire was divided into three sections (see Appendix):

Section A. General background information regarding respondents in the sample (e.g. location and size of property, number of years experience in rural management) was recorded. This information provided a general profile of the types of current and potential users of weather infor-

Table 1. How reliable would you consider the following sources of weather information to be?

Source	*Very reliable*	*Mostly correct*	*Correct only half the time*	*More wrong than right*	*Totally unreliable*
			(% of sample)		
Bureau	1	36	43	16	4
Leon Morandy	0	6	26	43	25
Lennox Walker	3	7	39	28	23

mation services. No attempt was made to correlate personal attributes of respondents with results of later sections of the questionnaire as the sample comprised individuals from a very wide range of backgrounds and locations across the State.

Section B. Perception of forecast information and climate risk. This section examined comprehension of climate and weather-related concepts including terms related to the Southern Oscillation. An attempt was made to measure the perceived accuracy requirements for forecast products that could affect on-farm decisions, and to meld scenarios of the occurrence of critical conditions with hazard-response behaviour in the form of contingency planning and decision-making in real, on-farm situations. Key factors in property owners' perception of 'drought' conditions were identified with a view to establishing the degree of usefulness of emphasis on these conditions in information services.

Section C. Perception of available services. This section identified those weather services that were most commonly utilised and were perceived to be most valuable by respondents. Perceptions of the reliability of existing (1988/89) services were measured and some factors which might limit future acceptance of new weather services were also identified from this section.

A mix of open-ended and closed question formats was used in the survey instrument. The open-ended questions facilitated a high yield of subjective information for the present study, and this information is being used in the development of future surveys using scaling techniques.

Results

A numbr of key variables measured in the survey emerged in the assessment of the perceived level of confidence in, and subsequent response to then established weather forecast services. These variables pertain to three interconnected areas: perception of the source of information; desire for reliability; and comprehension of terms and concepts associated with the forecast.

Perception of the source: available services

As noted above, the survey was conducted prior to the release of official long-range weather forecasts by both the Bureau and UQACRU. At the time, the commonly recognised and readily available information in *long-range* forecasts was from the private sources, Lennox Walker and Leon Morandy. The Bureau was seen as the primary source of *short-range* predictions (see Q.11, Q.12 and Q.13, Appendix). Respondents displayed a low to moderate level of confidence in the ability of readily accessible weather information sources of the time to accurately produce their respective forecast products.

Table 1 indicates that the Bureau is favoured as an information source over the private long-range forecasters. The results, however, are ambiguous particularly with respect to the interpretation of levels of user confidence in the Bureau. While 37 per cent of the sample stated that they believed Bureau forecasts were either 'very reliable' or 'mostly correct', 20 per cent were prepared to declare the service either 'more wrong than right' or 'totally unreliable'. By comparison, as primarily long-range weather forecasters, the private sources appear to be held in much less esteem than the Bureau. Approximately one-quarter of the sample regarded these sources as 'totally unreliable', with many respondents simply commenting that they did not take these private sources seriously.

In accordance with the aforementioned conclusion of Rogers and Shoemaker (1971), it could be suggested that reduced confidence on the part of rural managers in the ability of available sources to produce 'accurate' forecasts (long or short-range), as indicated by the survey results, may be a factor which could affect the initial degree of use of improved forecast products.

As a direct measure to gauge the perception of long-range forecasting as a concept, survey participants were also asked the question:

> How successfully do you believe that reliable and useful long-range (seasonal) weather forecasts can be prepared in the near future?

Results (Table 2) reflect a significant degree of uncertainty concerning the ability to produce 'reliable and useful' long-range forecasts, with 66 per cent of respondents nominating the categories 'with only limited success' or 'not at all successfully'. It should be noted that in this question, RMDC respondents had a more optimistic view, with 48 per cent selecting either 'very successfully'

Table 2. How successfully do you believe that reliable and useful long-range (seasonal) weather forecasts can be prepared in the near future?

	QCWA %	*RMDC* %	*Total* %
Very successfully	4	8	5
Somewhat successfully	26	40	29
Only limited success	57	40	52
Not at all successfully	13	12	14

or 'somewhat successfully'. This may be due to a higher level of awareness of scientific concepts among the RMDC group.

The possible role of the information source in contributing to confidence levels in long-range forecasting was examined by posing essentially the same question, but framed in terms of the Bureau (the most credible source) hypothetically issuing such a forecast.

How successful do you think that the Bureau of Meteorology would be at preparing *reliable and useful* long-range (seasonal) weather forecasts if they were to do so in the near future?

Results (Table 3) indicate that 58 per cent of those surveyed responded by choosing either 'with only limited success' or 'not at all successfully', representing a slightly more optimistic view toward a Bureau forecast, but seemingly not a convincing confirmation in the ability of the Bureau to produce such forecasts. Again, results from the RMDC sub-sample are more encouraging and may reflect the benefits of improved information and educational extension.

Table 3. How successful do you think that the Bureau of Meteorology would be at preparing *reliable and useful* long-range (seasonal) weather forecasts if they were to do so in the near future?

	QCWA %	*RMDC* %	*Total sample* %
Very successfully	2	9	4
Somewhat successfully	30	56	38
Only limited success	58	22	47
Not at all successfully	10	13	11

Identification of those factors contributing most to the level of confidence in information sources to produce 'reliable and useful' forecasts is a subject for further research. Nevertheless, comments made in response to open-ended items and additional unsolicited comments obtained in the survey provide insight into the probable key variables. With regard to both the Bureau short-range and private long-range forecasts 'unreliability' based on perceived past performance (whether it be justified in reality or not) was most often cited as contributing toward reduced confidence in that source. Related aspects including forecast timing (Bureau forecasts, in particular, often being 'late'), language used and confusion over regional definitions, were also mentioned as factors causing problems for users which detracted from the perceived value and reliability of the product. Such issues should be addressed in the design stage of any improved forecast system to maximise the effectiveness of the technology from the viewpoint of the users.

Desire for reliability

In the overall context of survey responses, perception of forecast reliability appears to be the single most important factor affecting the level of credibility of forecasts, and hence the degree of potential response to them. A high percentage of respondents (86 per cent) said that they had never changed their stocking rate or crop type in response to a published long-range weather prediction with 78 per cent claiming that they would only make changes based on such predictions if they were proven reliable (see Q.7 and Q.8, Appendix). Furthermore, many respondents strongly emphasised that they would prefer to see reliability estimates accompany forecast statements. An indication of this can be inferred from the responses to an item soliciting preferences for forecast 'types'.

With regard to the provision of forecast information, which of the following examples of forecast types would you prefer (please circle your choice)?

(a) 'there is a 70% (probability of 0.7) chance of above average rainfall'.

(b) 'there is a strong possibility of above average rainfall'.

As Table 4 shows, 77 per cent of the total sample recorded a preference for the probability statement (a). Unanimous support for this response was gained from the RMDC sub-sample.

The desire for reliability was further examined in the survey with continued emphasis on long-range forecasts. Respondents were asked to nominate a percentage reliability of a forecast predicting a weather extreme (drought or flood potential)

Table 4. With regard to the provision of forecast information, which of the following examples of forecast types would you prefer? (Please circle your choice.)
(a) 'there is a 70% (probability of 0.7) chance of above average rainfall'.
(b) 'there is a strong possibility of above average rainfall'.

	Results		
	QCWA %	*RMDC* %	*Total sample* %
(a)	67	100	77
(b)	33	0	23

at which point they would initiate a response (Q.10, Appendix). A median figure of 80 per cent reliability was demanded by both the QCWA and the RMDC components of the survey sample. Another question focusing on seasonal rainfall forecasts similarly asked respondents to consider a percentage reliability needed before contingency actions (e.g. changing stocking rate/crop type) would be taken. Again, a median figure of 80 per cent was recorded by both components of the survey sample (Q.9, Appendix).

There are some difficulties in interpreting what respondents actually mean by these reliability figures (see review of Murphy and Brown (1983)); nevertheless, the figure of 80 per cent was remarkably consistent across the sample so that, at face value, there appears to be a general acceptance of a one in five chance that predictions will be wrong. Whether this understanding would, in the context of 'real world' decision making, translate into a tolerance of a wrong prediction in the first, second or even third year of, for example, a five-year program of long-range forecasts from a new source is not clear and is likely to be related to individuals' perception of risk.

Thus, it seems by no means assured that the rural community will automatically adopt information from new long-range weather forecasting or otherwise improved forecast services, even if they are based on scientific data. As far as property managers are concerned, the sources must demonstrate a high degree of reliability, according to the users' criteria, before any property management or planning decisions would be based on them. An important role for appropriate presentation and educational extension of this type of information would seem mandatory for the success of improved forecast products. The authors have noted a high degree of positive feedback from rural producers when they were simply allowed to compare and note correlations between their own recollections of extreme seasons and time-series of Southern Oscillation indices in graphical form.

Perception of climate and weather terms/concepts

Possibilities exist for enhancing the acceptance of forecasts by adaptation of product design, product dissemination method and the nature of educational information included with products or publicised about products, or forecasting in general. One key opportunity exists in the area of terminology and concepts employed by weather services.

Worded forecasts, which generally consist of both verbal and numerical expressions, play an important role in the communication of weather information. Many expressions used in weather forecasts are subject to wide ranges of interpretation, and even misunderstanding, during the process of communication (Murphy and Brown 1983; Ayton 1988). This significantly reduces the usefulness of the information provided and can create potential for misuse of, or unwarranted mistrust towards a forecast product. It is therefore necessary to study the linguistic composition and interpretation of forecasts from the viewpoint of the end-users.

Terms and concepts investigated in the survey were either those which were frequently used in existing weather forecast products or those likely to be employed in future forecast services. The term drought and the terms/concepts related to the El Niño and the Southern Oscillation are of particular interest in the context of recent trends in long-range forecast methodology.

Defining drought. El Niño or ENSO events have been closely linked to periods of drought in Australia and, thus, good opportunities appear to exist for prediction of such occurrences (Bell 1986). The definition of drought, however, has always proved difficult, particularly at the interface between meteorological and agricultural drought (Heathcote 1969, 1988). This is an aspect that would need to be considered in the context of a forecast statement or media report which specifically used this term.

In the present study, perceptions of the conditions of drought were found to be very specific to region, industry and local environmental conditions. In the sample analysed, slightly more than half (54 per cent) of respondents defined drought in terms of the productivity of their properties, or else with reference to a wide range of indicators in the local environment (see Q.6, Appendix). Only 46 per cent of respondents defined drought purely in terms of a rainfall measure, and even these varied widely according to industry and location. These results emphasise a probable difficulty in attempting to use the term drought in regional long-range forecasting, as it will potentially be interpreted by individual rural managers in a wide, and very varied range of contexts. Thus, the use of such subjective terms is not recommended in forecasts.

El Niño. At the time of the survey, terms relating to the El Niño/Southern Oscillation appeared to be generally poorly understood. A question relating to familiarity with terms associated with the Southern Oscillation phenomenon was included as follows:

Are you familiar with any of the terms below: (please circle any term(s) with which you are familiar).
'Southern Oscillation'
'SOI'
'El Niño'
'ENSO'
'Anti-ENSO'.

Table 5. Are you familiar with any of the terms below? (Please circle any term(s) with which you are familiar.)

Term	*Percentage of sample familiar with term*		
	QCWA	*RMDC*	*Total sample*
'Southern Oscillation'	34	58	41
'SOI'	6	19	10
'El Niño'	63	85	69
'ENSO'	14	35	20
'Anti-ENSO'	9	31	15

For results see Table 5. Furthermore, another question revealed that only 52 per cent of those sampled understood that an El Niño or ENSO year generally implied decreased rainfall for eastern Australia (Table 6). Sixty-four per cent of the RMDC respondents had a correct understanding of the term.

Two negative outcomes of this situation could be that forecasts are either (a) ignored as a result of unfamiliarity with the terms and concepts, or (b) that forecasts are misinterpreted and this, again, may later unduly affect perceived reliability. In a similar context, Pittock (1986) has pointed out that adverse impacts can result from the two situations where either the forecast is believed and proves to be incorrect, or the forecast is not believed and proves to be correct. Again, the need for carefully designed educational extension connected with forecast services to assist in counteracting possible misinterpretation is underlined.

Implications and conclusion

In order to assist rural land managers to incorporate weather and climate information into their decision-making, consideration must be given to users' perceptions of available services. Such investigation is essential to ensure effective utilisation of new services, and to complement regional studies of connections between the El Niño/Southern Oscillation and agricultural production. Data from the present research indicate that the success of ENSO-based long-range forecast services in terms of effective use by a majority of rural managers may face a number of obstacles.

In a 'real world' forecast-response system, forecast information is filtered by user perceptions of the reliability of the source of the information before a decision or response is initiated. The present research has revealed that confidence in weather information services available at the time of the survey (1988/89) was low to moderate, and that the belief in the ability to produce long-range forecast information which is reliable and useful was also, at best, moderate. These results reflect perceptions held with regard to both short and long-range products (and are likely to be connected to past experiences and/or misconceptions associated with such forecast products). The more encouraging results from respondents in the RMDC group, who had been exposed to educational extension services, revealed a more optimistic potential for future long-range forecasts based on scientific concepts.

A demand for reliability estimates to accompany forecast statements was a strongly emphasised point in the survey data. Without demonstrated reliability levels of at least 70 per cent, and most commonly 80 per cent for forecasts, managers stated that they would be reluctant to use weather information as a planning tool, and as a basis on which to make decisions placing scarce capital and possibly livelihoods at risk. Managers' tolerance of imperfect forecasts must be examined together with perceived needs to enable the most appropriate mix of reliability and forecast specificity to be realised.

At the time of the survey, concepts and terms relating to the Southern Oscillation appeared to be poorly understood by many participants who, because of the self-selection bias in the sample, may be considered to be a group of property managers with a better than average awareness of scientific concepts. In addition, the term drought was subject to a wide range of interpretations. The results from the survey group seem to indicate that it would be quite erroneous to assume that long-range forecasting based on the El Niño/Southern Oscillation would be generally accepted and effectively used by the rural sector in the near

Table 6. If you were told by a reliable weather forecasting service that this year was an 'ENSO' or 'El Niño' year, would you understand what this implied? (Please circle your choice.)

	QCWA %	*RMDC* %	*Total sample* %
(a) would not understand	33	16	28
(b) yes, it implies more rain for Queensland	15	8	13
(c) yes, it implies less rain for Queensland	47	64	52
(d) yes, it implies something else (please explain)	5	12	7

future without adequate education and extension.

Identifying the discrepancies between actual and optimal use of long-range forecasts is the subject of ongoing research. An opportunity now exists for the authors to reassess the results presented in this paper through an evaluation of the perception and use of the new long-range forecast services which were offered for the first time in late 1989 by the Bureau and the UQACRU.

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Appendix. Selected questions and data from the survey referred to in text

Section A (general background information)

Q.1. In what region of the State is your property?

Q.2. What is the size of your property?

Q.3. What type of property/farm do you have?

(Results to Q.1,2 and 3 reflected in Fig. 1).

Q.4. For how long have you been a farmer/managing your property?

Mean = 28 years

Standard deviation = 14 years

Section B (perception of forecast information and climate risk)

See also Tables 4, 5 and 6.

Q.5. From your experience, do weather and climate variations make a significant difference to your production?

Results	Total sample
yes	98%
no	2%

Q.6. How would you describe a 'drought' in your area?

Results of this question were classified according to:

(i) 'subjective' responses (i.e. related to production such as pasture and crop conditions) - 54%, and;

(ii) 'objective' responses (i.e. nominations of specific rainfall character such as rainfall intensity and amounts over a particular period - 46%.

Q.7. In the past, have you changed your stocking rate/crop type or planting schedule according to long-range/seasonal weather predictions? (Please circle your choice.)

Total sample

yes 14% no 86%

Q.8. Would you change your stocking rate/crop-type or planting in the future, based on long-range weather forecasts if those forecasts were reliable? (Please circle choice.)

Total sample

yes 78% no 22%

Q.9. If 'yes', how reliable would the forecasts need to be before you would take the above-mentioned action? (i.e. in % or probability terms. Consider a seasonal forecast of above/below average rainfall for your region.)

Total sample

median 80%

mean 78%

standard deviation 13.7

Q.10. (With respect to a forecast of flood or drought potential) What level of reliability in a forecast would you need before you would take any positive action, such as formulating a contingency plan, based on that forecast? (i.e. in % or probability terms.)

Total sample
median 80%
mean 80%
standard deviation 10.4

Section C (perception of available services)
See also Tables 1, 2 and 3.

Q.11. What weather forecasting services can you get at present?
Bureau short-range T.V. or radio 96%
Bureau short-range or private long-range print media 43%

Q.12. What weather forecasting services do *most* farmers you know consult?
Bureau short-range T.V. or radio 76%
Bureau short-range or private long-range print media 29%

Q.13. What weather forecasting services do *you* consult *most* for your farm management at present? (Short and long-range if applicable.)
Bureau short-range T.V. or radio 66%
Bureau short-range or private long-range print media 20%