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Needs for applied climate education in agriculture

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Abstract. This paper reports on a purposive survey study which aimed to identify needs for the development, delivery and evaluation of applied climate education for targeted groups, to improve knowledge and skills to better manage under variable climatic conditions. The survey sample consisted of 80 producers and other industry stakeholders in Australia (including representatives from consulting, agricultural extension and agricultural education sectors), with a 58% response rate to the survey. The survey included an assessment of (i) knowledge levels of the Southern Oscillation Index and sea surface temperatures, and (ii) skill and ability in interpreting weather and climate parameters. Results showed that despite many of the respondents having more than 20 years experience in their industry, the only formal climate education or training undertaken by most was a 1-day workshop. Over 80% of the applied climate skills listed in the survey were regarded by respondents as essential or important, but only 42% of educators, 30% of consultants and 28% of producers rated themselves as competent in applying such skills. Essential skills were deemed as those that would enable respondents or their clients to be better prepared for the next extended wet or dry meteorological event, and improved capability in identifying and capitalising on key decision points from climate information and a seasonal climate outlook. The complex issue of forecast accuracy is a confounding obstacle for many in the application of climate information and forecasts in management. Addressing this problem by describing forecast ‘limitations and skill’ can help to overcome this problem. The survey also highlighted specific climatic tactical and strategic information collated from grazing, cropping and agribusiness enterprises, and showed the value of such information from a users perspective.

Additional keywords: applied climate needs, climate applications and education, cropping, graziers, ranchers.

Introduction

Australia’s climate is one of the most variable in the world (Nicholls *et al*. 1997). Over the past 20 years, a better understanding, explanation and prediction of climate variability has emerged through greater knowledge of climate processes such as the El Niño Southern Oscillation phenomenon (ENSO) (Clewett 2003; Clewett *et al*. 1991, 2003; Drosdowsky 2002; Hammer *et al.* 2001; McBride and Nicholls 1983; Meinke *et al*. 2005; Stone *et al*. 1996). Better appreciation of this climate variability and applications of seasonal climate forecasts are vital for sustainable resource management in rural industries. Benefits relate to more effective drought preparation, improvements in resource management, as well as conservation and agricultural output. Consequently, applied climate education and training as in a vocational education and training sector ‘Unit of Competency’(a component of a competency standard in the Australian Qualifications Framework, which is a statement of a key function or role in a particular job or occupation and incorporates the elements of competency, performance criteria and a range of variables) is essential for better utilisation of climate information and forecasts in management. It would also complement other resources (such as the internet) and training courses. Identifying the needs of selected groups expected to benefit was considered useful to inform design of applied climate educational materials. Although previous surveys (Austen *et al*. 2002; Keogh *et al*. 2004*a*, 2004*b*, 2005) have not directly considered applied climate education, they are useful in assisting us in identifying how learning resources and processes could be developed and improved.

Existing literature on the needs of applied climate education and training support the objective of our study. Meeting future agro-meteorological needs should incorporate services that enable producers to prepare for and reduce the impact of climate variability (Hatfield 1994; Hollinger 1994; Perry 1994; Stigter *et al*. 2000). Therefore, an improved understanding of the early warning systems including weather and climate prediction and initiatives that highlight the effects of global warming are important educational priorities (Nicholls 2003). There also

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needs to be strengthening of agro-meteorological networks and an improved understanding of climate and biological interactions, emphasising the development of strategies to adapt to climatic variability and change (Sivakumar *et al*. 2000), through greater adoption of research findings. Questions of knowledge, relevance, level, who needs it, delivery methodology to effectively enable users must be addressed. To begin to answer these questions, we present here a brief overview of the issues of appropriateness of knowledge and learning outcomes in applied climate education.

Supplying relevant climate information and developing understanding and skills to meet the needs of specific clients is imperative (Clark *et al*. 2003). Data issues need to be communicated to the 'right' client so that agro-meteorology can find 'windows of opportunity' for fruitful use (Rijks and Baradas 2000). According to Decker (1994), fundamental knowledge must include impacts of climate on agriculture and natural resources, derived from quality datasets (Carlson *et al*. 1994; Graham *et al*. 2000). Formal applied climate education is not meant as an 'either/or' to informal climate education in workshops, but is an additional approach to enhance knowledge and skills to better manage variability and climate change (George *et al*. 2005*a*, 2005*b*, 2005*c*, 2006*a*, 2006*b*).

Meinke *et al*. (2001) raise the importance of meeting client needs through partnerships among producers, scientists and advisors. Although some scientists may propose that producers make use of information provided by scientists (Meinke *et al*. 2001), we propose that with education and training, producers can be equipped with improved knowledge and skills and greater access to a range of climate tools and information (e.g. on the internet) to support informed decisions. This point is valid because we value the opinion of the agro-climate 'expert'. However, opinion of what climate information should be provided is sensitive as: (i) every farming decision is unique; and (ii) every property circumstance is different in relation to owners' attitudes to risk, financial position and lead-time requirements for the decision to be made. In addition, even with probabilistic forecasts, there is no one perfect forecast system (Vizard *et al*. 2005). We argue that users of forecasts should view a number of forecasts to assess consensus between methods before making an informed decision. Applied climate education should assist examination and interpretation of available forecasts, as vast amounts of information on the internet may overwhelm users (Jarvis 1995). Therefore, emphasising an analytical approach to decisions using knowledge based on climate science, soil–plant–animal–water interactions and business attributes through education is the basis taken by the authors. This approach has been reinforced from evaluations in 125 workshops with 1908 participants run by the senior author (D. A. George), with people from farming, extension and agribusiness backgrounds.

'Developing climatic risk management strategies' (DCRMS), is a nationally accredited Unit of Competency for vocational education, and was designed to harness recent developments in applied climate science for better management of climate variablility. The unit is aimed towards producers, consultants and agricultural and natural resource managers with the objective of building knowledge and skills for better management through:

(i) surveying climatic and enterprise data,
(ii) analysing climatic risks and opportunities, and
(iii) developing climatic risk management strategies.

The unit is now available to agricultural colleges, universities and registered training organisations, and is described in detail in a companion paper (George *et al*. 2006*a*). Notwithstanding the establishment of the elements (components of the work function, i.e. surveying climatic and enterprise data; analysing climatic risks and opportunities; and developing climatic risk management strategies) and performance criteria (terms which describe the work function in detail and are fundamental to the assessment process, e.g. in the element 'surveying climatic and enterprise data', some performance criteria are: (i) historical climatic data is obtained and interpreted from a range of sources, and (ii) weather and climatic risk factors are identified), a needs analysis was still warranted if it is agreed that the 'teaching,' primarily for agricultural producers, should emphasise a student-centred approach in which the students are critical in determining what and how learning occurs.

Therefore, the research objectives were to:

(i) assess the needs of producers, agribusiness, education providers for knowledge and skills applications of climate information,
(ii) collate opinions on content, processes of learning and format of an applied climate Unit of Competency, and
(iii) monitor the effectiveness of an applied climate Unit of Competency in terms of improvement of knowledge and skills, use of information on climate variability and seasonal climate forecasts in decision-making, and exposure to climate risk.

Methods

The purposive survey's research context, design, objectives, components and methods of analysis are given below. The final section describes methods used in a 'skills audit' as part of the survey methodology.

Research context of the purposive survey

An action research model with emphasis on a participatory approach (Carberry *et al*. 2002; McCown 2002; Nelson *et al*. 2002) was chosen as the research plan can be refined during implementation from feedback and joint discussions (Cohen and Manion 1994; Zuber-Skerritt 1993). Our work followed the following stages: stage 1, problem identification; stage 2, discussion with stakeholders; stage 3, literature review; stage 4, establishment of assumptions; stage 5, selection of appropriate research methodology; stage 6, selection of evaluation methodology; stage 7, trials with a pilot group of farmers and then training trainers; and stage 8, data analysis and conclusions.

Stage 1 is the identification of the 'problem', or 'problems' within its context. In this study the problems were that producers were facing difficulties using climate information and forecasts in management, and an absence of delivery of accredited applied climate education.

Stage 2 draws on preliminary discussions among interested stakeholders regarding applied climate education intervention that could be appropriate. Here, a national expert panel (called the 'ClimEd' Steering Committee; the ClimEd project established the Steering Committee and is also the name of the course which delivers specifically to the DCRMS Unit of Competency) was made up of 14 'experts' in the fields of climate, education, agriculture and natural resource management (Table 1) and was established following an open invitation for expressions of interest. The ClimEd Steering Committee operated from 2002 to 2004 to direct and further the research, and met at key milestones during project implementation. The Committee provided direction and support in the development, delivery and evaluation of the ClimEd Project and DCRMS Unit of Competency, and provided guidance on implementation of the purposive survey. It also ensured that educational process and content met agreed performance standards including the national focus applicability of the study. This ensured that the survey was sound and rigorous, and that its findings were utilised in the development, delivery and evaluation of educational resources.

In this paper we report on the survey aspect of the study, the purpose of which was to identify and assess the needs of and strategies being used by producers to better incorporate the climate component in enterprise and natural resource management. Findings from other stages of the research are detailed in companion papers (George *et al*. 2005*a*, 2005*b*, 2005*c*, 2006*a*, 2006*b*).

This survey sought to collect opinions of producers who may attend an applied climate course, consultants or extension staff who may provide climate advice to clients, and educators who deliver vocational agricultural education. Information collected would be used to identify applied climate and agriculture education needs and, thus, improve educational resources for vocational education. A purposive survey (Czaja and Blair 1996) is a type of non-random sample in which respondents are specifically selected. Results are indicative only. A purposive survey was selected in this instance because the elements and performance criteria for the Unit of Competency had already been established through an exhaustive process using two panels [a Training Package Advisory Committee and a Vocational Training Assessment Board detailed in a companion paper (George *et al*. 2006*a*)]. The members of these panels represented agriculture, horticulture and natural resource management and educational expertise. Names of prospective respondents to the survey were provided by the ClimEd Steering Committee which nominated people whose opinions they respected and valued to positively contribute to identifying climate education needs. The survey initially involved the design and pre-test of a questionnaire by 10 consultants, producers and educators. The questionnaire was subsequently finalised and administered by post and email to 138 people, comprising producers, educators and agribusiness industries.

In order to assess the needs of producers, agribusiness, education providers and others with regard to knowledge and skills of climate applications and to collate opinions with respect to the content, process and format of the DCRMS Unit of Competency, the survey had three objectives. These are presented as the research objectives, and, in addition, were to identify any other issues that may need to be addressed including providing support materials to enhance learning and assessment to ensure effectiveness of the Unit of Competency.

The survey was broken into four sections (A–D), as follows.

(i) Section A: general information about the respondent.
(ii) Section B: assessment of respondents' current knowledge of climate and applications of seasonal forecasts.
(iii) Section C: assessment of effects of the variable climate on enterprises and the types of processes and tools used in management decision-making.
(iv) Section D: indication of respondent's preferred method of presentation of the Unit of Competency.

The survey was distributed in October–November 2002, and respondents were given 8 weeks to complete and return their

Table 1. Composition of the nationally focused expert ClimEd Steering Committee

Organisation	Function of organisation
AgForce (represented and chaired by a Senior Executive Member and the Training officer)	State-wide (Queensland) producer organisation of about 8000 members with networks to all other state farming organisations
Producers × 4 (selection of four farmers based on experience and EOI from submissions following a national newspaper advertisement)	Representing farming, grazing and irrigation interests
National Research and Development (R&D) Coordinator for 'Managing Climate Variability'	Coordinator of the national body overseeing all applied climate research and development, with affiliations to other national research and development bodies encompassing crops, livestock and natural resource management
Dalby Agricultural College – Instructor	Vocational agricultural college representing students who are enrolled in vocational agricultural courses for temperate and tropical Australia in extensive and intensive agriculture industries
CB Alexander College – Principal	Representing NSW Primary Industries (State-wide government agricultural body) and a Registered Training Organisation specialising in agriculture
Bureau of Meteorology – Forecaster-researcher	National weather and climate body
Team DES (one member)	Agribusiness representative
The University of Queensland – Senior Lecturer	Internationally and nationally renowned educational body with linkages from secondary and vocational educational systems to tertiary institutions
Queensland Rural Industry Training Council CEO	The State Rural Advisory Training Body
Kondinin Farmer Group – Project Officer	Farmer operated organisation with approximately 10 000 members predominantly established in western and southern states and with networks to all other state-farming organisations
Department of Primary Industries and Fisheries, Queensland Climate Scientist and Educator	State-wide government agricultural body

surveys. Follow-up phone calls were made to a small number to ensure an improved response rate. The survey required respondents to use a range of indications comprising ticks, numerical ratings and self-worded statements. A weighted score system was used to obtain an overall ranking that would be meaningful on questions that had multiple answers and ratings. Responses to each question were collated as percentages, rankings and statements.

Skills audit

The skills audit refers to assessment of competence in 10 generic climate-related skills needed in agricultural operations. Respondents were asked to: (i) assess the importance of each skill to their business and its management by categorising each as essential, useful, or unimportant, and; (ii) rate their competencies in each as: nil (or no knowledge), ordinary, average, competent, or very competent, based on the work by Stephens and McGuckian (1994). The skills included were identified from feedback from participants in numerous workshops (George *et al*. 2000) as being the 10 most generically applicable to a broad range of agricultural and natural resource industries. They were: (i) investigate what makes it rain in your location; (ii) read and interpret weather maps; (iii) examine and investigate the causes and effects of ENSO on rainfall and its impact on climate variability and the business; (iv) view, interpret and discuss climatic data for your location (including averages, median, deciles, probabilities and statistical significance); (v) identify key decision points in the management system where seasonal climate forecasts may be useful; (vi) integrate climate data and seasonal climate forecasts in decision-making; (vii) review and interpret climatic data and seasonal forecast information sources and references; (viii) observe and discuss the benefits of short- and long-term climate forecasts; (ix) communicate climate variability and its implications to the business to others e.g. banks; and (x) being well prepared for the next dry or wet meteorological event.

Chi-square tests were used to test the assumption that respondents would rate their personal skill or knowledge of the stated topic as essential or useful but that few would assess their knowledge or skills as competent. The null hypothesis being: 'respondents are likely to rate the knowledge and skill importance equally across the three ratings, and were also likely to assess their knowledge and skill competence equally across the five variables'.

Results

A summary of the general information about respondents is provided, followed by assessment of current knowledge of climate and applications of seasonal climate forecasts. The effect of the variable climate on enterprise management and the types of processes and tools used in management is then presented, followed by preference for presentation of the Unit of Competency.

General information of survey participants

Most respondents were males aged 26–55 years living in New South Wales, South Australia and Queensland, and were agricultural producers (49%), consultants and extension officers (35%), and educators (16%). Most (54%) had greater than 20 years of experience in managing their business or in their chosen career and few had climate 'training' other than attendance at 1-day workshops (Table 2).

Respondents' current knowledge of climate

Over 80% of the applied climate skills listed in Section B of the survey were considered essential and useful, but only 30% of respondents considered themselves competent or very competent in those skills (Fig. 1; Table 3). Key points arising from the data collected from producers, educationists and agribusiness and extension are listed below.

Skill 1: investigate what makes it rain in your location

Over 70% of all groups rate this skill as useful, very few see it as unimportant and a minority see it as essential. The producers' ratings of knowledge levels were unequally distributed across all the categories with a tendency for the majority to rate themselves as 'average'.

Skill 2: read and interpret weather maps

Of producers, 66% of respondents see this skill as essential. Nearly equal percentages of consultants see it as either essential or useful, and 53% of educationists see it as useful. The producers' assessment of their knowledge levels were unequally distributed with 52% rating themselves as 'competent or very competent'.

Table 2. Classification of responses from section A: general information (n = 80)

Classification	Respondents (%)
Response rate	
Educators (n = 16)	81
Producers (n = 82)	48
Consultants/extension (n = 40)	70
Total (n = 138)	58
Significant sex	
Male	83
Significant states	
NSW, SA and Queensland	95
Groups represented	
Producers	49
Consultants/extension	35
Education	16
Age bracket (years)	
26–35	11
36–45	31
46–55	47
56–65	10
65 and over	1
Experience in their industry (years)[A]	
≤5	4
6–10	12
11–15	16
16–20	14
>20	54

[A]This 'experience in years' trend (with the majority more than 11 years experience) was similar between each of the education, farming, consultants and extension groups.

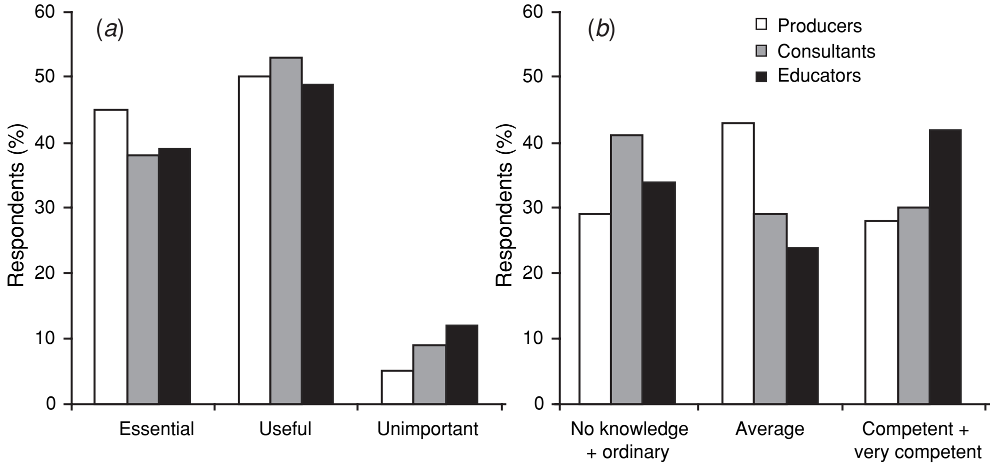

Fig. 1. Skills audit showing (*a*) the 'importance' of applied climate skills and (*b*) 'knowledge' level of those skills between producers, consultants and educators ($n = 80$).

Skill 3: examine and investigate causes and effects of ENSO

In total, 66% of respondents rate this as useful, with 8% seeing it as unimportant and 38% of educationists seeing it as essential when compared with producers (24%) and consultants (20%); 18% of producers rated themselves as competent or very competent.

Skill 4: view, interpret and discuss climatic data for your location

In total, 62% of producers and 69% of consultants see this skill as important, a greater percentage of educationists (54%) rate it as essential. About 15% of the educationists see it as unimportant, compared with 0 and 7% for the producers and consultants, respectively. The producers' ratings of knowledge levels were equally distributed across all the categories.

Skill 5: identify key decision points

The majority of all groups rated this skill as essential (61% producers, 52% of consultants and 46% of educationists), though educationists were more varied in their opinion with nearly equal percentages of educationists seeing at as essential or useful and 15% saying it was unimportant. The producers' ratings of knowledge levels were equally distributed across all the categories.

Table 3. Skills audit of producers: self assessment of current knowledge of climate and applications of seasonal climate forecasts ($n = 33–39$)
* $P < 0.05$; ** $P < 0.01$; n.s., not significant

Skill	Assessment of how important a skill may be to your business and its management				Assessment of how you rate your skill or knowledge of this topic			
	Essential	Useful	Unimportant	Significant	No knowledge and ordinary	Average	Competent and very competent	Significant
Investigate what makes it rain in your location	11	27	1	**	11	21	6	**
Read and interpret weather maps	25	13	—	**	4	14	20	**
Examine and investigate causes and effects of ENSO	8	23	2	**	14	14	6	n.s.
View, interpret and discuss climatic data for your location	15	24	—	**	15	12	12	n.s.
Identify key decision points	24	13	2	**	13	10	16	n.s.
Integrate climate data and seasonal climate forecasts	17	21	1	**	12	16	10	n.s.
Review and interpret climatic data and seasonal forecasts	8	27	2	**	15	17	4	*
Observe and discuss short term and long term climate forecasts	14	21	2	**	12	17	8	n.s.
Communicate climate variability to others (business)	15	15	8	n.s.	8	18	12	n.s.
Being well prepared for the next dry or wet meteorological event	34	4	—	**	5	22	11	**
Total	171	188	18	**	109	161	105	**

Skill 6: integrate climate data and seasonal climate forecasts

Similar percentages of producers, consultants and educationists see this skill as essential (44, 56, 39%, respectively) or useful (54, 40, 46%, respectively). Again a much higher percentage of educationists (15%) see this skill as unimportant. Less than 4% of the other two groups saw this as unimportant. The producers' ratings of knowledge levels were equally distributed across all the categories.

Skill 7: review and interpret climatic data and seasonal forecasts

In total, 73% of producers and 69% of educationists rated this skill as useful. 56% of consultants saw it as useful with 20% of the consultants seeing it as unimportant. No more than 8% of the other two groups saw it as unimportant; 11% of the producers tended to rate themselves with competent or very competent knowledge in this grouping.

Skill 8: observe and discuss short term and long term climate forecasts

Of the consultants, 69% of respondents saw this skill as useful. However, much closer percentages of producers and educationists saw this skill as either essential (38 and 38%, respectively) or useful (57 and 46%, respectively). Only 5% of the producers saw this skill as unimportant; however, 11% of the consultants and 15% of the educationists saw it as unimportant. The producers' ratings of knowledge levels were equally distributed across all the categories.

Skill 9: communicate climate variability to others (business)

Much closer percentages of all three groups were seen with this skill; 21% of the producers, 12% of the consultants and 23% of the educationists saw this skill as unimportant. This skill was seen as essential by 39% of the producers, 40% of the consultants and 46% of the educationists. The producers' ratings of knowledge levels were equally distributed across all the categories.

Skill 10: being well prepared for the next dry or wet meteorological event

The majority of the producers (89%) and consultants (77%) saw this skill as essential; however, equal percentages of the educationists (46%) saw it as either essential or useful. The producers' ratings of knowledge levels were unequally distributed across all the categories with a tendency for the majority (58%) to rate themselves as 'average' knowledge.

The conditional distributions of all groups combined showed that skill 10 was seen to have the highest percentage of essentials ratings (78%) and, therefore, to be the most important skill. The skill rated least important was 'communicating climate variability'. The greatest knowledge gap for producers was in the skill 'review and interpret climatic data and seasonal forecasts'.

Results of the knowledge questions are presented in Table 4. Assessment of knowledge levels of the Southern Oscillation Index (SOI) and sea surface temperatures (SSTs), mean, median, interpreting probability tables, interpreting forecasts from a statement and calculating values from a probability statement with a forecast value reveal that improvement is needed in all the groups, but the areas of need differ. The questions on mean and median numbers were answered least correctly by consultants and extension officers (73 and 69%, respectively). Interpreting a value from a probability table was positively answered by most groups with producers being the weakest with 84% correct. The results from questions on forecast interpretation and calculation of values from a forecast statement were answered most correctly by educators and producers (73 and 82%, respectively).

Effect of climate on management

Responses of participants have been collated according to the key decisions in enterprise management (Table 5). The responses on the impact of climate on key business decisions show that groups of respondents have different needs. For example, in farming, crop producers need climate information that relates to crop selection and agronomic inputs such as herbicide and fertiliser use, area to be grown and varieties. Graziers use climate information in decisions on buying, breeding, selling and agistment of livestock. Consultants and extension staff work with groups throughout the state and nationally, and need climatic information for a wide geographic area. All groups needed climate information with respect to sustainability of soil–plant–animal–water resources. The delivery of any applied climate course to meet these diverse needs is a challenge that any applied climate education Unit of Competency needs to address (Rijks and Baradas 2000; Stigter *et al*. 2000).

Table 4. Summary of correct responses to 'climate' questions (%)

SOI, Southern Oscillation Index; SST, sea surface temperature

Climate questions	Producers (n = 39)	Educators (n = 12)	Consultants and extension (n = 24–27)	Total (n = 75–78)
SOI is negative in an El Niño year (n = 78)	97	83	82	90
SSTs were cooler than normal in the central Pacific in La Niña years (n = 77)	45	58	44	47
Mean of a set of numbers (n = 76)	79	92	73	78
Median of a set of numbers (n = 76)	74	83	69	74
Interpreting a value from a probability table (n = 74)	84	100	96	91
Interpreting a forecast from a statement (n = 77)	63	75	63	65
Calculating values from a probability statement with a forecast value (n = 75)	82	50	68	72
Average	75	77	71	74

Table 5. Effects of climate on key business decisions listed by farming, agribusiness and consultants groups (*n* = 63)

Key decision in agriculture	Effects of climate variability on that decision
Cropping	Uncertainty in cropping, whether to grow more summer or winter type of crops Herbicide use: residual herbicides affect crop options so climate outlook affects types of herbicides. Residual herbicides are useful but can seriously limit options to take advantage of an event Fertiliser inputs: in combination with subsoil moisture, take into account forecasts for in-crop rainfall when deciding how much pre-plant fertiliser to apply. If negative (dry) outlook then fertiliser will only be a budget application (maintenance–nil). If positive (wet) outlook the extra will be applied to capitalise on expected in-crop rainfall Timing and variety: take note of forecasts regarding date of last occurring frost then decide how early to plant and with what varieties
Irrigated planting area	Crop selection: summer or winter type of crops depended on the probability of rainfall and irrigation allocations
Stocking rate	Estimation of the number of stock days of feed available by using climate information to assess the odds of receiving effective rain by nominal green date (i.e. date that we receive 50 mm in 2 weeks in 80% of years), stock numbers can be reduced or increased accordingly
Infrastructure	Awareness in being prepared to make a financial commitment to maintain bores, dams, hay storage etc to ease through dry spells
Staffing	Staffing level needs would be different during different times of the year. Knowing when the season will break would be useful

Table 6 shows the responses to questions seeking ranking of the main barriers to using information about the variable climate and seasonal climate forecasts, in descending order of highest (1 = main barrier) to lowest rating (11 = least barrier). All groups listed the main barrier to be ‘uncertainty over accuracy’, which was followed by ‘perceived inaccuracy’, ‘competing information’, and ‘forecast difficult to interpret’.

In conjunction with the question about the main barriers to using climate and forecast information, respondents were asked to suggest ways to overcome each barrier. The results for the main barrier, ‘uncertainty over accuracy’, are described in a footnote to Table 6. The summarised remaining comments from respondents on what they considered to be the main barriers and how to overcome these are shown in Table 7.

The three main points emerging from Table 7 are the importance of (i) improving education and skills levels on understanding climate and forecasts; (ii) the need to show how climate information and forecasts can be used in daily operations; and (iii) the need to be aware of interpretation, limitations and accuracy of any given climate information or forecast.

Preference for delivery of a Unit of Competency in applied climate education

Preferences of participants on educational presentation, format of material and course activity are shown in Table 8. Respondents clearly preferred presenters who were knowledgeable and skilled in climate and weather (Table 8), and suggested a combination of presenters including consultants, educators, producers or ‘champions’ (enthusiastic producers who successfully use and recommend climate information). Respondents preferred material to be presented in ‘distance education’ mode, with a ‘mix’ of methods including face-to-face and a diverse range of options. Producers preferred an intensive week-long course (away from peak farm activities) but with follow-up about 6 weeks later, whereas others suggested a course for about 3 h a week over a 13-week period.

Table 6. Barriers to using variable and seasonal climate forecast information ranked in order of perceived ‘greatest barrier’ to ‘least important’ barrier

Barriers	Producers (*n* = 39)	Educators (*n* = 12)	Consultants and extension (*n* = 27)	Total (*n* = 78)
Uncertainty over accuracy[A]	1	1	1	1
Perceived inaccuracy	3	3	2	2
Competing information	2	2	4	3
Forecast difficult to interpret	7	3	3	4
Not enough flexibility	6	5	3	6
Additional information necessary	4	4	5	5
Lack access to expertise	5	4	6	7
Difficult to access information	8	5	9	8
Value not demonstrated	9	6	7	9
Proof of value necessary	10	4	8	10
External constraints	11	7	10	11

[A]Suggestions of ways to better understand and manage the ‘uncertainty over accuracy’ limitations in using climate information are: need for more localised forecasts, not general; need to increase knowledge of limitations to accuracy; develop more accurate forecasts with higher degrees of certainty; demonstrate past accuracy; education; and more research and development and always provide skill scores (*n* = 57).

Discussion

The ClimEd Steering Committee helped select individuals to survey with responses from a broad background to assist in the development of process and content of educational resources. The participatory action research approach (Zuber-Skerritt 1993) was used when the research program was implemented and established and refined through time with feedback and joint discussions. There were a number of cycles of the planning–acting–observing–reflecting spiral implemented in the needs survey and subsequent follow-up with the Steering Committee (Zuber-Skerritt 1993). The implications of needs identified in the survey for applied climate education and suggestions on benchmarking for assessing outcomes are discussed.

Applied climate education needs

This study confirms that some Australian agricultural producers and others, have begun to further adapt their practices to adjust to climate variability and climate change, and are looking to improve their skills and knowledge to better integrate climate variability in their management through a variety of sources including information channels such as the internet and also via education and training (Tables 5, 7 and 8).

The greatest need for better integration of climate forecast information in management was to overcome 'uncertainty over accuracy' and 'perceived inaccuracy' (Tables 6 and 7). A forecast is said to have 'accuracy' when what has been forecast is in exact conformity to what has occurred, e.g. a forecast that states 80% chance of exceeding the median for the next 3 months will on 8 times out of 10 occasions when this forecast is stated, have rainfall over that 3-month period equal to or exceeding the median rainfall. This forecast will also have on 2 occasions out of 10, rainfall for a 3-month period less than the median. Assessment of forecast accuracy are not routinely performed although it can be presumed any forecasts provided are the most accurate possible. Respondents in this survey sought greater accuracy of forecasts. However, given that any forecast examines global land–ocean–atmospheric interactions that are inherently difficult to predict with 100% accuracy all the time (Buckley 2002; Vizard *et al*. 2005), the next best scenario is to know when a forecast has 'skill' or 'reliability', or, in other words, the limitations of such a forecast.

Two statistical tests commonly used in assessing the 'reliability' of statistical-based seasonal forecasts in Australia, are the Kruskal–Wallis (KW) and Kolmogorov–Smirnov (KS) tests. These tests analyse probability distributions and are useful in gauging the following three key components of forecast 'skill' and reliability:

(i) consistency for extended periods during the year,
(ii) consistency as lead-time is advanced (i.e. the gap between the SOI period and the rainfall period), and
(iii) spatial coherence at multiple locations throughout a region.

A forecast is said to have 'skill' when it is statistically significant (Clewett *et al*. 2003). Statistical tests to evaluate the skill of seasonal forecasts are useful. They help to remove erroneous results in the data, and to reveal where tools such as the

Table 7. Summarised comments on remaining '…barriers to using information about climate and seasonal climate forecasts...' and suggestions on '…how these barriers may be overcome…' ($n = 80$)
BoM, Bureau of Meteorology Australia

Barrier	Ways to overcome barrier
Forecast difficult to interpret	More knowledge and more skills; better understanding; climate course to be site specific; education; understanding of probabilities is poor (and needs to be improved)
Additional information necessary	Forecasts are not an exact science; variability occurs, hence develop risk strategies to include climate forecasts; forecast on a regional or local basis; supply forecasts for other values in a range not just above or below the median (e.g. 80% probability); learning to find out what is unknown about the climate but needed to be known to make better-informed decisions
Proof of value necessary	Case studies of value in decision making; identify and use 'champions'; more education on how to access information
Lack of access to expertise	Increase skills of users; are we using most appropriate forecasts and methodology e.g. sunspots?; access to BoM website; contact lists (of experts)
Difficult to access and assess forecast information	Need knowledge and skills to assess information for specific locations; skill level needs improving and value needs demonstrating
External constraints	Forecasts are usually too late; individuals are committed to an action long before BoM releases 'drought forecasts'; need to show how forecasting can be used in day-to-day business practices
Value not demonstrated	Case studies of value for specific decisions; 'champion' concept and examples on promotion material; identify and promote use of 'champions'
Competing or conflicting forecast information	Learn how to interpret data and analyse such data; need a simple unbiased comparison of the main sources; scientific forecasters (as distinct from 'weather prophets') need better public relations skills and to 'come clean' with assessment of their performance; skill level needs to be proven
Not enough flexibility to be able to respond to forecast	Learn the basics in forecasting and maintain an up-to-date reference guide and database of information to aid in predicting the future; case studies; more time to be able to respond to a changed weather and climate pattern sooner; need 100% confidence of impending drought in April; once a decision is taken need more precise agronomic advice
Perceived inaccuracy of forecast	Be clear about reliability and limitations of information; demonstrate past accuracy; education on what the forecast really means; increased awareness of probabilities; measure and improve forecast accuracy
Other	'I have found it necessary to make my own interpretation of the above issues and factor it into my own assessment of any given forecast'; 'if the time is right to plant and the ground is wet enough – you have to plant regardless of the seasonal forecast'; lead times of forecasts need to be longer; need to provide accurate climate change information

SOI and SST have ‘real’ rather than ‘artificial’ skill as indicators of future events. Users should avoid, or at least be very wary, of using seasonal forecasts that are statistically ‘not significant’.

As a consequence of this survey highlighting the need for any applied climate education to address the issue of climate forecast ‘accuracy’ and ‘uncertainty’, it is imperative forecasts need to be verified before incorporation into risk management plans, and that attention is needed with risk management plans in cases where forecasts are not ‘skilful’ using other climate information such as historical data. This will ensure that all participants will benefit from the Unit of Competency even if forecasts are not ‘skilful’ in their region and, or at times when their key decisions are made. Attention in these areas will assist in making a course relevant to larger numbers of people and enterprises. Satisfactorily addressing of these issues should lead to greater uptake of climate information and application of seasonal climate forecasts in agricultural and natural resource management.

Although it is obvious that ongoing improvement in climate forecast accuracy is necessary and knowledge about the limits of accuracy are needed to overcome the barriers, respondents also requested specific localised forecasts (Table 6). However, ‘competing or conflicting information’ also rated highly in all groups especially in relation to confusion about conflicting forecast maps in the media. Suggestions of how to overcome this barrier included improved learning to help interpret and analyse forecast data. This would also assist overcoming the next ranked barrier – ‘difficulty of interpreting a forecast’. A forecast for a specific region or local area was suggested as being the best way to address the barrier of ‘necessary additional information’, as was the proposal of a forecast in text or by maps of forecast statements expressing ‘80% probability of exceedance’, rather than ‘chance of exceeding the median’ statements, also found by Clewett *et al*. (2000*b*). It suggests producers would rather know what is forecast at an 80% probability level rather than the 50 : 50 expression commonly used and is discussed more fully by Coventry (2000). Learning to better interpret and analyse data, and understanding knowledge about reliability and limitations of any forecasts, are necessary requirements to overcome this barrier (Sivakumar *et al*. 2000).

The issue of ‘not enough flexibility’ referred to a forecast being far too short a time frame to adjust management or provide advice, and this was particularly important for consultant and extension staff, presumably for client advice. Having up-to-date forecast information to provide to clients, having supporting case studies, and longer forecast lead times were suggested as ways to overcome this barrier. ‘Accessibility of information’ and ‘external constraints’, were perceived as being least important in barriers to using climate information and seasonal climate forecasts, although timely and location specific information was deemed to be the way to overcome these barriers.

Respondents showed significant interest in the climate and weather information. The skills audit (Table 3), reinforced climate variability as being critical and that there was genuine interest in furthering their own knowledge. The use of ‘champions’ to examine best ways to use this information to

Table 8. Ranking of preferences on presenters, material presentation and course offering
1, most preferred; 2, next most preferred and so on; —, not rated (n = 78)

Presentation data	Producers (n = 39)	Educators (n = 12)	Consultants and extension (n = 27)	Total (n = 78)
Preferred presenter				
Does not matter so long as competent in climate and weather	1	1	1	1
Combination of presenters	1	2	2	2
Bureau of Meteorology Officer	2	3	3	3
Others	2	2	5	3
‘Champion’ in the same field as yourself	2	—	4	4
Consultant	3	—	5	5
Educators	—	—	6	6
Agriculture officer	—	—	6	6
Farmer	3	—	—	6
Preferred material presentation				
Distance education	1	1	1	1
CD-ROM	2	3	2	2
Conventionally	2	3	2	2
Other (e.g. as appropriate; some face to face; mix of CD-ROM and paper; consider range of options; [there are] benefits in bringing people together)	3	2	3	3
Electronically, by web	4	3	4	4
Preferred course offering				
1 week of 40 h with a 1 day follow up 6 weeks later	1	2	1	1
Internet at own pace	3	1	1	2
3 h week × 13 weeks	2	2	2	3
Assessment by recognition of prior learning	4	3	2	4
Other (e.g. depends on need to travel; unsure of best way; schedule for block but away from peak farm activities)	5	4	3	5

make better decisions was suggested. Targeted and timely educational packages should integrate ‘champions’, and involve other extension and consultants to encourage greater uptake of information by managers in agricultural and natural resource industries, as also found by Keogh *et al*. (2005). The skills considered most essential were those that would enable respondents and their clients to be better prepared for the next wet or dry meteorological event and is supported in the literature (Clewett *et al*. 2000*a*; George *et al*. 2000, 2005*a*).

Periods of rainfall deficit and longer-term drought are major concerns for agricultural and natural resource industries and limit production and affect resource management (Table 3). This study has highlighted the necessity for improvements or adjustments to be made to educational courseware to inform short- and long-term decision-making and accommodate different learning styles (Honey and Mumford 1986). Enhancing the capability of owners, managers and operators to use climate information and forecasts potentially increases production, enhances resource management and reduces reliance on government intervention (Munro and Lembit 1997).

Implications of needs for applied climate education

Clients preferred ‘distance education’ as the approach accessing an applied climate Unit of Competency. There are many forms of distance education, but the expectation here is accessibility and flexibility for the learner, in terms of media, timing and location for learning. The clear message was that proposed applied climate education packages should be accessible from a clients’ home or workplace rather than expecting them to undertake conventional classroom-based courses, although there was some support for the latter. The implication for educators is to offer a range of activities to suit the identified needs and deliver these in an attractive mode. Other modes that received support were an intensive week-long course followed-up with clients about 6 weeks later (away from peak activities), or alternatively a course for about 3 h a week over a 13-week period, similar to findings of Kilpatrick (1997, 1999) and Roberts (2000). The pre-eminent qualification of a presenter was that of soundness in climate and weather knowledge, or an ‘expert’ in the field, which supports findings from Kilpatrick (1999).

This study identified climate knowledge and skills that are in demand in farming, agribusiness and extension and education sectors (Tables 3 and 4). The demand should translate to strong motivation for participation in applied climate education, providing the needs of potential clients as outlined above are addressed. It has also emphasised the importance of examining specific industry and location needs and tailoring educational packages accordingly. The outcome should be enhanced capacities to integrate climate information into production and natural resource management strategies to improve business success.

Table 3 shows that 42% of educationists believe they are competent or very competent in applied climate education skills compared with 28% producers and 30% of consultants. However, the skills tests (Table 4) showed no apparent difference in knowledge levels between all groups. It is possible some educationists may be over-confident and some producers under-confident of their skills (Kruger and Dunning 1999).

Benchmark for assessing effectiveness of applied climate education

The summary of correct responses to the ‘climate’ questions provided in the survey (Table 4) can act as a benchmark that may be used to assess the impact of applied climate education on knowledge and skills of clients. The three most correctly answered questions were about SOI, the mean of a set of numbers and interpreting a value from a table and need no further discussion. The four questions answered most incorrectly involve SSTs, the median of a set of numbers and interpreting a forecast.

The limited knowledge of SST indicates there is likely to be confusion about warmer than normal SST in the central equatorial Pacific Ocean being associated with El Niño years, and cooler than normal SSTs occurring in La Niña years. This ocean–atmosphere relationship is critically important for a comprehensive understanding of ENSO and consequent weather and climate in Australia (McBride and Nicholls 1983).

The two questions involving forecast interpretation and calculation of values from a forecast statement indicate that assumptions about clients’ ability to interpret a forecast from a statement and calculate values from a probability statement with a forecast value could be overly optimistic. About 30% of participants in our survey incorrectly answered these questions, and reinforces earlier findings, that many clients have difficulty interpreting a forecast (Paull and Hall 1999, 2000).

The question concerning the median figure is important because it is usually quite prominent in many forecasts. About 70% of producers, consultants and extension respondents answered this correctly. This indicates about 30% of clients misinterpret the median value, and the subsequent meaning of a forecast, and confirms findings by Keogh *et al.* (2004*b*).

After a well-designed package of applied climate education has been delivered, there should be improvements in the knowledge and skills about SSTs, the median of a set of numbers and interpreting a forecast. However and equally important, is not just the ‘knowledge’ levels, but the ‘end result’ and ‘practice change’ following any applied climate education (Bennett 1976), and should be complementary to any knowledge gains. To assess the effectiveness of the educational package, surveys of participants should be undertaken both before and after participation, and should include those who participated in the present study who subsequently undertake the applied climate education course.

Conclusion

A majority of applied climate skills listed in the survey are regarded as essential or important, but only 30% of all the respondents rated themselves as competent in those skills. The skills that respondents considered most essential were those that would enable them to be better prepared for the next wet or dry meteorological event. Thus, there should be strong motivation of agriculture and natural resource managers to participate in applied climate education. The complex issue of forecast accuracy is an obstacle for many to apply climate information and forecasts in management and might be overcome by describing forecast ‘limitations and skill’. A forecast for a specific region or local area, and a forecast in text or by maps of forecast statements expressing '80% probability of exceedance', were suggested as being the best way to address a number of barriers that were precluding individuals from using information about climate and seasonal climate forecasts.

The 'elements' and 'performance criteria' of the Unit of Competency rated highly as a useful way for 'teaching', 'learning' and 'applying' climatic concepts in agriculture and other industries. Consequently, the diverse agriculture and climate which confronts Australian producers, combined with ongoing or future climate change, strongly suggests that applied climate education will be one of the major challenges for the future of Australian rural industries. Therefore, it is recommended that follow-up or future work in this area begin with the trial and evaluation of the Unit of Competency on a pilot focused group of producers. It is further recommended that more educators, including vocational and other teachers, be trained to meet the increasing demand for climate education and agriculture in the future. Investigating how effective this training is would also be valuable research to better understand teaching and learning for improved applied climate education for the future. There exists a body of evidence of farmer demand for access to applied climate education and training. This demand justifies the development of an applied climate training course on the use of leading-edge information technologies which can assist Australian producers' better manage climate and environmental risks. Mechanisms are needed to update any course, resource and trainers as new climate science, climate impact tools and climate change scenarios are developed. Such a course is a responsible approach to disseminating high-technology information to a broad audience who may not necessarily have a background in the science underpinning climate information and assist in improving confidence, knowledge and skills to better manage climate variability and change.

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