CSIRO PUBLISHING
www.publish.csiro.au/journals/ajar *Australian Journal of Agricultural Research*, 2007, **58**, 935–938

Preface: Climate Predictions for Better Agricultural Risk Management

Holger Meinke[A,B], *M. V. K. Sivakumar*[C], *Raymond P. Motha*[D], *and Rohan Nelson*[E]

[A]Crop and Weed Ecology, Department of Plant Sciences, Wageningen University, PO Box 430, 6700 AK Wageningen, The Netherlands.
[B]formerly: Queensland Department of Primary Industries, PO Box 102, Toowoomba, Qld 4350, Australia.
[C]World Meteorological Organization, 7bis Avenue de la Paix, 1211 Geneva 2, Switzerland.
[D]U.S. Department of Agriculture, World Agricultural Outlook Board, 1400 Independence Avenue, S.W., Room 4441 South Building, Washington, D.C. 20250, USA.
[E]CSIRO Wealth from Oceans Flagship, GPO Box 284, Canberra, ACT 2601, Australia.

Agriculture is arguably one of the most climate-sensitive sectors in our global economy. Many developing countries remain heavily dependent on agriculture for national income, while agriculture occupies a special place in the national psyche of many developed nations. Hence, any effort that helps to reduce the vulnerability of this sector to climate-related risks is likely to lead to considerable global benefits, both economic and social. Seasonal climate forecasts[1] (SCFs) are seen as one way of reducing the sensitivity of rural industries and communities to climate risk, but adoption of these technologies has so far failed to live up to the expectations of the scientific community. To help understand why, the Commission for Agricultural Meteorology (CAgM) of the World Meteorological Organization (WMO) established an International Expert Team (ET) on 'Impact of Climate Change/Variability and Medium- to Long-Range Predictions for Agriculture'. This ET was part of the Open Program Area Group 3 (OPAG 3) of CAgM.

In February 2005, WMO together with the Queensland Department of Primary Industries and Fisheries (DPI&F) organised and hosted a Workshop of the ET in Brisbane, Australia. The choice of Australia to host this workshop was quite deliberate; Australia is exposed to extreme climate variability and is already living with the impacts of climate change (Hammer *et al*. 2000; Meinke *et al*. 2006). 'Learning from climate variability to adapt to climate change' has become the Australian approach to climate risk management. Australian farmers have to be competitive without most of the subsidies accessible to their counterparts in Europe or the USA. Consequently, the Australian agricultural sector has developed coping mechanisms and strategies that are well adapted to the prevailing climatic conditions and capable of accommodating further change. The Australian experience is relevant for many other parts of the world where farmers self-manage climate risk, particularly in the semi-arid tropics and subtropics. The choice of location was therefore logical and it is hoped that the outcomes from this workshop will contribute towards building increased resilience to climate-related risks, regardless of location.

The terms of reference given to the ET were

(*a*) To appraise and report on current capabilities in the analyses of climate change/variability and long-range prediction studies, specifically as they relate to and affect agriculture, rangelands, forestry, and fisheries at the national and regional levels;
(*b*) To produce a review on the current status of methodologies for the presentation of seasonal-to-interannual prediction products and applications to the agricultural end user;
(*c*) To review the availability and suitability of software packages for the calculation of appropriate seasonal climate variability indices for agricultural applications; and
(*d*) To make recommendations on research and development activities needed to improve the technology for the benefit of agriculture, rangelands, forestry, and fisheries.

The workshop resulted in a set of detailed recommendations to WMO that specifically addressed the following 8 points: training and capacity building, collaboration and partnerships, integration and whole systems approaches, assessment and review, research and development needs, policy linkages and communication with end-users. Further details of the workshop are reported by Garbrecht *et al*. (2005).

The scientific outcomes from this workshop are briefly summarised below

The paper by Motha (2007) takes a global perspective and sets the scene by pointing out that many extreme climate events are a consequence of known climate phenomena. Some of these phenomena can be predicted, but appear to be modulated by climate change in terms of frequency and intensity of these events. There is some scientific evidence that the accuracy of both our statistical methods and forecasts based on Global Circulation Models (GCMs) might increase with time. Such scientific advances in climate science need to be merged with similar advances in our understanding of the dynamics of agricultural systems. This might be achieved by designing

[1]Note that the acronym 'SCF(s)' is used here for 'seasonal climate forecast(s)' as well as for 'seasonal climate forecasting'.

 10.1071/ARv58n10_PR 0004-9409/07/100935

downscaling methods that connect seamlessly with agricultural simulation models to convert site-specific data into information suitable for decision making.

Statistical methods are still the most widely used approach to produce SCF products. This is in spite of the fact that GCMs, which account dynamically for many climate/environment interactions, have been under development for several decades. Power *et al*. (2007) therefore ask: how can these climate models become more useful for risk managers and what are the factors inhibiting their adoption? They identify 3 key impediments, namely (*a*) low forecast skill, (*b*) a mismatch between the forecasts provided and user requirements, and (*c*) the difficulties arising from the complexity and the probabilistic nature of the forecast. Power *et al*. (2007) are cautiously optimistic that progress can be made. They point to two 'revolutions' currently under way; one is our enhanced ability to monitor the ocean system via the Argo float program, and the second is much improved data gathering of the global climate systems via satellites. The former will drastically improve parameterisation of GCMs, while the latter provides the much-needed data for model evaluation. The authors conclude that rapidly increasing computing power will allow us to increase the resolution and accuracy of GCMs and their derivatives, thereby increasing not only their relevance to the intended problem domain but also their scientific credibility.

Ash *et al*. (2007) highlight the constraints and opportunities in applying SCF from the perspective of farmers in Australia. They stress that farmers need to make management decisions on a daily basis in the face of climate variability. Adoption of the existing knowledge depends strongly on the variables that are forecasted and specifically on their accuracy, likely economic and natural resource benefits, and how well they are communicated. They point to the insufficient integration of forecast information with farmers' decision making as a key constraint in the widespread adoption of SCF. In particular, the probabilistic nature of the forecasts needs to be better communicated. To achieve better integration, effort is required to better target (*a*) regions with useful forecast skill, (*b*) farming systems or enterprises that are amenable to incorporation of SCF, and (*c*) specific farming decisions that have a low downside risk. The incorporation of SCF into farming decisions also needs to account for the adaptive capacity of farmers and rural communities by recognising the complexity of the system and the fact that climate is just one variable in a matrix of many, all of which are relevant for decision making under uncertainty and risk management.

Based on their experience in the USA, Garbrecht and Schneider (2007) discuss how impediments for the successful implementation of SCF delivery systems at the farm level can be overcome. Similar to Ash *et al*. (2007), they note that for successful adoption of SCF: (*1*) regions need to posses skilful and actionable forecasts, (*2*) regions need to be agriculturally active and support crops that are sensitive to climate variability (for the US, only the Florida peninsular and eastern and southern Texas appear to fulfil this criterion), and (*3*) processes need to be in place that encourage agricultural service agencies to include forecast-based decision support in their services. The authors stress the importance of participatory approaches that include all interested parties to ensure success in the development, implementation, and communication of farm-specific prediction products.

Hayman *et al*. (2007) report that while 30–50% of Australian farmers take note of SCF, integrating this information into decisions on farm is a greater challenge than first thought. Using adoption theory, they compare probabilistic SCF to other innovations that farmers are encouraged to adopt (e.g. new varieties, no-tillage, or precision farming). Based on this, Hayman *et al*. conclude that SCF is a complex innovation that has a low level of compatibility with how farmers make decisions, mainly because attribution of advantages are difficult to make in any single year. In spite of this, SCF as an innovation has the advantage of being low cost, and can be applied across the whole farm (economies of scale) and across a range of enterprises (economies of scope). Some SCF applications can have high educational value, allowing users to learn about their range of available and possible *choices*, *chances*, and *consequences*. Hypothetical management decisions can be evaluated *in silico* rather than via long and costly *in vivo* experimentation. This can help decision makers to improve their clarity of thinking by translating imperfect information based on SCF into practical risk management. Hence, future improvements of SCFs need to consider their dual role as (*a*) an innovation in farm management, and (*b*) a means to build capacity for better farm-level risk management.

Picking up the theme of risk management, Hertzler (2007) argues that a new approach is needed to make better decisions under uncertainty. He proposes the use of *real options analysis* as a means to decide when to keep options open and when to foreclose options and create new ones. The real options approach combines common sense with mathematical rigour by quantifying the potential future value of uncertain forecasts and by outlining new ways that risks can be managed and externalised via risk sharing contracts (e.g. developing new insurance products such as index yield insurance). Using diverse examples such as managing risks of cropping or grazing enterprises, divorce or property rights, Hertzler demonstrates how a real option approach might work if farmers and the financial sector collaborate in developing such novel financial tools. By providing these examples, he also dispels the myth that a 50 : 50 forecast has no value. In fact, the opposite might be the case—the more emphatic the forecast, the less value it might have for managing externalised risks. While there is certainly scope for financially astute farmers to adopt and benefit from financial risk management instruments of this kind, their broader adoptability in both developed and developing nations is yet to be explored.

From risk management the discussion moved on to the importance of creating a supportive policy environment for the self-management of climate risk by rural industries and communities. In their two-part series, Kokic *et al*. (2007) and Nelson *et al*. (2007) argue that, at least in Australia, a relevance gap exists between climate science and the goals of drought policy. Currently, science provides policy with analyses of simple climate variables such as rainfall and temperature, which are largely beyond the influence of policy. They show how this relevance gap can be narrowed via the intelligent integration of biophysical and socioeconomic models that use SCF to predict the impacts of climate variability on rural livelihoods.

Through a novel application of M-quantile regression, they make a simple, econometric farm income model responsive to SCF by integrating it with crop and pasture models. The resulting bioeconomic modelling system is capable of forecasting the direction of movement in Australian farm incomes at the beginning of the financial year.

Nelson *et al*. (2007) go on to show how forecasts of farm financial performance from this bioeconomic modelling system can be used to overcome the moral hazard and timing issues that have been used to justify reliance on simple biophysical measures of climate risk in Australian drought policy. They also use the model to relate climate-induced income variability to the diversity of farm income sources, providing a practical measure of adaptive capacity that can be positively influenced by policy.

In addressing the relevance of our science to both rural communities and policy advisers, the ET reflected on aspects of practice and institutional design that maximise its societal value. The discussion surrounding Ash *et al*. (2007), Garbrecht and Schneider (2007), and Hayman *et al*. (2007) highlighted the difficulties farmers have in integrating SCF into their decision making, which were echoed by Nelson *et al*. (2007) in the policy domain. While science is geared towards providing detailed, quantitative solutions to precise questions, decision makers such as farmers and policy makers require holistic evaluations of multiple sources of risk. Breaking down the science–decision making relevance gap highlights the importance of creating boundary-spanning organisations (Cash and Buizer 2005) that nurture societally responsive (and therefore valuable) climate science. Nelson *et al*. (2007) drive this point home with a quote by the famous statistician John Tukey, who said: *Far better an approximate answer to the right question, which is often vague, than the exact answer to the wrong question, which can always be made precise.*

The workshop participants concluded that the notion of using SCF as a means to achieve better risk management is sound, but depends on redefining the concept of climate knowledge and who is likely to benefit from it. Integrating SCF to improve real life decision making—either on the farm or in policy—is challenging and requires integrative and participatory methods embedded within institutions capable of and interested in supporting this kind of science. All participants agreed that future research needs to focus on improving the skill and relevance of SCF to specific decision makers. Successful application of SCF requires approaches that are relevant and credible to decision makers, and delivery of SCF technologies in a manner that is legitimately focused on their interests (Cash and Buizer 2005).

Essential to achieving relevance, credibility, and legitimacy is matching the development of SCF technology with the needs of decision makers operating in diverse contexts across multiple scales. There was general recognition at the workshop that potential users of SCF in both developing and developed countries have diverse climate risk management needs. Part of the reason for slow uptake of SCF has been limited attention to contextually relevant communication of SCF to specific user groups. Participatory engagement to understand user needs and adoption constraints is crucial to realising the societal value of SCF.

Workshop participants also agreed that the rhetoric and lexicon of climate scientists needs to shift beyond forecasts of climate variability and change to embrace a broader concept of ‘climate knowledge’. This broader concept would empower both decision makers and scientists by defining the achievements of science against the participatory evolution of user relevant outcomes across diverse contexts and multiple scales. This requires approaches that integrate our knowledge of climate risk with the vulnerability of natural and socioeconomic systems to create a new kind of climate knowledge much closer to the holistic management of multiple risks faced by decision makers.

Development and adoption of climate applications is particularly constrained in developing countries due to a lack of human, financial, and institutional capability. The workshop highlighted disconnects between efforts to build the science capacity necessary to develop SCF, and the broader multi-disciplinary research necessary to achieve adoption. There is a significant opportunity for developing countries to learn from the experiences of developed nations in building societally responsive climate science practice and institutions.

Among others, the workshop drew on insights gained from the CLIMAG program, a recently completed international research effort that documented the advance made in climate prediction (Hansen *et al*. 2006). However, no matter how good the science is, some inherent uncertainty will always remain. In such an uncertain world, people have options. They have the opportunity, but not the obligation, to take action when presented with alternative scenarios based on climate knowledge. The adoption of SCF takes place within a process of deciding which risks should be retained and managed adaptively, not managed at all, or shared through some form of risk sharing mechanism. Scientists who are developing forecasts and forecast products must not only be aware of this socio-economic context, they must also engage closely with the end-users of these products to design adoptable tools and/or methods.

So far, climate prediction science has, by default, driven the development of SCF and related applications and tools. Experience over the last decade indicates the need for a problem and user oriented approach to forecast application development that is characterised by participatory approaches without disciplinary dominance (Garbrecht *et al*. 2005). This is likely to require an ongoing re-think and adaptation of scientific practice and institutions.

References

Ash A, McIntosh P, Cullen B, Carberry P, Stafford Smith M (2007) Constraints and opportunities in applying seasonal climate forecasts in agriculture. *Australian Journal of Agricultural Research* **58**, 952–965.

Cash D, Buizer J (2005) Knowledge–action systems for seasonal to interannual climate forecasting. In ‘Summary of a Workshop, Report to the Roundtable on Science and Technology for Sustainability, Policy and Global Affairs’. (The National Academies Press: Washington, DC) Available at: http://books.nap.edu/catalog/11204.html (last accessed 05/10/2007).

Garbrecht J, Meinke H, Sivakumar MVK, Motha RP, Salinger MJ (2005) Seasonal climate forecasts and adoption by agriculture. *EOS, Transactions, American Geophysical Union* **86**, 227. doi: 10.1029/2005EO240005

Garbrecht JD, Schneider JM (2007) Climate forecast and prediction product dissemination for agriculture in the United States. *Australian Journal of Agricultural Research* **58**, 966–974.

Hammer GL, Nicholls N, Mitchell C (Eds) (2000) 'Applications of seasonal climate forecasting in agricultural and natural ecosystems: the Australian experience.' (Kluwer: Dordrecht, The Netherlands)

Hansen JW, Sivakumar MVK, Bates BC (Eds) (2006) Advances in applying climate prediction to agriculture. *Climate Research* **33**, Special 16.

Hayman P, Crean J, Mullen J, Parton K (2007) How do probabilistic seasonal climate forecasts compare with other innovations that Australian farmers are encouraged to adopt? *Australian Journal of Agricultural Research* **58**, 975–984.

Hertzler G (2007) Adapting to climate change and managing climate risks by using real options. *Australian Journal of Agricultural Research* **58**, 985–992.

Kokic P, Nelson R, Meinke H, Potgieter A, Carter J (2007) From rainfall to farm incomes—transforming advice for Australian drought policy. I. Development and testing of a bioeconomic modelling system. *Australian Journal of Agricultural Research* **58**, 993–1003.

Meinke H, Nelson R, Kokic P, Stone R, Selvaraju R, Baethgen W (2006) Actionable climate knowledge—from analysis to synthesis. *Climate Research* **33**, 101–110. Open access at: www.int-res.com/articles/cr_oa/c033p101.pdf (last accessed 05/10/2007).

Motha RP (2007) Implications of climate change on long-lead forecasting and global agriculture. *Australian Journal of Agricultural Research* **58**, 939–944.

Nelson R, Kokic P, Meinke H (2007) From rainfall to farm incomes – transforming advice for Australian drought policy. II. Forecasting farm incomes. *Australian Journal of Agricultural Research* **58**, 1004–1012.

Power SB, Plummer N, Alford P (2007) Making climate model forecasts more useful. *Australian Journal of Agricultural Research* **58**, 945–951.