Introduction and Overview

A.K.S. Huda[1], R.G. Packham[1], J.F. Clewett[2] and D.A. George[2]

CLIMATE variability has a large impact on agricultural production, human health and the well-being of communities throughout the world; therefore research in this field has a high priority in many countries, including Australia. The impacts of climate variability are particularly relevant in those countries affected by the El Niño/Southern Oscillation (ENSO) phenomena, such as Australia, Indonesia, southern Africa and India. For example, the 1982–83 El Niño caused devastating drought in southern Africa, India and Australia, and forest fires in Indonesia. The four-year 1991–94 El Niño caused famine and the death of thousands in Africa, and agricultural losses of more than $6 billion in the Australian state of Queensland. In East Java, the ENSO-related drought in 1991 caused 190 000 ha of rice to be abandoned due to insufficient water for irrigation at a cost of $28m in lost inputs. The drought of 1997–98 in Indonesia and Papua New Guinea caused significant crop losses and forest fires, resulting in one of the largest famine relief operations mounted by the Australian government to aid these countries. During the mid-1950s and 1970s, higher than average rainfall provided opportunities for better harvests in many parts of Australia, whilst the early 1930s and 1990s brought drought and crop failures.

Farmers and those involved in the agricultural sector are well aware of climate variability. The ability to understand, monitor and predict this climatic variability provides an opportunity to put historical experiences into perspective and to evaluate alternative management strategies for making improved decisions to take advantage of good years whilst minimising the losses during the poor years (Huda, et al. 1991; Huda, 1994; Pollock et al. 2001). Significant progress has been made by scientific research over the last decade to understand the atmospheric and oceanic processes causing ENSO, and this knowledge is now used to make seasonal climate forecasts on a regular basis. However, a significant problem remains of translating seasonal climate forecast (SCF) information into appropriate actions by farmers and other resource managers so that the potential benefits from forecasts are captured. This problem can be overcome in a number of ways, including:

- identifying the key decisions and practices in the farming cycle to which forecast information may be applied;
- improving the tactical and strategic responses to information; and
- education and effective communication.

This introductory chapter highlights how this publication fits within the ACIAR-funded project *Capturing the benefits of seasonal climate forecasts in agricultural management* by addressing some of the issues related to the use of seasonal climate forecasting (as listed above) through some selected case studies. This chapter also briefly outlines the understanding of ENSO and Seasonal Forecasting Methods (SFM) building on some of the publications arising out of this project.

Context of the ACIAR project and its scope

Several agencies throughout the world are now supporting research and extension programs concerning the application of ENSO-based seasonal forecasts in agriculture. This activity is occurring in countries such as Africa, Australia, India, Indonesia and other southeast Asia countries, and the north and south American continents. An example is the recently completed project *Capturing the benefits of seasonal climate forecasts in agricultural management* funded by the Australian Centre for International Agricultural Research (ACIAR) which involved the participation of some 35 staff from 10 agencies in four countries (Indonesia, Zimbabwe, India and Australia) (Clewett 2004a). Three major components of this study that were successfully achieved, were:

- understanding the mechanisms and impacts of ENSO and assessing the skill of ENSO-based seasonal forecasts;
- application of seasonal forecasts in communities via participative problem-solving extension

[1] School of Environment and Agriculture, University of Western Sydney, Hawkesbury Campus, Locked Bag 1797, Penrith South D.C. NSW 1797, Australia.
e-mail: s.huda@uws.edu.au
[2] Queensland Cenre for Climate Applications, Department of Primary Industries, Tor Street, Toowoomba, Qld, 4350, Australia.

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processes to improve the decision-making skills of farmers;

- development of decision-making support systems for seasonal forecast technologies such as workshop processes, printed materials and software including climate analysis tools and agricultural models.

These three issues are central to other chapters in this book and are thus discussed in more detail.

Understanding of ENSO and seasonal forecasting methods

Clewett (2004b) considered opportunities for application of seasonal climate forecasts in Indonesia, Zimbabwe, India and Australia. Forecasts based on the Southern Oscillation Index (SOI) were used to assess the amount, timing and frequency of seasonal rainfall in four study regions. The paper included a review of seasonal forecast methods. Opportunities to use forecasts were considered in relation to grazing systems and streamflow in Australia, management of rangelands in Zimbabwe, irrigation management in Indonesia and dryland cropping systems in southern India.

The weather in Australia is generated as the atmosphere circulates over the continent and its surrounding oceans. From day to day, the weather is controlled by the systems of high and low atmospheric pressure and the fronts that we see on synoptic weather charts on television and in newspapers, and also by upper air systems. However, these systems are only a local response to the general circulation of the atmosphere around the entire Earth (Clewett et al. 2003).

The two main seasonal forecast tools used in this project were the Southern Oscillation Index and an index of Sea Surface Temperature (SST). The historical values of the SOI (1876–2004) were based on the work of Troup (1965) and Allan et al. (1996b) and represent standard deviations (×10) of differences in air pressure anomalies between Tahiti and Darwin. The SOI is provided by the Bureau of Meteorology and is updated and periodically revised on their website. The SST index is also provided by the Bureau and is for the SST 9 phase seasonal forecast developed by Drosdowsky (2002).

The seasonal forecast analysis method was based on established relationships derived and substantiated from the work of McBride and Nicholls (1983), Nicholls (1984a, 1984b, 1984c, 1986, 1991), Allan (1988), Ropelewski and Halpert (1987, 1989), Clewett et al. (1989, 1991b), Allan and Pariwono (1990), Hastings (1990), Drosdowsky and Williams (1991).

The general circulation

The general circulation is driven by temperature differences caused as the sun heats the Earth's surface unevenly — the equator receives most solar radiation, the polar regions the least.

The higher latitudes are effectively no extra distance from the Sun, but they receive less radiation per unit of surface area because of the more oblique angle of incidence. The effect is greatest over water, which absorbs radiation when the sun is overhead, but reflects more than 70% when the rays are oblique. Much of the radiation towards the poles is reflected off atmospheric clouds and surface ice.

The Southern Oscillation is strongly associated with rainfall in eastern Australia. When sea temperatures are lower than normal around Indonesia and pressures are higher than normal, northern and eastern Australia often experience droughts; when sea temperatures are higher than normal, these areas often receive above-average rainfall.

Because an unusually cool sea off northern Australia usually coincides with an unusually warm sea off South America — known there as El Niño — and a weak Walker Circulation, the combined system is often referred to as the El Niño/Southern Oscillation (ENSO) phenomenon. The reverse situation, with a strong Walker circulation and colder sea surface temperatures off South America, is called La Niña or Anti-ENSO.

The Southern Oscillation has an irregular cycle averaging about four years. The cycle develops through close three-dimensional interactions of the atmosphere and ocean, and is associated with droughts or heavier than average rainfall over many parts of the world.

The key indicators for predicting weather in eastern Australia are:

- Southern Oscillation Index;
- temperature of the sea surface across the tropical Pacific Ocean;
- strength and direction of Pacific trade winds; and
- location of cloud in the tropical Pacific.

Sea surface temperatures in the eastern Indian Ocean may allow improved prediction of winter rainfall over parts of southern, eastern and northern Australia.

The Southern Oscillation Index (SOI)

The strength of the Southern Oscillation is measured by the difference in air pressure between the two regions; the commonly-used 'Troup' index reflects the air pressure difference between Darwin and Tahiti, records for which started in 1869 and 1876 respectively. This Southern Oscillation Index usually ranges from –30 to +30.

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When the Southern Oscillation Index is strongly positive, the trade winds blow strongly across the warm Pacific picking up plenty of moisture; much of eastern Australia is then likely to receive above-average rainfall.

When the SOI is strongly negative, trade winds are weak, or even reversed, and rainfall in the Indonesian and Australian region can be much below average — a possible drought in an El Niño or ENSO event.

These differences in sea surface temperature between the east and west of the equatorial Pacific cause another great vertical circulation of air — the Walker Circulation (Fig. 1).

The Walker Circulation has three main elements:

- air flows west across the tropics of the Pacific (southeast trade winds), being warmed and gathering moisture from the warmer waters of the western ocean;
- it is uplifted over the Indonesian region, dropping the moisture as rain; and
- the dry air then flows east, at an altitude of about 12 000 metres, to sink again over the normally cold waters of the eastern Pacific.

This 'normal' Walker Circulation is greatly changed during extreme phases of the Southern Oscillation. It is strengthened when the sea surface temperature in the eastern Pacific is abnormally low La Niña. It is weakened when that water becomes abnormally warm, making the cross-Pacific air pressures more equal; the trade winds weaken and may even reverse becoming westerly El Niño.

These phases of the Southern Oscillation result from inter-related changes in the atmosphere and ocean in three dimensions.

The changes include:

- temperatures of the ocean surface;
- levels of the ocean;
- circulation of the ocean (currents and upwelling in the ocean);
- temperatures of the atmosphere (surface and upper level);
- pressures within the atmosphere (upper and lower levels); and
- circulations of the atmosphere (winds and cells).

How quickly does the SOI change?

If the Southern Oscillation behaved in a regular cycle, it would allow climate predictions one or two years into the future. Unfortunately, although the average cycle is about four years, strong negative or positive phases occur irregularly at intervals of three to six years.

Extreme phases of the Southern Oscillation usually last for about nine months once they have become established.

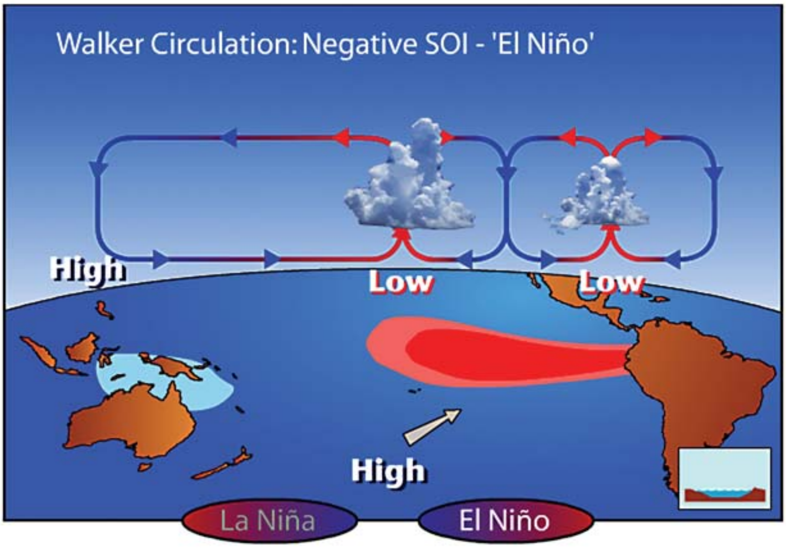
Droughts often break when the SOI rises rapidly from extremely low values even if it does not become positive; for example, when it changes from −15 to 0. These trends, or phases up or down, are also used as indicators.

While the Southern Oscillation modifies the climate pattern, the weather continues its natural variability under other influences. These are sometimes so dominant that the Southern Oscillation cannot be a totally reliable indicator of future weather.

Issues related to seasonal climate forecasting

One issue is the use of seasonal forecasts for predicting when events will happen, such as the date of onset of the wet season. Timing of when events occur is of great importance in agriculture. Break of season rains often start a flurry of activity in agricultural communities, such as planting of crops, and thus ENSO-based forecasts of when the wet season will start can be of great value. Median date of onset is a highly variable statistic and thus statistically significant differences are difficult to find without long data sets. Clewett (2004b) showed that ENSO influences are strong in Indonesia and northeastern Australia and can alter the median date onset by several weeks. In contrast, in India and Africa where ENSO influences are not so strong the median dates for planting are altered by a week or so. Quite often a major difficulty with this kind of analysis is the lack of daily data in digital format. Forecasts on the timing of events are important in grazing systems regarding date of onset of pasture growth. They are also important in irrigation systems regarding the timing of river flows and availability of irrigation water.

The seasonal forecast capabilities used in this project have been developed from results of soundly based research on the characteristics of ENSO. The impacts of ENSO have been shown to vary with time of year and location, and to be stronger in the southern areas of Indonesia and northeastern Australia than in Zimbabwe or southern India (for north-east monsoon). People gain confidence in using risky seasonal forecasts when they understand the physical basis of ENSO and thus the reasons for its influence on global, regional and local climate patterns. The relationships of ENSO with changes in the characteristics of seasonal rainfall (timing, frequency of events and amount) at their own location, and consequent impacts on agriculture, are important. Learning to use ENSO information in management is maximised by combining 'hands on'



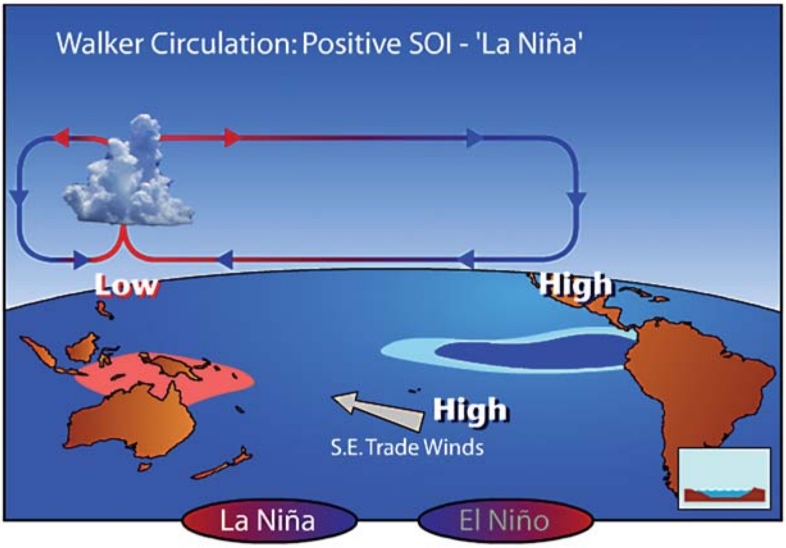


Figure 1. Walker Circulation (after, Rainman, Clewett et al., 2002, 2003).

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learning with the software with participation in a workshop where people can test their ideas and also listen to the knowledge and experience of others.

Perceptions of climatic risk

As individuals, people have different needs and learning styles, and thus respond to information in different ways (Clewett, 2004b). Cumulative probability distributions often provide an effective mechanism for scientists to communicate with each other. However, in communicating with the farming community we have found that other diagrams and ways of expressing risk are more effective, such as frequency plots, pie charts, box plots and time series. The simplest statement for communicating risk has been the percent chance that seasonal rainfall will be above or below the median rainfall (or above or below the average) (Stone et al., 1996). While this very simple statement of risk is now widely used in the agricultural media in Australia, the research by Coventry (2001) shows that this statement can be easily misinterpreted by some people because of confusion about probability issues and thus on-going education processes are needed. The text by Hammer et al. (2000) provides a recent review of the application of seasonal climate forecasting in Australian agriculture and natural ecosystems. In this latter text, the paper by White (2000) highlights the potential value of seasonal climate forecasts to agriculture, but also recognises the substantive difficulties that people have in applying probability-based information to management decisions.

The fullest understanding of climate risk often occurs where people have been able to view all of the historical rainfall (for example 100 years of data) as a time-series histogram. These diagrams showing the sequence of historical events can be particularly useful because they are an analogue of people's memory patterns. Research (Coventry, 2001) has shown that people are more able to assimilate statements about frequency (for example seven years in ten) than the more abstract probability statement (for example, 70% chance). Simplicity is often the key to comprehension. Comprehension empowers people with ownership of the forecast and thus gives them confidence in moving towards using it in their decision-making.

Participation and decision-making with farmers

Though several methods for forecasting seasonal climate are available, this area requires refinement, further strengthening and extension. Nicholls (1999) discussed some of the constraints to the effective use of climate forecasts and suggested that forecasters need to understand the difficulties faced by the users and to make adjustments for them in the way forecasts are prepared and disseminated. However, a significant problem remains in translating the seasonal climate forecast information into appropriate action by farmers to minimise risk. The problematic issues include how climate and weather information (forecast) can be used to make improved decisions for a number of practices including crop/variety selection, sowing time, sowing area, fertiliser application, harvesting, estimation of yields, crop quality and marketing.

Farmers bear the consequences of the decisions taken. For some farmers it is not just an issue of profit and loss but whether can they grow enough food to feed their family and livestock (food security). Thus it is very important for the researchers, extension and community workers to build rapport with farmers based on trust and mutual respect. Most agricultural research scientists in Australia still regard 'technology transfer' as the main concept underpinning extension practice (Macadam, 2000). In this model we are led to believe that progress in agriculture is achieved through transferring the results of scientific research to farmers. Informed critics point to the simplistic assumptions of this model, particularly about farmers not simply being passive recipients of the knowledge of researchers, which has largely discredited this concept (Rollings, 1988; Bawden and Macadam, 1991; Drinan, 1992; Pretty, 1995; and Ison and Russell, 2000). The process of technology transfer would be more effective through mutual interaction and respect for each other's values — a move from a linear to a circular model of information exchange. One result of this has been an increased use of participative action research and other learning-based approaches to better respond to the needs and opinions of local people.

Macadam (1997) traces the historical development of alternative extension paradigms in Australia and identifies the emergence of an appreciation of the need to enhance clients' capacity to make informed and critical decisions. He calls this paradigm, with its emphasis on empowering clients, a 'learning paradigm'; and contrasts this circular approach with the linear, teaching approach inherent in the technology transfer model. To make this switch in practice is, however, a complex and challenging endeavour, introduced in a paper by R.G. Packham on page 35.

Huda et al. (2000) discussed how researchers could build activities into their programs that help them to participate with farmers in experiencing what it means to:

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- collect climate information (from whatever source);
- make sense of the information in terms of likelihood of events occurring;
- use decision support tools and techniques to explore biological outcomes, economic risks and potential returns; and then
- take decisions based on this informed analysis, while also bearing the consequences of such decisions.

Thus researchers need to ask:

- How do farmers currently make decisions related to seasonal climate issues?
- How might farmers be educated about using new knowledge of seasonal climate forecasting?
- How might they use these forecasts for decision-making?
- How might farmers develop confidence in the use of such forecasts?
- What are the prerequisites to learning for farmers?
- How might we integrate information (for example, production, pests control, marketing)?
- How might we best disseminate information?
- How might we reach all farmers?

Why a participatory approach? The need for farmers and scientists to work together

Many agricultural decisions are more uncertain than complex. In dryland farming there are often fewer 'levers to pull', but a lot of uncertainty. What research can do is put numbers on that uncertainty and discuss options with farmers. Working with farmers on an issue as multifaceted as risk management is not a case of one way, unambiguous information flows to farmers, teaching farmers or even providing decision support for farmers. Nor is it a case of just listening to farmers and observing what they are doing. Rather, it is a case of intervening, of joining a complex *dance* where it is never clear who is leading whom, and where both farmers and scientists are prepared to modify and learn new 'dance steps' as they manage farming systems (Hayman, 2001).

Huda et al. (1992) and Huda (1994) demonstrated the benefits of working with farmers from the beginning of a project to evaluate alternate management strategies that minimise climatic risk to wheat production in low rainfall areas of southern Australia. At the onset of this project, it was found that trying to provide definitive answers using scientific knowledge and climate models was not what farmers wanted or needed.

Through dialogue with farmers, extension workers and researchers from other disciplines, it was realised that farmers have few options in their management processes to use this complex information. What they needed was simple *rules of thumb* at critical points (often narrow windows) — such as for planting, harvesting, etc — to make better informed decisions that minimised their risk and maximised their opportunities as far as was possible, given the fact that the future may never be fully known.

In response to this situation, and as part of the ACIAR project, it was decided to organise a workshop (Huda and Packham, 2000) to share the experiences of researchers, farmers, community/extension workers and others about issues of working participatively with farmers. We hoped that this would improve and influence future aspects of both the ACIAR project and other climate-related agricultural research. This report emerges from that workshop.

It provides an appreciation of how a participatory approach can be used in a seasonal climate forecasting application context. The case studies presented include the assessment of the impact of climate variability on crop production and water availability in both Australia and the partner countries of India and Indonesia.

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