

Drought Science and Drought Policy in Australia: A Risk Management Perspective

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Abstract

This paper describes Australian science about, and policies to deal with, drought from a risk management perspective. Coverage includes a review of recent policies, the role that the Bureau of Rural Sciences (BRS) plays within the Commonwealth Department of Agriculture, Fisheries and Forestry-Australia in relation to drought, and Australian examples of seasonal forecasting tools and services.

Background: Australia's Drought Policies in the 1990s

The National Drought Policy (1992)

Australians farm an island continent where production agriculture operates in a highly unreliable climate. Up to 80% of Australia's agricultural products are destined for the international marketplace, where prices fluctuate in an increasingly open and competitive economy. These two sources of risk—the recurring cycles of drought and changing economic values for commodities—are two very significant drivers of risk in Australian agriculture.

Policies that provided direct subsidies and other forms of support to underwrite drought risk were phased out in 1992 with the inception of the National Drought Policy, developed by Australia's Commonwealth and state governments through the policy development process at ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). The three principles of the policy are to

1. encourage primary producers and other sections of rural Australia to adopt self-reliant approaches to managing climatic variability;
2. maintain and protect Australia's agricultural and environmental resource base during periods of extreme climatic stress; and
3. ensure early recovery of agricultural and rural industries, consistent with long-term sustainable levels.

The core principle, *self-reliance*, maintained that farmers and regional professionals were in the best position to develop the agronomic systems, practices, and business strategies that would manage frequent agronomic droughts in Australia. This moved Australia's drought policy away from a subsidy-based, reactionary or "crisis driven" approach. The setting was created in which drought is considered a normal part of the Australian farming environment. State and

Commonwealth governments negotiated the staged removal of subsidy-based support for drought, including transaction-based business support particularly for transport, water, and livestock provided by state and territory governments. The framework focused rural Australia on developing risk management strategies to manage climate and market variability.

Following our (BRS) experience with evaluating drought in the 1990s, the concept of self-reliance is one of the key principles for understanding Australia's approach to managing drought. In the long run, it is hoped that through continued improvement of risk management strategies, future meteorological (i.e., deficiency in rainfall) droughts will have decreased impact on agricultural production.

Drought Exceptional Circumstances (DEC, 1995)

In 1994-95, much of eastern Australia was gripped by a severe meteorological drought. Analyses demonstrated that rainfall during this period was in the lowest 5% of historical observations for some locations. In some subregions, pasture availability and crop yields were the lowest or second lowest in the 100-year record. At that time, the government developed the policy of Drought Exceptional Circumstances (DEC), allowing the Commonwealth Minister for Agriculture to allocate business and welfare support for affected producers.

After consulting the states and territories, a national framework for assessing DEC was established (ARMCANZ resolution 1F, August 18, 1995). While acknowledging the principles of the National Drought Policy, the framework noted circumstances that warranted direct government intervention. These were defined as rare and severe events: rare being a 1 in 20 year event, and severe being either more than 12 months or at least 3 consecutive failed seasons, depending on the nature of the production system being considered. The framework revolved around the assessment of 6 criteria:

1. meteorological conditions;
2. agronomic and stock conditions;
3. water supplies;
4. environmental impacts;
5. farm income levels, and
6. scale of the event.

The agreement stated that DEC would be indicated when the combined impact on farmers of the six criteria was a rare and severe occurrence, and that meteorological conditions would be the threshold or primary condition. Drought support continued until it could be demonstrated that climatic and agronomic conditions had returned to a level that was considered normal.

The Rural Adjustment Scheme Advisory Council (RASAC), with representatives from government, rural industry, and the farming community, was the key advisory body, reporting to the Commonwealth Minister for Agriculture, while the final decision rested with the Commonwealth government's Cabinet of Ministers. The assessment was based on a formal application from the state government in which the affected region was located. RASAC also sought independent information, including scientific analysis from the Bureau of Rural Sciences.

Exceptional Circumstances (1999)

The use of rainfall as the trigger or core criterion attracted considerable controversy, with debates between state and Commonwealth analysts regarding the effectiveness of rainfall and its use in the DEC decision-making process. Notwithstanding the validity of either perspective, the government formally broadened the concept of DEC to Exceptional Circumstances (EC) in 1997. This acknowledged that other risks—outside or relating to rainfall variability—such as pests, disease, frosts, and waterlogging—would be formally considered in an assessment. Assessments of “multiple peril” created challenges, particularly in the integration of different events with meteorological drought.

The Commonwealth Government’s *Agriculture—Advancing Australia* package recognized that there are exceptional circumstances beyond the scope of normal risk management, and in these exceptions the government should provide assistance. In 1999, new criteria were agreed to by the Commonwealth and states (ARMCANZ Resolution 3D, March 5, 1999), specifically:

1. the event, or events, must be rare and severe;
2. the effects of the event, or events, must result in a severe downturn in farm income over a prolonged period; and
3. the event must not be predictable or part of a process of structural adjustment.

The key indicator, a severe income downturn, should be tied to a specific rare and severe event, and be beyond normal risk management strategies employed by responsible farmers.

The ARMCANZ criteria define rare events as those that occur, on average, once every 20 to 25 years. The event is severe if it lasts for a prolonged period, or more than 12 months, and is of a scale to affect a significant proportion of farm businesses in a region.

The Role of the Bureau of Rural Sciences in Drought Assessment

Risk Assessment Framework

Risk assessment involves the application of analytical tools to decision making, as well as the development of communication and management strategies that appropriately deal with uncertainty and the perception of risk. In Australia, generic approaches to risk assessment, like the Australian Standard in Risk Management (Australian Standard 1999), have been refined and applied to climate risk assessment for implementation of drought policies like EC. There are a number of key lessons, discussed briefly below, from our experience with the application of these approaches to drought risk assessment.

Risk analysis is a decision-making tool and needs to be distinguished from research science (Morgan and Henrion 1990). Described as a trans-science (Jacob and Hellström 1998), analysis for decision makers is driven by a policy problem, in this case the diagnosis of a rare and severe drought event. This contrasts with research science, where the problems and approaches are fundamentally driven by the research paradigm.

The application of analysis methods from scientific research to a policy problem is not always seamless and there may need to be substantial revision to refine these into risk analysis tools. Correspondingly, the routine application of risk analysis tools will not provide the perfect scientific analysis for every policy problem. The risk analyst must decide if it is appropriate to undertake analysis with the existing techniques or to return to scientific theory for a more adequate solution. Our approach has been to maintain an ongoing dialogue with decision makers and the research community, allowing continued innovation in the development of risk analysis tools and methods.

Ultimately, it is the responsibility of the risk analyst to form a defensible judgment for decision makers addressing uncertainty. The judgment is focused on addressing the policy problem, allowing the analysis to drive the answer, and is based on the best available scientific evidence. (Interestingly, this evidence usually evolves and sometimes improves over time.) There are usually no single answers, models, or solutions to these types of problems, and model selection in risk analysis is important in forming the final judgment.

Because of the direct linkages between analysis and a policy problem, risk analysis is not (or should not be) a “black box” or a linear process. Risk analysis is iterative and will be refined through a number stages. Both the analysis and the policy question can be refined throughout these iterations. One approach to ensuring the objectivity and independence of a risk analysis is to clearly frame the policy problem, defining how far the objective analysis can be taken and where the value judgments of decision makers will influence decisions.

Uncertainty is a component in all analyses, judgments, and decisions, including those relating to drought in Australia. A common approach to dealing with uncertainty in decision making has been to ignore it. However, when uncertainties are important, this can create an “erosion of trust” in the final outcome and lead to the eventual rejection of objective analysis from future decisions. There is opportunity for risk analysts to identify and communicate, in plain English, the important uncertainties throughout the iterations of a risk analysis.

There have been few attempts to systematically analyze uncertainty in climate risk assessment. We have developed the *Integrated Toolset* (discussed in the section on evaluation) to allow uncertainty to be estimated and tracked in the analysis of future regional-scale droughts in Australia using rigorous statistical techniques. This risk analysis tool will also provide flexibility in the geographic scale of analysis, allowing greater precision to be achieved through each iteration of climate risk analysis. Importantly, the modeling approach allows tracking of model and measurement errors throughout these iterations.

Most failures of risk assessment point toward a loss of trust between the stakeholders, the analysts, and the “expert judgments” on which the decisions are ultimately based (Slovic 1997). This can impede the flow of pertinent information between these players, creating inefficiencies and leading to more uncertainty in final decisions and inevitably more publicly controversial outcomes. This is certainly the case in the DEC process in Australia, where there were reported attempts of state and territory governments and farmer organizations to exploit perceived

shortcomings in information and analytical systems, in an effort to have more Commonwealth funding channeled to local communities (White and Karris 1998).

Strategies involving rural communities, states, and the Commonwealth exist in Australia to improve the communication of drought policy rationale, its implementation, and analysis; these have been beneficial in some evaluations. Communication is a major problem with the current EC assessment processes. Some stakeholders don't understand or accept the rationale or methods used in the process. Many see the objective analysis undertaken in the review process as a "black box" and do not trust the results of the scientific modeling undertaken by BRS and others. Those affected by decisions often question the long-term historical perspective that is taken to define rare and severe events.

Although there are no easy answers, communication is one area where we are looking to improve future evaluations of drought and other events that affect agriculture. However, risk theorists suggest that communication alone will not lead to a more equitable risk assessment process, and that there may be benefits in the development of mechanisms that do not, or only partially, rely on trust. There may be opportunities to develop approaches that manage trust with appropriate checks and balances (Slovic 1997). Moves toward a more participatory drought response strategy and a full partnership between the states and Commonwealth are being considered as possible future directions in Australia.

General Approach to Assessing Drought Applications

(see also: <http://www.affa.gov.au/csg/rpc/excirc/handbook/contents.html>)

As part of the EC assessment process, the BRS is called on by NRAC (the National Rural Advisory Council, the successor to the Rural Adjustment Scheme Advisory Council, or RASAC), to integrate available scientific evidence and provide interpretation with the aid of models and expert opinion (ARMCANZ Resolution 3D, March 5, 1999). NRAC advises the Commonwealth Minister on matters relating to Exceptional Circumstances and other agricultural issues, providing balanced judgment in a decision-making environment that is subject to uncertainty. The level of expertise provided by NRAC is crucial to the review process, particularly in cases that are marginal. In formulating its decision, NRAC also draws on advice from the Australian Bureau of Agricultural and Resource Economics (ABARE) for analyses of income and financial data.

In addition, a selection of NRAC members visits the application area during the process of assessment, providing opportunity for producers to individually or collectively state their case for assistance. The field visits are an important phase of the assessment process. They provide opportunity for NRAC to consult with a wide range of stakeholders, gain on-ground reports of conditions, and collect the information necessary to make informed judgements. The BRS is generally invited to accompany NRAC on these visits and uses these opportunities to collect additional data and information from local agricultural professionals.

The formal assessment methodology used by the BRS in its assessment can be characterized as a two-stage process.

The first stage establishes the context in which agriculture operates in a given region, whereby climatic, production, and natural resource variability are described. The risk characterization is achieved in part by analysis of Commonwealth Bureau of Meteorology climate records, application of production data from the Australian Bureau of Statistics, (in some cases) grass growth and production simulation studies, monitoring from satellite (remote-sensed data), and sourcing published agronomic research. Information, usually published material that is also available to producers, is collected to provide a preliminary appraisal of risk management strategies in the region. A high level of consultation is maintained with independent industry professionals and recognized experts.

The second stage is the formal risk analysis in which the event—be it climatic or otherwise—is analyzed to determine its historical frequency and its agronomic impact. Analysis methods, described in further detail below, generally involve assessment of climate records, application of crop or pasture simulations, production monitoring from field trials, and the interrogation of remote-sensed data. The risk analysis determines, on balance, if the objective indicators provide evidence of a 1 in 20-25 year event that can be linked to a severe decline in producers' income, as is required for declaration of Exceptional Circumstances (ARMCANZ, 1999).

Evaluation

The BRS receives a range of evidence relating to an EC case in the form of a submission or case provided by the state or territory concerned, as described earlier. In addition, it may undertake additional analysis as described below.

Climate data are analyzed to determine background temporal rainfall distribution and variability—based on approximately 100 years of records—as well as to characterize the specific event against this 100-year background. Analyses are carried out using point and spatially continuous data.

Point Data (Climate)

Point-based analyses might include simple presentations of specific events and their long-term historical context; the former is usually expressed in both millimeter and percentile terms while the latter is usually in millimeters only. This kind of analysis is usually performed using a commercial spreadsheet program and assists in establishing prima facie whether an event is near the 1:20 (or 5th percentile) level. A series of moving averages, ranging from 1-month to 36-month moving windows, can be used at this stage to determine the temporal scale of the drought event (Smith and McKeon 1998). Figure 1 shows an analysis of rainfall in millimeters for a site in southern Australia using four different averaging “windows” (similar analyses are performed on rainfall expressed as percentiles).

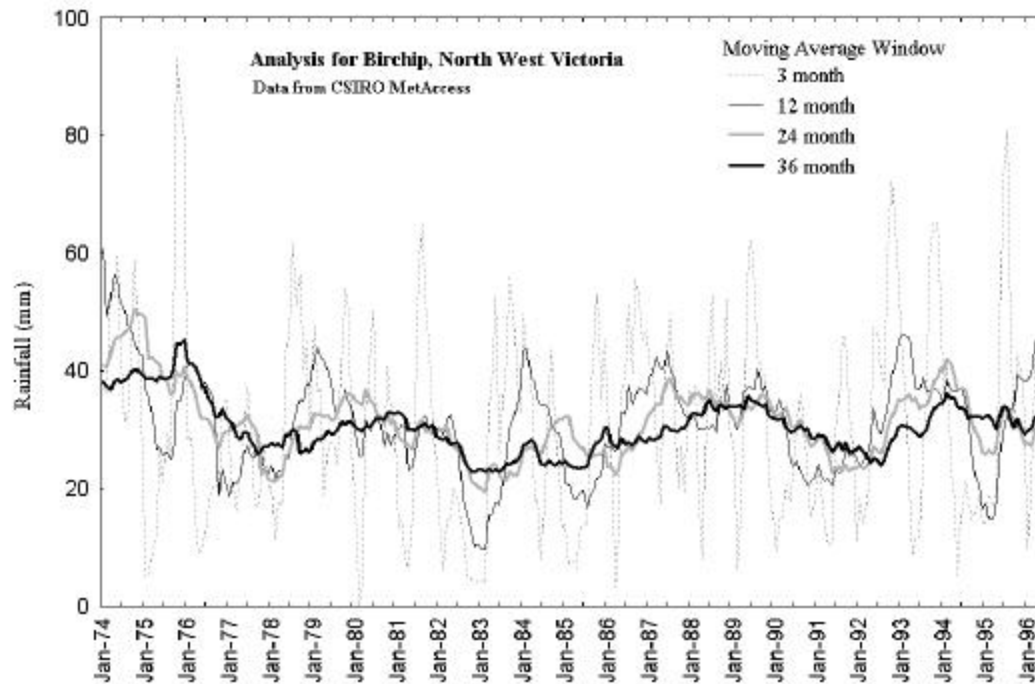


Figure 1. An example of the use of moving averages to determine the temporal scale of drought events using different averaging windows and applied to 20 years of observed rainfall at a site in southern Australia.

It is important to note that this is not the final indicator of an exceptional drought; for example, there have been instances in which a 5th percentile drought was apparent at an 18-month time scale while the important agronomic production season (spring) within this 18-month period was at the 60th percentile. Generally, periods greater than 12 months having rainfall at the 5th percentile, with failed production seasons within this period, are considered for further analysis. If one or more sites (points) appear to be close to this threshold, the BRS usually proceeds to produce maps (i.e., as continuous surfaces) derived from these points, since conditions between the points are equally important, if not more so, than those experienced at the measuring sites.

Spatial Analysis

Other sources of information, particularly useful in broader regional contexts, are maps of both long-term and specific events based on gridded rainfall data from the Commonwealth Bureau of Meteorology. The grids are computer generated using the Barnes successive correction technique. This technique applies a weighted average to data reported within set grids across Australia (Jones and Weymouth 1997). On most maps, each grid represents a square area with sides of approximately 25 km. The size of the grids is limited by the relative sparsity of rainfall measuring stations in some areas of Australia.

Data from individual stations can be variable in length and continuity, whereas the gridded data provides a continuous record of rainfall for at least 100 years across all of Australia. Thus the gridded data, in particular, lends itself to a diverse range of statistical analyses that can be based

on continuous periods of time—for example, months, seasons or years—or on repeated periods of time such as sequential production periods.

It is important to note that the BRS also independently analyzes rainfall records from non-official stations, where these are available. This enables a cross-check of the gridded data, and addresses any queries with regard to smoothing that can be inherent in some of the more data-rich areas when using the Barnes successive correction technique. This is particularly the case in regions of marked spatial climate variability.

This sort of analysis is useful for determining broad-scale climatic features where broad-scale topographic features and mesoscale climatic processes influence rainfall patterns. Alternatively, maps of rainfall reliability may be produced, meaning maps of the probability of receiving the seasonal average in a predetermined way. Such maps are useful for determining whether rainfall is likely to be distributed through a season or more likely to be the consequence of a few large-volume rainfall events, based on the analysis of historical records. This latter technique has been made a relatively simple task through the development of the BRS Rainfall Reliability Wizard (see, for example, <http://www.brs.gov.au/agrifood/reliability.html>).

Experience in applying this model framework has shown that the 25 km spatial resolution can be deficient in some cases, particularly where small application regions are defined by the states, or when the application boundaries bisect one or more of the grid cells. It was also difficult in some cases to explain the interpretation of this output at this scale to local producers, decision makers, and agricultural professionals who were not climate scientists. There was a need to develop a more flexible and robust modeling framework that could be applied within the timeframe of the assessment process and improve the communication of factors that influence rainfall at local scales.

To achieve this, the BRS's *Integrated Toolset* project has enabled sophisticated surface fitting and contouring routines as described in Hutchinson (1998a, 1998b), and known as ANUSPLIN, in a desktop Geographic Information System (GIS). The model framework is currently being coupled with a data warehouse called SILO (<http://www.dnr.qld.gov.au/longpdk/>) to provide a real-time operational tool for drought risk analysis. This system has the following features and capacities:

- ANUSPLIN surface-fitting and contouring routines for creating grid or raster “surfaces” from point features that may be irregularly spaced, noisy sample points (e.g., fitting a continuous surface to point rainfall data).
- The capacity to perform statistical interpolation as well as three-dimensional modeling of rainfall processes, allowing finer, “local scale” spatial resolution in model output.
- The capacity to interpolate existing grid surfaces to a user-defined extent and cell size.
- Explicit spatial error diagnostics.
- The capacity to query grids, points, lines, and polygons in a similar manner (e.g., produce spatial statistics for grids underlying user-defined areas like pasture trail paddocks or EC application areas).
- The capacity to accept user-defined and spatial coordinate inputs (e.g., keyboard entry of latitude and longitude of the location of a “weather station” or sample point).

Remote Sensing

Reflective remote sensing is used operationally in the assessment of drought in Australia (McVicar and Jupp 1998). Generally, two standard sources of data are used: reflectance data from the NOAA Advanced Very High Resolution Radiometer (AVHRR) and Thematic Mapper (TM) data from the LANDSAT earth resources satellite system (LANDSAT 6). In the assessments of frost impact on cereal production in 1998, NOAA thermal remote sensing was employed. To assess widespread flooding in the same year, an integration of LANDSAT, SPOT (Système Probatoire d'Observation de la Terre), and RadarSat data was commissioned.

For assessment of the impact of drought on vegetation in an application region, a standard multispectral transformation is applied to two-week composite AVHRR data: the Normalized Difference Vegetation Index (NDVI). At 1.1 km² resolution, imagery from this approach provides a spatial estimate of plant greenness across an application area.

Temporal analysis can also be carried out on constrained sets of pixels, usually chosen to be representative of the application area, and if possible free from significant tree cover. The NDVI time sequences allow between-year comparison of vegetation flushes, as well as estimation of the rates of senescence and vegetation decay in landscapes. Examples of these types of analyses are available at the Environment and Resources Information Network (Environment Australia) website at <http://www.environment.gov.au/psg/erin/satellite/>.

When an application area is spatially small, risk characterization can be assisted by the classification of LANDSAT TM data. At 30-meter resolution, this enables maps of land uses, such as pasture communities, irrigation areas, and the spatial extent of cropping infrastructure, to be generated. Our techniques include the following: standard image analysis; unsupervised classification using clustering algorithms; supervised classification using maximum likelihood rules; radiometric image enhancements like density slicing and convolution filtering.

In assessing regional droughts, there can be considerable advantage in integrating LANDSAT TM and AVHRR data with each other and with other data sources, including cadastral layers, appropriately scaled climate surfaces, and, importantly, verification from field-based assessment. The *Integrated Toolset* provides the software platform to achieve this level of integration on a portable computer. Field-based verification can range from spatially referenced pasture trials to observations of pest population density to photographs spatially and temporally referenced by producers in a region. Portable Global Positioning System (GPS) technology has been tested on field visits to application areas and has aided in the internal analysis of data by BRS, but has not been presented in formal reports to decision makers.

It is important to note that the NDVI is a measure of plant greenness, and there are limitations in applying the index to assessment of agricultural production. There can be discrepancies between the level of green “flush” monitored by the NDVI and plant growth: “green droughts” and false autumn breaks occur frequently in southeastern Australia, while trees in woodland areas can affect the index.

The enhanced NDVI or eNDVI refers to a research project (in progress) being conducted by the BRS and its collaborators (CSIRO Divisions of Land and Water and Atmospheric Research).

The research is investigating approaches to take the current measure to one of direct assessment of biomass. The basic methods here include the “un-mixing” of satellite pixels to separate tree, annual, and perennial grass components and linking the grass components to biomass estimates via deterministic pasture models, including that of Kumar and Monteith (1981). This project is due for completion in June 2001.

Pasture and Crop Simulation

Debates regarding the effectiveness of rainfall for crop or pasture production led to considerable research and application of simulation studies in many of the original DEC reviews, and similar studies have been applied tactically in the assessment of EC. Generally, simulation involves the computer generation of historical production data (output) from daily climate record (input), given the modifiers of soil moisture balance, varietal differences in plant growth represented by mathematical functions, and (in some models) simulated management tactics. Once the historical production record is simulated, frequency and impact risk analyses are conducted on the data set. This approach offers the advantage of a longer-term production record, but (usually) only as far back as 1956 because of constraints in Australia’s recording of daily temperature.

Caution should be adopted when applying simulation studies to decision making. It is important to ensure that the models have been well calibrated for a given production system and regional setting, and that an independent validation has been included in the study. Without considerable work to achieve a high level of precision, many simulation studies will not have the sensitivity to depict the difference between a 1 in 10-15 and a 1 in 20-25 year event.

A number of research groups produce real time output or provide the modeling frameworks to simulate the influence of climate variability for most of Australia’s agricultural regions. We cannot hope to provide a full directory of all of these groups, but we refer you to the work carried out by a number of researchers:

- The construction of the National Drought Alert Strategic Information System by the Queensland Centre for Climate Applications (Queensland Department of Natural Resources). This project delivers national-scale simulation using the GRASP modeling framework, and involves ongoing work with other state government agricultural departments to validate and calibrate the model (see <http://www.dnr.qld.gov.au/longpdk/>). It has improved the level of drought preparedness for many of Australia’s regions. Similar work, applying the APSIM model to wheat production, is also being conducted.
- The temperate production system models GRAZFEED and GRASSGRO have been developed by the CSIRO Division of Plant Industry and in collaboration with state governments from southern Australia (Donnelly et al. 1998). This type of model has been applied as a decision support tool to facilitate tactical on-farm decision making and provide information for benchmarking climate risk management practices, and as a tool in farm group facilitation. There are many success stories in which farm groups and extension officers have integrated the model into existing research and extension activities.

- The wheat production system simulator STIN, produced by Agriculture Western Australia, provides regular within-season output, providing information to assist producers and grain traders in making within-crop decisions relating to drought (Stephens 1998).

Australian Examples of Seasonal Forecasting Tools and Services

It is important to note that seasonal forecasting or “outlooks” per se are not part of routine *assessments* of DEC and EC submissions, although they may be used in consideration of revoking areas from DEC; for example, a number of months in the growing season at or above the 40th percentile rainfall—in combination with a favorable seasonal outlook—may be sufficient to revoke an area from DEC assistance. Having said that, seasonal forecasting is an increasingly important aspect of drought management at the farm and policy level, as it has proved to be a valuable early warning tool. Through the strategic use of seasonal forecasting, Australia is in a position to significantly improve some aspects of drought preparedness.

Under the Commonwealth’s *Agriculture—Advancing Australia* package, funding is administered by the Land and Water Research and Development Corporation to the Climate Variability in Agriculture Program (CVAP). An important focus of CVAP is the continuing development of Australia’s capacity to forecast the seasons ahead. Australia has a considerable climate and seasonal forecasting community, which is linked to similar efforts all around the world. The following are examples only. Approaches include Global Circulation Models (GCM), with and without coupled oceans; use of analogue seasons and years; and Southern Oscillation Index (SOI)-based statistical approaches. A wide range of point-based and spatial outputs is available with various lead times, for various seasonal lengths, and based on different models and approaches.

Commonwealth Bureau of Meteorology

The Commonwealth Bureau of Meteorology offers a range of products and services (see <http://www.bom.gov.au/climate/ahead/>). For example, at this writing, they have made available continental-scale maps that show the probability of exceeding the median rainfall, August 2000 to October 2000. Similar maps are provided for maximum and minimum temperatures, along with explanatory text. The Bureau also provides a wide range of other climate and weather products online.

Queensland Departments of Primary Industry and Natural Resources

In recent years the Queensland Departments of Natural Resources and Primary Industries have undertaken significant research, development and extension aimed at improving management for climatic variability. As shown in their web site (<http://www.dnr.qld.gov.au/longpdk/>), they offer a range of decision-support information services, tools, and training developed to help clients to better manage climatic risks and opportunities. Importantly, this service is aimed very much at agriculture and agricultural prediction. For example, tropical and sub-tropical grasses are simulated on a 5 km grid and have been calibrated for a broad range of pasture communities, soil types, and climatic conditions, and when linked to seasonal outlooks can provide agronomically relevant risk management information.

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Acknowledgements

We would like to acknowledge the contributions of the following people from the BRS: Professor Craig Pearson, Dr. James Walcott, Dr. John Sims, Mr. Tim Brinkley, Ms. Prachi Jain,

and Mr. Phillip Rosewarne; and from the Department of Agriculture, Fisheries and Forestry-Australia, Mr. Don Banfield and Mr. David Mortimer.