Roles and opportunities for using models to aid the management of agricultural and other natural resources within a variable climate

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Abstract Australian rural producers and other land managers are being encouraged, under the National Drought Policy, to be more self-reliant in the way they cope with our highly variable climate. Models have a major role in this process. This includes the use of statistical and General Circulation Models as the basis of improved seasonal forecasting, and hydrological and agronomic models for monitoring regional changes in soil moisture and vegetative cover, Decision Support Systems to estimate the value of adapting management to take advantage of seasonal forecasts or in managing climate variability *per se*, and agronomic models to determine whether rural producers are eligible for government support during extended periods of particularly severe drought. This paper will discuss issues associated with model development and use, and highlight opportunities for further studies and applications.

1. INTRODUCTION

Australia is a predominantly arid continent with a highly variable climate and a high incidence of drought [McBride and Nicholls 1983]. Government support for drought-affected farmers has been considerable, leading to a 1989 review of drought policy. In August 1992, the Federal and State governments adopted a National Drought Policy (NDP) that marked a major philosophical shift in drought policy in Australia. The NDP states that "Drought is one of several sources of uncertainty affecting farm businesses and is part of the farmer's normal operating environment. ... Its effects can be reduced through risk management practices which take all situations into account, including drought and commodity price downturns."

The objectives of the NDP are to:

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

Under the NDP, farmers are expected to assume greater responsibility for managing the risks arising from climate variability. This requires the integration of financial and business management with production and resource management to ensure that the financial and physical resources of farm businesses are used efficiently. The role of government is to help create the overall environment which encourages producers to adopt improved property management practices through a system of incentives, information transfer, education and training, landcare group projects and research and development.

The NDP envisaged that there might be exceptional circumstances which were beyond the capacity of normal risk management for industry. Specific arrangements for the declaration and revocation of Drought Exceptional Circumstances (DEC) were determined in October 1994 and discussed at MODSIM 95 by White *et al.* [1995]. These arrangements have been the subject of on-going critical research [White and Bordas 1997].

The 'Agriculture - Advancing Australia' initiative announced recently by the Federal Government [Anderson 1997] foreshadows a phasing down of direct financial support to rural industries, the need for continued business support through exceptional circumstances to be reviewed in 2001–02. This does not obviate the need for objective scientific and economic criteria and tools to determine exceptional circumstances due to drought and other events that would warrant financial assistance from the Federal Government.

Research aimed at improving the capacity of farmers to be more self-reliant has been undertaken through the National Climate Variability Program (NCVP) administered by the Land and Water Resources Research and Development Corporation (LWRRDC) [White 1995]. A significant proportion of this has involved the further development and application of models and Decision Support Systems.

The roles and need for extensive use of models within the NCVP, and associated work aimed at assessing the extent and severity of drought that was co-ordinated through the Bureau of Resource Sciences (BRS), will be addressed in this paper. Opportunities for further analyses and model-based activities to aid the management of our agricultural and other natural resources will be highlighted.

2. CLIMATE MODELS FOR SEASONAL FORECASTING

The past decade has seen a great deal of progress in the understanding of our climate systems, and in anticipating climate events, particularly El Niño. This has resulted in a cultural change, not only within the meteorological community, but also amongst many farmers and their advisers. This has been particularly so in Queensland, where the impact of El Niño has been particularly severe, and where many agricultural and other natural resource scientists have gained a significant appreciation of the underlying climatological concepts and then developed tools that would aid rural producers in their farm planning and decision making. There has also been a major education program involving the community.

2.1 Statistical forecasts

Since 1989 the Bureau of Meteorology has been issuing seasonal outlooks for the next 3 months, based primarily on the Southern Oscillation Index (SOI). This is based on the long-term trend in the differences in atmospheric pressure between Darwin and Tahiti, and has proved a reasonably reliable indicator over much of eastern Australia, with respect to spring and summer rainfall [McBride and Nicholls 1983]. There is also a significant signal in the south-west of Western Australia.

A new forecast system, based on near-global patterns of sea surface temperatures (SSTs) has been developed. It shows more skill than the SOI-based operational system and is being tested for operational implementation.

The phase of the SOI [Stone *et al.* 1996] is also being used to produce seasonal outlooks, the information being made available to farmers and their advisers in north-eastern Australia.

2.2 General Circulation Models (GCMs)

Lead times in terms of years rather than months are needed to attain significant financial benefits in many pastoral systems. There is therefore a robust case for further research to extend seasonal forecasts to annual and beyond.

GCMs of the global climate have been shown to offer more promise in extending forecasts from 3 to 12 months than the SOI, particularly in terms of forecasting changes in SSTs in the central and eastern tropical pacific. This longer lead time would certainly be more useful to livestock producers. The GCMs have yet to be properly tested for rainfall prediction, although their SST predictions can be used statistically to estimate changes in the SOI and rainfall with reasonable success.

The Bureau of Meteorology has been using a coupled ocean-atmosphere model to predict El Niño since 1994. This year the outlooks have included a probability forecast of El Niño from this model.

2.3 Value of seasonal forecasts

Accuracy of forecasting does not necessarily equate with its value to resource managers. Obviously, if the information is not used, then even though it may have value, no benefit is obtained. If the forecast is inaccurate then the information is likely to have negative value in the current season.

The value of seasonal forecasts to crop producers can be significant, but it varies with management and initial conditions, as well as with cropping systems and location [e.g. Hammer *et al.* 1996; Marshall *et al.* 1996]. The forecasts can influence decisions on when and what area to sow, and whether to irrigate and/or fertilise a crop. However, preliminary studies using models of grassland systems identify that the financial benefits may not be easily realised based on existing skill levels, lead times and decision points [Stafford Smith *et al.* 1996]. In some areas even high skill levels appear to offer low financial benefits in the medium term, despite increased animal welfare and protection for soils and vegetation [Bowman *et al.* 1995]. This highlights the need for further research to determine whether and how the management and timing of decisions of many grassland systems should be modified to take advantage of forecast information.

3. MANAGING TO DEAL WITH CLIMATE VARIABILITY *PER SE*

Increased self-reliance by rural producers requires the ability to manage both crop and livestock enterprises exposed to a variable climate and to minimise the impact of drought. It also requires the ability to more effectively manage risk: production risk, environmental risk, financial risk and market risk [White 1997]. Improved seasonal outlooks are but one approach to assisting farmers to become more self-reliant. Ways of offsetting the risks associated with climate variability in order to create opportunities require a systems approach [Hammer and Nicholls 1996].

Biophysical models of agricultural systems are an effective means of determining the responsiveness of soil moisture, plants and livestock to changing climatic conditions, and for determining the effectiveness of the rainfall. Since such models should also be realistically responsive to changes in management, the effects of both management and climate can be studied simultaneously. For example, Fouché *et al.* [1985] used a model to show how the frequency and duration of droughts on the South African veldt increased with stocking rate.

The more variable the climate, the more valuable models are as adjuncts to field experimentation. This is in part because a field experiment of say only three years in duration is more likely to be an unrepresentative sample of the long-term behaviour of a farming system.

With the emphasis on managing risk, there is therefore a need to encourage farmers to use appropriate Decision Support Systems (DSS). In many instances this will be done indirectly through a participatory dialogue with advisers who are familiar with the value and use of such tools. In this way farmers will become better informed about the variability in the environment in which they operate, and better able to make appropriate decisions to improve the productivity, sustainability and financial viability of the farming systems which they manage.

There are a number of DSS for analysing climate data, as well as a range of models and DSS to improve the management of the land [White *et al.* 1993]. Increased use of these DSS will need a high level of field testing, extensive consultation with users as to their decision requirements, adequate software support, and careful monitoring of their adoption and use.

Models and other DSS have an important role in identifying those management strategies that are financially viable and exposed to minimum physical and financial risk, particularly in areas exposed to a variable climate. However, they are only of value if they are embedded in a broader vision, of acknowledging that DSS are not an end in themselves, but are a very useful, possibly essential tool, in achieving improved management and self-reliance.

4. INDICATORS OF DROUGHT EXCEPTIONAL CIRCUMSTANCES

Models have been used by BRS and collaborating organisations to assess the effectiveness of rainfall and to improve the objective estimation of DEC. Rainfall and other climate data collected for approximately 100 years have been input into models of farming systems in order to characterise and rank past droughts, and determine appropriate indicators and criteria for estimating the severity and extent of future droughts [White 1996].

Studies to date include using :

- a model of a Merino ewe flock grazing an annual ryegrass and subterranean clover pasture near Heathcote in northern Victoria [White *et al.* 1995];

- a model of an annual grass and subterranean clover pasture grazed by either Merino wethers or breeding ewes at Wellington in the Central Tablelands of New South Wales [Donnelly and Freer 1996];

- a rangeland model at Charleville (south-west mulga country, sheep) and Charters Towers (northern speargrass, cattle) in Queensland [Stafford Smith and McKeon 1996];

- a Stress Index model to estimate long-term wheat yields and soil moisture accumulation at 16 representative sites across the Australian wheat belt [Stephens 1996];

- an Agricultural Production Systems Simulator [APSIM, McCown *et al.* 1993] to assess the severity of drought on wheat-fallow, sorghum-fallow and wheat-sorghum (opportunity cropping) production systems at a range of sites throughout north-eastern Australia [Keating *et al.* 1996]; and

- a composite measure of the financial situation of farm families and generated regional estimates using ABARE survey data [Proctor *et al.* 1996]. They proposed that the estimates could be used in conjunction with rainfall and other seasonal data to generate benchmarks of one in 25 year economic events.

A workshop at the conclusion of these studies [White and Bordas 1997] concluded that rainfall, soil moisture, grassland and crop production (or an index thereof), liveweight gain, supplementary feed requirements, net farm income or a measure of financial stress are all useful indicators of DEC. Of these, the three most reliable indicators of rainfall deficit and effectiveness are simulated grassland and crop production, and the estimated requirements of livestock for supplementary feed, based on appropriate management regimes. The feasibility of taking account of significant long-term climate shifts was also demonstrated. The feasibility of an income-based approach to determining exceptional circumstances due to climatic and other events, as advocated by Thompson *et al.* [1996], is still a matter of debate. These studies will be reported in detail in a forthcoming issue of the international journal, *Agricultural Systems*.

Integrating spatial data sets, including remotely sensed data, with agronomic models, is leading to the development of *AussieGrass*, the National Drought Alert Strategic Information System [Brook 1996]. This system, which has been used to estimate changes in total standing dry matter across Queensland, and the spatial extent of drought, has been of considerable assistance to RASAC in evaluating the severity of drought across that State. It has been extensively tested against field and remotely sensed data. A complementary system, the Sustainable Land Use Information System (SLUIS), is being developed within the BRS [Lyons *et al.* 1997]. Other ways in which remotely sensed data can be used in drought evaluation have been reviewed by McVicar [1997].

5. OPPORTUNITIES FOR FUTURE RESEARCH

The NCVP was reviewed in 1997, at the request of LWRRDC, by Hassall and Associates Pty Ltd [1997] and ASIT Consulting. It was consequently recommended, *inter alia*, that the NCVP continue to foster elements of GCM development and climate prediction, particularly where these focus on areas of high climate variability and low forecasting skill, and that the NCVP co-ordinate research to identify where climate forecasts improve the productivity, environmental, financial and social benefits to owners and managers of major agricultural and other natural resource systems across Australia. It was further recommended that NCVP continue to investigate risks, benefits and opportunities for using seasonal forecasts to improve the management of water and other natural resources, and the level of skill necessary and achievable in different parts of Australia.

More efficient management of water (e.g. irrigation water allocations, infrastructure requirements), and forest resources (e.g. nursery plantings, bushfire control, wildlife and pest management) would almost certainly be achievable through using available forecasts. Improved forecasts of spring reservoir inflows in the south-east and summer inflows in the east coast of Australia are attainable [Chiew and McMahon 1997]. Success in using ENSO to forecast rainfall in eastern Australia in the latter parts of the year up to two months in advance, complemented by ongoing research in seasonal forecasting, opens up major opportunities for improved water management [Long and McMahon 1996].

There are clearly opportunities for natural resource managers outside agriculture to capitalise on increased awareness of climate variability, and even use seasonal forecasting to aid in planning their management and monitoring programs. For example, many of the flora and fauna of northern Australia are highly attuned to the highly variable climate imposed by ENSO [Nicholls 1991; Norman and Nicholls 1991; Flannery 1994]. The Macquarie Marshes is a case in point. The colonial nesting birds probably need at least two good breeding events per decade, these depending on the frequency and nature of rainfall events on the Macquarie Marshes and other Australian wetlands [W. Johnson, personal communication]. River managers could use ENSO predictions to guide environmental flows to the Marshes, as well as give advance warning of the threat of algal blooms.

6. CONCLUSIONS

Research investment in atmospheric science, associated with studies of the greenhouse effect, projects under the NCVP, and related agricultural research and software development, is setting a sound basis for improving the management of our rural lands. A cultural shift is already evident, particularly in north-eastern Australia, where the ravages of drought have been high, and where climatologists, agricultural systems modellers and analysts, and extension personnel, have joined forces with the rural community to provide tools and develop strategies that can improve self-reliance and the management of the land.

Emphasis is on increasing awareness of climatic trends, through improved seasonal forecasting, and an improved ability to plan for and cope with climate variability *per se*. The value and use of these for different agricultural systems and environments is now the subject of intensive research.

A few opportunities for using seasonal forecasts to improve the management of our indigenous and exotic flora and fauna, and our water resources, in this ENSO-influenced continent of drought and flooding rains, have been highlighted. There are major opportunities here for further research.

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