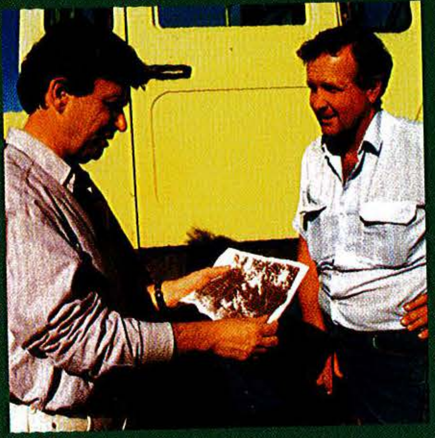
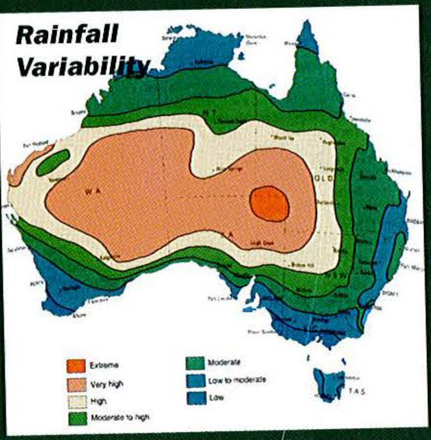
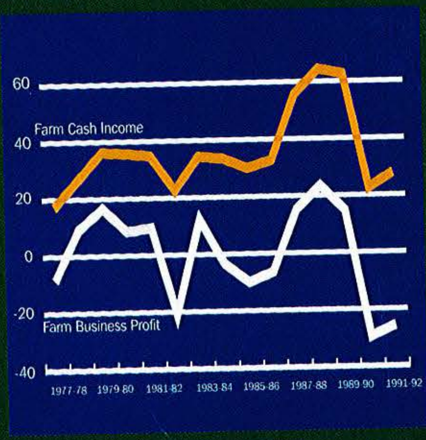
Review of the National Climate Variability R&D Program

Occasional Paper CV02/97







Climate Variability Series

Land & Water Resources Research & Development Corporation

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Review of the National Climate Variability R&D Program

OCCASIONAL PAPER CV02/97

Land & Water Resources
Research & Development Corporation

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"Australia's infertile soils and the trials of ENSO have forced some unusual adaptations on its plants and animals. These adaptations are varied and sometimes wondrous, but all share a few themes, which are as follows: parsimony born of resource poverty, low rates of reproduction and strict obedience in following and exploiting brief windows of opportunity as they open erratically over the land"

Tim Flannery, *The Future Eaters—An ecological history of the Australasian lands and people,* Reed Books, 1994.

Contents

Foreword and Review Response

The Program

The National Climate Variability R&D Program was established under the National Drought Policy in 1992 and subsequently extended for a second phase in 1995. The aims of the program are to facilitate greater adoption of practices increasing productivity and sustainability of Australian agriculture through improved management responsiveness to climate variability. The program targets improved management of risks and opportunities related to climate variability through:

- improving the skill of seasonal climate forecasts and broadening their use in management,
- improved monitoring of drought and production at the regional level, and
- development of decision support approaches for farm management.

Phase two of the program will come to a conclusion around the middle of 1998, and so it was appropriate that the Management Committee comprising the partners in the program[1] should review the program. The review was intended to provide feedback to the Committee on how it could strengthen the effectiveness of the program in its final year and to lay the foundations for possible further phases of the program in future years. The review was undertaken by Hassall and Associates, and this document is the submission by that firm against the review's terms-of-reference. This foreword incorporates the Management Committee's response to the review recommendations.

In developing its response, the Management Committee appreciated that the scope and depth of the review document would provide a comprehensive basis for developing a third phase of the program Such an extension to the program has been strongly recommended as a component of the Commonwealth's Integrated Rural Policy Package (IRPP). The program, however, currently deals with a large number of diverse stakeholders, including several industries and their respective R&D Corporations, and so further consultation with these stakeholders will be required before a definitive response can be given on some recommendations. Notwithstanding this, the Management Committee is firmly of the view that this document, and its recommendations, should be widely circulated to engender discussion and elicit response from a much wider audience than the present Committee deals with on a day to day basis. This is highly desirable in terms of raising awareness about the critical importance of managing our rural industries and natural resources sustainably in a climatically variable, if not hostile, environment. It is also important as a fundamental contribution to any forthcoming strategic planning process for a Phase III.

Response to the Review

The review has raised a number of issues which will need to be addressed in future planning. The Committee notes first and foremost that the program is generally seen to have been very successful at involving rural industries directly in the support of climate variability R&D and the development of relevant risk management tools. This has contributed in particular to a greater level of investment, much of it private sector, in long-term climate prediction capability.

For the three specific issues raised in the executive summary, the Committee's response follows.

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1 Land and Water Resources R&D Corporation, Rural Industries R&D Corporation, Grains R&D Corporation, Forest and Wood Products R&D Corporation, Sugar R&D Corporation, Dairy R&D Corporation, International Wool Secretariat, National Farmers' Federation and the Commonwealth Department of Primary Industries and Energy.

First, the perceived low profile of the program among interest groups is viewed as a challenge for any small program attempting to have a national impact across a wide range of industries and interest groups. There is inevitably some fragmentation of the profile given the wide range of organisations, funding sources, and variety of projects in the program. This is expected to be less an issue in the future, particularly as the efforts of projects supported under the first two phases come to fruition and begin to result in the availability of a range of products. Together with the implementation of a communications strategy tied to the program, we can expect to see a greater level of awareness about, and adoption of, climatic risk management tools.

Second, the lack of customer focus noted in some projects is also of concern to the Management Committee. This issue will be addressed in future project design procedures which will be strengthened to include consultation before, during and after the research phase.

Finally, the Committee recognises the importance of improving measures of progress in climate forecasting skill—this will be addressed early in any forthcoming phase of the program.

Responses to each of the specific recommendations listed in the review are presented in the tables on the following pages.

Where the program will head in future will partly be defined by the policies and priorities of the present Government. Indications are, however, that it would like to see a greater level of activities which reflect the broader stakeholder interests in managing with climatic variability. Furthermore, while the Government recognises that previous phases of the program have had strong accountability arrangements at the project level, including well defined performance indicators, it will seek for these arrangements to be further imbeded at the program level.

The process by which the Management Committee will address the issues raised in the report and to develop a third phase of the program will include eliciting broad stakeholder response to the review and convening a national workshop of representative stakeholder interests. The proposed outputs of the workshop will be agreement to a future program goal, program objectives, program strategies, management and reporting arrangements, funding arrangements and partnerships, and linkages between the program and other climate variability R&D efforts throughout Australia

I hope that you find this report of interest and invite you to respond to it.

DR JOHN TAYLOR
CHAIRPERSON, MANAGEMENT COMMITTEE
NATIONAL CLIMATE VARIABILITY R&D PROGRAM

Program Recommendations

Review Recommendations	NCVP Response
Recommendation: The program goal be clarified by substituting 'Australia's land, water and vegetation resources' for 'Australian agriculture'.	The current goal is to facilitate greater adoption of practices increasing productivity and sustainability of Australian agriculture through improved management responsiveness to climate variability. Changes to the goal to either clarify wording or to reflect a broader emphasis beyond agriculture will be revised as appropriate by the strategic planning process.
R1 We recommend that the NCVP Program's Objectives, Strategies, Priorities and Implementation be changed to those presented in Table 7. (see the text at page 21 for full details). The primary change is to base the sub-programs on the following; • Managing natural resources in a variable climate • The impact of climate variability on our human, agricultural and natural resource base • Marketing the program and its products	The current program structure, based on the government of the day's directions in establishing the program, has the three components: • Climate Forecasting • Drought Risk Management • Decision Support A major advantage of this structure is the resulting classification into largely generic, regional and industry-specific applications each with differing funding, management and user involvement considerations. Whilst recognising that the proposed changes are motivated to achieve clearer links, for example between climate forecasting and decision support applications, there may also be opportunities to address linkages at the project design level. However, the more important overall issue to be determined first is the scope of the program and this will be a key part of the strategic planning process.

Table 1
Program recommendations for proposed sub-program 'Managing natural resources in a variable climate'

Review Recommendations	*NCVP Response*
R2 NCVP coordinate 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.	Accepted as a broad direction for the program although the emphasis needs to be on identifying potential applications of seasonal climate forecasts by industries and regions and determining research priorities. Current projects in the program are also identifying the scope to directly forecast events such as the break of the season and frost frequency of direct relevance to specific industries.
R3 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.	Supported in principle and recognising that the value of improvements in forecasting skill and lead time will depend also on the potential application and may not be simply related to climate variability or existing skill.
R4 NCVP identify appropriate standards and procedures for benchmarking forecast skill as a matter of urgency, so that progress, or lack of it, in forecasting can be clearly identified.	Supported in principle and recognising that there are complex issues involved in comparing skill for different types of forecast. The recommendation will be discussed with major relevant stakeholders and researchers to determine a proposal which should also consider current international developments.
R5 NCVP support the future development of research projects that combine Action Learning with the development and implementation of appropriate planning and management (DSS) tools.	The requirement for projects in the program to involve an appropriate degree of consultation and participation between researchers and the users of the research will be maintained.
R6 NCVP ensure that integrated pasture–livestock, cropping and land degradation models are used to identify sustainable whole-farm systems within a variable climate. This would aid strategic and tactical planning to benefit the soil, vegetation and livestock, as well as the financial and social well being of the farmer.	The general principle of climate variability research recognising and addressing broader sustainability and wholefarm systems perspectives is supported. However, the greater complexity of integrated bio-economic research perspectives is also recognised as a constraint on possible approaches.
R7 In conjunction with other programs in LWRRDC, NCVP should call for projects addressing the scope of seasonal climate forecasts to contribute to sustainable resource management; for example in forecasting wind and water erosion hazard and developing appropriate response strategies.	The general principle is supported within an overall framework which would develop a balanced and integrated approach to applications related to agricultural productivity and natural resource management.
R8 With support from the Rural and Land Resources Divisions of DPIE, NCVP commission biophysical/bioeconomic case studies into the impacts of taxation and other policy instruments on productivity and sustainability, particularly with respect to land degradation for the rangelands, grasslands and cropping industries [DPIE/LWRRDC/MRC/IWS/GRDC/RIRDC]	The priority for the issue will be determined with relevant policy agencies and recognising the complexities of research integrating taxation policies with bioeconomic models.
R9 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.	The recommendation is supported. In addition to the current project, there is scope for further research for example in collaboration with the irrigation industry and on opportunities to forecast environmental flows.

Summary Recommendation

R10 The R&D priorities for the funding of projects under the sub-program 'Managing natural resources in a variable climate' should be consistent with R1 to R9 inclusive.

Table 2
Program recommendations for proposed sub-program 'The impact of climate variability on our human, agricultural and natural resource base'

Review Recommendations	***NCVP Response***
R11 NCVP coordinate and contribute to the development of a comprehensive national archive of calibrated NOAA AVHRR imagery across Australia.	The priority for national coordination in the calibration of remote sensing imaging has been recognised as a task in the current AussieGrass project. Approaches which contribute to effective applications will be considered with relevant agencies.
R12 NCVP continue supporting vegetation monitoring and the development of drought alert information systems with a capacity to monitor and reduce the risk of land degradation, thereby leading to more sustainable resource management.	Supported. Priority will be given to coordinated national approaches integrated with the Land and Water Audit and developed with agencies with responsibilities for sustainable resource management in grazing lands.
R13 NCVP commission an investigation into the feasibility of estimating and monitoring stock numbers in near-real-time across Australia.	Stronger evidence of the feasibility of improved monitoring of stock numbers is required before resources could be committed. The gains would need to be considered in relation to those from other opportunities for improved monitoring of grazing systems.
R14 NCVP examine the possibility of developing software which integrates the effects of climate variability and climate change on our natural resources.	Given the focus of the program on risk management in relation to climate variability, climate change aspects (for example recent temperature trends) should be recognised if they are relevant to current risk management decisions.
R15 NCVP determine the effectiveness of pest and weed management during drought and the ability to maintain pests and weeds at low densities once a particular drought is over [under the National Feral Animal Control Strategy].	As part of the strategic planning process for the program, consultation will be undertaken with other agencies and programs including the National Feral Animal Control Strategy to determine opportunities for greater use of a climate variability perspective and to determine responsibilities for R&D and implementation.

Summary Recommendation

R16 The R&D priorities for the funding of projects under the sub-program 'The impact of climate variability on our human, agricultural and natural resource base' should be consistent with R11 to R15 inclusive.

Table 3
Program recommendations for proposed sub-program 'Marketing the program and its products'

Review Recommendations	NCVP Response
R17 NCVP develop and implement a marketing plan which includes targets for policy makers, R&D Corporations, and resource managers. Attention should focus on the products and messages that are to be provided, on the production of databases of target audiences, and on a range of media (including print, multimedia and the Internet).	The basic thrust of the recommendation to give greater priority to communication aspects is supported. Details will be resolved as part of the strategic planning process and recognising also the need to strengthen communication activities within projects. Best management practices in extension and adoption practices, previously developed through RDC joint ventures, will be utilised.
R18 NCVP fund training for extension officers and private consultants in the use of relevant DSS tools to aid the management of agricultural systems, and appropriate strategies for managing risk.	The purpose of the recommendation to broaden the network of trainers in the application of climate variability research is supported. The program will consider effective means to achieve national coverage through for example the development of training systems and greater private sector involvement.
R19 NCVP co-provide three PhD or Master's levels scholarships with other R&D Corporations, or possibly LWRRDC, to address the future need for trained researchers conversant with climate variability issues and approaches.	The purpose of the recommendation to increase the skills base in climate variability research is supported. Mechanisms to be considered will include opportunities to strengthen training opportunities in projects generally and opportunities developed with other R&D Corporations.

Summary Recommendation

R20 The R&D priorities for the funding of projects under the sub-program 'Marketing the program and its products' should be consistent with R17 to R19 inclusive.

Table 4
Program recommendations for management and administration

Review Recommendations	***NCVP Response***
R21 The role of the NCVP in assisting policy development should be a matter for the Management Committee to review, preferably by the preparation of a position paper.	The Recommendation will be considered as part of the strategic planning process and recognising that policy-related research will be more effective if strong links are established between researchers, policy agencies and those impacted by policy changes.
R22 The composition of the Program's Management Committee be reviewed.	The recommendation will be considered in the broader context of program management generally and as part of the strategic planning process. Issues to be considered include alternatives for involvement of users and technical expertise through the strategic planning process itself and through project steering committees.
R23 NCVP commission a pilot study to determine whether there are suggestive trends by looking at patterns of climate variability, degradation and species loss across whole regions in respect of the characteristics of industry and environment in different regions	Some existing projects in the program such as AussieGrass are developing the tools to gain a better understanding of the historical relationship between climate variability and resource degradation. The strategic planning process will consider the priority for broader resource management issues and opportunities for collaboration with environmental agencies on relevant aspects.
R24 The NCVP commission an innovative study to examine resource management strategies that may have merit in a land of droughts and flooding rains	The opportunity to develop innovative strategies to take advantage of recent developments in understanding climate variability should continue to be an underlying theme in the program. The recommendation is therefore supported as a general guiding principle for projects submitted for funding.

Executive Summary

Seasonal climate variability has had, and will always have, a profound affect on Australia's agriculture and natural resources. The National Climate Variability R&D Program is an innovative R&D program designed to address some of the management issues that relate to climate variability.

The potential for R&D to contribute to improved management of risks and opportunities involves *in part* the realisation of the promise of improved seasonal climate forecasting. The lead times with respect to adoption are often long and the alternative approaches (statistical studies of ENSO and sea surface temperatures, as well as the use of Global Climate Models) all require investigation. Regional monitoring, using satellite imagery and agronomic modelling, is already supplying useful information about resource condition. Performing this monitoring in real time, in times of drought and flooding rain, offers many opportunities to target policy and relief measures more effectively. However national collation and dissemination of some seasonal climate information, notably rainfall, still falls short of user requirements.

Self reliance is very much about managing climate (and price) variability *per se*. Although quite a number of decision support systems have been produced, few have been used as yet by those for whom they were designed. Those which have been used are usually designed with the user deeply involved in the process of construction, and the NCVP can be proud of funding some of these. There seems to be a considerable need to look at the relationship between climate variability and resource degradation, most of which occurs as a consequence of droughts and flooding rains. The beneficiaries of this information range from policy makers to resource managers.

The portfolio of projects funded by the NCVP and the overall performance of the program were assessed by questionnaires, personal and telephone interviews, and were supplemented by literature supplied and available from other sources. Most of the projects were worthy and contributed to the aims of the program. Projects funded nearly always had high scientific merit and had met, or would meet, the objectives set. The projects have generated considerable output, such as conference papers, scientific papers, models and decision support systems, videos and others. Most of these were of a very high quality. Many projects have not contributed yet to improved resource management, which is expected given the short time frame of the Program, although some have the potential to contribute to management in the medium and long-term. Judging by the leverage in funding obtained, the program exhibits high value for money. The NCVP has been instrumental in establishing a network of researchers exploring climate variability. There has also been an increase of media attention in some of the R&D products from the NCVP. Important problems raised in our review were: the low profile of the program among interest groups; the lack of customer focus in some projects; and the inability to measure progress in forecasting, due to the lack of adequate, comprehensible measures of performance.

In assessing the program's goals, objectives and strategies, we recommend some minor changes in the wording of the objectives. We also recommend that, for the possible third phase, two existing sub-programs, 'Climate forecasting' and 'Decision support', be collapsed into 'Managing resources in a variable climate'; that 'Drought Risk Management' be re-named 'The impact of climate variability on our human, agricultural and natural resource base', and that a new program 'Marketing the Program and the Products' be established.

Under each sub-program, we have identified priority areas for funding. These are:

1. Managing Resources in a Variable Climate:
   - NCVP coordinate 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;
   - 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;
   - NCVP identify appropriate standards and procedures for benchmarking forecast skill as a matter of urgency, so that progress, or lack of it, in forecasting can be clearly identified;
   - NCVP support the future development of research projects that combine Action Learning with the development and implementation of appropriate planning and management (DSS) tools;
   - NCVP ensure that integrated pasture–livestock, cropping and land degradation models are used to identify sustainable whole-farm systems within a variable climate. This would aid strategic and tactical planning to benefit the soil, vegetation and livestock, as well as the financial and social well being of the farmer;
   - In conjunction with other programs in LWRRDC, NCVP should call for projects addressing the scope of seasonal climate forecasts to contribute to sustainable resource management; for example in forecasting wind and water erosion hazard and developing appropriate response strategies;
   - NCVP commission biophysical/bioeconomic case studies into the impacts of taxation and other policy instruments on productivity and sustainability, particularly with respect to land degradation for the rangelands, grasslands and cropping industries; and
   - 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.
2. The Impact of Climate Variability on our Human, Agricultural and Natural Resource Base:
   - NCVP coordinate and contribute to the development of a comprehensive national archive of calibrated NOAA_AVHRR imagery across Australia;
   - NCVP continue supporting vegetation monitoring and the development of drought alert information systems with a capacity to monitor and reduce the risk of land degradation thereby leading to more sustainable resource management;
   - NCVP commission an investigation into the feasibility of estimating and monitoring stock numbers in near-real-time across Australia;
   - NCVP examine the possibility of developing software which integrates the effects of climate variability and climate change on our natural resources; and
   - NCVP determine the effectiveness of pest and weed management during drought and the ability to maintain pests and weeds at low densities once a particular drought is over [Under the National Feral Animal Control Strategy].

3. Marketing the Program and the Products:
   - NCVP develop and implement a marketing plan which includes targets for policy makers, R&D Corporations, and resource managers. Attention should focus on the products and messages that are to be provided, on the production of databases of target audiences, and on a range of media (including print, multimedia and the Internet);
   - NCVP fund training for extension officers and private consultants in the use of relevant DSS tools to aid the management of agricultural systems, and appropriate strategies for managing risk; and
   - NCVP co-provide three PhD or Master's levels scholarships with other R&D Corporations, or possibly LWRRDC, to address the future need for trained researchers conversant with climate variability issues and approaches;

We also recommend that the management committee review the NCVP's role in assisting policy development, as well as review the composition of the committee.

The role of humans in creating increased climate variability and the role of climate variability in shaping our people, causing degradation and loss of biodiversity, are being re-examined by historians and anthropologists. We recommend that, not only should the NCVP play a part in that re-examination, but it should also look to some of the lessons that can be learnt and applied from these studies.

SECTION 1

Introduction

This review is part of the standard procedures of the Land & Water Resources Research and Development Corporation (LWRRDC) to ensure that Research and Development (R&D) programs are accountable and responsive to the needs of investors, providers and users. The National Climate Variability R&D Program (NCVP) has been operational for five years, through two lots of three year phases, which allows an effective assessment of its achievements. In addition, the review is timely in that it can contribute to the planning of a possible third phase of the program.

The current aims of the NCVP are to facilitate greater adoption of practices increasing productivity and sustainability of Australian agriculture through improved management responsiveness to climate variability. The program targets improved management of risks and opportunities related to climate variability through:

- developing skills and broadening use of seasonal forecasts;
- improved monitoring of drought and production at the regional level; and
- development of decision support approaches for farm management.

The NCVP has received funding of $4.6 million from the Federal Government, and has attracted a further $2 million contribution from other R&D Corporations. LWRRDC has also contributed over $440,000 from its general reserves to support the NCVP.

The Terms of Reference for this Review are to—

1. Assess for agriculture and natural resource management, the potential for R&D to contribute to improved management of risks and opportunities related to climate variability. Identification of benefits and likely beneficiaries should be included.
2. Assess the achievements of the NCVP against its stated goals and objectives, including an assessment of:
   - the likely contribution of the portfolio of completed and current projects in the National Climate Variability R&D Program to improved management of risks and opportunities related to climate variability;
   - the program's value for money; and
   - the program's communication and administrative performance.
3. Assess the suitability of the current goals, objectives and strategies of the NCVP for ensuring that R&D contributes to improved management of risks and opportunities related to climate variability. Suggest alternative goals, objectives and strategies that could be adopted in a possible third phase of the program.
4. Identify gaps, and propose appropriate directions for the program including R&D focus, adoption, communication, management, evaluation and industry funding partnership arrangements, to contribute to more efficient and effective achievement of program goals and objectives both in its current phase and a possible 3rd phase.

Section 2 of the review outlines the approach of the reviewers. Section 3 outlines the specific responses to the review's terms of reference. The recommendations in the review are highlighted in the appropriate places in Section 3. Section 4 provides an epilogue.

SECTION 2

Methodology

Hassall & Associates used three prime sources of data:

- documentation associated with the NCVP and the individual projects (including publications and extension activities);
- the views of researchers funded by the NCVP; and
- contributions from 'interest' groups.

A combination of questionnaires and personal/fax/telephone interviews were used to gain the perspectives of researchers and interest groups. Interest groups included R&D Corporations, State and Commonwealth agencies (such as DPIE, BRS), NFF and private firms. A full list people and organisations contacted can be found in Appendix E.

Personal interviews were conducted with:

- researchers based in major centres (Canberra; Brisbane and Toowoomba; Perth; Adelaide; and Melbourne);
- interest groups in the above locations, as well as Sydney; and
- Management Committee members based at the above locations.

Open-ended questionnaires were used to obtain perspectives of people not based in the major locations, as well as to structure the interviews. Three questionnaires were developed and sent to:

1. all researchers funded under NCVP (excluding minor communication projects);
2. major interest groups, *including* the NCVP Management Committee; and
3. the NFF Farm Management Business Committee (at the suggestion of Julie Austin of the NFF)

The questionnaires and personal interviews revealed themes and issues, which were then verified and discussed by the reviewers and the NCVP Coordinator. The discussions took the form of compiling, exploring and refuting/confirming the points raised in the interviews and questionnaires. The themes also assisted the selection of criteria used in the 'evaluation matrices' (Appendix C) which contribute to the assessment of the current portfolio of projects (see response to the second term of reference on page 13).

The reviewers were supplied with a great deal of literature, both NCVP-funded and related research, by those interviewed. In addition Dr David White, an acknowledged expert in the field of climate variability and drought, grassland management and decision support systems (DSS), provided appropriate selections from his bibliography, as well as review papers that he and others had written. We also tried out some of the DSS and used the World Wide Web (WWW) to access information about many topics, such as the latest seasonal forecasts from the Bureau of Meteorology (BoM) and the Queensland Department of Natural Resources (QNR) 'Long Paddock' site.

SECTION 3

Responses to the Terms of Reference

First Term of Reference

Assess for agriculture and natural resource management, the potential of R&D to contribute to improved management of risks and opportunities related to climate variability. Identification of beneficiaries and likely benefits should be included

FORECASTING

The extent to which seasonal forecasts can be improved is still difficult to assess. Current effort is two-fold: to enhance statistical methods using the Southern Oscillation Index (SOI) and sea surface temperatures (SST); and making General Circulation Models (GCMs) more reliable and relevant to agriculture. The latter, in particular, have substantial *potential* for agriculture and resource management, as forecasts might give managers in excess of 12 months to plan for climatic events. However, there is some uncertainty as to whether this potential will be realised. Improving statistical methods, although likely to be constrained to a three months lead time, still have the potential to improve certain management decisions (eg. tactical cropping decisions). It also appears that the potential might be more easily attained in Queensland than in other areas in Australia.

Forecasts are only valuable when they can be used to improve the productivity, sustainability and financial viability of farming systems (keeping in mind type I and type II errors). It is naive to assume that better forecasts will automatically lead to benefits on farms. Developing skill in the use of forecasts is also necessary, as has been approached in the current program through regional crop forecasting and the use of Decision Support Systems (DSS) to aid crop and pasture management.

Demand

- The National Farmers Federation, in its publication 'New Horizons', endorses the view of many farmers that improved seasonal forecasting is a high research priority to assist them in managing their properties.
  - This was also highlighted in surveys undertaken in Queensland (Stone and Marcussen 1994) and Western Australia (Elliott and Foster 1994) within Phase I of the NCVP (Nicholls *et al.* 1995).
- Managers of water and other climate-sensitive sectors of the economy would like to see significant advances in skill levels and lead times in seasonal forecasting.

Value of seasonal forecasting

- The benefits of improved seasonal forecasts vary between industries and across the country (Appendix A).
  - Soils and vegetation in pastoral areas exposed to high climate variability would benefit through de-stocking in advance of drought. Financial benefits with current skill levels and lead times may not be easily realised.
  - Crop producers in north-eastern Australia appear to be thinking more about whether or not to sow or fertilise a crop if the chance of a harvest is significantly diminished.
  - Demands for irrigation water can be better estimated.

- Studies have shown that forecasts with low skills or unexpected outcomes in some years can greatly offset the benefits of forecasts with higher skills in other years For example, if stocking rates are increased or crops sown in anticipation of an above-average season that does not eventuate then losses can be high. If stock or crops are not sown in anticipation of a drought that does not eventuate, the opportunity cost is also high.

Potential of R&D

- Lead times in terms of years rather than months are needed for significant financial benefits in many pastoral systems. There is therefore a robust case for further research to extend forecasts from seasonal to annual and beyond.
  - GCMs have been shown to offer more promise from 3 to 12 months than the SOI, particularly in terms of forecasting changes in Sea Surface Temperatures in the central and eastern tropical Pacific (Kleeman *et al.* 1995). This longer lead time would certainly be more useful to livestock producers in particular. Furthermore, although the statistical models are quite unreliable during autumn, this is not the case with the GCMs. Even though the GCMs still leave a lot to be desired in terms of forecasting rainfall, the SST information can then be used statistically to estimate changes in the SOI and rainfall with reasonable success.
  - DSS-based studies could be used to determine the scope for different agricultural systems and areas to benefit from forecasts with greater lead times.
- Streamflow is also associated with the El Niño–Southern Oscillation (ENSO) and its influences on Australian rainfall. Chiew and McMahon (1997) have shown that ENSO can be used with some success to forecast rainfall in eastern Australia in the latter parts of the year up to two months in advance, and to improve the forecasts of spring reservoir inflows in the south-east and summer inflows in the east coast of Australia.

Benefits and beneficiaries

- Sensitivity of rainfall to the SOI is highest in north-eastern Australia, so there is already a useful skill level in these areas, particularly relating summer rains to the spring SOI. The addition of SST information is adding further to the skill level in Queensland, and should add even more skill to forecasts in central and southern Australia, particularly with respect to forecasting rainfall in late winter and spring.
- Where the skill is currently lowest then the scope for improvement would appear greatest. Whether or not it is attainable or of value is another matter. The Bureau of Meteorology (BoM) is now basing its seasonal outlooks on the SOI and an index based on Indian Ocean sea surface temperatures. Since the addition of more predictors (ie. >2) may lead to a spurious increase in accuracy, we conclude that the potential for substantial further improvement using statistical techniques is relatively low. Nevertheless it is acknowledged that there may be opportunities to use alternative indices which may complement or replace those used at present.
- In order to improve forecasting beyond three months, which is essential if we are going to significantly benefit the pastoral industry, then on the basis of current information we are almost certainly going to be reliant on GCMs. This is a costly R&D investment, which should be borne by all climate-sensitive sectors that stand to benefit most from this investment. However, we are heartened that the SST predictions from the GCMs are already showing lead-times of in excess of 12 months.
  - Given the influence of the oceans on our climate systems it is essential that research continue to be focused on the ocean-atmosphere models. It is now acknowledged that accumulated soil moisture and vegetation surfaces (albedo) also influence climate, as does the topography (orography), so that further attention to incorporating these refinements to higher resolution models is probably warranted.

- The beneficiaries of this work are all managers of climate-sensitive sectors, including land and water managers.

REGIONAL DROUGHT

Drought monitoring has potential, some of it already realised (QPI20), to contribute to policy making. Given the need for an objective system to rationalise payments for drought relief, an attempt to systematically provide data on the status of droughts is useful. Regional and national monitoring may be aided through the use of agronomic models. Monitoring also includes stock numbers and production, vegetative cover and land degradation, which may have implications with respect to leased land in several States. Remote sensing of green vegetation already contributes to decisions on stocking rates, land clearing and bushfire management.

The other big potential comes from crop forecasting. More accurate estimates, and earlier, of crop production can help logistics/planning and marketing of crops. The potential of R&D to contribute to these activities is high, some progress having recently been made in linking crop yields to seasonal forecasts (ABA6).

Climate monitoring

- Rural Australia is highly exposed to climate variability and climate change. The last four decades have been dominated by periods of above-average rainfall over a large area of Australia. This has meant that many rural producers have not appreciated just how vulnerable they were to climate variability and drought.
  - — Climate shifts over decades need to be monitored, along with changes in land use and the implications for structural adjustment. It is acknowledged that climate has always been changing, but the rate of change is likely to accelerate due to anthropogenic interferences with the climate system. The implications this has for climate variability and on rural communities need to be better understood.
  - — BoM maintains its climate data base, ADAM, with daily rainfall records for its network of more than 3,000 weather stations, many of these records lasting for more than 120 years.
- Issues of data quality from BoM need to be addressed, including perceived deficiencies in the quality and quantity of climatic data.
  - — There is an issue of pre-1957 climate data other than rainfall not having been digitised, which means an incomplete understanding of climate change and climate variability across Australia. This also creates difficulties when using agronomic modelling to place current droughts and climate variability in long-term perspective.
- The Bureau of Meteorology Research Centre (BMRC) has been looking at satellite imagery to determine where and how much rain has fallen. This includes monitoring irradiances (cloud top temperatures; which bear a reasonable relationship with rainfall in the tropics, but not over much of Australia), NDVI data, and using cloud imagery for rain versus no rain (but not the quantity of rain) in delineated areas where rain has fallen. Their assessment is that there may be an advantage in say ten years time from satellite imagery, eg. from examining cloud patterns.

Other scientists are more optimistic (eg. Bryceson 1994). There may even be scope to enhance rainfall estimation using neural network analysis through monitoring cloud movement, spectral characteristics and changes in shape over different areas of the continent.

Agronomic monitoring

- Even though rainfall data will indicate that drought conditions exist, the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (NOAA_AVHRR) data, if properly processed and interpreted will define more accurately the geographic area affected and estimate the production losses associated with these conditions.
  - — Studies in Western Australia have focused on standardising and improving the accuracy of satellite monitoring of green vegetation (Cridland *et al.* 1994; Smith 1994, 1995; Smith *et al.* 1994). Changes in satellite imagery over time show that it is possible to identify changes in vegetation condition and use these to determine appropriate stocking rates.
  - — There is still a need to obtain a comparable set for eastern Australia through 1994 when the drought was at its most severe.
- Remotely sensed data can be used in a number of ways to aid drought assessment, though it is probably at its most useful when used in combination with agronomic models, for this can provide a better indication of feed reserves on the ground.
- The Queensland Department of Natural Resources (QNR) proposes to generate monthly maps of total standing dry matter in Queensland back to the turn of the century, and then place this on their Long Paddock Web site. Progress in drought monitoring and assessment in Australia will have been made when all States and Territories can do this.
  - — The National Drought Alert Strategic Information System, recently renamed AussieGrass, has made considerable progress in monitoring the extent and severity of drought in Queensland, and anticipating feed deficits and threats to land degradation (Brook *et al.* 1996). This system has already proved invaluable in monitoring the extent and severity of agricultural drought throughout Queensland and beyond (cf. drought exceptional circumstance evaluations—see White 1997). There is now a commitment from Western Australia, South Australia, the Northern Territory and New South Wales to integrate agronomic models describing their agricultural systems into AussieGrass.
  - — The rainfall decile maps produced by this team had a major influence on the former Prime Minister and policy makers in DPIE in terms of emphasising the extent and severity of drought in 1994. In future it should be possible to provide percentile maps for different time periods of Total Standing Dry Matter covering the whole of Australia. This would give greater focus to drought assessment.
  - — Independent and anonymous scientific referees have strongly endorsed the approach taken at Indooroopilly, viz. "Their work has become a benchmark and an inspiration for others working in the area of climate variability, vegetation growth and animal production. The linking of their research to the advances in meteorological forecasting has been inspirational and gives hope for significantly improved natural resource use and understanding, particularly in the arid and semi-arid environments of Australia." The challenge now is to extend this work across Australia, and make agronomic assessments for all seasons accessible on-line.
  - — There has been considerable effort already put into validating the underlying model GRASP (GRASs Production; McKeon *et al.* 1990) over space and time. GRASP has been developed and tested for the tropical and sub-tropical rangelands of Queensland, and is currently being evaluated in the Northern Territory. In our opinion, it is essential that this work be extended to other areas of Australia, given the diversity of grassland and agricultural systems that are being monitored.

— The full collaboration of other States and CSIRO will be essential to having agronomic models representative of other major agricultural systems across Australia properly developed, tested and incorporated within the Drought Alert System (AussieGrass). This has been addressed, at least in part, in the planning workshop (CWE14) leading up to Phase II of this project (QNR3). The GrassGro model of Moore *et al.* (1997) for temperate grasslands of Australia would appear to be an essential component of such a system.

- Critical to the development and use of the above systems is the need to incorporate the most reliable agronomic models available for different agricultural systems, and to test these extensively throughout Australia.

  — At the National Drought Alert Workshop (CWE14), conducted in Brisbane (30 October–1 November 1997), it was agreed that the Northern Territory, Western Australia, South Australia and New South Wales would collaborate in extending the AussieGrass system across those areas of Australia.

  — There needs to be spatial and temporal modelling of temperate grasslands, based on GrassGro (Moore *et al.* 1997), and of the rangelands of southern and central Australia, together with crop modelling. Given the number of beneficiaries from having such models, NCVP should look at joint partners in funding future work in this area. Emphasis in the future should see an expansion of model testing, training of extension officers, research scientists and private consultants in their use, and an assessment of marketing opportunities, acknowledging that the GrazPlan software that includes GrassGro is already being marketed through Horizon Software.

  — A major problem is the lack of current information on stocking rates across Australia. There are opportunities in electronic monitoring and satellite technologies that should be investigated to see whether a reliable 'real-time' monitoring system could be developed.

Land use monitoring

Sectoral shifts in response to climate variability, climate change, technological innovation, and environmental, economic and social pressures need to be monitored, and policy options analysed.

— To analyse policy options, a geographically referenced resource information system is envisaged to provide a basis for the objective analysis of past policies and new policy options (Walker and Young 1996).

Regional modelling

- Regional modelling raises issues of spatial resolution and integration relative to information needs and objectives, and the need to seamlessly interface between different information systems. Such modelling can capitalise on spatial systems such as AussieGrass to look at the socio-economic consequences of changes in productivity.

- Effective linking and interpretation of relevant information data sets are essential to the drought monitoring process (Brook and Carter 1994).

Socio-economic monitoring

Socio-economic assessments are crucial to appreciating the impact of climate variability and particularly drought, and furthering the development of appropriate government policy. There is a need to develop an integrated agricultural systems framework so that socio-economic information can be related to biophysical data and models. The feasibility of such a framework has recently been investigated within the Bureau of Resource Sciences (BRS) (Karssies 1997). The BRS, in collaboration with State Departments of Agriculture and Water and CSIRO, has developed a DSS framework linking biophysical, productivity and socioeconomic model components for irrigated areas of the Murray–Darling Basin (Malafant and Fordham 1997). The aim is to identify the impact of policy and program options at regional and Basin levels over the next 20 years. There is the potential to adapt this type of approach to dryland areas exposed to climate variability.

Benefits and beneficiaries

- QNR has demonstrated (QPI20) that if you get the climate, soils, vegetation, livestock density, and remote sensing data sets in place, and have an extensively tested agronomic model (GRASP, for the northern rangelands) and GIS, then you have the basis of a first-class drought monitoring system. Furthermore, this system can be used to provide feed deficit and land degradation alerts.
  - — The highest priority is to get this operational in other States, through AussieGrass. This will require testing GRASP in the Northern Territory, identifying appropriate rangeland models for southern, central and Western Australia, as well as a temperate grassland model, almost certainly GrassGro (CSIRO Division of Plant Industry). There are also a number of crop models that can be used, if required. Incorporating these models into AussieGrass, and testing them extensively with the cooperation of the other States and Territories, has to assume high priority.
- Remote sensing has had relatively limited use, though the benefits are starting to be appreciated. The real value comes about in inter-year comparisons of seasons, and in using the remote sensing information with other data sets and models, including as one source of material for model validation (as in the AussieGrass project).
  - — There is a need for NOAA_AVHRR data sets to be properly calibrated and archived for eastern as well as Western Australia, including rectifying as much as feasible the lack of information when the recent drought reached its greatest intensity in 1994.
- Timely information on sheep and cattle numbers, with at least some discrimination in terms of age and sex, is essential and is unlikely to be addressed through the Australian Bureau of Statistics. This is important for model-based systems such as AussieGrass, as well as in estimating the extent and severity of droughts and which areas are being subjected to or are at risk from overgrazing.
  - — The capacity of airborne and satellite platforms to provide information on monitoring populations of domestic animals and vertebrate pests warrants further work.
  - — Regional and national managers and policy makers would be the initial beneficiaries of such information, though benefits would then flow on to producers who could take advantage of advice on appropriate grazing pressure, or where suitable agistment could be found.

DECISION SUPPORT

A number of decision support systems have already been developed to aid resource managers, mostly farmers and their advisers, to compare management options under different climatic conditions. These DSS have been used as a framework for various research programs targeted at addressing managers decisions, but are only being used by a small proportion of farmers (and there are various reasons for this). Some of the potential of DSS can be illustrated by the DroughtPlan project of the NCVP (CWE8). This investigated developing DSS with farmers as partners, in order to realise the full potential of those DSS (which were identified as consisting of a range of tools and learning activities as well as computer models). DSS and related models can also help by putting current droughts and variations into historical perspective as well as highlighting the need for management to take both short- and long-term climate variability into account.

The National Drought Policy aims to make farmers as self-reliant as possible in their ability to plan for and manage drought. For this 'self-reliance' policy to be viable, further development and promotion is needed of decision support systems that meet the drought and farm management needs of individual farmers.

Models and other DSS have an important role in identifying those management strategies that are exposed to minimum physical and financial risk, particularly in areas exposed to a variable climate. They are also very important in providing understanding and information. 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 increased self-reliance. Given that there are already a number of DSS available, detailed models are probably only justifiable for the broader programs such as CWE8 and DAS12. Guidelines for determining whether or not DSS are required are discussed by Syme and Bennett (1979).

The focus should be on identifying when different approaches to decision support and management planning are the most appropriate (in relation to types of people, types of problems) and how they should then be carried out.

— Many of the individual products developed during the course of the NCVP also warrant further support. In addition to *Australian Rainman* and *Rangepack Herd-Econ*, these include:

  BB-SAFe (Buy/Breed-Sell/Agist/Feed evaluator)

  GrazeOn to help producers undertake forage budgeting and potential stock numbers over periods of three months to three years, initially in Mitchell grasslands.

  Pasture Supply and Demand Calculator to assess dry season feed

  Carrying Capacity Calculator for determining safe stocking levels;

  Grasp Pasture Production Calculator to assess how El Niño affects pasture production;

  Decision Trees helps people compare alternatives in dry years; and

  RISKHerd for assessing the impacts of taxation and other policy instruments.

A range of DSS are also being developed by CSIRO Division of Plant Industry to aid decision making on temperate grasslands. These include MetAccess for analysing climate data, LambAlive that determines threats to neonatal lamb survival, GrazFeed for determining livestock nutrient requirements to achieve desired levels of production, and GrassGro for predicting the growth of temperature pastures in response to season and management. These are all being integrated into the GrazPlan framework (Donnelly *et al.* 1997; Moore *et al.* 1997).

Probably the most important factor in managing climate variability in the grasslands and rangelands of Australia is determining optimum stocking rates, and trading policies, taking into account both environmental and economic criteria. DSS of grazing systems have a major role in these determinations, and in achieving increased self-reliance.

Benefits and beneficiaries

There needs to be more emphasis on linking productivity and land degradation models, to help identify sustainable agricultural systems as a consequence of applying specific management practices within a variable climate.

- Emphasis should continue on making DSS as user-friendly as possible, at the same time acknowledging that some complex problems also require comprehensive answers;
  - there are often instances when a very simple DSS (not necessarily computer-based) can be developed through the use of very sophisticated computer models;
  - it is important that all DSS continue to be extensively tested against relevant data, not only by the authors.

NATURAL RESOURCE MANAGEMENT

There is no work on the interactions between industry and climatic variability in affecting natural resource conservation in rangelands, especially biodiversity. This is a major topic, depending on understanding local extinction and re-invasion processes for different types of organisms. A pilot study to determine whether there are suggestive trends by looking at patterns of species loss across the whole regions in respect to the characteristics of industry and environment in different regions is advocated. There are obvious public interest concerns here (both direct impacts and on whether support is appropriate for industry in some regions, or whether it is simply going to have deleterious effects in the long-term which will damage the image of the industry as a whole), but it also has a vital effect on image and long-term competitiveness of the industry.

ENSO has a major impact on flora and fauna in northern Australia (Nicholls 1991, Norman and Nicholls 1991; Flannery 1994). Many birds are migratory, and other species have devised a range of strategies to cope with drought. There are major opportunities in terms of improved management of riverine and wetlands systems through increased research in this area.

Second Term of Reference

Assess the achievements of the NCVP against its stated goals and objectives, including an assessment of:

- *the likely contribution of the portfolio of completed and current projects in the National Climate Variability R&D Program to improved management of risks and opportunities related to climate variability;*
- *the program's value for money; and*
- *the program's communication and administrative performance.*

THE LIKELY CONTRIBUTION

From the information collected by interviews, questionnaires and the literature supplied by both those funded by the NCVP and by others, project evaluation matrices were built (Appendix B). The NCVP has funded 27 R&D projects (which excludes administration and communication projects). A small amount of funding is, as yet, unallocated ($120,000).

Criteria used for evaluating the portfolio were derived from points raised in the interviews and questionnaires. All the comments are subjective—indeed the need for resource managers (or 'clients' if different) to be involved in project and product evaluation, during the project itself, is essential (such as with CWE8).

There are 18 criteria: the first three criteria relate to 'quality of R&D', the next six to 'improving resource management', the next two to 'outputs', the next four to 'administrative issues', and the next four are 'miscellaneous'. The criteria explore whether full potential has been captured or not, rather than judge 'pass/fail'. The criteria look at the projects within the context of the program, and are not meant to substitute for detailed project evaluations. Recommendations have been made at the end of certain criteria, otherwise the need for further action is fully addressed by the changes to aims, objectives, priorities and implementation (see the third term of reference on page 19).

Contribution to program

This criterion reflects whether the program has been enhanced by the inclusion of a particular project. A high–medium–low scale was used. Most of the projects ranked highly. Only one project ranked low (DAN6) as it appears as an isolated attempt to tackle an issue beyond the scope of the NCVP.

Scientific merit

On the whole, the scientific merit of the portfolio is remarkable. A high number of quality publications arise from, or are related to, the NCVP portfolio (see Appendix G). Quite a few projects contribute to 'breaking new ground', and others to consolidating previous innovations and knowledge (such as QNR9 building on QPI20). Where projects rank lower (UNE16, FRD2), it is usually because the approach is not using resources fully or because the outputs (expected or realised) require further validation than that given in the project design.

Likelihood of meeting the objectives

Some projects had finished and their objectives had been met. One project (CEX1) did not meet its original objectives, and in one case (ABA1) the objectives were revised. Some of the current projects, however, appear overly ambitious and the likelihood of meeting their original objectives is questioned. Research is unpredictable, and some of the forecasting and monitoring projects in the current portfolio are risky investments.

In the case of forecasting it is difficult to determine whether progress is being made, or not, because of the absence, or the complexity of the statistical procedures being used. There are no simple measures provided to assess current skill levels, and whether they are increasing; or benchmarks and criteria that can be used in evaluating progress.

Staff at the BoM use 'Linear Error Probability Space' (LEPS), which is complicated and hard to interpret. QDPI use the 'ability' of the forecast to shift the cumulative probability distributions (of rainfall, frosts, etc). There was a lot of confidence by scientists, that skills would increase, but this could not be confirmed by the consultancy.

Improved the management responses to climate variability

The projects were assessed to whether they *had* contributed to resource management, or not. This is a very difficult criterion to meet given the short-term nature of most of the projects and the long-term nature of resource management. Some of the projects indirectly contributed to improved resource management through the provision of information (such as DAS12). Other projects contributed through influence on policy decisions or changes in agency approach (QPI20, CWE8). Some current projects were judged as potentially able to improve management, for example through the provision of better forecasts. However, most projects have not actually improved resource management, as yet. Over time, it is expected that more of the projects will have a greater impact on the management of climate variability.

Meeting needs of resource managers

Some projects were not designed to meet the needs of resource managers, but other audiences (eg. ABA1 and ARM1). For those where meeting resource manager needs is the prime purpose, the ideal is that resource managers have fully expressed their needs and that these have been taken on board in the design of the project—this is how this criterion has been assessed. It does not assume that we, the reviewers, know the needs of clients. Every NCVP project should demonstrate a clear perception of resource managers' (farms, environmental, water) needs.

Some projects were outstanding in the attempt to meet the ongoing needs of resource managers, such as CWE8. Others did not meet needs (UNE16, UNE17). Overall, more attention is needed as to how seasonal forecasts could be *used* in the decision making process, although CWE8 made a useful start in this direction.

As an aside, not many of the projects were geared towards capturing opportunities offered by climate variability for resource managers.

Range of clients

The clients of the projects were sometimes not defined in the project designs, which usually meant that the main audience was other climate variability scientists. Clients ranged from LWRRDC (in the case of commissioned consultancies—eg. MAC1), researchers (COR2, CWE14, MRC1), agency staff, policy makers (ABA1, ABA6) to resource managers (DAS12, QPI38). With the caveat that resource managers could be a more prominent client group, the range seems adequate for a R&D portfolio.

Client involvement

Increased participation by resource managers in the R&D is seen internationally as a way to improve the relevance of the R&D products (Syme and Bennett 1979; Stuth and Stafford Smith 1993; Rôling 1994; Webber and Ison 1995). Client involvement also places an additional validation loop into the R&D. An implicit scale is used, from no involvement to consultation to full and active participation. Different project designs, incorporating more or less participation, are relevant to different tasks. Most projects have some level of consultation. However, given the complexity of climate variability and management responses, it is argued that a high proportion of projects should have more participation rather than none.

Two projects (CWE8 and MAC1) tried to address farmer needs explicitly by considering Action Learning, Adult Education, and Property Management Planning principles, and how to work with farmers as partners. These principles could increase client involvement in a desirable way.

Evaluation questionnaires, such as are regularly used by the Kondinin Group (see DAS12), are a good way for the client to provide direction for the service.

Impact of findings on client group

The impact, or potential impact, varied enormously, from none apparent (MAC1) through to better information (CAR3, QPI20) through to LWRRDC halting development of certain options (ARM1). A few projects had a high impact (CWE14, CWE8) usually because they either involved clients fully, or they provided quality information at just the time it was being requested (eg. QPI20). Current projects are, of course, hard to assess. Some of these have the potential to make outstanding contributions in their fields (eg. BOM1, COR2, QNR9).

Improved self-reliance of resource managers in the long-run

The motivation for this criterion comes from the focus of the 1992 National Drought Policy, and also from the observation that self-reliance is a more desirable option than assistance payments. It is difficult within the time frame of most of the projects to improve self-reliance—this is a complex task. The criterion is not relevant for all projects, as the client group did not include resource managers. Some of the projects have some potential to contribute to improving self-reliance in the long-run.

Outputs and communication of outputs

There were a mass of conference papers, scientific papers, models and decision support systems, videos and other outputs generated by the projects in the NCVP. These have been of a high quality. Some commercialisation is now taking place (DAN6). A number were looking to the WWW to provide output (QNR9, QPI20).

We saw some need for LWRRDC to encourage some occasional papers to cover 'works in progress'. The provision of 'fax-back' services, in QDPI and SA/WA (DAS12) has been received with enthusiasm by some farmers. Interview evidence suggests that these services are used in interesting ways (particularly in financial management issues). Fax-back also offers some opportunity to test the demand for a product, especially if it is accompanied with a small charge.

Administrative issues

Many different problems were raised, although common problems were the difficulties associated with collaborating over large distances, and collaborating between diverse institutions.

Leverage

Leverage is addressed directly in 'The Program's value for money' on page 17. In many projects leverage has been high, and it is suggested that this is a good measure of the programs value for money.

Worthy of additional funding from LWRRDC

If a project applied for more funds to do similar things then, in the reviewers opinion, should LWRRDC fund it? A large proportion of the projects had been appropriately resourced, and the project had fulfilled its needs. A few projects were considered worthy (eg. CWE8), and these have been incorporated into our recommendations.

Main use of LWRRDC funds

Most of the LWRRDC funding goes to salaries.

Issues raised

These related to the outcomes of the individual projects.

Collaboration

This captures whether other people are involved in the research, and whether there is consultation, or active participation. This complements previous criteria, in that it notes extensive researcher collaboration (eg. COR2) as well as collaboration with resource managers (eg. CWE8). The establishment of a network of researchers is seen as a high achievement of the NCVP.

Public–private linkages

Few of the projects appeared to have captured that potential (although the private provision of some R&D is noted). DAS12 is one of the few attempts to involve private sector providers, in this case the Kondinin Group.

Overall assessment

All projects were valuable, and most were worthy activities given the priorities identified at the time. The overall assessment is that the NCVP has achieved very well, and has taken a few isolated research projects and provided a coherent (and important) research program and network of researchers.

THE PROGRAM'S VALUE FOR MONEY

A quantifiable measure of the value for money of the NCVP is in terms of the funds from outside sources. If independent organisations, with their own aims and priorities, also contribute to the projects then it is our opinion that the R&D is seen as *valuable*. This is indeed the case with the NCVP. Several R&D Corporations, as well as research organisations, have contributed funds to the NCVP or NCVP projects. This leverage effect is shown in Appendix C by projects and for the program. R&D Corporations have provided around $2.6 million to 11 of the 27 projects either by partnership funding or by contributions to a fund for generic projects. This is equivalent to 60% of the NCVP funds of $4.6 million. When contributions of other funds, mainly from research organisations, are included the total leveraging is almost $5 for every dollar contributed by the NCVP. Whilst leverage can provide some measure of the value for the program, future R&D projects should not be funded on the basis of whether they can leverage funding or not.

An alternative measure of the value of the program is in terms of the social benefits of reducing the social and financial impact of climate variability. For example, the Commonwealth Government spent $212 million on Drought Relief Payments, and $198 million in Exceptional Circumstances payments between 1993–1996. The NCVP budget comes to 2% of these payments (and they are by no means the whole cost of the droughts between 1993–1996). If the NCVP could avoid 2% of payments, through either better preparation for drought, better management of climate variability, or better monitoring of drought, then the program would have paid for itself.

Table 5 provides a qualitative appraisal of the costs and benefits of the program. The benefits, if estimated, look likely to far exceed the costs of the NCVP.

Table 5
Qualitative costs and benefits of the program

Costs	Benefits (potential)	Benefits (realised)
NCVP program ($8M)	avoiding degradation	improving accessibility to data
research organisation and third party contributions	taking advantage of opportunities	providing cross-RDC links
	increasing production gross margins (in some cases)	informing policy makers on severity of drought (more efficient allocation of drought support)
	reducing financial risk	establishing a network of researchers
	improved revegetation and restoration works	increasing awareness of climate variability and ENSO
	improved bush-fire management	
	raised LWRRDC profile	

The above three measures all indicate that the NCVP has provided high value for money.

THE PROGRAM'S COMMUNICATION AND ADMINISTRATIVE PERFORMANCE

This section covers the overall program; the projects having been covered in 'The likely contribution' on page 13.

The attempts by the coordinator to engage attention of other R&D corporations are admired. The coordinator has generally consulted widely, involving expert practitioners in a wide range of disciplines, including climatologists, engineers, economists, and agricultural, social and natural resource scientists. These attempts have acted to stimulate organisations to see climate variability research as a priority area, speed up research relating to the goals of the NCVP, and it has also lead to the establishment of a wide network of climate variability researchers.

Awareness of seasonal climate forecasting, the Southern Oscillation Index (SOI), and some of the R&D products from the Program has increased, especially if some of the recent media attention and the use of infofax and the Internet in accessing information is taken as a guide. A small number of farmers, concentrated in Queensland, are directly using some of the products from the R&D. Other resource managers do not appear to use the products at all, and many appear to be unaware of them. The monitoring of droughts and seasonal conditions has already provided some input into regional and national decisions concerning the severity and extent of droughts.

A perception, repeated in the interviews, is that the current use of R&D (ie. adoption of practices), particularly the DSS, is low. 'Low' seemed to relate to 'the total number of farmers and resource managers using the products' rather than 'how many farmers and resource managers could reasonably be expected to be using the Program's products'. The latter is much more difficult to assess, for it takes into account the nature of the R&D products and whether they are actively promoted. One of the research projects (CWE8) showed the difficulties of increasing use of R&D in a short time frame (two years), even given the emphasis on participation of resource managers in the R&D process.

The awareness, however, of the NCVP was also very low in the interest groups that were contacted. Some researchers were also unaware of NCVP funding and priorities—largely because these projects included other R&D corporations as their main contact. Some measures at the program level have been taken to improve this:

- conducting a conference 'Of Droughts and Flooding Rains' (1995);
- inputs into the 2nd Australian Conference on Agricultural Meteorology;
- funding workshops, such as with the sugar industry, to seek collaboration;
- publication of occasional papers; and
- publication of 'fact sheets' (which focused on funds rather than 'outputs').

In addition, a television program for 'Cross Country', broadcast across Australia on the commercial Seven Network, is proposed that will cover three key projects.

This lack of profile for the NCVP is a concern, especially as any funding for the program will depend on the marketing of the program, and especially marketing the achievements of the various projects. Marketing might also address some of the issues of a low utilisation of research results, and might give a good indication as to the 'value' of certain products. This point is picked up in the next section.

A very small number of researchers and interest groups expressed concern at a lack of transparency in reviewing proposals and decisions made about which projects are funded. The reviewers are satisfied that proper procedures are in place, especially under LWRRDC's Quality Assurance. For example, independent referees are used. However, the perception remains, even if it is only among a few people, and measures should be undertaken to ensure that NCVP's integrity is not questioned.

Combining proposals has been seen as a way to improve collaboration, and to scale up regional proposals to national projects. This has had some desirable effects. Combining proposals was met with some opposition in certain cases, and was effective only because there were sufficient personal relationships in place. Extra steps need to be undertaken before proposals are combined: to make it explicit that combining projects is likely, and to call for 'expressions of interest' before calling for competitive tenders.

The reviewers have not commented on the performance of the coordinator—indeed there appears a lack of performance indicators by which comments could be possible. We were impressed by the overall dedication and achievements of the NCVP coordinator. As a matter of principle, we urge LWRRDC to develop appropriate performance measures, and indeed to consider the overall training needs of all its Program Coordinators.

Third Term of Reference

Assess the suitability of the current goals, objectives and strategies of the NCVP for ensuring that R&D contributes to improved management of risks and opportunities related to climate variability. Suggest alternative goals, objectives and strategies that could be adopted in a possible third phase of the program.

THE GOAL OF THE PROGRAM

"The program is funded by the Commonwealth Government under National Drought Policy and aims to facilitate greater adoption of practices increasing productivity and sustainability of Australian agriculture through improved management responsiveness to climate variability.

"The program targets improved risk management through:

- developing skill and broadening use of seasonal climate forecasts;
- improved monitoring of drought and production at regional level;
- development of decision support approaches for farm management."

Clearly limiting the program to 'Australian agriculture' is a restriction that has not been followed in some of the research programs. It is also far more restrictive than the Mission Statement of LWRRDC, which is "To provide national leadership in utilising R&D to improve the long-term productive capacity, sustainable use, management and conservation of Australia's land, water and vegetation resources. The corporation will establish directed, integrated and focused research and development programs where there is clear justification for additional public funding to expand or enhance the contribution of R&D to sustainable management of natural resources". Substitution with the phrase 'Australia's land, water and vegetation resources' would not only bring the program in to line with LWRRDC's Mission Statement, but would also reflect better the current content of the program.

STRATEGIES

The following strategies were provided in the Program Development Report of March 1995.

Table 6
Objectives, Strategies, Priorities and Implementation of the NCVP in Phases I & II

Sub-Program	Climate Forecasting	Drought Risk Management	Decision Support
Objectives	(a) improved seasonal climate forecasts based on statistical approaches using ENSO and Sea Surface Temperatures and (b) General Circulation Models ensuring their development is geared to needs of the agricultural sector	Improved drought alert systems incorporating both resource management risks and commodity forecasts.	Improved tools for farmers and land managers to manage production and resource risks.
Benefits	mainly generic	mixed	mainly to growers of specific commodities
Strategies/Priorities			
— advancing knowledge	High	Low	Medium
— expanding coverage	High	Medium	High
— integrating production and resource risk management	Low	High	High
Implementation	Commission applied and strategic projects with Bureau of Meteorology and CSIRO Atmospheric Research and Oceanography	Investigate options for current drought alert project expansion and investigate options for improved commodity forecasting	Request priorities from collaborating Corporations as a basis for defining proposed projects.

Two issues need to be discussed. Firstly we need to reiterate some points made previously and then we need to discuss the sub-program structure as it was in Table 6 and as we recommend in Table 7.

One conclusion that can be drawn from the previous two terms of reference is that there is some evidence that forecasting may or may not be useful to resource managers, depending on their ability to respond. A second point is that there is plenty of evidence that unless the resource managers are fully involved, then any assistance that R&D may offer could be of limited or no use to the audience. So we see that the whole process of 'climate forecasting' and 'decision support' needs to be put together and considered as one sub-program. This also allows an effective linking mechanism to promote cross-disciplinary R&D. If sub-division becomes necessary, then it should be on the basis of resource type rather than separation of forecasting from supporting the decision. We are calling this combined sub-program **'Managing natural resources in a variable climate'.**

A large amount of the work previously called 'Drought risk management' has been in monitoring drought and production. We believe that this work should be expanded, but that the title should reflect an expanded view, not only beyond drought to all states of the weather, but also to reflect that climate variability affects rural communities, land, water etc. This sub-program we are calling **'The impact of climate variability on our human, agricultural and natural resource base'.**

Finally we believe that not only does the NCVP have some products to market, but that, in many cases, market testing should be done before new initiatives are investigated. This sub-program we are calling **'Marketing the program and its products'.**

To reflect the changes of emphasis that we believe should be made in Phase III of the program, we propose the following:

Recommendation

R1 *We recommend that the NCVP Program's Objectives, Strategies, Priorities and Implementation be changed to those presented in Table 7.*

The details of these changes are reflected in our recommendations for the possible Phase III in the next section.

Table 7
Objectives, Strategies, Priorities and Implementation of the NCVP in Phase III

Sub-program	Managing natural resources in a variable climate	The impact of climate variability on our human, agricultural and natural resource base	Marketing the program and its products
Objectives	Improved use of SCF and DSS in agricultural, water and environmental decisions	Increasing monitoring and understanding of the impacts of climate variability	To ensure the Program delivers useful products and outcomes.
Beneficiaries (Target audiences)	Resource managers, suppliers, traders and policy	Policy makers and resource managers	Policy makers and resource managers
Strategies/priorities			
Supporting decisions	Medium	Low	High
Participation of Resource Managers	High	Low	Medium
Exploiting opportunities	Medium	High	High
Recommendations to Implement	R10	R16	R20

Fourth Term of Reference

Identify gaps, and propose appropriate directions for the program including R&D focus, adoption, communication, management, evaluation and industry funding partnership arrangements, to contribute to more efficient and effective achievement of program goals and objectives both in its current phase and a possible 3rd phase.

MANAGING NATURAL RESOURCES IN A VARIABLE CLIMATE

Managing agricultural resources within a variable climate involves planning in advance for adverse seasons. This includes financial planning, which may be as simple as preparing two budgets in anticipation of the coming season, assuming a drought year and an 'average' season. It also includes being aware of taxation incentives and implications. On grazing properties it certainly involves being aware of the biophysical and financial implications of choice of stocking rate and stock trading and feeding strategies. It also includes many other farm strategies, including choice of vegetation, land use, and fodder reserves. More recently the use of seasonal forecasts has added an extra dimension to achieving self-reliance within a variable climate. Managing other natural resources in a variable climate will involve a similar level of planning.

Uncertain benefits from seasonal forecasts (R2)—This review has highlighted what appears to be the low use of seasonal forecasts across much of Australia. Preliminary studies using models of grassland systems identify that the financial benefits may not be easily realised based on existing skill levels and lead times (Stafford Smith *et al.* 1996). In some areas even high skill levels appear to offer low financial benefits (Bowman *et al.* 1995). The value of seasonal forecasts to crop producers can be significant, but it varies with management and initial conditions, as well as with cropping system and location (eg. Marshall *et al.* 1996; Hammer *et al.* 1996).

R2 *NCVP coordinate 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.*

Improvements in forecasting skill (R3)—The research being performed to improve forecasts (BOM1, COR2, SRD2) has demonstrated that there are a number of opportunities for improvement, both in terms of areas where little of no forecast skill is presently available and using different methods where forecast skill has been achieved.

R3 *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.*

Benchmarking of forecasting skill (R4)—However in many cases our ability to discern whether progress was being made or not, was limited by a lack of any simple statistical procedure to ascertain forecast improvements.

R4 *NCVP identify appropriate standards and procedures for benchmarking forecast skill as a matter of urgency, so that progress, or lack of it, in forecasting can be clearly identified.*

DSS and Action Learning (R5)—Self-reliance includes being able to effectively manage complex agricultural systems that are exposed to a variable climate. Scientists often develop simulation models and DSS to understand system behaviour and how the management of such systems may be improved. Major advances have been achieved through the DroughtPlan project (CWE8) that involved both DSS development and Action Learning. It is important to keep the momentum going in this area, particularly as a benchmark against which to determine future progress has now been established. The DroughtPlan project (CWE8) represented a major effort in developing and using state-of-the-art DSS, workshops, consultation and education to develop economically viable drought management strategies whilst sustaining the land resource base. It will take time and ongoing funding, as well as scientific commitment to ensure the realisation of the program goals.

R5 *NCVP support the future development of research projects that combine Action Learning with the development and implementation of appropriate planning and management (DSS) tools.*

Sustainable whole-farm systems (R6)—Much of the effort associated with the development of DSS for farming systems has concentrated on either grazing or cropping enterprises. There is a definite need to increase the coverage of DSS to cover a wider selection of Australian mixed farming situations, especially to examine the behaviour of these systems for sustainability in a variable climate.

R6 *NCVP ensure that integrated pasture–livestock, cropping and land degradation models are used to identify sustainable whole-farm systems within a variable climate. This would aid strategic and tactical planning to benefit the soil, vegetation and livestock, as well as the financial and social well being of the farmer.*

Land degradation (R7)—Effective crop–pasture–livestock integration is a major determinant of success in the management of whole farms, which needs to be taken account of in the Property Management Planning process. Being multi-disciplinary, and demanding of scarce resources and expertise, crop–pasture–livestock integration is an area that has been typically under-funded. Multi-enterprise farms dominate the wheat–livestock zone, much of which is exposed to high climate variability and exhibits substantial land degradation. The effective integration of land use, land management and climate variability is an essential component in achieving ecologically sustainable development throughout much of rural Australia.

R7 *In conjunction with other programs in LWRRDC, NCVP should call for projects addressing the scope of seasonal climate forecasts to contribute to sustainable resource management; for example in forecasting wind and water erosion hazard and developing appropriate response strategies.*

Policy instruments (R8)—A better understanding is required of the impacts of taxation and other instruments on resource sustainability. The RISKFARM software is excellent for looking at the impacts on production, but not at whether there were real feedbacks (positive or negative) to resource condition, and consequently whether the rhetoric of intent with these policy instruments is really met. However, it is desirable that the Rural and Land Resources Divisions of DPIE have input into this work, so that such research may lead to administrative changes.

R8 *With support from the Rural and Land Resources Divisions of DPIE, NCVP commission biophysical/bioeconomic case studies into the impacts of taxation and other policy instruments on productivity and sustainability, particularly with respect to land degradation for the rangelands, grasslands and cropping industries [DPIE/LWRRDC/MRC/IWS/GRDC/RIRDC].*

Water and other natural resources (R9)—More efficient management of water (eg. irrigation water allocations, infrastructure requirements), and forest resources (eg. 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 need only one good breeding per decade and they can get that from one above average rainfall season. 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.

R9 *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.*

Summary Recommendation:

R10 *The R&D priorities for the funding of projects under the sub-program 'Managing natural resources in a variable climate' should be consistent with those set out in Table 8, which concisely lists the key recommendations for this sub-program.*

Table 8

R&D Priority
R2 NCVP coordinate 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.
R3 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.
R4 NCVP identify appropriate standards and procedures for benchmarking forecast skill as a matter of urgency, so that progress, or lack of it, in forecasting can be clearly identified.
R5 NCVP support the future development of research projects that combine Action Learning with the development and implementation of appropriate planning and management (DSS) tools.
R6 NCVP ensure that integrated pasture–livestock, cropping and land degradation models are used to identify sustainable whole-farm systems within a variable climate. This would aid strategic and tactical planning to benefit the soil, vegetation and livestock, as well as the financial and social well being of the farmer.
R7 In conjunction with other programs in LWRRDC, NCVP should call for projects addressing the scope of seasonal climate forecasts to contribute to sustainable resource management; for example in forecasting wind and water erosion hazard and developing appropriate response strategies.
R8 With support from the Rural and Land Resources Divisions of DPIE, NCVP commission biophysical/bioeconomic case studies into the impacts of taxation and other policy instruments on productivity and sustainability, particularly with respect to land degradation for the rangelands, grasslands and cropping industries [DPIE/LWRRDC/MRC/IWS/GRDC/RIRDC].
R9 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.

THE IMPACT OF CLIMATE VARIABILITY ON OUR HUMAN, AGRICULTURAL AND NATURAL RESOURCE BASE

Sustainable management of pastoral systems in Australia is highly dependent on appropriate stocking rates and stock trading strategies, so that the resource base is not overgrazed during periods of drought. DSS of pasture–livestock systems have had a major role in identifying appropriate management strategies in these areas, often being a necessary adjunct to field experimentation. Detailed monitoring of our grasslands and rangelands is proving essential to ensure that the resource base is not unduly exploited and further degraded.

A National Archive of NOAA_AVHRR imagery (R11)—Project CEX1 has provided a set of calibrated remote sensing imagery (NOAA_AVHRR) for Western Australia since 1991. A complete set of calibrated remote sensing imagery for the whole of Australia back to 1982 is highly desirable, so that changes in vegetation and drought severity are properly benchmarked. There is a need for a widely accepted 'best processed' National NDVI dataset so that the Western Australian products can be tested in other areas of Australia.

Satellite imagery can be invaluable within a GIS containing agronomic models, both in terms of identifying vegetation type and land use, and as a source of validation material.

Software tools for examining sequences of images, and placing current images in an historical context, need to be more generally available. Remotely sensed data also need to be more accessible, which is expected soon, given the imminent arrival of interactive GIS on the World Wide Web.

Priority areas are:

- Investigating alternatives to the NDVI as a measure of vegetation condition and cover, based on additional sensors on later satellites;
- Obtaining national agreement on appropriate calibration coefficients for the NOAA imagery;
- Ground truthing the Western Australian products in environments different to those in which they have been developed;
- Commissioning, in collaboration with the CSIRO Office of Space Science and Applications (COSSA), ERIN and the CSIRO Earth Observation Centre, the development of a comprehensive archive of calibrated NOAA_AVHRR imagery across Australia.

R11 *NCVP coordinate and contribute to the development of a comprehensive national archive of calibrated NOAA_AVHRR imagery across Australia.*

A National Drought Alert Strategic Information System (R12)—This is seen by many scientists as a high priority, building on the work undertaken within QPI20, and the subsequent planning workshop (CWE14) and project (QNR9). The AussieGrass system should enable detailed vegetation monitoring, and provide farmers with feed deficit and land degradation alerts in time to take evasive action.

Further requirements include:

- Extending AussieGrass beyond QNR9, so that we have a truly national system for estimating land degradation alerts (through total standing dry matter, feed utilisation rates and feed deficits) across Australia. This work is already underway, but it will certainly require the use of GrassGro (CSIRO Plant Industry) and other models representative of vegetation types currently not incorporated into the system, plus extensive validation.
- Adapting AussieGrass to ensure seamless interfacing with other national and State systems.

R12 *NCVP continue supporting vegetation monitoring and the development of drought alert information systems with a capacity to monitor and reduce the risk of land degradation, thereby leading to more sustainable resource management.*

Monitoring stock number in near real time (R13)—Research is needed to determine how stock numbers, flock and herd structure and grazing pressure can be monitored across Australia, so as to improve feed deficit and land degradation alerts, and determine whether stocking rates exceed the carrying capacity of the land. This might take advantage of recent developments in remote sensing, electronic monitoring technology and population modelling.

R13 *NCVP commission an investigation into the feasibility of estimating and monitoring stock numbers in near-real-time across Australia.*

Integrating climate variability and climate change (R14)—There is a need to develop software which takes account of both short and longer term climate impacts. For example, a consortium consisting of Hassall & Associates together with the State agencies across the Murray–Darling Basin, CSIRO Division of Atmospheric Research and some other research agencies, is proposing to develop a package that will help river managers with both short (monthly) and longer (future decades) decisions.

R14 *NCVP examine the possibility of developing software which integrates the effects of climate variability and climate change on our natural resources.*

Pest and Weed management (R15)—Drought provides an opportunity to control pests when their numbers are naturally low and they are concentrated around areas with water. It is also during dry periods and drought that there is greatest competition between domestic stock and feral animals and the greatest potential for land degradation due to excessive grazing pressure—highlighting the need for management at this time. A major issue is strategic management of vertebrate pests in refuge areas during drought.

R15 *NCVP determine the effectiveness of pest and weed management during drought and the ability to maintain pests and weeds at low densities once a particular drought is over [Under the National Feral Animal Control Strategy].*

Summary Recommendation

R16 *The R&D priorities for the funding of projects under the sub-program 'The impact of climate variability on our human, agricultural and natural resource base' should be consistent with those set out in Table 9, which concisely lists the key recommendations for this sub-program.*

Table 9

R&D Priority
R11 NCVP coordinate and contribute to the development of a comprehensive national archive of calibrated NOAA_AVHRR imagery across Australia.
R12 NCVP continue supporting vegetation monitoring and the development of drought alert information systems with a capacity to monitor and reduce the risk of land degradation, thereby leading to more sustainable resource management.
R13 NCVP commission an investigation into the feasibility of estimating and monitoring stock numbers in near-real-time across Australia.
R14 NCVP examine the possibility of developing software which integrates the effects of climate variability and climate change on our natural resources.
R15 NCVP determine the effectiveness of pest and weed management during drought and the ability to maintain pests and weeds at low densities once a particular drought is over [Under the National Feral Animal Control Strategy].

MARKETING THE PROGRAM AND ITS PRODUCTS

The need for a marketing plan (R17)—The low awareness of the NCVP is a concern. Any future funding for the program will depend on the marketing of the program, and especially marketing the achievements of the various projects. Marketing might also address some of the issues of low utilisation of research results, and might give a good indication as to the 'value' of certain products.

Electronic packaging and dissemination of information on climate, pasture growth estimates and crop yield forecasts, and maps of drought-declared areas are possible. LWRRDC is in a good position to deal with this marketing. It is likely that a combination of approaches will be needed to improve communication (and ultimately self-reliance), encompassing our later recommendation calling for a training of extension officers, agricultural consultants and future researchers.

Marketing will also directly influence the questions about 'adoption of current R&D products'.

Farmers were less prepared for the drought in the 1990s because of high farm debt; a consequence partly attributable to high interest rates in the late 1980s and various commodity price collapses. Many properties were also being managed by a generation of farmers who were largely unaware of just how dry their regions could become, as the average rainfall has been higher in the last 50 years compared to the last 100 years. Add to this a range of social and environmental issues in remote areas, a loss of vision about the future of Australian agriculture, and declining political influence in rural Australia, and the stage is set for reduced capacity to plan for and withstand the rigours of drought. Many researchers are concerned by the perceived problems facing resource management in the future. Highly trained resource managers are essential to the well being of Australia's natural resources, as are highly competent researchers.

R17 *NCVP develop and implement a marketing plan which includes targets for policy makers, R&D Corporations, and resource managers. Attention should focus, on the products and messages that are to be provided, on the production of databases of target audiences, and on a range of media (including print, multimedia and the Internet).*

Training for public and private extension officers (R18)—The reviewers were impressed with the recent funding of a project to develop and market RAINMAN3 (RDC7). We feel that this is an example of what is possible, even if public–private linkages do not appear to have been exploited to the fullest.

R18 *NCVP fund training for extension officers and private consultants in the use of relevant DSS tools to aid the management of agricultural systems, and appropriate strategies for managing risk.*

Training of our future resource managers (R19)—One important, but untapped, market for current R&D products is tertiary education and, for products like RAINMAN3, secondary education. This market is especially important since some students become tomorrow's resource managers. Other untapped markets include: the building and construction industries, tourism, and mining, as well as the present markets of agricultural producers, policy makers, water authorities and environmental managers.

Although not part of this review we noted that there were areas in Australia where technical competence to handle, much less develop, DSS was very low. In our casual discussions with teachers of resource management courses, we became concerned that the need for adequately trained natural resource managers with skills in computing, simulation and action learning would not be met.

R19 *NCVP co-provide three PhD or Master's levels scholarships with other R&D Corporations, or possibly LWRRDC, to address the future need for trained researchers conversant with climate variability issues and approaches.*

Summary Recommendation

R20 *The R&D priorities for the funding of projects under the sub-program 'Marketing the program and its products' should be consistent with those set out in Table 10, which concisely lists the key recommendations for this sub-program.*

Table 10

R&D Priority
R17 NCVP develop and implement a marketing plan which includes targets for policy makers, R&D Corporations, and resource managers. Attention should focus, on the products and messages that are to be provided, on the production of databases of target audiences, and on a range of media (including print, multimedia and the Internet).
R18 NCVP fund training for extension officers and private consultants in the use of relevant DSS tools to aid the management of agricultural systems, and appropriate strategies for managing risk.
R19 NCVP co-provide three PhD or Master's levels scholarships with other R&D Corporations, or possibly LWRRDC, to address the future need for trained researchers conversant with climate variability issues and approaches.

MANAGEMENT AND ADMINISTRATION

The integration of the NCVP with other relevant activities in the LWRRDC portfolio is desirable. Links are especially strong with the: National Program for Irrigation R&D; Indicators for sustainable production systems; Barriers to adoption of sustainable production systems; Rehabilitation and Management of Riparian Lands R&D Program; Maintenance of condition, productive capacity and environmental values of rangelands; National River Health Program; National Eutrophication Management Program; National Groundwater R&D Program; National Wetlands R&D Program; and Catchment hydrology and management. The reviewers see the desirability of climate variability R&D *informing* these other programs and activities. Whilst the NCVP marketing plan may include an internal LWRRDC audience, integration may be best achieved at the LWRRDC level.

One issue on which there was little agreement was whether the NCVP should engage in policy research. One side of the argument is that the NCVP and its project teams, probably had more 'grass roots' contacts with those who have to cope with climate variation and were, therefore, an appropriate source of policy ideas and information. The other side of the argument was that policy makers pay very little attention to research that they have not initiated and been involved with (similar to the involvement of producers in DSS). We saw these issues being resolved by two processes; policy research should only be undertaken with the direct involvement (including funding) of the policy officers who would have to try to implement the policy, and clear direction on this issue from the Management Committee.

The issue of where NCVP should stand in relation to policy development was symptomatic of debate about where the role of a research investor ends. NCVP can be seen to be much wider than LWRRDC, as evident by the collaboration with other RDCs (which we praise). Our review did not include comments about BoM, the Sustainable Land Use Information System (SLUIS) and the Asia Pacific Institute for Climate Applications (APICA), for example, even though we suggest that these are important issues that should be taken up with the DPIE.

The composition of the management committee reflects an attempt to incorporate 'investors' (ie. R&D Corporations) on the committee, but it appears to be at the expense of users and technical expertise. We do not advocate increasing the size of the Committee, only a discussion amongst the Committee of what they see as their contributions and what other contributors are needed.

Recommendations

R21 *The role of the NCVP in assisting policy development should be a matter for the Management Committee to review, preferably by the preparation of a position paper.*

R22 *The composition of the Program's Management Committee be reviewed.*

EVALUATION

This review has focused on program level considerations rather than a detailed assessment of individual projects. The reviewers are satisfied that project assessment procedures are in place, but draw attention to the measures of performance that are outlined in the project schedules. Many of these appear vague, and some do not emphasise adoption or use of the R&D products (the former is probably the major concern). Again, RDC7 is highlighted as a project that has very sharp and clear measures of performance which can be easily checked by auditors, investors and resource managers. No recommendations are made on this point, because it is acknowledged that the project schedules do not represent all of the negotiation and checking between LWRRDC and researchers.

The need for adequate benchmarking of seasonal climate forecasts, was addressed in a previous recommendation. We also wish to emphasise that:

1. not many of the measures of performance are actually being done by outside parties. In some cases, LWRRDC acceptance has to be seen as adequate, but not all the time. Thus when referring to 'supporting decisions' and 'improving management', fund managers need to also be involved in checking that this is occurring.

2. there should be more attention to the processes of evaluation **embedded** in the research process (eg. Stafford Smith *et al.* 1996), instead of being left to the final stages of the project. This is a fundamental feature of Action Research. It also relates to the above, in that resource managers, or the people affected by the research, have some sort of control on the research process.

INDUSTRY FUNDING PARTNERSHIP ARRANGEMENTS

The reviewers have admired the efforts to engage other R&D Corporations in the NCVP and provide co-funding. The co-funding, as a major implicit strategy of the NCVP, should continue. Some R&D Corporations, such as Meat Research Corporation (MRC), seem strangely absent from present arrangements, especially given that the grazing industry is probably the biggest beneficiary of climate variability R&D both in terms of production and decreased degradation of rangelands. MRC is going through some restructuring at present, but it appears to be a suitable organisation with which to expand R&D co-funding arrangements. Even though some of the R&D is generic, certain industries such as grazing and cropping will probably benefit the most in the short term, which indicates that they should contribute the most (the size of the present GRDC contribution is noted).

Private sector funding, with the exception of contributions from the Kondinin Group and Goodman Fielder, is an untapped source. The marketing initiatives previously recommended are one positive step to attract more private funding. The Australian Wheat Board, for example, may provide funding for research that improves its market position. The Kondinin Group itself appears very active in both the provision and funding of R&D, and could be encouraged to contribute more. The 'public good' nature of some of the climate variability R&D is not a total constraint to private funding. The United Kingdom shows many examples of sponsorship of 'public good' measures, such as BP's 'Going for Green' initiative, and Electricity Boards' sponsorship of different conservation groups. Indeed, some private companies contribute to Landcare.

SECTION 4

Epilogue

Although we have followed the terms of reference as required, we have a feeling that the importance of climate variability and human occupation of the Australian continent is only just being realised. To give an example, consider the following:

"In the Australia of 100,000 years ago there were over 50 species of medium or large specialised herbivorous marsupials. There were also several gigantic herbivorous birds and turtles. Each species would doubtless have had its own favourite food type. Working in concert, their browsing and grazing probably maintained a complex vegetation mosaic which supported all of them and allowed a diversity of plants to coexist." (Flannery, 1994, p 232). Flannery suggests that the first human (Aboriginal) invasion 40,000 to 60,000 years ago, lead to megafaunal extinction and, as a consequence of inadequate grazing pressure, a rapid increase in the frequency of fires, both as a consequence of increased fuel load and as a consequence of 'fire-stick farming', and the development of a fire-tolerant landscape, where nutrient loss was far greater.

"As a result, most of northern Australia is covered with eucalypt woodlands today. After rain the water drains rapidly away, for the plants and thin soil cannot hold it. The release of moisture to the atmosphere through the narrow eucalypt leaves is insufficient to form significant clouds. As a consequence, the rainfall gradient between coast and inland is incredibly steep in northern Australia. Without the help of broad-leaved plants, the rainfall does not normally penetrate far enough south in sufficient quantity to fill the drainages that flow into the lake." (Flannery, 1994, p 235).

Australia's rivers could not have been too bad before the second (European) invasion, 200 years ago, for as Lines (1991) points out "Aborigines also practised river control and on northern rivers built dams to enlarge the areas of lagoons available for fish, plant and bird life. In south-western Victoria Aborigines built dykes, races, canals, traps and stone walls to create marshlands for fish, eels and birds." (p 10). But the Europeans and their cloven-hoofed animals certainly caused havoc with the landscape. "It is not possible now, even with Leichardt's scanty records, to reconstruct the aspect of the country of the Wadja people The changes brought about by sheep and cattle, and by the disappearance of the Aborigines, were certainly immense, and if perhaps few plant and animal species have entirely disappeared, their distribution and frequency must then have been very different. What has changed most of all under the white regime has been the watercourses, the tracks of the Rainbow Serpent, whose waters then ran clear and whose banks and their lost fringing lagoons were the chief support of the Aboriginal people. So F.M. Bell of Camboon Station, east of the Dawson, remembered being told that even in the great floods of the nineties the Dawson River still ran with pure water, staying a swim for months afterwards—"not dirty floodwater but quite clear, fed by the numerous springs and creeks". The lily lagoons, the swamps and the reed beds, long trampled and drained now, edged the rivers and their tributary creeks, feeding and nesting places for many thousands of water birds; the deep springy grasslands of the flats were thick with annual grasses and herbage, birds sang everywhere, and the clean scent of the land stayed in Bell's nostrils in his old age as a wistful memory." (Wright, 1981, p 13).

"To meet debt repayments pastoralists increased their flocks, and through overstocking, degraded the land. In Monaro, New South Wales, one squatter reported on the consequences:

Before the passing of the Land Act ... the Matong Creek ... was a succession of deep waterholes, there being no high banks, and grass grew to the water's edge. Hundreds of wild ducks could be seen along these waterholes, and platypus and divers were plentiful. Five years after the passing of the Act the whole length, instead of being a line of deep waterholes, became a bed of sand, owing to the soil erosion caused by sheep. The water only came to the surface in flood time when it spread the sand over the flats." (Lines, 1991, p 96)

It appears that humans have slowly exacerbated the droughts and flooding rains that now provide the conditions for further wind and water erosion, as well as biodiversity loss. As has also been evident in other countries in the world where climate variability is high, it is the combination of human mismanagement and adverse seasons, particularly the overstocking of land in times of drought, that exacerbates land degradation (desertification) and threatens the sustainable utilisation of pastoral lands. As Fouché et al. (1985) observed when modelling veldt production in South Africa, overstocking increases the number, duration and probability of droughts. This can also have a deleterious effect on the ability of the vegetation to limit soil erosion (White *et al.* 1980; Morley and Daniel 1992).

The bigger picture is that our extreme climate variability is a driving force that, with a lot of human help, is leading to the rapid degradation of our Nation. If our farmers are going to achieve increased self-reliance then they will have to become more aware of the physical, ecological, and global political and economic environment in which they are operating, and the skills and tools to enable them to adapt to changes in this environment. The NCVP goes a small but invaluable way to addressing this need.

Recommendation

R23 *NCVP commission a pilot study to determine whether there are suggestive trends by looking at patterns of climate variability, degradation and species loss across whole regions in respect of the characteristics of industry and environment in different regions.*

This could well contain some assessment of the validity of Flannery's claims of climate change as a consequence of vegetation change and some grand plans to arrest the soil and nutrient loss that we are facing at present.

The spring and early summer rains of 1996–97 resulted in the cotton farmers of the Macquarie Valley, many of whom are clients of Hassall & Associates, reaping a bountiful harvest; the last of which is being gathered as we write this report. The breeding of the colonial nesting birds in the Macquarie Marshes was one of the best since records have been kept. So both humans and animals are following the "strict obedience in following and exploiting brief windows of opportunity as they open erratically over the land" (Flannery, 1994). Yet not everybody was prepared. Hassall & Associates was kept very busy through Spring, Summer and Autumn assisting the Murray–Darling Basin Commission to settle more than 150 claims for compensation arising from the release of water from the Hume Weir, causing an additional artificial flood on the Murray River.

Unless we have totally misread the abilities of native plants and animals, they cannot forecast 'El Niño' events. Like the ideas that are the motivation of DAS12, they make the most of the current knowledge to determine what to do next. This applies equally to the blooming of the Channel Country after a flood, to the triage of desertion of chicks in nests, which the Straw-necked Ibis does as soon as flood levels drop in the Marshes.

The first problem is that, in mimicking nature, we may be rushing into decisions that will not necessarily be the best under all circumstances, and may not be the best-bet decisions in any case. Apart from that, we can now forecast seasonal conditions, thanks partly to the previous research of the NCVP, as well as monitor vegetation indices across the whole nation in real time. So how should we now behave?

Humans, especially suburban Australians, seem to wish to banish the uncertainties of nature, by having well watered gardens and assured supplies of all foods, whether seasonally produced, or not. But these requirements for everything to be as uniform and as guaranteed as possible are not the strategies that Flannery suggests that are necessary for survival, ie. "parsimony born of resource poverty, low rates of reproduction and strict obedience in following and exploiting brief windows of opportunity as they open erratically over the land". To propose, as Morley and Graham (1971) did, that one of the most important strategies for producers to survive during drought is the reduction in household income, seems to be a typical Flannery Strategy. Equally, we suggest, the 'Beef Roads' concept and construction of the 1970s is a Flannery Strategy. There must be many more that these phrases will conjure up. And it would help if someone were asked to do it.

Recommendation

R24 *The NCVP commission an innovative study to examine resource management strategies that may have merit in a land of droughts and flooding rains.*

SECTION 5

References

Bowman, P.J., McKeon, G.M. and White, D.H. (1995). The impact of long range climate forecasting on the performance of sheep flocks in Victoria. *Australian Journal of Agricultural Research*, **46**, 687–702.

Brook, K.D. and Carter, J.O. (1994). Integrating satellite data and pasture growth models to produce feed deficit and land condition alerts. *Agricultural Systems & Information Technology* **6**(2), 38–40, 54–56.

Brook, K.D., Carter, J.O., Danaher, T.J. McKeon, G.M., Flood, N.R. and Peacock, A. (1992). The use of spatial modelling and remote sensing for monitoring and forecasting of drought-related land degradation events in Queensland. *Proceedings of the 6th Australasian Remote Sensing Conference*, Wellington, New Zealand, November 2–9, 1992, Volume 1, 140 149.

Brook, K. *et al.* (1996). Development of a National Drought Alert Strategic Information System. Final report on QPI 20 to Land and Water Resources Research and Development Corporation (May 1996) (6 volumes).

Bryceson, K.P. (1994). Using GMS satellite data to estimate the areal location and quantity of rain. *Agricultural Systems & Information Technology* **6**(2), 37, 51–53.

Bryceson, K.P. and White, D.H. (editors) (1994). Proceedings of a workshop on *Drought and decision support.* Bureau of Resource Sciences, Canberra, 63 pp.

Bryceson, K.P., Brook, K.D. and White, D.H. (1993). Integration of spatial data and temporal models to improve drought preparedness, monitoring and management. *In* Proceedings of the "Applications of advanced information technologies for the management of natural resources" conference, Spokane, Washington, June 17–19, 1993, pp. 158–166.

Caughley, G. (1987). Ecological relationships. *In* G. Caughley, N. Shepherd and J. Short, eds. "Kangaroos: their ecology and management in the sheep rangelands of Australia", Cambridge University Press, London, pp. 159 187.

Chiew, F. and McMahon, T. (1997). Seasonal forecasting of rainfall and streamflow in Australia. *Climate prediction for agricultural and resource management*, Australian Academy of Science (in press).

Chiew, F.H.S., McMahon, T.A., Dracup, J.A. and Piechota, T. (1994). El Niño/Southern Oscillation and streamflow patterns in south-east Australia. *Civil Engineering Transactions, Institute of Engineers, Australia*, CE36(4), 285–291. Eliason, P. (1989). Australia: Drought assistance and land degradation. *Drought Network News*, University of Nebraska, **1**(2), 2–3.

Clarkson, N.M. and Clewett, J.F. (1996). Australian Rainman: the first two years and future development. *Proceedings of the second Australian Conference on Agricultural Meteorology*, The University of Queensland, 1–4 October 1996, pp. 93–97.

Clewett, J.F. and Drosdowsky, L. (1996). Study 1: Use of the Southern Oscillation Index as a drought management tool. *In* 'DroughtPlan: Building on participation' by D.M. Stafford Smith, J.F. Clewett, A.D. Moore, G.M. McKeon, R. Clark and many others (1996b). Full project report, Working paper No. 10, pp 120–124.

Clewett, J.F., Howden, S.M., McKeon, G.M. and Rose., C.W. (1991). Optimising farm dam irrigation in response to climatic risk. *In* R.C. Muchow and J.A. Bellamy, (eds). 'Climatic risk in crop production: models and management for the semiarid tropics and subtropics', pp. 307–328. Wallingford (CAB International).

Cridland, S.W., Burnside, D.G. and Smith, R.C.G. (1994). Use by managers in rangeland environments of near real-time satellite measurements of seasonal vegetation response. *In* 'Mapping resources, monitoring the environment and managing the future'. *Proceedings of the 7th Australasian Remote Sensing Conference*, Vol. 2, 1–4 March, Melbourne.

Donnelly, J.R., Moore, A.D. and Freer, M. (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises—I. Overview of the GRAZPLAN project, and a description of the MetAccess and LambAlive DSS. *Agricultural Systems* **54**, 57–76.

Dudley, N.J. and Hearn, A.B. (1993). El Niño effects hurt Naomi irrigated cotton growers, but they can do little to ease the pain. *Agricultural Systems* **42**, 103 126.

Eliason, P. (1989). Australia: Drought assistance and land degradation. *Drought Network News*, University of Nebraska, **1**(2), 2–3.

Elliott, G. and Foster, I. (1994). Requirements for seasonal climate forecasts by agricultural producers in Western Australia. Milestone report to LWRRDC, NCVP funded project BOM1, Department of Agriculture, Western Australia, 40 pp.

Flannery, T.F. (1994). The future eaters, Reed Books, Chatswood NSW, 423 pp.

Fouché, H.J., de Jager, J.M. and Opperman, D.P.J. (1985). A mathematical model for assessing the influence of stocking rate on the incidence of droughts and for estimating the optimal stocking rates. *Journal of the Grassland Society of South Africa* **2**(3), 3–6.

Hammer, G.L., Chapman, S.C., and Muchow, R.C. (1996). Modelling sorghum in Australia: The state of the science and its role in the pursuit of improved practices. In M.A. Foale, R.G. Henzell and J.F. Kneipp (eds). *Proceedings of the Australian Sorghum Conference*, Tamworth, 20 to 22 February 1996 Australian Institute of Agricultural Science, Melbourne, Occasional Publication No. 93, pp. 43–61.

Hammer, G.L., Holzworth, D.P. and Stone, R. (1996). The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. *Australian Journal of Agricultural Research* **47**, 717–737.

Hunt, B.G. (1994). The use of global models in deriving seasonal climate outlooks. *Agricultural Systems & Information Technology* **6**(2), 11–15.

Jessop, R. (1977). The influence of time of sowing and plant density on the yield and oil content of dryland sunflowers. *Australian Journal of Experimental Agriculture and Animal Husbandry* **17**, 664.

Karssies, L.E. (1997). An Australian agricultural systems framework to identify opportunities for and constraints to improving productivity .A Feasibility Study for RIRDC (in press).

Kleeman, R., Moore, A.M. and Smith, N.R. (1995). Assimilation of subsurface thermal data into a simple ocean model for the initialisation of an intermediate tropical couple Ocean–Atmosphere forecast model. *Monthly Weather Review* **123**, 3103–3113.

Lines, W.J (1991). Taming the Great South Land: A History of the Conquest of Nature in Australia. Allen & Unwin, Sydney

Long, A.B. and McMahon, T.A. (1996). Review of research and development opportunities for using seasonal climate forecasts in the Australian water industry. Occasional Paper No. CV02/96.

Malafant, K. and Fordham, D. (1997). Integration frameworks in agricultural and resource planning and management. In 'Climate prediction for agricultural and resource management', Australian Academy of Science (in press).

Marshall, G.R., Parton, K.A. and Hammer, G.L. (1996). Risk attitude, planting conditions and the value of seasonal forecasts to a dryland wheat grower. *Australian Journal of Agricultural Economics* **40**, 211–233.

Meyers, G., Schiller, A., Godfrey, S. and McIntosh, P. (1997). Oceanic influences on variability of climate in Australia. *Climate prediction for agricultural and resource management*, Australian Academy of Science (in press).

McKeon, G.M. and White, D.H. (1992). El Niño and better land management. *Search* **23**, 197–200.

McKeon, G.M., Day, K.A., Howden, S.M., Mott, J.J., Orr, D.M., Scattini, W.J. and Weston, E.J. (1990). Management for pastoral production in northern Australian savannas. *Journal of Biogeography* **17**, 355–372.

Moore, A.D., Donnelly, J.R. and Freer, M. (1997). GRAZPLAN: decision support systems for Australian grazing enterprises. III. Pasture growth and soil moisture submodels, and the GrassGro DSS. *Agricultural Systems* (in press).

Morley, F.H.W. (1994). Drought predictions and budgets. In 'Merinos, money and management' F.H.W. Morley (ed.), A Post Graduate Foundation Publication, The University of Sydney, pp. 249–262.

Morley, F.H.W. and Daniel, G. (1992). Soil loss, drought and stocking rates. *Proceedings of the Australian Society of Animal Production* **19**, 323–325.

Morley, F.H.W. and Graham, G.R. (1971). Fodder conservation for drought. *In* J.B. Dent and J.R. Anderson, (eds). 'Systems analysis in agricultural management', Elsevier, Amsterdam, pp. 125–141

Nicholls, N. (1986). Use of the Southern Oscillation to predict Australian sorghum yield. *Agricultural and Forest Meteorology* **38**, 9–15.

Nicholls, N. (1991). The El Niño–Southern Oscillation and Australian vegetation. *Vegetation* **91**, 23–36.

Nicholls, N. (1995). Development of improved seasonal climate forecast systems. Milestone report to LWRRDC, NCVP funded project BOM1, Bureau of Meteorology Research Centre, 69 pp.

Norman, F.I. and Nicholls, N. (1991). The Southern Oscillation and variations in waterfowl abundance in south-eastern Australia. *Australian Journal of Ecology* **16**, 485–490.)

Rôling, N. (1994). In Proceedings of the International Symposium on Systems-Oriented Approaches to Agriculture and Rural Development, Montpellier, France

Rimmington, G.A. and Nicholls, N. (1993). Forecasting wheat yields in Australia with the Southern Oscillation Index. *Australian Journal of Agricultural Research* **44**, 65–632.

Scoccimarro, M., Mues, C. and Topp, V. (1995). Climate variability and farm risk. Australian Bureau of Agriculture and Resource Economics, Occasional Paper No. CV01/95, ABARE report to Land and Water Resources Research and Development Corporation.

Smith, R. (1994). Australian vegetation watch. Final Report to the Rural Industries Research and Development Corporation. RIRDC reference No. DOL-1A.

Smith, R.C.G. (1995). Drought monitoring of the Australian continent by satellite. Final report to Land and Water Resources Research and Development Corporation, LWRRDC reference No. CEX1.

Smith, R.C.G., Adams, J. and Hick, P.T. (1994). Forecasting wheat yields from satellite observations. In Mapping resources, monitoring the environment and managing the future. Proceedings of the 7th Australasian Remote Sensing Conference, Vol. 2, 1–4 March, Melbourne.

Stafford Smith, M (1996). Reflections on research, management and evaluation processes in DroughtPlan. In Evaluating the use of SOI forecasts in north Queensland using the Herd-Econ/GRASP linked model. DroughtPlan Working Paper No. 9/LUCNA Working Paper No. 1, CSIRO Alice Springs, pp. 131–141.

Stafford Smith, M., McKeon, G., Ash, A., Buxton, R. and Breen, J. (1996). Evaluating the use of SOI forecasts in north Queensland using the Herd-Econ/GRASP linked model. DroughtPlan Working Paper No. 9/LUCNA Working Paper No. 1, CSIRO Alice Springs, 50pp.

Stone, R.C. and Marcussen, T. (1994). Queensland producer requirements from seasonal climate forecast systems, Milestone report to LWRRDC, NCVP funded project BOM1, QDPI, 42pp.

Stone, R.C., Hammer, G.L. and Marcussen, T. (1996). Prediction of global rainfall probabilities using phases of the Southern Oscillation Index. *Nature* **384** (21), November 1996, pp. 252–255.

Stuth, J.W. and Stafford Smith, M. (1993). Decision support for grazing lands: an overview. In J. Stuth and B. Lyons (eds.),'Decision Support Systems for the Management of Grazing Lands', UNESCO-MAB Book Series, pp. 1–35.

Syme, G.J. and Bennett, D. (1979) Bridging the Operations Research–Applications Gap in Agriculture *Proceedings of the Fourth National Conference, Australian Society for Operations Research, Melbourne, 20–22 August 1979 pp 331–350.*

Thompson, D. *et al.* (1996) Analysing drought strategies to enhance farm financial viability. Final report to the Land & Water Resources Research & Development Corporation and the Rural Industries Research & Development Corporation, 164 pp.

Trapnell, L.N. and Fisher, W.W. (eds.) (1993). Proceedings of a workshop *Incorporating Risk into Decision Support and Farm Business Management Systems*, ed., Melbourne, 9–11 November, pp. 66–68.

Walker, P. and Young, M. (1996). INSIGHT: a future-orientated and spatially-explicit modelling system for evaluation of land use alternatives. Report from the CSIRO Division of Wildlife & Ecology to the Rural Industries Research and Development Corporation.

Webber, L. and Ison, R. (1995). Participatory rural appraisal design: conceptual and process issues, Agricultural Systems, 47: 107–131.

White, B.J. (1992) Managing with climate variability. A Program Development Report for the Land and Water Resources Research and Development Corporation, Canberra.

White, D.H. (1996). Objective scientific and economic criteria for estimating the extent and severity of drought, *Proceedings of the 2nd Australian Conference on Agricultural Meteorology.* University of Queensland, 1–4 October 1996, pp. 78–82.

White, D.H. (1997). Risk assessment and management: Case study—drought and risk. *Proceedings of the National Outlook Conference: Commodity markets and resource management*, 4–6 February 1997, Australian Bureau of Agriculture and Resource Economics, Canberra, pp. 98–103.

White, D.H. and Bordas, V. (editors) (1997). Proceedings of a workshop on *Indicators of drought exceptional circumstances*, Bureau of Resource Sciences, Canberra, 30 September–1 October, 1996 (in press).

White, D.H., McConchie, B.J., Curnow, B.C. and Ternouth, A.H. (1980). A comparison of levels of production and profit from Merino ewes and wethers grazed at various stocking rates in northern Victoria. *Australian Journal of Experimental Agriculture and Animal Husbandry* **20**, 296–307.

Wright, J. (1981). The Cry For the Dead. Oxford University Press, Melbourne.

APPENDIX A

The value of seasonal outlooks

The value of a seasonal outlook depends on the skill or accuracy of the forecast, and its marginal value relative to other readily available sources of information to the manager of a particular production system. Benefits from accurate forecasts in one year, can be more than totally offset by an incorrect forecast in another year. Other sources of information such as available feed or soil moisture, or the fact that a farm is stocked well below capacity, may render a forecast of limited value. Flock or herd structure, and the number or timing of decisions on a farm, may also mean that a lead time of only three months is of limited value. Likewise it should be kept in mind that mean annual rainfall, inter- and intra-year variability in rainfall, climatic systems, the reliability of different indices for seasonal forecasting, and major agricultural systems all vary dramatically across Australia. The reliability of seasonal outlooks also varies with time of year. From a national viewpoint one also needs to take into account the adoption rate by farmers, and whether there are net benefits to the economy.

Although reference is made in this report to skill levels and the accuracy of seasonal forecasts, the authors are aware that seasonal forecasts are presented as probabilities. Accuracy is therefore expressed relative to the median of the probability distribution.

Almost of the studies to date have assumed that seasonal outlooks are based on the Southern Oscillations Index (SOI). However, both Pacific Ocean and Indian Ocean Sea Surface Temperatures (SSTs) are now being used to improve the accuracy and lead times associated with seasonal outlooks. In the future use is also likely to be made of the output from General Circulation Models (GCMs) (Hunt 1994; Meyers *et al.* 1997).

Cropping and irrigation

Monitoring the SOI can aid in the forecasts of wheat yields in Australia, near the date of sowing and well before harvest (Rimmington and Nicholls 1993). They also observed a negative correlation with the SOI in the year before sowing, due in part to the tendency for years of positive SOI (wet years) to follow years of negative SOI (dry years) and *vice versa.*

Clewett *et al.* (1991) used a crop model and 60 years of historical climate records to study grain sorghum production from a shallow storage irrigation scheme in Queensland. They aimed to determine the optimum design of a shallow farm dam and optimise irrigation scheduling. They showed that spring values of the SOI are linked to subsequent and large changes in the probability distributions of rainfall, runoff, water storage, crop production and gross margins. Growing crops in seasons with a strongly negative SOI before planting were unprofitable, compared with seasons with a strongly positive SOI before planting. SOI data can therefore be used to adjust the management strategy according to the level of climatic risk.

In the northern part of the Australian grain belt, significant increases in profit (up to 20%) and/or reduction in risk (up to 35%) can be achieved with wheat crops based on a seasonal forecast available at planting time (Hammer *et al.* 1996). This can be achieved through tactical adjustment of nitrogen fertiliser application or cultivar maturity with significant financial benefits (Marshall *et al.* 1996).

Opportunistic crops are those that are not sown every year, only when moisture conditions are adequate. For example, if soils in north-western Victoria have adequate moisture in October, then a sunflower crop can be sown with a high probability of a good harvest (Jessop 1977). In a similar way, seasonal forecasts can be used to determine whether a particular cereal, oilseed or legume crop should be sown, based in particular on the probability of a favourable harvest. There seems scope to do this in Queensland with sorghum crops (Nicholls 1986; Hammer et al. 1996).

The El Niño–Southern Oscillation (ENSO) has a dominant effect on climate in a number of the world's large-scale irrigation areas. Dudley and Hearn (1993) modified existing models to examine irrigation options for cotton growers in the highly variable, summer rainfall environment of the Namoi Valley of northern New South Wales. They showed that expected returns were markedly reduced if the SOI was negative at planting time. However, they concluded that little could be done in the way of operational management decisions to reduce the harmful effects of a dry SOI event, or enhance the beneficial effects of a wet SOI event, given the current water allocation scheme. They suggested that if irrigators knew the current SOI before the commencement of each cotton season, more profitable timing of investment in plant and equipment might result. These benefits might be extended to suppliers of farm inputs and to processors.

Rangelands

A large part of the rangelands in the eastern half of Australia is particularly sensitive to the climatic events of El Niño, with consequences for stocking rate and land degradation. A policy of reducing stocking rate on the basis of El Niño forecasts can significantly reduce environmental degradation in adverse seasons (McKeon and White 1992).

Stafford Smith *et al.* (1996) evaluated SOI forecasts as a means of managing property stocking rates in the Charters Towers region of northern Queensland. Forecasting strategies appeared to have little benefit given today's skills with the SOI, but improved skill has considerable potential both to improve economic returns and to help protect the resource. Sensitivity studies showed that the system being studied was particularly sensitive to assumptions about buying and selling decisions, and long-term impacts on vegetation condition.

Stafford Smith (1996) concluded that:

1. forecasting with the current skill and currently suggested tactics based on SOI values has modest long-term *economic* benefits for grazing enterprises at present, at least in the Dalrymple Shire in Queensland;
2. forecasting with the current skill and tactics based on SOI values can already provide some benefits in terms of long-term resource protection;
3. forecasting with possible future skill based on new climate modelling approaches has considerable potential for economic and environmental benefits in the future, and there may also be better tactics for using the current SOI skill;
4. important as the future of seasonal forecasting may be, a focus on getting the utilisation rates and associated stocking rate strategies right will have more immediate and bigger economic and environmental benefits.

Clewett and Drosdowsky (1996) found that winter SOI values were useful in terms of reducing the risks of lost animal production, overgrazing, land degradation, and costs associated with supplementary feeding. However, they noted that many primary producers make important management decisions during autumn when climate forecasting has low skill. They therefore concluded that future climate research needs to target this 'predictability gap'.

In the more remote areas of northern Australia, cattle graze extensively on sub-tropical grasslands. Management inputs are kept to a minimum, stock being handled only at the time of the annual muster, usually in summer, so that seasonal forecasts are of limited use.

There are also large populations of grey and red kangaroos in the rangelands of Australia. These reproduce in direct response to green biomass which is in turn responsive to recent rains (Caughley 1987). However, it is during subsequent dry periods that their presence, and those of other vertebrate pests, becomes more apparent, in part because their survival is assisted by stock watering systems on farms. Drought is therefore an appropriate time to intensify programmes of vertebrate pest control.

Temperate grasslands

Morley (1994) contends, after examining rainfall data for Bendigo, Holbrook and Goondiwindi, that most variations in rainfall are essentially random, and that having information on the SOI for the months June to August adds little accuracy to predicting how much to feed stock in late summer–autumn in southern Australia compared with information on August and September rainfall, the amount of pasture dry matter in December, and the pasture dry matter in other months.

Bowman *et al.* (1995) examined the value of seasonal outlooks to wool producers in northern and Western Victoria assuming forecast accuracies for the next 12 months of 60, 80 and 100%. They concluded that the financial benefits for wool producers of reliable seasonal outlooks in southern Australia are probably substantially less than generally anticipated, although there could be significant benefits in protection of the natural resource base, and in reducing livestock deaths. The more accurate the seasonal forecasts, the better was the long-term financial performance of the farm.

These preliminary studies show that the financial benefits of seasonal outlooks to managers of grazing livestock may not be easily realised. This appears to be a consequence of a) inadequate climate forecasting skills over much of the continent, including insufficient lead times, and b) few decision points and limited flexibility with grazing livestock systems, requiring longer lead times in which to prepare for adverse events. It is therefore recommended that:

- there be concerted research effort to identify where and how climate forecasts can improve the management, sustainability and financial viability of different agricultural systems (see response to first term of reference on page 6);
- research to improve skill levels in seasonal forecasts (accuracy and lead times) using both statistical (Southern Oscillation Index and Pacific and Indian Ocean Sea Surface Temperatures) and GCMs be sustained.

APPENDIX B

Project Descriptions and Evaluations

Table 11
List of R&D projects

Project Code	Title	Principal researcher	Objectives	Total RDC funding (see Appendix C)	Contribution to this review
ABA1	Drought and the economic performance of agriculture	Dr S. Beare, ABARE	• To quantify the level and variability of production, prices and incomes; • To determine if there are differences in the level of risk faced by farms between regions and industries, and • To investigate the impact of climatic change on production risk using seasonal indicator variables.	$30,692	Interviewed
ABA6	Integrating climate forecasting into yield predictions for the agricultural sector	Mr R. Allen, ABARE	• To improve the national forecasting ability for yields of grains by establishing that there is a relationship between the Southern Oscillation Index (SOI), SOI phases and yields for each State, and then applying this relationship for yield forecasting for each State in Australia. • To establish relationships between the SOI and yields in the wool and beef industries in Australia. • To test whether there is any relationship between movements in the SOI and grain yields for the United States, Canada and Argentina for the countries as a whole and at selected regional locations.	$37,990	Interviewed
ARM1	Insurance based risk management for drought	Mr B. Mayers, Agricultural Risk Management P/L	• To define technical and administrative constraints to development and implementation of rainfall or weather based drought insurance programs in general; • To undertake an international survey and review of rainfall- or weather-based insurance programs and determine how these constraints have been addressed. • To review the success and longevity of these overseas programs. • To review technical and administrative constraints to adoption of this technology in Australia. • To plan and initiate a technical awareness program for Australian underwriters based on the above results.	$21,000	Questionnaire sent, not returned
BOM1	Development of improved climate forecasting systems	Dr N. Nicholls, Bureau of Meteorology	• To develop an improved statistical seasonal climate prediction system, using observed global and regional sea surface temperatures as predictors. • To test the use of the Bureau of Meteorology Research Centre (BMRC) atmospheric general model in seasonal climate prediction. • To investigate the implications of intra-seasonal oscillations for seasonal climate predictions. • To conduct studies to facilitate the development and application of improved seasonal predictions to rural industry at the regional level. • To develop statistical prediction methods, also using sea surface temperature patterns as predictors of specific seasonal climate indices useful for rural industry.	$620,245	Interviewed
CAR3	Atlas of near-global ENSO and climate variability since 1871	Dr R. Allan, CSIRO Division of Atmospheric Research	• To develop and publish an atlas of near-global ENSO patterns and climatic variability since 1871.	$45,000	Interviewed
CEX1	Drought monitoring of the Australian continent by satellite	Dr R. Smith, CSIRO Div. Exploration and Mining (now Dept. of Land Administration)	• To develop a NDVI time series free of sensor and atmospheric bias with which to monitor drought in pastoral areas; • To standardise and improve the accuracy of satellite monitoring of green vegetation cover from the NOAA_AVHRR satellite, so that a comparable measure is generated on the eastern and western sides of Australia.	$50,000	Interviewed

Table 11 — List of R&D projects (continued)

Project Code	Title	Principal researcher	Objectives	Total RDC funding (see Appendix C)	Contribution to this review
COR2	Development and testing of climate models for seasonal prediction for Australia	Dr G Meyers, CSIRO Division of Oceanography	Through enhanced collaboration between DO, DAR and BMRC, advance the development of a numerical general circulation model (GCM) of the oceans (O) and the atmosphere (A) for seasonal forecasting of Australian climate by: • assessment of forecasts of Australian rainfall using a stand-alone AGCM with predicted sea surface temperature (SST), and simulation of other weather variables with observed SST. • improvement of the existing OGCM in areas that have a strong influence on Australian rainfall, in particular the Indonesian Seas and the Indian Ocean. • development of a prototype coupled OGCM–AGCM for seasonal prediction.	$914,737	Questionnaire returned
CWE8	Grazier-based profitable and sustainable strategies for managing climate variability	Dr M. Stafford Smith, CSIRO Division of Wildlife and Ecology	With producers, to develop economically-viable drought management strategies to increase animal production efficiency whilst sustaining the land resource, by: • cooperating with producers to identify their needs for supporting decisions related to stocking rate strategies through time • documenting, with producers and extension agencies, a substantial series of case studies of the biology and economics of key existing and improved strategies in difficult grazing land regions of Australia • developing an understanding of the links between climatic variability, production levels and biological rates (births and deaths) in grazing lands from producer and research records • integrating economic, animal production and forage production models from QDPI and CSIRO to identify the response and sustainability of these strategies in relation to climatic variability, seasonal forecasts and economic conditions • developing, with producers, a series of procedures and decision support tools for producers to test alternative strategies on their own properties, and extension agencies and educational institutions in property management planning activities.	$630,000	Interviewed
CWE14	Planning and preparation for Phase 2 of drought alert (QPI20)	Dr M. Howden	• Extend the current prototype to an operational system which provides specified products assisting in sustainable management of major national pasture resources; • Ensure proposed extensions, development and validation of the system are guided by user requirements for specified products; • Develop data sharing and integration with related systems (eg. Sustainable Land Use Information System being developed by the BRS) so that information for policy purpose is complementary and can be used within known levels of confidence; and • Ensure that the proposed LWRRDC funding of $750,000 over three years has a catalyst role in stimulating matching components from potential collaborators and from other R&D Corporations.	$22,028	Conversation
DAN6	Optimum replacement of farm machinery under conditions of capital rationing	Ms K Fraser, NSW Agriculture	• To construct a spreadsheet model which can provide information on the outcomes of various machinery replacement options given different farm equity levels. • To develop an optimisation model from this spreadsheet which can identify the optimum replacement of farm machinery under any farm equity situation. • To extend the results established from the model, to industry. • To program the model to make it available on computer disk for use by farmers, their advisers, financial institutions, consultants and government agencies.	$52,500	Questionnaire sent, not returned

Table 11 — List of R&D projects (continued)

Project Code	Title	Principal researcher	Objectives	Total RDC funding (see Appendix C)	Contribution to this review
DAS12	Decision support for climatic risk management in dryland crop production	Mr J. Egan, South Australian Department of Primary Industries	• To develop decision aids and management strategies to assist farmers to deal with crop production decisions that are greatly affected by climatic risks, relevant to each of the dryland cropping regions of Australia. • To facilitate collaboration between research workers in dryland cropping regions across Australia, in the use and development of broadly applicable and interchangeable decision support software.	$515,381	Questionnaire returned
FRD2	Climate and fisheries on the S.E. Australian Continental Shelf and Slope	Dr T. Koslow, CSIRO Division of Fisheries	To assist in developing better management models for temperate Australian fisheries by assessing the role of oceanographic and climatic variability on historical changes in SE Australian fish stocks by: • developing indices of deepwater productivity and temperature, based on physical and chemical analyses of the growth rings of bamboo coral; • developing time series of relative growth for long-lived fish species on the shelf and slope in the SEF; • developing times series of temperature for the SE Australia shelf off Tasmania and NSW from the growth rings of mollusc shells; and • examining statistical relationships among: the above environmental and fishery indices; available records of climate from the Maria Island station; terrestrial records of regional rainfall, wind, and temperature; apparent recruitment to orange roughly from ageing data; and long-term records of fish landings in the SEF.	$20,000	Questionnaire returned
MAC1	Farmers training needs for managing climate risk	Mr P Wylie, Macro Agricultural Consultants	To contribute to identification of R&D priorities for the National Climate Variability R&D Program by: • Reviewing current and planned training activities and associated major products (publication, software, etc.) targeted at managing climate risk. Coverage to include use of the climate record, seasonal climate forecasts and more novel aspects of 1–5 day weather forecasts. • Documenting major training materials, modules, etc. used in training programs for managing climate risks. • Collating major issues, opportunities, etc. which are relevant to identifying R&D priorities for managing climate risks.	$16,000	Questionnaire sent, not returned
MRC1	Strategies for maximising the persistence of perennial grasses through drought	Dr J. Scott, University of New England	• To examine the effects of grazing intensity and droughts varying intensity and seasonal timing on the persistence/mortality of a wide range of introduced and native temperate perennial grasses. • To define the stress thresholds which threaten the persistence of this range of perennial grasses in a way which will be useful both to producers and to those developing models incorporating persistence and botanical composition changes, such as GrassGro. • To provide the necessary factual information on seasonal susceptibilities to drought and grazing stresses to the major perennial grasses which will provide a basis for economic assessments to be made of the risks due to grazing during drought. • To link with the 18 grazing management sites established under the MRC Key Program and located in the high rainfall zones of NSW, Vic Tas and SA. An understanding of grazing and drought stresses on perennial grass production and persistence will be a vital component in interpretation of the results from the grazing management sites.	$146,413	Questionnaire returned
QNR3	The Australian On-Line agro-meterological	information service (Weather-wise) Mr A. Beswick, QNR	• To provide a rich source of national meteorological data that is readily accessible to decision makers, researchers and educationalists, particularly in the agricultural arena. • To develop a coordinated information service that will facilitate further adoption of climatic risk management techniques by landholders and agribusiness. • To provide a framework to encourage future additions to the agro-meteorological data bank. • To establish the collaborations required to ensure that the system remains operational beyond the term of this research funding.	$452,935	Questionnaire returned

Table 11 — List of R&D projects (continued)

Project Code	Title	Principal researcher	Objectives	Total RDC funding (see Appendix C)	Contribution to this review
QNR9	Australian grassland and rangeland assessment by spatial simulation: 'Aussie GRASS'	Mr. K. Brook, QNR	• To further technical development and eventual operationalisation of 'Aussie GRASS', a national grassland and rangeland assessment model (whose prototype was developed in QPI20) that can explore and calculate: pasture and scrubland growth using the best mix of State and CSIRO models; climatic and drought analyses; the historical context of various biophysical values, including pasture biomass; the question of herbivore carrying capacity and land sustainability; and the quantitative risks of land degradation in the context of local State environments, animal numbers and seasonal climatic forecasts; • To facilitate a nationally coordinated effort of spatial grazing modelling; • To develop a nationally integrated extension program that: targets at, and markets to, land management clients at a district scale; delivers climatic risk and grazing management products to land-holders, local drought and catchment committees, landcare groups, land managers, and executive government; is delivered by local agencies in each State, yet sharing common national extension lessons and technical distribution systems; and is developed by participative group processes that produce a process of iterative development and feedback; • To develop, calibrate and validate the best pasture models for different eco-climatic zones such as: the winter perennial/scrubland zone across the south of the continent (WA, SA, W-NSW), and the high rainfall temperate pasture systems of Eastern NSW; • To further calibrate and validate the GRASP pasture model in the NT and Kimberley, as well as integrate the extent of savanna burning in the NT and WA; • To facilitate the development of a national distribution system that provides at a continental scale, both a standardised archive of historical NOAA imagery and a standardised regular feed of newly acquired imagery, that have been processed, navigated, radiometrically corrected and mosaiced to an agreed national standard; • To explore how to interface: new seasonal climate forecasting systems such as produced by the BRMC's new SST prinicpal component analysis (this system unlike the SOI has considerable skill in southern Australia); and also potentially within the project's lifetime, forecasts from GCMs of the atmosphere produced by the US Scripps Institution of Oceanography and the CSIRO Division of Atmospheric Research; and • To explore ways to develop synergies with other relevant research projects and also how to supplement the funding base for such a large national project.	$753,630	Interviewed
QP120	Development of a national drought alert strategic information system	Mr K. Brook, QNR	• To development a national drought alert strategic information system with emphasis on Australia's rangelands and based on a spatial model of pasture growth and utilisation coupled with seasonal climatic forecasts. • To develop a spatial database of functional modelling inputs, viz, soil water, stock density, pasture type, tree cover, near real-time meteorology, remotely sensed data, and using the total rainfall record for the last 120 years and climate record for the last 35 years. • To collect a complete set of independent validation data for Queensland, and a partial set of validation data in other states. • To validate the spatial model in Queensland and partial validation of the model in other states. • To adapt model outputs to produce maps of feed deficit and land condition alerts, and computer visualisations of evolving rainfall and pasture droughts in the context of a historical probability. • To improve wheat forecasts by coupling of simulation models of wheat production to the rangelands spatial modelling framework. • To communicate the modelling methodology to collaborating organisations in CSIRO, New South Wales, Victoria, South Australia, Northern Territory and Western Australia as a powerful integrated framework for ongoing development. • To communicate the results of the project to land managers, extension officers and scientists.	$611,000	Interviewed

Table 11 — List of R&D projects (continued)

Project Code	Title	Principal researcher	Objectives	Total RDC funding (see Appendix C)	Contribution to this review
QP138	Evaluating the role of seasonal climate forecasting in tactical management of cropping systems in north-east Australia	Dr R. Stone, QDPI	To evaluate (in terms of profit and sustainability) the implications of seasonal forecasting on key cropping system decisions such as crop choice and cropping sequence. This will be achieved by: • Incorporating tested, objectively derived, seasonal climate forecast systems into cropping systems models (eg. the Agricultural Production System Simulation Model, APSIM). • Evaluating tactical decisions such as crop choice and cropping systems options using simulation analysis. • Incorporating estimates of price risk in evaluations by consideration of domestic demand patterns and forward international price. • Collaborating with growers 'on-farm' on appropriate use of simulation analysis results and through provision of grower/extension workshops.	$596,427	Interviewed
QP139	Seasonal streamflow forecasts to improve management of water resources (RAINMAN Streamflow project)	Mr N. Clarkson	To catalyse improvements to rural, agricultural, environmental and urban water management in Australia by: • developing methods to forecast streamflows and runoff that are based on streamflow persistence and the latest developments in seasonal climate forecasting by June 1998. • assembling a national streamflow and runoff data set from 500 locations throughout Australia for use in the Australian Rainman software package by June 1998. • working with water managers (mainly primary producers and water authorities) in four representative regions of Australia to assess the value of streamflow/runoff forecasts in water management by June 1999. • building a communications program that will facilitate adoption of improved practices during the project and importantly, beyond the end of this project, by June 1999.	$346,590	Interviewed
RDC4	Australian farm families' experience of the drought in the 1990s: a sociological perspective	Prof G. Lawrence, Central Queensland University	• To begin to understand the way in which drought is socially constructed and how such constructions influence on-farm drought strategies. • To identify and analyse when and in what ways resource management strategies used by farm families were altered during the recently experienced drought.	$53,326	Questionnaire returned
RDC7	Further development and application of AUSTRALIAN RAINMAN to improve management of climate variability	Dr J. Clewett	To enhance management of climate variability throughout Australia by building knowledge and skills in rural communities about climatic risks and opportunities, seasonal forecasts, and ways to improve management decisions. This will be achieved by: • further developing the AUSTRALIAN RAINMAN package to version 3 as a windows, multi-media CD, Internet compatible product in standard, professional and educational formats by December 1997; • establishing an effective promotion/marketing strategy that seeks to improve management , has active cross links with extension, education and agribusiness, and uses a sales target of 5,000 packages with 50,000 users in three years (Dec. 1999) as a surrogate performance measure; and • implementing a business plan so that benefits from this project are on-going, and self-funding with regard to future activities such as development of AUSTRALIAN RAINMAN version 4 with improved seasonal forecast tools and streamflow/runoff data by December 1998.	$50,000	Interviewed (indirectly)
SRD2	Seasonal rainfall and winter crop yield forecasting for southern Australia	Mr J. Egan, South Australian Research and Development Institute (SARDI)	• To refine and validate, using statistical techniques, the seasonal rainfall and winter cereal crop yield forecasting technique developed for South Australia. • To have a scientific paper describing the techniques accepted for publication in the Australian Meteorological Magazine, by meeting referees' comments. • To extend the agricultural relevance of the forecasting technique by developing prediction equations for other seasonal rainfall criteria, including monthly (April, May and June) and total growing season (April to October) rainfall. • To assess the potential for extending the technique to other agricultural regions of southern Australia, by developing prediction equations for seasonal rainfall at Merredin and Esperance in WA, Birchip in Victoria, and Wagga Wagga and Dubbo in *NSW.*	$50,005	Questionnaire returned

Table 11 — List of R&D projects (continued)

Project Code	Title	Principal researcher	Objectives	Total RDC funding (see Appendix C)	Contribution to this review
UME24	R&D opportunities for using seasonal climate forecasts in the Australian water industry	Prof. T. McMahon, University of Melbourne	• To review current research and development and operational use of seasonal climate forecasting in water resources management and design. • To review constraints to use of seasonal climate forecasts. • To review in brief the impact of new knowledge on ENSO-related persistence in hydrological series on risk in water resources management and design. • To prioritise the major opportunities for further research and development, the appropriate responsibilities and source of funds, and mechanisms (commissioning nominated institutions or a public call).	$15,000	Interviewed
UNE16	Economic monitoring/ forecasting of rural business	A/Prof R. Powell, University of New England	• To undertake a pilot development of an economic monitoring and forecasting system for the New England–North West region of NSW; • To establish a survey base for quarterly monitoring of non-farm business in the region; • To develop farm output and income forecasting methods and investigate the role of drought forecasts in those methods; and • To prepare a manual on the methods for extension to other regions.	$12,336	Questionnaire sent, not returned
UNE17	Analysing drought strategies to enhance farm financial viability	A/Prof R. Powell, University of New England	• To adapt existing whole-farm models (eg. RISKFARM, MUDAS and TACT) to analyse the financial outcomes and risks associated with common drought management strategies. • To apply the models to case study farms in NSW and WA to generate guiding examples of the financial outcomes of drought management strategies. This will include an examination of inventory management, financial management, on-farm and off-farm investment. • To analyse the taxation implication of these strategies, in particular focussing on the importance of the different marginal tax rates for on and off-farm investment and capital gains. • To develop a training kit and workshops encapsulating the project findings for farmers and their advisers.	$312,992	Discussion
WRD1	Exploiting drought opportunities: control of total grazing pressure in rangelands	Dr R. Hacker, NSW Agriculture	• To evaluate the potential to reduce kangaroo grazing pressure by excluding them from stock watering points in eastern Australia. • To determine the effectiveness of trapping at stock watering points in reducing feral goat populations. • To provide guidelines for pastoralists on application of techniques for control of kangaroo and goat grazing pressure.	$62,000	Questionnaire returned
WRD2	Extension of the results of fertiliser research to graziers by development of a pasture nutrition sub-module for Grassgro	Dr. J. Donnelly, CSIRO Division of Plant Industry	• To improve the profitability and sustainability of agriculture by further developing an existing decision support system which gives extension officers and wool producers easy access to current research results. Specifically, the project aims to: construct a C, N, P and S nutrition sub-model for the pasture and animal models used in GrassGro; and test the predictive ability of the prototype model.	$113,525	Interviewed, piloted questionnaire
Coordination and communication					
AGE1	Program management for the NCVP	Dr B. White, AGEC Consulting	n/a	$194,006	Mediator
COS1	Coordination of Managing the National Climate Variability conference	Ms S. Kruck, Conference Solutions	• To provide the management and administrative support structure for the National Climate Variability Conference (16–17 Nov. 1995); and to produce the proceedings of the conference.	$4,469	Nil
INF2	Drought research in process	Mrs P., Handyside, Infoscan P/L	n/a	#	Nil
UQL9	2nd Australian conference on agricultural meteorology	Mr P. Noar, Bureau of Meteorology	• To organise and convene the 2nd conference of agricultural meteorology in Brisbane (Oct. 1996)	$5,000	Nil

Table 12 — Portfolio evaluation

Project	Sub-Program	Contribution to Program	Scientific Merit	Likelihood of meeting objectives	Improved management responses to climate variability	Meeting the needs of resource managers	Range of clients	Client involvement	Impact of findings on client group	Improved self-reliance of resource managers in long-term
ABA1	regional monitoring	Medium. Provide insight on fluctuations.	Medium. Farm survey data traditionally unreliable.	Objectives changed. Revised objectives met.	Very little, but showed regional patterns of risk	n/a	LWRRDC, CV researchers, policy makers	Some	Marginal	n/a
ABA6	Regional monitoring	High. Improve yield forecasting	High. Present yield forecasts use average yield (rather than expected)	Medium–low.	Potential through better yield forecasts	n/a	ABARE staff, policy makers (potentially Wheat Board)	Some	ABARE have used the yield forecasts.	n/a
ARM1	n/a	Medium. Provide information on insurance industry	Medium.	Objectives met.	No, but explored insurance issues	n/a	Directly LWRRDC.	(cf consultancy)	LWRRDC halted development of this option.	n/a
BOM1	Forecasting	High, through improving forecast relevance	High. Project expands forecasting ground	Questionable. Upgraded outlook service implemented.	Potentially, through 'better' forecasts (longer lead times and higher skill levels—needed by graziers)	Potentially, as client consultation has been sought	High range, as research is generic	Some consultation on content/format. Input through National Committee on Agro-meteorology and other scientists.	If better forecasts, with longer lead times, result then very high. Otherwise questionable	Potentially through providing better forecasts
CAR3	Forecasting	High. A 'text' on ENSO.	High. For use by other climatologists and CV researchers	High.	Limited potential through providing information.	(not directly)	Climatologists only? Potentially wider?	Some	Informative.	N/a
CEX1	Monitoring	High. Satellite imagery potentially important	High. Aids other research efforts.	Medium. Did not meet original objectives.	Potentially. Some use in bush-fire management, stocking levels and drought assessment.	n/a	State and national agencies.	Some.	Some use in planning and decision making at regional and national level. Limited grazier use in W.A.	Indirectly through visualising resource status
COR2	Forecasting	High. GCM development with SST forecasts 12+ months out.	High	Medium. Prototype developed.	Potential through better rainfall forecasts	(Not directly).	Climatologists CV researchers (and potentially for producers)	Collaboration with scientists, some consultation between oceanographers and farmers.	Potentially high.	Potentially through providing better forecasts
CWE14	Regional monitoring	High, through setting priorities for further research	Medium-high	Objectives met.	No direct effects (benefits through new project—QNR9).	N/a	Climate variability researchers	Extensive	High.	N/a
CWE8	DSS	High, for Rangelands	High	Objectives set high. Performance high	Some changes in agency approach. Some changes with graziers (more if continued effort?).	Yes, built into the project design.	Graziers, regional managers, agency researchers, policy makers	High collaboration, with Action Learning principles	Potentially high, study also serves as a benchmark	Some. Recognised that DSS includes wide range of tools. Adoption still quite low.

Table 12 — Portfolio evaluation (continued)

Project	Sub-Program	Contribution to Program	Scientific Merit	Likelihood of meeting objectives	Improved management responses to climate variability	Meeting the needs of resource managers	Range of clients	Client involvement	Impact of findings on client group	Improved self-reliance of resource managers in long-term
DAN6	DSS	Low.	Medium	Objectives met	Limited.	Perhaps useful but probably not high priority for most	Producers, NSW Agriculture advisers, banks?	None evident, though project was preceded by consultation	Low—but useful as it is being commercialised? Kondinin Group saw value in it.	Limited.
DAS12	DSS	Medium–High.	Medium–high	High	Some graziers used DSS-pilot project.	To some extent	Farmers, agency researchers	High.	Yield forecasts being used in interesting ways (financial management)	Some.
FRD2	DSS	Medium. Explores fishing resource and CV (new area).	Medium–high	High	Potentially through better fishery management	n/a	Mainly scientists, perhaps policy makers	Scientist involvement	Base for further models	n/a
MAC1	DSS	Medium–high. PMP can ground CV outputs.	Medium–high	Objectives met	Limited (explored an issue, identified problems)	n/a	LWRRDC, other agencies indirectly	(cf. Consultancy)	Seemingly low	(It investigated whether one way, PMP, was viable)
MRC1	DSS	Medium–high. Managing perennial species important.	Medium–high.	Objectives met.	Some, through managing perennial species	Some—project identified through consultation	Other researchers (mainly one modeller)	Communication between scientists. No resource managers involved.	Provide input into models	Some, through providing data
QNR3	Forecasting	High. Provide basic data.	Medium–high	Medium–high	Indirectly through providing access to climate data to managers	Potentially	Researchers, policy makers, resource managers	Collaboration between scientists	Provide on-line (accessible) information	Potentially through provision of useful climate information
QNR9	Monitoring	High, build on achievements of QPI20	High	Medium–high (difficult to achieve collaboration from all states)	Potentially inform regional decisions.	Some	Policy makers, regional land managers, other researchers	Collaboration between researchers. Policy makers and resource managers to be consulted.	Potentially high (policy makers)	Indirectly some, through linkages with QNR3.
QPI20	Monitoring	High.	High	Objectives met	Some national and state decisions, with respect to drought, used this	N/a	Policy makers, regional land managers, other researchers	Collaboration between researchers.	Output has been used in some state (Qld) and national decisions regarding drought severity.	(Clear message that only exceptional drought would get government assistance). Also in provision of information.
QPI38	DSS	High. The implications of forecasts	Medium–high (only looking at some decisions)	High	For some, probably direct improvements	For some, definitely, probably for other farmers as well	Farmers, other researchers.	Some collaborating farmers.	Potentially high. Might raise awareness of coping with climate risk. Depends on relevance of key decisions analysed	Potentially. Increasing awareness of ENSO.

Table 12 — Portfolio evaluation (continued)

Project	Sub-Program	Contribution to Program	Scientific Merit	Likelihood of meeting objectives	Improved management responses to climate variability	Meeting the needs of resource managers	Range of clients	Client involvement	Impact of findings on client group	Improved self-reliance of resource managers in long-term
QPI39	DSS	Medium–high. Stream-flow effects range of resource uses	Medium–high	High	Possibly	To some extent	Water managers, water users, policy makers, researchers	Through consultation and regional workshops	Potentially provide data for decisions, and improved practices	Potentially
RDC4	Monitoring	High. Sociological perspective	Medium–high	High	Only indirectly, though social perspectives are important	(can help identify these and give an understanding of why people react to drought as they do)	Researchers, policy makers	Through interviews and research process	As background information, and as a complement to scientific efforts	Through lessons learnt
RDC7	Forecasting (prefer DSS)	High	Medium–high	Medium–high	Wider awareness of RAINMAN, climate variability and forecasts	(A valuable tool)	Extension agencies, educationists, farmers	Will need to be high (project just commenced)	Wider use of RAINMAN (improved version)	Potentially (also will help correct distorted picture of "normal" climate)
SRD2	Forecasting	Medium–high	Medium–high	Medium high	New technique may improve forecasts	(experimental)	Scientists, potentially producers	Scientists	New technique for forecasting	In long run, if skill develops
UME24	Forecasting	Medium	Medium–high	Objectives met.	(exploration)	n/a	LWRRDC (future funding?), water managers	Consultation with water managers and hydrologists	(Encouraged debate about conservative nature of allocation decisions)	n/a
UNE16	DSS (prefer monitoring)	Medium	Medium	Most were met (not manual)	Only indirectly	n/a	Researchers, policy makers	None apparent	Limited	n/a
UNE17	DSS	Medium–high. Taxation and economic factors.	Medium–high	Objectives met.	(Suggested that self-reliance difficult in major droughts)	Potentially, but did not achieve fully.	Policy makers, farmer groups	Some farmer workshops	Limited	Some.
WRD1	DSS	Medium. De-stocking benefits in drought depends on grazing pressure control	Medium–high	Objectives met.	Through information on exclusion devices.	(issue became less important though progress of project) Consultation preceding project.	Researchers, extension agencies, producers	Some graziers involved in trials.	Some graziers have used results.	To some extent
WRD2	DSS	Medium—some sustainability components	Medium–high	High	Through expanded model. Indirect	n/a	Extension agencies, other researchers	None until later stages.	Potentially explore options and enhance current use of . Grassgro model (extension agencies)	n/a

Table 13 — Portfolio evaluation (continued)

Project	Outputs	Communication of outputs	Admin. issues	Leverage (cf. Value for money)	Worthy of additional funding from LWRRDC	Main use of LWRRDC funds	Issues raised	Collaboration	Public–private linkages	Overall assessment
ABA1	Occasional paper, conference paper	—	Staff turnover a problem	Some.	Appropriately resourced	Salaries	Extent of price and yield variability and geographical distribution	With economists	None.	Low-cost. Some benefits. Good to raise CV issues with ABARE. Presentation of maps and data was effective.
ABA6	Yield forecasts	—	Staff turnover	Some.	Appropriately resourced	Salaries	Easy to extend wheat forecasts to other grains	Some collaboration between economists and scientists. Other opportunities not taken.	None	Useful project. Should be encouraged to finish quickly.
ARM1	Occasional paper, conference paper	Has followed-up with insurers (an awareness program)	None evident.	No leverage.	Appropriately resourced	Salaries	• non-willingness to insure. Perhaps a lack of demand.	Consultation with insurers	Private provision.	Useful overview, but still questions outstanding.
BOM1	Milestone reports; prototype system; conference papers; WWW site	Seasonal outlooks available through hard copy, infofax and WWW	Problems with withholding funds (but accounting problems), collaboration problems	High leverage accelerating this research.	• A Federal Gov't. matter?	Salaries	• long term funding required (more than NCVP), • duplication of efforts,	With scientists; steering committee	None (although this may change as Slatyer Review recommendations are implemented)	Worthy project, potential pay-offs are high. Has given an awareness of farmer needs to BoM (also user demands justify BoM's work)
CAR3	Atlas published	Through Atlas and CD-ROM	None raised	Some.	Updates should be commercial.	Operating	—	With scientists	Through commercialisation?	Worthy.
CEX1	Final report, conference papers	Through QPI20 project	Lack of institutional collaboration	High.	Possibly	Travel, and capital	Correction for atmospheric interference.	Some with resource managers and with scientists (esp. QPI20)	none	Worthy. Side benefits in terms of forecasting of wheat
COR2	Prototype developed (inc. SST)	(active on media)	Difficulty with institutional collaboration. Problems of distance.	High.	Yes, but returns are very long term	Salaries	Links between GCM and agricultural models	With scientists	None	Worthy project, especially if it can "capture ground for agriculture and GCMs", and can deliver better forecasts.
CWE14	Research proposal	No	—	No leverage.	Appropriately resourced	Salaries	Addressed in research proposal	Extensive with researchers	None	Worthy, ensured previous prototype was usefully extended. Increased collaboration in that project.

Table 13 — Portfolio evaluation (continued)

Project	Outputs	Communication of outputs	Admin. issues	Leverage (cf. Value for money)	Worthy of additional funding from LWRRDC	Main use of LWRRDC funds	Issues raised	Collaboration	Public–private linkages	Overall assessment
CWE8	DSS (9 products), reports, scientific papers, conference papers	Through papers and through extension networks.	Too many people (>50) increased transactions costs and management, but set up a good network.	Very high.	Yes, especially to continue AL processes.	Salaries and travel	Active collaboration, DSS definition and development	High, with resource managers, agency researchers	None apparent	Worthy. Still has to be accepted by some producers and scientist
DAN6	DSS	Documented, now being commercialised	—	Very high leverage.	Appropriately resourced	Operating and travel	Dramatic decrease of farm capital equipment	Minor (between agencies)	Yes, through funding and commercialisation	Solid project but hard to see how it contributes to CV R&D.
DAS12	DSS, faxback system, papers	One part of the project included fax-back	Coordination of project difficult. Variable contributions of sub-projects.	Very high.	Appropriately resourced, as being followed up by proposals to GRDC.	Salaries	Climate information might not change optimal decision (for planting crops)	High level between researchers, also farmer involvement.	Kondinin group involved in the fax-back.	Worthy of attention.
FRD2	None as yet (recent project)	No communication built into design	—	Very high	Probably appropriately resourced	Operating	—	High between scientists	None	Low cost project, only just commenced. A new area for CV R&D.
MAC1	final report, occasional paper, conference paper	Was follow-up undertaken?	—	No leverage.	Appropriately resourced	Salaries	Adult learning approaches are desirable for CV R&D	Consultation with PMP facilitators and agency staff	Private R&D provision	Worthy. Issues of Adult learning and determining what R&D is valued, should influence design of other projects.
MRC1	Papers, conference paper	—	Disruption to experiments	Leverage through agent MRC.	Appropriately resourced	Salaries	Persistence of perennial species during drought; complementing field experimentation with models	With scientists	None	An important project.
QNR3	Too early	Built in through WWW, educational courses	—	High leverage	Too early to say	Salaries	—	With scientists	None	Project has only just commenced.
QNR9	Too early	WWW, etc	—	High leverage	Too early to say	Salaries, operations	National coordination, Interfacing of different models	Collaboration (nationally) with researchers	None	Project has only just commenced.
QPI20	Conference papers, WWW (Long Paddock), GRASP model, etc	Through WWW, etc	Some States provided little support to the national project	High leverage	A follow-up project has been funded.	Salaries	Pasture growth a better determinant of drought than rainfall per se.	Collaboration (nationally) with researchers	Some private funding (Goodman-Fielder)	Worthy project which has been fully followed up.

Table 13 — Portfolio evaluation (continued)

Project	Outputs	Communication of outputs	Admin. issues	Leverage (cf. Value for money)	Worthy of additional funding from LWRRDC	Main use of LWRRDC funds	Issues raised	Collaboration	Public–private linkages	Overall assessment
QPI38	Too early	Built in with grower workshops	—	High leverage	Early, but appropriately resourced, as 1) has been seeded, 2) industry specific (seek their funds)	Salaries	—	Work with some farmers to build and evaluate models	None (except through collaborating farmers)	Worthy project.
QPI39	Too early	Built in communication program (achievable?)	—	Some leverage.	Too early to say	Salaries	—	Consultation with water industry	None	Worthy project
RDC4	Conference papers, papers	Feedback to participants built in	Negotiated with RIRDC	None	Probably (if can synthesis a wide diversity of information)	Salaries	Social consequences of drought. How drought perceived (including 'signs' of drought)	With participants	None	Worthy project.
RDC7	Too early	Active marketing	—	Very high leverage	Too early to say	Salaries	Active marketing needed, broaden use of DSS	Will be necessary for marketing	(Could be beneficial)	Worthy project.
SRD2	Paper, conference paper,	—	Some small delays	Some leverage	If technique is refined, yes.	Salaries	Extending forecast skills in other states (also less ENSO influenced). Whether Indian Ocean effects lead to better predictions	Scientists	None	Worthy project.
UME24	Occasional paper	—	Some cost overruns borne by consultancy	None	Appropriately resourced	Salaries	Water managers conservative, and don't make use of forecasts (yet).	Consultation with water authorities	Private provision	Worthy project.
UNE16	Final report, conference papers	Manual proposed but not undertaken	Manual not prepared	Some leverage	Appropriately resourced	Salaries	Limited market for this information	None apparent	None	Project could have delivered more
UNE17	conference papers	Some workshops	Some adverse communication; problems collaborating over distance	Some leverage.	Appropriately resourced (but issue remains)	Salaries	Overall risk portfolio, not just climate risk; take advantage of good years.	Between agencies	None	Solid project.
WRD1	Video, field days, papers	Through field days	Some problems with variable seasons	Leverage through agent IWS	Appropriately resourced	Operations, salaries	Devices can exclude kangaroos, but medium term protection of pastures unlikely. Graziers more interested in self-mustering technology	Between scientists, some graziers involved in trial.	None	Solid project with clear output.
WRD2	Too early	Commercialisation of software	Unaware of NCVP funding.	Leverage through agent IWS	Appropriately resourced	Operations	Improve grazing models with nutrient cycling sub-module	Primarily with scientists	Through commercialisation of software	Solid project; but relevance to climate variability should be stronger.

APPENDIX C

NCVP Funding allocations

Table 14
Proportion of funding

Project	Sub-Program	NCVP core funds $	NCVP core funds % of Total	RDC funding Project-Specific*	RDC funding Generic	Total NCVP & RDC	Total Other R&D Agencies	Ratio of Funds Other Agencies/ NCVP core
ABA1	2	30,692	0.7			30,692	9,905	0.3
ABA6	2	37,990	0.9			37,990	0	0.0
ARM1		21,000	0.5			21,000	0	0.0
BOM1	1	538,995	12.8		81,250	620,245	984,435	1.8
CAR3	1	45,000	1.1			45,000	30,000	0.7
CEX1	2	50,000	1.2			50,000	100,000	2.0
COR2	1	677,237	16.1		237,500	914,737	1,965,000	2.9
CWE8	3	450,000	10.7	180,000		630,000	2,489,688	5.5
CWE14	2	22,028	0.5			22,028	0	0.0
DAN6	3	27,500	0.7	25,000		52,500	203,000	7.4
DAS12	3	190,381	4.5	325,000		515,381	1,115,000	5.9
FRD2	3	20,000	0.5	85,748		105,748	50,959	2.6
MAC1	3	16,000	0.4			16,000	0	0.0
MRC1	3	146,413	3.5	255,417		401,830	651,000	4.5
QNR3	1	221,685	5.3	150,000	81,250	452,935	1,006,231	4.5
QNR9	2	653,630	15.5		100,000	753,630	1,754,000	2.7
QP120	2	262,250	6.2	155,000	193,750	611,000	2,759,000	10.5
QP138	3	192,800	4.6	403,627		596,427	1,086,097	5.6
QP139	3	0	0.0	346,590		346,590	584,000	
RDC4	2	34,576	0.8	53,326	18,750	106,652	0	0.0
RDC7	1	50,000	1.2	50,000		100,000	968,000	13.6
SRD2	1	37,505	0.9		12,500	50,005	77,611	2.1
UME24	1	15,000	0.4			15,000	0	0.0
UNE16	3	12,336	0.3			12,336	17,700	1.4
UNE17	3	156,496	3.7	156,496		312,992	458,962	2.9
WRD1	3	62,000	1.5	208,120		270,120	103,910	1.7
WRD2	3	113,525	2.7	162,168		275,693	664,705	5.9
unallocated		120,000	2.8			120,000	0	
TOTAL		**$4,205,039**	**100.0**	**2,556,492**	**725,000**	**7,486,531**	**17,079,203**	**4.1**

* Project-specific RDC funding includes $814,779 administered by the managing RDC as shown in Table 16

Table 15
Total NCVP breakdown

Item	Funding ($'000s)	%
R&D (NCVP and RDC)	7,484*	91
Communications — projects COS1, UQL9, INF2 — publications, conference costs	198	2
Planning and Evaluation	45	1
Program Support 194K—Project AGE1 292K—Program Managers salary, travel for management committee, workshop expenses, Program Coordinator expenses (97–99)	486	6
TOTAL	**8,213**	**100**

* Table 14 total program expenditure (NCVP & RDC) reduced by $2,541 due to misallocation of non-R&D expenditure item (program support)

Table 16
Co-funded project details (indicates project manager where not LWRRDC)*

Project	Funding ($)	Co-Funders	Project	Funding ($)	Co-Funders
CWE8	180,000	MRC, WRD	QPI38	403,627	GRDC, RIRDC
DAN6	25,000	GRDC	QPI39	346,590	LWRRDC
DAS12	325,000	GRDC, RIRDC	RDC4	53,326	RIRDC*
FRD2	85,748	FRDC*	RDC7	50,000	RIRDC*
MRC1	255,417	MRC*	UNE17	156,496	RIRDC
QNR3	150,000	RIRDC	WRD1	208,120	IWS*
QPI20	155,000	GRDC, GF	WRD2	162,168	IWS*
TOTAL		**(14 Projects)**			**$2,556,492**

Note: the above excludes RDC contributions of $725,000 to generic projects as listed in Table 14

Table 17
Contributions to sub-programs

Sub-Program	No of Projects	Funds	% Total R&D Funds
Climate forecasting	7	$2,197,922	29.4
Regional monitoring	7	$1,611,992	21.5
Decision support	12	$3,535,617	47.2
Other (misc. & unallocated)	1	$141,000	1.9
TOTAL	**27**	**$7,486,531**	**100.0**

APPENDIX D

Abbreviations used in the Report

ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
APICA	Asia–Pacific Institute for Climate Applications
BMRC	Bureau of Meteorology Research Centre
BoM	Bureau of Meteorology
BRS	Bureau of Resource Sciences
COSSA	CSIRO Office of Space Science and Applications
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
CV	Climate variability
DAR	The CSIRO Division of Atmospheric Research
DPIE	Commonwealth Department of Primary Industries and Energy
DRDC	The Dairy Research & Development Corporation
DSS	Decision Support System; often based on a simulation model, but not always (not all simulation models are DSSs)
ENSO	El Niño–Southern Oscillation Index
ERIN	Environmental Resources Information Network
GCM	General Circulation Model of the World's Atmosphere
GF	Goodman Fielder
GIS	Geographic Information System
GRDC	The Grains Research & Development Corporation
IWS	International Wool Secretariat
LWRRDC	The Land & Water Resources Research & Development Corporation
NCC	National Climate Centre
NCVP	The National Climate Variability R&D Program
NFF	National Farmers' Federation
NOAA	National Oceanic and Atmospheric Administration (USA)
NOAA_AVHRR	NOAA's Advanced Very High Resolution Radiometer
NRIC	National Resources Information Centre
QDPI	Queensland Department of Primary Industries
QLC	Queensland Landcare Council
QNR	Queensland Department of Natural Resources
R&D	Research and Development
RIRDC	The Rural Industries Research & Development Corporation
SLUIS	Sustainable Land Use Information System (developed by the BRS)
SOI	The Southern Oscillation Index; see http://www.bom.gov.au
SRDC	The Sugar Research & Development Corporation
SST	Sea Surface Temperature
WWW	World Wide Web

APPENDIX E

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APPENDIX F

A Short History of the NCVP and Related Actions

National Drought Policy

In Australia, government policies helped create socio-economic features of agricultural production which served to perpetuate responses that may be inappropriate to drought-prone areas (Eliason 1989). On 12 April 1989, the then Minister for Primary Industries & Energy, John Kerin, announced the establishment of an independent government task force to undertake a comprehensive review of national drought relief policies. Simultaneously, the Minister for Finance confirmed that the Commonwealth Government had decided to remove funding for drought relief from the Natural Disaster Relief Arrangements (NDRA) as of July 1989.

The Drought Policy Review Task Force recommended that drought should no longer be regarded as a natural disaster but as an integral part of a highly variable climate. Government policy should be aimed at assisting farmers to cope with this variability, particularly by assisting them to improve their decision-making frameworks. It therefore proposed a new National Drought Policy, and based on the following three objectives.

These were:

1. to encourage primary producers and other segments of rural Australia to adopt self-reliant approaches in managing for climatic variation;
2. to facilitate the maintenance and protection of Australia's agricultural and resource base during periods of increasing climatic stress; and
3. to facilitate the early recovery of agricultural and rural industries to levels consistent with long-term sustainable production.

In August 1992, the then Minister for Primary Industries and Energy, Simon Crean, announced agreement between the Australian Commonwealth Government and the State Governments in establishing the National Drought Policy.

The policy sees drought as a normal feature of the Australian environment. The policy recognises that drought is only one of several sources of uncertainty affecting farm businesses and is part of a farmer's normal operating environment. However, its effects can be minimised through good management practices. The main focus is on farm management which takes into account the risks associated with drought and adheres to the principles of sustainable agriculture.

Associated with the launch of the National Drought Policy was a commitment of government funding over the next four years into a communication strategy, drought-related research and development, and additional education and training programs related to risk management and drought preparedness.

Drought-related research and development

FIRST THREE-YEAR PROGRAM

The NDP, with its thrusts on risk management, self-reliance and sustainability issues included a three year allocation of $2.1 million for research. Further funds of $2.5 million for continuing research were allocated in the Drought Relief Package of late 1994.

The program is managed by the Land and Water Resources Research and Development Corporation, with assistance from the Rural Industries R&D Corporation. The program has been managed for LWRRDC and RIRDC by a Committee which currently includes representatives from other major R&D corporations, DPIE and the National Farmers' Federation. Their initial task following the review process was to set broad priorities and a management framework. Given the emphasis in the NDP on risk management the broader program title 'Managing with Climate Variability' rather than drought R&D was seen as essential to emphasise opportunities for less reactive responses to drought and opportunities to manage across the full range of climate variability.

The research recommendations concentrated on climate prediction and farm management, particularly decision support systems. As also recommended, a workshop on 'Drought and decision support' was organised by the then Bureau of Rural Resources in 1992 and the outcomes of the workshop (Bryceson and White 1994) were a further input to the planning process. Further valuable input into the planning process was the workshop on 'Risk management and decision support' convened by the Victorian Department of Agriculture in November 1992 (Trapnell and Fisher 1993).

The NDP context, together with the processes developed by LWRRDC for planning and management of National R&D programs provided a straight forward basis on which to proceed. LWRRDC processes emphasised:

- the need for a national review of existing research so that coherent priorities can be set;
- the value of collaborative projects;
- early and continuing involvement of research uses; and
- the value of some commissioned research in priority areas.

The review of existing research and the development of strategies are documented in the program development report (White 1992). Some major points were:

- the widespread support for improving seasonal climate forecasts;
- the need for a limited number of large collaborative projects to achieve a national impact in the short term;
- an emphasis on generic or cross-commodity issues;
- the need to make existing models more relevant for decision support rather than to fund development of new models; and
- emphasis on development of decision support tools with farmer groups, and including Property Management Planning Workshops as set up as part of the NDP.

The priorities for the National Climate Variability R&D Program include:

- climate forecasting;
- drought risk monitoring; and
- decision support for farm risk management.

There were 12 projects in the first phase of the program which commenced in 1993. Contributions from other R&D corporations of about $1.2 million in Phase 1 were critical in terms of lifting the profile of a new research focus, and the broader base that the program has achieved has helped maintain producer and government confidence.

In addition to the program of research and as part of the communication component of the National Drought Policy, a compendium of current drought R&D listing 103 projects was developed (LWRRDC 1993).

SECOND THREE-YEAR PROGRAM

Following advice in early 1995 from the Minister for Primary Industries and Energy of further funding of $2.5 million over three years to 1996–97, the second phase of the program was implemented in 1995–96. The major directions developed were:

- the need to have a broader funding base involving other R&D corporations to ensure generic research had an adequate priority
- giving priority to improvements in seasonal climate forecasting
- expanding applications of seasonal climate forecasting into priority areas such as water resources management

Generic projects of benefit to many industries, such as improved climate forecasting are funded through a collaborative effort involving LWRRDC, RIRDC, GRDC, SRDC, IWS, DRDC and the Forest and Wood Products R&D Corporation. Projects on improved risk management in specific industries are funded jointly between the National Climate Variability R&D Program and individual R&D corporations.

Funding from the seven corporations totals $725,000 over a three year period and focuses on climate forecasting and drought risk monitoring strategies. Three projects were planned in 1995–96 in the generic component of the program on improving seasonal climate forecasts. The first project was an extension of a collaborative one between the Bureau of Meteorology and State Departments of Agriculture (Queensland and Western Australia) to make use of sea surface temperatures in prediction and to develop forecasts of climate indices specifically for rural industries. There is an additional smaller project planned to evaluate a different forecast methodology developed in South Australia. The third project, the major generic project being funded, aims to accelerate the development of climate models of the oceans and atmosphere for seasonal prediction.

The generic contributions for the three years from July 1995 to June 1998 from the seven participating R&D corporations are as follows:

R&D Corporation	***Funding***
IWS	150,000
Forest and Wood Products	10,000
Grains	250,000
Sugar	60,000
Dairy	75,000
Rural Industries	80,000
Land and Water Resources	100,000
TOTAL	**$725,000**

LWRRDC and RIRDC also hosted the first major national conference on climate variability entitled 'Of droughts and flooding rains'. This was held in Canberra in November, 1995.

In late 1996 there were a number of workshops and conferences of relevance to the NCVP. The Bureau of Resource Sciences had received separate funding of $452,000 to develop regionally sensitive meteorological, agronomic and environmental criteria that can assist DPIE to make consistent and equitable Exceptional Circumstances declarations in Australia. It subcontracted a considerable part of the research to various CSIRO Divisions and State Departments of Agriculture/Primary Industries and to the Australian Bureau of Agriculture and Resource Economics (White 1996). BRS conducted a workshop in Canberra in October 1996 on 'Indicators of Drought Exceptional Circumstances' (White and Bordas 1997).

The Second Australian Conference on Agricultural Meteorology was held at the University of Queensland, 1–4 October 1996. It was hosted by the National Committee on Agro-meteorology with the support of the Bureau of Meteorology and sponsorship from LWRRDC, Campbell Scientific Australia Pty Ltd and Environdata Australia Pty Ltd. A number of papers arising from the NCVP were presented at this conference.

A LWRRDC-sponsored workshop was held in Brisbane to discuss Phase II of the propose National Drought Alert Strategic Information System (since renamed as AussieGrass) from 31 October–1 November 1996. This achieved a commitment from most States and Territories to a collaborative role in extending the spatial and temporal grassland monitoring system that was working so effectively for Queensland, and had been of considerable assistance to BRS, DPIE and the Rural Adjustment Scheme Advisory Council (RASAC) (White 1996; White 1997) in their assessments of Drought Exceptional Circumstances, to other areas of Australia.

INTERNATIONAL DEVELOPMENTS

In recognition of Australia's world-class research in applications of seasonal climate forecasting, contributions were made as part of the Australian delegation to the Washington Forum on Forecasting El Niño: Launching of the International Research Institute in 1995. Australian experience in climate variability also assisted the Asia Pacific Network (APN) for Global Change Research in setting priorities for climate research.

Projects in Phase 1 of the Program

Climate Forecasting	
BOM1 Development of an improved seasonal climate forecasting system	Original project was extended to 12/97
CAR3 El Niño—Southern Oscillation and Climate Variability (Atlas & CD ROM) .	To be published Nov. 1996, which will complete the project.
Drought/Monitoring	
QPI20 Development of a national drought alert strategic information system	Phase I completed. Extension being considered under CV2. GRDC and Goodman Fielder co-funded component on wheat forecasting
ABA1 Drought and the economic performance of Australian agriculture	Project completed and published as Occasional Paper CV 01/95 'Climate Variability and Farm Risk'
UNE16 Economic monitoring/forecasting for rural business	Project completed, Manual for rural business in preparation
CEX1 Drought monitoring of the Australian continent by satellite	Project completed
WRD1 Exploiting drought opportunities—control of total grazing pressure in rangelands	In progress and managed by IWS, to finish 9/96.
Drought Research in Progress	Bibliography of 103 projects, published in 1993.
MRC1 Strategies for maximising the persistence of perennial grasses through drought	In progress and managed by MRC, scheduled to finish 6/96. Results severely affected by groundwater intrusion to rain out sheltered plots
Financial Risk	
DAN6 Optimum replacement of farm machinery under conditions of capital rationing.	Project completed other than commercialisation of software being negotiated. GRDC co-funds
UNE17 Analysing drought strategies to enhance farm viability.	Project completed, report published by CARE (Centre for Agricultural and Regional Economic) now independent of UNE. RIRDC co-funded.
ARM1 Insurance-based risk management for drought	Project completed and published as Occasional Paper CV 02/95 'Insurance Based Risk Management for Drought'.

Decision Support	
SRD1 Decision support for climatic risk management in dryland crop production.	Final Report due November 1996; GRDC and RIRDC co-fund.
CWE8 Grazier based profitable and sustainable strategies for managing climate variability.	Project (DroughtPlan) completed. Major detailed report to be published as LWRRDC Occasional Paper CV01/97. IWS and MRC co-funded.

Projects in Phase II of the Program

Climate Forecasting			
BOM1	Development of Improved Seasonal Forecast Systems.	*Bureau of Meteorology Research Centre*	Extension of Phase One project, on schedule
COR2	Development and Testing of Climate Models for Seasonal Prediction for Australia.	*CSIRO Oceanography*	Commenced 1995–96, on schedule
QNR3	An Agro-Meteorological Information Service for Rural Communities.	*Queensland Department of Natural Resources*	To commence 1996–97, co-funded by RIRDC
RDC7	Further Development and Application of AUSTRALIAN RAINMAN to Improve Management of Climate Variability	*Qld Dept. Primary Industries*	To commence April 1997
SRD2	Seasonal Rainfall and Winter Crop Yield Forecasting for South Australia.	*S.A. Research & Development Institute*	To commence 1996–97
UME24	Review of R&D Opportunities for Using Seasonal Climate Forecasts in the Water Industry.	*University of Melbourne*	Consultancy completed 1995–96, published as CV02/96
Drought Monitoring			
MAC1	Improved Management of Climate Risk	*Macro Consulting*	Consultancy completed 1995–96, published as CV01/96
QNR9	Australian Grassland and Rangeland Assessment by Spatial Simulation—'Aussie GRASS'	*Qld Dept. Natural Resources*	To commence April 1997
QPI20	Development of a national drought alert system	*Qld Dept. Natural Resources*	Extension scheduled for 1996–97
RDC4	Australian Farm Families' Experience of the Drought in the 1990s.	*Central Queensland University*	Commenced 1995–96, co-funded with RIRDC, on schedule
Decision Support			
ABA6	Integrating Climate Forecasting into Yield Predictions for the Agricultural Sector.	*ABARE*	Completed 1995–96, Final Report rescheduled to due Nov. 1996
FRD2	Climate and Fisheries on the South-east Australian Continental Shelf.	*CSIRO Fisheries*	Commenced 1996–97, co-funded & managed by FRDC
QPI38	Evaluating the Role of Seasonal Climate Forecasting in Tactical Management of Cropping Systems in North-east Australia.	*Qld Dept. Primary Industries*	Commenced 1995–96, co-funded by GRDC and RIRDC, on schedule
WRD2	Extension of the Results of Fertiliser Research to Graziers by Development of a Pasture Nutrition Sub-module for GRASSGRO	*CSIRO Plant Industry*	Commenced 1995–96, co-funded and managed by IWS

APPENDIX G

Publications arising from, or closely related to, the NCVP

Abrecht, D.G. and Balston, J.M.(1996). Rules for managing the break of the season. In *Proceedings of the 2nd Australian Conference on Agricultural Meteorology*, Brisbane, October 1996, p 111–115.

Allan, R. (1994). Historical climatology of pressure anomalies, ENSO and Australian rainfall. *Agricultural Systems & Information Technology* **6**(2), 15–18.

Allan, R. and Lindesay, J. (1995). The global ENSO picture: interannual and decadal variability. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. Occasional Paper CV03/96, pp. 16–22.

Allan, R., Lindesay, J. and Parker, D. (1996). El Niño Southern Oscillation and Climatic Variability. (Atlas and CD-ROM), CSIRO Publishing. 408 pp.

Allan, R.J., Beck, K. and Mitchell, W.M. (1990). Sea level and rainfall correlations in Australia: tropical links. *Journal of Climate* **3**(8), 838–846.

Angus, J.F. (1991). The evaluation of methods for quantifying risk in water limited environments. *In* R.C. Muchow and J.A. Bellamy, eds. 'Climatic risk in crop production: models and management for the semiarid tropics and subtropics', pp. 39–53. Wallingford (CAB International).

Anon. (1990). National Drought Policy Final Report. Drought Policy Review Task Force. Australian Government Publishing Service, Canberra.

Anon (1996). Mid-term review of the Rural Adjustment Scheme (RAS). A submission by The Bureau of Meteorology (October 1996).

Balston, J.M., Abrecht, D.G. and Egan, J.P. (1996). Delivering relevant, timely seasonal information to farmers in Mediterranean dryland cropping areas. In *Proceedings of the 2nd Australian Conference on Agricultural Meteorology*, Brisbane, October 1996, p 304–307.

Boschma, S.P., Scott, J.M. and Rapp, G.G. (1996). Strategies for maximising the persistence of perennial programs through drought, Sub-program 3.2, Temperate Pasture Sustainability Key Program. Final report to Meat Research Corporation, M.401—drought study—northern site, 58 pp.

Bowman, P.J., McKeon, G.M. and White, D.H. (1995). The impact of long range climate forecasting on the performance of sheep flocks in Victoria. *Australian Journal of Agricultural Research*, **46**, 687–702.

Bowman, P.J., White, D.H., Cottle, D.J. and Bywater, A.C. (1993). Simulation of wool growth rate and fleece characteristics of Merino sheep in southern Australia. Part 2—Assessment of biological components of the model. *Agricultural Systems* **43**: 301–321.

Brook, K. *et al.* (1996). Development of a National Drought Alert Strategic Information System. Final report on QPI 20 to Land and Water Resources Research and Development Corporation (May 1996) (6 volumes).

Brook, K.D. and Carter, J.O. (1994). Integrating satellite data and pasture growth models to produce feed deficit and land condition alerts. *Agricultural Systems & Information Technology* **6**(2): 38–40, 54–56.

Brook, K.D., Carter, J.O., Danaher, T.J., McKeon, G.M., Flood, N.R. and Peacock, A. (1992). SWARD: Statewide analysis of risks of land degradation in Queensland. *Agricultural Systems and Information Technology Newsletter.* **4:** 9–11.

Brook, K.D., Carter, J.O., Danaher, T.J., McKeon, G.M., Flood, N.R. and Peacock, A. (1992). The use of spatial modelling and forecasting of drought-related land degradation events in Queensland. *Proceedings of the 6th Australasian Remote Sensing Conference*, Wellington, New Zealand, 2–6 November, 1992, **1**: 140–149.

Bryceson, K.P. (1993). Locust survey and drought monitoring—two case studies of the operational use of satellite data in Australian Government Agencies. *The International Institute for Aerospace Survey & Earth Sciences (ITC) Journal* **3**: 267–275.

Bryceson, K.P. (1994). Using GMS satellite data to estimate the areal location and quantity of rain. *Agricultural Systems & Information Technology* **6**(2), 37, 51–53.

Bryceson, K.P. and White, D.H. (editors) (1994). *Proceedings of a workshop on 'Drought and decision support'*. Bureau of Resource Sciences, Canberra, 63 pp.

Bryceson, K.P., Brook, K.D. and White, D.H. (1993). Integration of spatial data and temporal models to improve drought preparedness, monitoring and management. In Proceedings of the international conference on 'Applications of advanced information technologies for the management of natural resources', Spokane, Washington, June 17–19, 1993, pp. 158–166.

Bullen, F. (1993). Mapping Australia's vegetative cover using multi-temporal AVHRR data. *NARGIS Conference.*

Buxton, R. and Stafford Smith, M. (1996). Managing drought in Australia's rangelands: four weddings and a funeral. *Rangelands Journal* **18**: 292–308.

Buxton, R., Eddy, D., many pastoralists and extension personnel, Moore, A.D. and Stafford Smith, M. 1995–6. *DroughtPlan Stream 2 Regional Report Series: Longreach/Richmond, South West Queensland, Western New South Wales, South Australia, Central Australia, Kimberleys, Central Western Australia, Central Tablelands NSW.* CSIRO Alice Springs.

Buxton, R., Stafford Smith, M. and Eddy, D. 1996. *Drought Management on Australian Grazing Enterprises.* CSIRO/LWRRDC Occasional Paper Series, Canberra. In prep.

Campbell, B.D., McKeon, G.M., Gifford, R.M., Clark, H., Stafford Smith, D.M., Newton, P.C.D., and Lutze, J.L. (1995). Impacts of atmospheric composition and climate change on temperate and tropical pastoral agriculture in *Greenhouse 94: Climate Change* CSIRO, Melbourne pp 171–89.

Cane, M., Zebiak, S.E. and Dolan, S.C. (1986). Experimental forecasts of El Niño. *Nature* 321, 827–832.

Carroll C., Littleboy M. and Halpin M. (1992). Minimising soil erosion and runoff by maximising cropping opportunities. *Mathematics and Computers in Simulation* **33**: 427–432.

Carter, J.O. et al. (1996). Development of data rasters for model inputs, Final Report on QPI 20 to Land and Water Resources Research and Development Corporation (May 1996). pp 76.

Carter, J.O., Brook, K.D., Danaher, T.J. and McKeon, G.M. (1992). A strategic information system for real-time management of rangelands during drought using spatial modelling methodology. In *Proceedings of the Twentieth Annual International Conference of the Australasian Urban and Regional Information Systems Association Incorporated,* Gold Coast, 25–27 November, 1992, pp. 229–237.

Caughley, G. (1987). Ecological relationships. *In* G. Caughley, N. Shepherd and J. Short, eds. 'Kangaroos: their ecology and management in the sheep rangelands of Australia', Cambridge University Press, London, pp. 159–187.

Champagne, J., Herczeg, A.L. and Simpson, H.J. (1995). Precipitation and river discharge in the headwaters of the River Murray in south-east Australia related to ENSO forecasts of SST for the Niño-3 region of the Pacific Ocean. Abstract, International Scientific Conference—Tropical Oceans and Global (TOGA) Programme, Melbourne, 2 pp.

Chiew, F. and McMahon, T. (1997). Seasonal forecasting of rainfall and streamflow in Australia. *Climate prediction for agricultural and resource management,* Australian Academy of Science (in press).

Chiew, F.H.S., McMahon, T.A., Dracup, J.A. and Piechota, T. (1994). El Niño/Southern Oscillation and streamflow patterns in south-east Australia. *Civil Engineering Transactions, Institute of Engineers, Australia,* CE36(4), 285–291.

Clark, R. (1994). Stream 1 report on drought management in central Queensland: experience and perspectives of four producer groups. QDPI.

Clarkson, N.M. and Clewett, J.F. (1996). Australian Rainman: the first two years and future development. *Proceedings of the second Australian Conference on Agricultural Meteorology,* The University of Queensland, 1–4 October 1996, pp. 93–97.

Clewett, J.F. (Ed.) (1994). *Modelling Animal Production, Reproduction and Mortality.* DroughtPlan Working Paper No. 2; QDPI Toowoomba. 20pp.

Clewett, J.F. and Drosdowsky, L. (1996). Study 1: Use of the Southern Oscillation Index as a drought management tool. *In* 'DroughtPlan: Building on participation' by D.M. Stafford Smith, J.F. Clewett, A.D. Moore, G.M. McKeon, R. Clark and many others (1996b). Full project report, Working paper No. 10, pp 120–124.

Clewett, J.F. and McKeon, G.M. (1990). The use of seasonal rainfall forecasting in agricultural management in Queensland—case studies in pasture use and shallow storage evaluation. In *First International Symposium on Integrated Land use Management for Tropical Agriculture.* **7**: 1–16.

Clewett, J.F. and Stafford Smith, M. (1994). *Decision Support Products.* DroughtPlan Working Paper No. 4; QDPI Toowoomba. 31pp.

Clewett, J.F., Cavaye, J.M., McKeon, G.M., Partridge, I.J. and Scanlan, J.C. (1991). Decision support software as an aid to managing pasture systems. *Tropical Grasslands* **25**: 159–164.

Clewett, J.F., Howden, S.M., McKeon, G.M. and Rose., C.W. (1991). Optimising farm dam irrigation in response to climatic risk. *In* R.C. Muchow and J.A. Bellamy, eds. 'Climatic risk in crop production: models and management for the semiarid tropics and subtropics', pp. 307–328. Wallingford (CAB International).

Clewett, J.F., McKeon, G.M. and Rickert, K.G. (1987). PROBE: an evaluation of pasture management options for beef enterprises in northern Australia. In *Computer Assisted Management of Agricultural Production Systems* (Eds D.H. White and K.M. Weber). A.R.I., Werribee. pp. 109–16.

Cogle A.L., Littleboy M., Rao K.P.C., Smith G.D., and Yule D.F. (1996). Soil management and production of Alfisols in the semi-arid tropics. III Long term effects on water conservation and production. *Australian Journal of Soil Research* **34**:113–126.

Cridland, S.W., Burnside, D.G. and Smith, R.C.G. (1994). Use by managers in rangeland environments of near real-time satellite measurements of seasonal vegetation response. In Mapping resources, monitoring the environment and managing the future. Proceedings of the 7th Australasian Remote Sensing Conference, Vol. 2, 1–4 March, Melbourne.

Crosby D.H. and Egan J.P. (1995). Climate risk management in agriculture. In 'Weather, Climate Variability and Agriculture', training manual for PISA Property Management Planning and extension staff workshops, published by Climate and Consultancy Services, Bureau of Meteorology, SA, p 67–80.

Dawes, W.R. and Short, D.L. (1993). The efficient numerical solution of differential equations for coupled water and solute dynamics: the WAVES model. Technical Memorandum 93–18. Division of Water Resources, CSIRO Australia.

Day, K.A., McKeon, G.M. and Orr, D.M. (1993). Comparison of methods for assessing productivity of native pastures in Queensland. *XVII International Grassland Congress Palmerston North, New Zealand.* pp 784–5.

Donnelly, J.R. and Freer, M. (1996). Using the GrassGro decision support system to establish objective criteria for the definition of exceptional drought. Report to the Bureau of Resource Sciences, Canberra, from the CSIRO Division of Plant Industry, Canberra.

Donnelly, J.R., Moore, A.D. and Freer, M. (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises—I. Overview of the GRAZPLAN project, and a description of the MetAccess and LambAlive DSS. *Agricultural Systems* **54**, 57–76.

Drake, V.A. (1991). The influence of weather and climate on insect pests and insect-borne diseases: an Australian perspective. *In* 'Conference on Agricultural Meteorology—Extended abstracts', National Committee on Agro-meteorology, Melbourne, 17–19 July, 1991, pp. 189–196.

Dudgeon, G., Nilsson, C.S. and Fry, W.B. (1990). Rangeland vegetation monitoring using NOAA_AVHRR data: 1. Improving the spatial and radiometric accuracy of NDVI data. *Proceedings of the 5th Australian Remote Sensing Conference*, Perth, Western Australia, pp. 218–227.

Dudley, N.J. and Hearn, A.B. (1993). El Niño effects hurt Naomi irrigated cotton growers, but they can do little to ease the pain. *Agricultural Systems* **42**, 103–126.

Easdown, W. and Hammer, G.L. (1996). *Summer crop management in northern NSW and Queensland.* Final Report on QDPI component of LWRRDC Project DAS12.

Egan, J. and Hammer, G. (1996). Managing climate risks in grain production. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. Occasional Paper CV03/95, pp. 98–105.

Egan, J.P. (1995). Managing with our variable climate for crop production. In *Proceedings of Agronomy Technical Conference*, Adelaide, March 1995, p 175–180.

Egan, J.P. and Balston, J.M. (1996). Farming by season type. In *Proceedings of Farming Systems Developments 1996 Workshop*, Adelaide, March 1996, p 147–148.

Egan, J.P. and Balston, J.M. (1996). Managing climate variability. Helping farmers do it better. In *Proceedings of 6th Community Landcare Conference*, Renmark SA, July 1996, p 29–33.

Egan, J.P., Balston, J.M. and Abrecht, D.G. (1996). Adjusting cropping programs to match seasonal expectations in low rainfall districts of South Australia. In *Proceedings of 2nd Australian Conference on Agricultural Meteorology*, Brisbane, October 1996, p308–311.

Egan, J.P. and Hammer, G.L.(1995). Climate variability and cropping—managing climate risks in grain production. In *Proceedings of Managing with Climate Variability Conference*, Canberra, November 1995, LWRRDC Occasional Paper CV03/95, p98–105.

Egan, J.P., Robinson, S.D., Abrecht, D.G., Hammer, G.L. and Huda, A.K.S. (1993). Climate variability management and its application in Property Management Planning. In *Proceedings of National Conference of Soil and Water Conservation Association of Australia*, Adelaide, October 1993, p 225–227.

Elliott, G. (1995). Climatic risks to agricultural production in the south west of Western Australia. In *Abstracts of the Australia New Zealand Climate Forum*, Wirrina Cove Resort SA, February 1995, p 7.

Elliott, G. and Abrecht, D.G. (1994). Requirements for decision support systems and tools for dryland crop production in Western Australia. *MCV Project Milestone Report*, Department of Agriculture WA, December 1994.

Elliott, G. and Foster, I. (1994). Requirements for seasonal climate forecasts by agricultural producers in Western Australia. Milestone report to LWRRDC.

Foran, B. (1994). Use of NOAA_AVHRR data and NDVI for monitoring rangeland condition in Central Australia. Proceedings of a workshop on Drought and Decision Support (edited by K.P. Bryceson and D.H. White), Bureau of Resource Sciences, Canberra, pp. 32–33.

Foran, B. and Pearce, G. (1990). The use of NOAA_AVHRR and the normalised vegetation index to assess the 1988/89 summer growing season in Central Australia. Proceedings of the 5th Australasian Remote Sensing Conference, Perth, October 1990, pp. 198–207.

Foran, B. and Stafford Smith, D.M. (1991). Risk, biology and drought management strategies for cattle stations in Central Australia. *Journal of Environmental Management* **33**,17–33.

Foran, B.D. and Stafford Smith, D.M. (1991). Risk, biology and drought management strategies for cattle stations in Central Australia. *Journal of Environmental Management* **33**: 17–33.

Fraser, K. and Batterham, R. (1996). Decisions on farm machinery replacement. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. Occasional Paper CV03/95, pp. 116–120.

Freebairn D.M., Littleboy M., Smith G.D. and Coughlan K.J. (1990). Optimising agronomic practice in response to climate risk: soil surface management, (Invited paper). *International Climatic Risk in Agriculture Symposium*, 2–6 July 1990, University of Queensland.

Freer, M., Moore, A.D. and Donnelly, J.R. (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises—II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS. *Agricultural Systems* **54**, 77–126.

Freudenberger, D. and Hacker, R. (1995). The short-term effect of selectively excluding kangaroos from stock watering points. *Proceedings of the 10th Australian Vertebrate Pest Control Conference*, Hobart, Tasmania, pp. 309–312.

Freudenberger, D.O., Hacker, R.B. and Brill, B.J. (1995). Management of total grazing pressure in rangelands by manipulating access to water supplies. In *Ecological Research and Management in the Mulgalands—Conference Proceedings* (edited by M.J. Page and T.S. Beutel), University of Queensland Gatton College, pp. 133–138

Gardner E.A., Freebairn D.M., Doherty J.E., Shaw R.J., Littleboy M., Titmarsh G., Silburn D.M., Connolly R.D. and Begbie D. (1993). Hydrological tools to assist decision making in integrated catchment management. *15th Federal Convention of the Australian Water and Waste Water Association*, 18–23 April 1993, Gold Coast, Australia.

Gardner E.A., Littleboy M. and Beavers P. (1995). Using a water balance model to assess the hydrological implications of on-site effluent disposal. 16th Federal Convention of the Australian Water and Waste Water Association, April 1995, Sydney, Australia.

Gordon, H.B. and Hunt, B.G. (1991). Droughts, floods, and sea-surface temperature anomalies: A modelling approach. *International Journal of Climatology* **11**, 347–365.

Groffman, P.M. and Likens, G.E. (editors) (1994). Integrated regional models: interactions between humans and their environment. Chapman and Hall, New York, 157pp.

Grundy M.J., Littleboy M. and Heiner I.J. (1992). Improving land evaluation: A case study of the use of an agricultural systems model with land resource survey. AURISA 1992 Conference, 25–27 November 1992.

Hacker, R. (1996). Managing grazing pressure in rangelands. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. Occasional Paper CV03/96, pp. 79–84.

Hacker, R.B., Freudenberger, D.O. and Brill, B.J. (1996). Tactical management of total grazing pressure in rangelands by manipulating access to water supplies. Final report to the International Wool Secretariat and to LWRRDC, DAN210, 31 pp.

Hacker, R.B., Wang, K-M., Richmond, G.S. and Lindner, R.K. (1991). IMAGES: an Integrated Model of an Arid Grazing Ecological System. *Agricultural Systems* **37**: 119–163.

Hafi, A. and Stephens, D. (1995). Wheat yield forecasting. *Australian Commodities* **2**(3), September 1995, 288–289.

Hamblin, A. and Kyneur, G. (1993). Trends in wheat yields and soil fertility in Australia. Bureau of Resource Sciences, 141 pp.

Hammer, G.L. and Muchow, R.C. (1991). Quantifying climatic risk to sorghum in Australia's semiarid tropics and subtropics: model development and simulation. *In* R.C. Muchow and J.A. Bellamy, eds. 'Climatic risk in crop production: models and management for the semiarid tropics and subtropics', pp. 205–232. Wallingford (CAB International).

Hammer, G.L. and Nicholls, N. (1996). Managing for climate variability—the role of seasonal climate forecasting in improving agricultural systems. *Proceedings of the second Australian Conference on Agricultural Meteorology*, The University of Queensland, 1–4 October 1996, pp. 19–27.

Hammer, G.L., Chapman, S.C., and Muchow, R.C. (1996). Modelling sorghum in Australia: The state of the science and its role in the pursuit of improved practices. In M.A. Foale, R.G. Henzell and J.F. Kneipp (eds). *Proceedings of the Australian Sorghum Conference*, Tamworth, 20 to 22 February 1996 Australian Institute of Agricultural Science, Melbourne, Occasional Publication No. 93, pp. 43–61.

Hammer, G.L., and McKeon, G.M. (1984). Evaluating the effect of climatic variability on management of dryland agricultural systems in north-eastern Australia. In '*Need for climatic and hydrologic data in agriculture of South-east Asia*' (Ed. E.A. Fitzpatrick). A workshop sponsored by United Nations University at Canberra, 12–15 December 1983. pp. 209–19.

Hammer, G.L., Chapman, S.C. and Muchow, R.C. (1998). Modelling sorghum in Australia: the state of the science and its role in the pursuit of improved practices. In *Proceedings of 3rd Australian Sorghum Conference* (edited by M. Foale and R. Henzeil for AIAS), in press.

Hammer, G.L., Holzworth, D.P. and Stone, R. (1996). The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. *Australian Journal of Agricultural Research* **47**, 717–737.

Hammer, G.L., McKeon, G.M., Clewett, J.F. and Woodruff, D.R. (1991). Usefulness of seasonal climate forecasts in crop and pasture management. *In* 'Conference on Agricultural Meteorology–Extended abstracts', National Committee on Agro-meteorology, Melbourne, 17–19 July, 1991, pp. 15–23.

Hammer, G.L., Woodruff, D.R. and Robinson, J.B. (1987). Effect of climatic variability and possible climatic change on reliability of wheat cropping—a modelling approach. *Agricultural and Forestry Meteorology* **41**, 123–142.

Hastings, P.A. (1990). Southern Oscillation influences on tropical cyclone activity in the Australia/south west Pacific region. *International Journal of Climatology* **10**, 291–298.

Hayman P.T. and Rummery, R. (1994). *Summer crop decision support.* Preliminary report (July 1994).

Hayman PT and Huda AKS (1995). Can climate information improve fallow management decisions on the Liverpool Plains? In *Abstracts of the Australia New Zealand Climate Forum,* Wirrina Cove Resort SA, February 1995, p 11.

Hayman, P.R., Cox, P. and Huda, S. (1996). Will more climate information assist farmers better to assess and manage the risk of opportunity cropping on the Liverpool Plains. *Proceedings of the second Australian Conference on Agricultural Meteorology,* The University of Queensland, 1–4 October 1996, pp. 67–71.

Hayman, P.T. (1996). *Conservation farming in a variable climate.* Moree Conservation Farming Conference, Moree NSW, August 1996, 9 pp.

Hayman, P.T. and Collett, I.J. (1996). Estimating soil water. To kick, to stick, to core or compute? In *Proceedings of 8th Australian Agronomy Conference*, Toowoomba, Qld, January–February 1996, p 664.

Hayman, P.T., Cox, P.G. and Huda, A.K.S. (1996). Will more climate information assist farmers better to assess and manage the risks of opportunity cropping on the Liverpool Plains? In *Proceedings of 2nd Australian Conference on Agricultural Meteorology*, Brisbane, October 1996, p 67–71.

Hayman, P.T., Freebairn, D.M. and Huda, A.K.S. (1996). Opportunity cropping on the Liverpool Plains: a comparison of risk assessment by farmers and simulation models. In *Proceedings of 8th Australian Agronomy Conference*, Toowoomba Qld, January–February 1996, p 293–296.

Heathcote, R.L. (1991). Managing the droughts? Perception of resource management in the face of the drought hazard in Australia. *Vegetation* **91**, 219–230.

Hendricksen, R.E., Rickert, K.G., Ash, A.J. and McKeon, G.M. (1982). Beef production model. *Proceedings of the Australian Society Animal Production* **14**: 204–8.

Hobbs, T.J., Sparrow, A.D. and Landsberg, J.J. (1994). A model of soil moisture balance and herbage growth in the arid rangelands of central Australia. *Journal of Arid Environments* **28**: 281–298.

Holton, I. (1996). Seasonal and yearly prediction of rainfall and crop yields in South Australia. *Proceedings of the second Australian Conference on Agricultural Meteorology*, The University of Queensland, 1–4 October 1996, pp. 127–129.

Huda, A.K.S., Rahman, M.S., Egan, J.P., Holloway, R.E. and Lymn, A.S. (1993). Assessing and managing cropping risks in low rainfall areas of southern Australia using agroclimatic data. Technical Paper No. 34, South Australian Department of Primary Industries, Adelaide.

Huda, A.K.S., Rahman, M.S., Holloway, R.E., Egan, J.P., and Lymn, A.S. (1994). Reducing the risk of cropping in low rainfall areas of southern Australia. *Agricultural Systems & Information Technology* **6**(2), 72–74.

Hunt, B.G. (1994). The use of global models in deriving seasonal climate outlooks. *Agricultural Systems & Information Technology* **6**(2), 11–15.

Hunt, B.G. (1997). Global climatic models: long term predictions, annual to decadal. *Climate prediction for agricultural and resource management*, Australian Academy of Science (in press).

Hutchinson, M. (1991). The application of thin plate smoothing splines to continent-wide data assimilation. In *Data assimilation systems* (edited by J.D. Jasper), BMRC Research Report No. 27, Bureau of Meteorology, Melbourne, pp. 104–113.

Johnston, P.W. and McKeon, G.M. (editors)(1992). Evaluation of property management opportunities for western Queensland. Project DAQ 05P, Final report to the Australian Wool Corporation, 107 pp.

Johnston, P.W., McKeon, G.M. and Day, K.A. (1997). Objective 'Safe' Grazing Capacities for South-West Queensland Australia: Development of a Model for Individual Properties, *The Rangeland Journal* **18**: 224–58.

Keating, B., Meinke, H.R. and Dimes, J.P. (1996). Prospects for using a cropping systems simulator to assess exceptional droughts. Report to the Bureau of Resource Sciences, Canberra from the Agricultural Production Systems Research Unit, Toowoomba.

Kingwell, R.S. and Schilizzi, S.G.M. (1994). Dryland pasture improvement given climatic risk. *Agricultural Systems* 45, 175–191.

Kingwell, R.S., Morrison, D.A. and Bathgate, A.D. (1992). The effect of climatic risk on dryland farm management. *Agricultural Systems* **39**, 153–175.

Kingwell, R.S., Pannell, D.J. and Robinson, S.D. (1993). Tactical responses to seasonal conditions in whole-farm planning in Western Australia. *Agricultural Economics* **8**, 211–21.

Kleeman, R., Moore, A.M. and Smith, N.R. (1995). Assimilation of subsurface thermal data into a simple ocean model for the initialisation of an intermediate tropical coupled ocean–atmosphere forecast model. *Monthly Weather Review* **123**: 3103–3113.

Littleboy M. (1994). PERFECT cropping systems model. In, Procedures for Economic Assessment of management Options for Dryland Salinity. Report of a Workshop. Land and Water Resource Research and Development Corporation Occasional Paper 06/94.

Littleboy M. and Silburn D.M. (1989). The effect of surface management on runoff and soil loss: A modelling approach. 4th Queensland Hydrology Symposium, Institution of Engineers Australia (Queensland Division), 1–2 February 1989, University of Queensland.

Littleboy M., Bryant M.J., Grundy M.J. and Gooding D.O. (1992). Spatial applications of the PERFECT model to study the impact of soil erosion on production. *Agricultural Systems and Information Technology* **4**(2): 11–14, Bureau of Rural Resources.

Littleboy M., Cogle A.L., Rao K.P.C., Freebairn D.M. and Smith G.D. (1994). A Crystal Ball for Indicators of Unsustainability: 'PERFECT' Looks Ahead for Vertisols and Hardsetting Alfisols of the Semi-Arid Tropics. International Soil Science Society Conference, Mexico.

Littleboy M., Cogle A.L., Smith G.D., Yule D.F. and Rao K.P.C. (1996). Soil management and production of Alfisols in the semi-arid tropics. IV Simulating decline in productivity caused by soil erosion. *Australian Journal of Soil Research* **34**:127–138.

Littleboy M., Coughlan K.J., Silburn D.M. and Boaler L.J. (1990). Modelling erosion productivity relationships. Working Papers—Erosion/Productivity and Erosion Prediction, 5th Australian Soil Conservation Conference, March 1990, Perth, pp 34–43.

Littleboy M., Grundy M.J., Bryant M.J., Gooding D.O. and Carey B.W. (1992). Using spatial land resource data and computer simulation modelling to evaluate sustainability of wheat cropping for a portion of the eastern Darling Downs, Queensland. *Mathematics and Computers in Simulation* **33**: 463–468.

Littleboy M., Sachan R.C., Smith G.D. and Cogle A.L. (1996). Soil management and production of Alfisols in the semi-arid tropics. II Deriving USDA curve numbers from rainfall simulator data. *Australian Journal of Soil Research* **34**:103–112.

Littleboy M., Silburn D.M., Freebairn D.M., Woodruff D.R. and Hammer G.L. (1992). Impact of soil erosion on production in cropping systems. I. Development and validation of a simulation model. *Australian Journal of Soil Research,* **30(5)**:757–774.

Littleboy M., Smith D.M. and Bryant M. (1996). Simulation modelling to determine suitability of agricultural land. *Ecological Modelling* **86**: 219–225.

Long, A.B. and McMahon, T.A. (1996). Review of research and development opportunities for using seasonal climate forecasts in the Australian water industry. LWRRDC Occasional Paper No. CV02/96.

Ludwig, J.A. and Marsden, S.G. (1995). A simulation of resource dynamics within degraded semi-arid landscapes. *Mathematics and Computers in Simulation* **39**: 219–224.

Ludwig, J.A., Tongway, D.J. and Marsden, S.G. (1994). A flow-filter model for simulating the conservation of limited resources in spatially heterogeneous, semi-arid landscapes. *Pacific Conservation Biology* **1**: 209–213.

Lyons, W.F., Shao, Y. Munro, R.K., Wood, M.S., Hood, L.M. and Leslie, L.M. (1997). Soil moisture modelling and prediction over the Australian continent utilising simulations from a land surface schema. In 'Climate prediction for agricultural and resource management', Australian Academy of Science (in press).

Malafant, K. and Fordham, D. (1997). Integration frameworks in agricultural and resource planning and management. In 'Climate prediction for agricultural and resource management', Australian Academy of Science (in press).

Marshall, G., Parton, K., and Hammer, G.L. (1996). Value of a forecast in wheat growing. *Australian Journal of Agricultural Economics* 40: 211–233.

Marshall, G.R. and Parton, K.A. (1996). Value of seasonal forecasting to a wheat grower. *Proceedings of the second Australian Conference on Agricultural Meteorology*, The University of Queensland, 1–4 October 1996, pp. 62–66.

Mayers, B. (1995). Insurance opportunities for drought. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. Occasional Paper CV03/96, pp. 64–68.

Mayers, B. (1995). Insurance-based risk management for drought. LWRRDC Occasional Paper No. CV02/95

McBride, J.L., and Nicholls, N. (1983). Seasonal relationships between Australian rainfall and the Southern Oscillation. *Monthly Weather Review* **111**, 1998–2004.

McCook, R.W. (1992). MetAccess. *Agricultural Systems & Information Technology* **4**(1), 39–41.

McCown, R.L., Hammer, G.L., Hargreaves, J.N.G., Holzworth, D.P. and Freebairn, D.M. (1996). APSIM: A novel software system for model development, model testing and simulation in agricultural systems research. *Agricultural Systems* **50**: 255–271.

McIntosh, P., Meyers, G., Godfrey, S. and Schiller, A. (1996). The role of the oceans in Australia's climate variability. *Proceedings of the second Australian Conference on Agricultural Meteorology*, The University of Queensland, 1–4 October 1996, pp. 107–110.

McKeon, G.M. and Howden, S.M. (1992). Adapting Grazing Management to climate change and seasonal forecasting. *Australian Rangeland Society 7th Biennial Conference*, Cobar, New South Wales. 5th–8th October, 1992. p12–18.

McKeon, G.M. and Rickert, K.G. (1984). A computer model of the integration of forage options for beef production. *Proceedings Australian Society Animal Production.* **15**: 15–19.

McKeon, G.M. and White, D.H. (1992). El Niño and better land management. *Search* **23**, 197–200.

McKeon, G.M., Brook, K.D., Carter, J.O., Day, K.A., Howden, S.M., Johnston, P.W., Scanlan, J.C. and Scattini, W.J. (1994). Modelling utilisation rates in the black speargrass zone of Queensland. *Proceeding of 8th Australian Rangelands Conference*, Katherine, June 1994 pp 128–132.

McKeon, G.M., Carter, J.O., Johnston, P.W. and Orr, D.M. (1988). A methodology for measuring native pasture production: GUNSYND. In *Proceedings of Fifth Biennial Australian Rangelands Conference*, Longreach, 1988. pp. 115–8.

McKeon, G.M., Day, K.A., Howden, S.M., Mott, J.J., Orr, D.M., Scattini, W.J. and Weston, E.J. (1990). Management of pastoral production in northern Australian savannas. *Journal of Biogeography.* **17**: 355–72.

McKeon, G.M., Howden, S.M., Abel, N.O.J. and King, J.M. (1993). Climate change: adapting tropical and subtropical grasslands. *Proceedings of the XVIIth International Grassland Congress*, Palmerston North, New Zealand, **II**, 1181–1190.

McKeon, G.M., Howden, S.M., Silburn, D.M., Carter, J.O., Clewett, J.F., Hammer, G.L., Johnston, P.W., Lloyd, P.L., Mott, J.J., Walker, B., Weston, E.J. and Willcocks, J.R. (1988). The effect of Climate Change on Crop and Pastoral Production in Queensland. In Pearman, G.I. (ed). *Greenhouse, Planning for Climate Change.* CSIRO Division of Atmospheric Physics, Melbourne. pp. 546–63.

McKeon, G.M., Rickert, K.G. and Ash, A.J. (1982). Simulation studies on burning and stocking rate. *Proceedings Australian Society Animal Production.* **14**: 208–10.

McKeon, G.M., Rickert, K.G. and Scattini, W.J. (1986). Tropical pastures in the farming system: case studies of modelling integration through simulation. *Proceedings of Third Australian Conference on Tropical Pastures* (Eds G.J. Murtagh and R.M. Jones). Tropical Grassland Society, Brisbane. pp. 91–100.

McKeon, G.M., Rickert, K.G., Ash, A.J., Cooksley, D.G. and Scattini, W.J. (1982). Pasture production model. *Proceedings Australian Society Animal Production.* **14**: 201–4.

McKeon, G.M., Rickert, K.G., Robbins, G.B., Scattini, W.J. and Ivory, D.A. (1980). Prediction of animal performance from simple environmental variables. *Fourth Biennial Conference, Simulation Society of Australia*, Brisbane 1980. pp. 9–16.

McVicar, T.R. (1997). The use of remote sensing to aid decisions on drought exceptional circumstances. Report to the Bureau of Resource Sciences, Canberra, from the CSIRO Division of Water Resources.

Meinke, H., Stone, R.C., and Hammer, G.L. (1996). SOI phases and climatic risk to peanut production: a case study for northern Australia. *International Journal of Climatology* 16, 783–789

Meyers, G. (1995). Predictability and the role of the oceans in the climate system. Proceedings of Managing with Climate Variability Conference *'Of droughts and flooding rains'*, 16–17 November 1995. LWRRDC Occasional Paper CV03/96, pp. 10–15.

Meyers, G., Schiller, A., Godfrey, S. and McIntosh, P. (1997). Oceanic influences on variability of climate in Australia. *Climate prediction for agricultural and resource management*, Australian Academy of Science (in press).

Milford, J.R. and Dugdale, G. (1990). Estimation of rainfall using geostationary satellite data. In *Applications of remote sensing in agriculture* (edited by M.D. Steven and J.A. Clark), pp. 97–110.

Milham, N., Hardaker, J.B. and Powell, R. (1993). RISKFARM: A PC-based stochastic whole-farm budgeting system, Centre for Agricultural and Resource Economics, University of New England.

Mitchell, B. (1994). Using mean sea level anomalies as an indicator of regional climate variability. *Agricultural Systems & Information Technology* **6**(2), 19–21.

Moore, A.D., Donnelly, J.R. and Freer, M. (1991). GrazPlan: an Australian DSS for enterprises based on grazed pastures. In *Decision Support Systems for Resource Management* (edited by J.R. Stuth and B. Lyons) Texas A&M University, College Station, Texas, USA, pp. 19–22.

Moore, A.D., Donnelly, J.R. and Freer, M. (1997). GRAZPLAN: decision support systems for Australian grazing enterprises. III. Pasture growth and soil moisture submodels, and the GrassGro DSS. *Agricultural Systems* (in press).

Moore, A.D., Mayer, D., Pepper, P. and Freer, M. 1995. Modelling of research data on reproduction and mortality of cattle and sheep. *DroughtPlan Working Paper* No. 5. CSIRO, Alice Springs.

Moran, R. (1995). Climate prediction services and the water industry. Paper presented at WMO Conference on Climate Prediction Services, Melbourne, 6 pp.

Moran, R. (1995). Drought planning and management for urban water supplies in Victoria, Australia. American Water Resources Association Annual Summer Symposium on Water Resources and Environmental Hazards: Emphasis on hydrological and cultural insight on the Pacific Rim, 10 pp.

Morley, F.H.W. (1994). Drought predictions and budgets. In 'Merinos, money and management' (editor F.H.W. Morley), A Post Graduate Foundation Publication, The University of Sydney, pp. 249–262.

Morley, F.H.W. and Daniel, G. (1992). Drought, stocking rate and soil loss. *Proceedings of the Australian Society of Animal Production* **19**, 323–325.

Morley, F.H.W. and Graham, G.Y. (1971). Fodder conservation for drought. *In* J.B. Dent and J.R. Anderson, eds. 'Systems analysis in agricultural management'; pp. 125–141. Elsevier, Amsterdam.

Morrison, D.A., Kingwell, R.S., Pannell, D.J. and Ewing, M.A. (1986). A mathematical programming model of a crop–livestock farm system. *Agricultural Systems* **20**: 243–268.

Nicholls, N. (1986). Use of the Southern Oscillation to predict Australian sorghum yield. *Agricultural and Forest Meteorology* **38**, 9–15.

Nicholls, N. (1988). El Niño–Southern Oscillation and rainfall variability. *Journal of Climate* **1**, 418–421.

Nicholls, N. (1995). Development of improved seasonal climate forecast systems. Milestone report to LWRRDC.

Nicholls, N. (1995). Improved statistical and model approaches for seasonal climate forecasting. Proceedings of Managing with Climate Variability Conference *'Of droughts and flooding rains'*, 16–17 November 1995. Occasional Paper CV03/96, pp. 6–9.

Nicholls, N. (1995). Modelling climatic variability, Chapter 5 in: *Climate Change: Developing Southern Hemisphere Perspectives*, edited by T.W. Giambelluca and A. Henderson-Sellers, Wiley, (in press).

Nicholls, N. and Wong, K.K. (1990). Dependence of rainfall variability on mean rainfall, latitude and the Southern Oscillation. *Journal of Climate* **3**, 163–170.

Nicholls, N.(1984). Seasonal relationships between Australian rainfall and north Australian sea-surface temperature. *Extended abstracts, Conference on Australian rainfall variability*, Australian Academy of Science, Australian Bureau of Meteorology, pp. 71–73.

Nicholls, N., (1989). Sea surface temperatures and Australian winter rainfall, *Journal of Climate* ***2***, 965–973.

Nicholls, N., Drosdowsky, W., Frederiksen, C., Kleemand, R. and Smith, N. (1997). Seasonal climate predictions. *Climate prediction for agricultural and resource management*, Australian Academy of Science (in press).

Noble, I.R. (1975) Computer simulations of sheep grazing in the arid zone. Unpublished PhD. thesis: University of Adelaide, Australia.

Pepper, P., Mayer, D., McKeon, G.M. and Moore, A.D. 1996. Validation of reproduction and mortality rates for northern Australian beef and sheep breeders. *DroughtPlan Working Paper* No. 5. QDPI, Brisbane.

Pickup, G. (1995). A simple model for predicting herbage production from rainfall in rangelands and its calibration using remotely sensed data. *Journal of Arid Environments* **30**: 227–245.

Pickup, G. (1996). Estimating the effects of land degradation and rainfall variation on productivity in rangelands: an approach using remote sensing and models of grazing and herbage dynamics. *Journal of Applied Ecology* **33**: 819–832.

Powell, R. (1996). Impacts of climate variability on rural business. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. LWRRDC Occasional Paper CV03/96.

Pressland, A.J. and McKeon, G.M. (1989). Monitoring animal numbers and pasture condition for drought administration—an approach. *Proceedings of 5th Australian Soil Conservation Conference*, Perth. pp. 17–29.

Pressland, A.J. and McKeon, G.M. (1989). Monitoring animal numbers and pasture condition for drought administration—an approach. *Proceedings of 5th Australian Soil Conservation Conference*, Perth. pp. 17–29.

Rickert, K.G. and McKeon, G.M. (1982). Soil water balance model: WATSUP. *Proceedings Australian Society Animal Production.* **14**: 198–200.

Rickert, K.G. and McKeon, G.M. (1985). Models for native pasture management and development in south-east Queensland. In *Ecology and Management of the World's Savannas* (Eds J.C. Tothill and J.J. Mott). Australian Academy of Science, Canberra), pp. 299–302.

Rickert, K.G. and McKeon, G.M. (1987). 'SIMPROBE': a spread sheet model to assess options for forage management and integration of beef cattle properties. In '*Proceedings of the Fifth Biennial Conference of the Simulation Society of Australia*'. R.M.I.T. 11–13 May 1987.

Rickert, K.G. and McKeon, G.M. (1988). Computer models of forage management on beef cattle farms. *Mathematics and Computers in Simulation* **30**: 189–194.

Rickert, K.G. and McKeon, G.M. (1991). Modelling as an aid to systems evaluation. In '*The nature and dynamics of dryland of rangeland farming systems'*. (Eds V.R. Squires and P. Tow). Oxford Press. pp208–221.

Rickert, K.G., McKeon, G.M. and Prinsen, J.H. (1981). Growing beef cattle on native pasture oversown with fine-stem stylo in subtropical Australia. *Proceedings XIV International Grasslands Congress*. pp. 762–65.

Rickert, K.G., McKeon, G.M., Scattini, W.J. and Williams, L.E. (1984). Integration of feed sources in Queensland grazing lands in '*Native Pastures in Queensland: The resources and their management*' (Eds) W.H. Burrows, J.C. Scanlan and M.T. Rutherford. pp. 198–210. Queensland Department of Primary Industries Information Series QI87023, Queensland Government Printer, Brisbane.

Ridge, P. and Wylie, P. (1996). Improved management of climate risk. LWRRDC Occasional Paper CV01/96.

Ridge, P. and Wylie, P. (1996). Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. Occasional Paper CV03/96, pp. 126–130.

Rimmington, G.M. and Nicholls, N. (1993). Forecasting wheat yields in Australia with the Southern Oscillation Index. *Australian Journal of Agricultural Research* **44**, 625–632.

Robbins, G.B., Bushell, J.J. and McKeon, G.M. (1989). Nitrogen immobilisation in decomposing litter contributes to productivity decline in ageing pastures of green panic (*Panicum maximum* var. trichoglume). *Journal of Agricultural Science Cambridge.* **113**: 401–6.

Robinson, S.D. and Abrecht, D.G. (1994). TACT: A seasonal wheat sowing decision aid. User Manual.

Russell, J.S. (1991). Prospects for incorporation of long-term weather forecasting into crop decision support systems. *In* R.C. Muchow and J.A. Bellamy, eds. 'Climatic risk in crop production: models and management for the semiarid tropics and subtropics', pp. 467–487. Wallingford (CAB International).

Scanlan, J.C. and McIvor, J.G. (1993). Pasture composition influences soil erosion in *Eucalyptus* woodlands of northern Queensland. *Proceedings of the XVIIth International Grassland Congress,* Palmerston North, New Zealand p65–66.

Scanlan, J.C. and McKeon, G.M. (1993). Competitive effects of trees on pasture are a function of rainfall distribution and soil depth. *Proceedings of the XVIIth International Grassland Congress Palmerston North, New Zealand.* p2231–2.

Scanlan, J.C., McKeon, G.M., Day, K.A., Mott, J.J. and Hinton, A.W. (1994). Estimating safe carrying capacities of extensive cattle grazing properties within tropical semi-arid woodlands of north-eastern *The Rangeland Journal* **16**: 64–76.

Scanlan, J.C., McKeon, G.M., Day, K.A., Mott, J.J. and Hinton, A.W. (1994). Estimating safe carrying capacities of extensive cattle grazing properties within tropical semi-arid woodlands of north-eastern Australia. *The Rangeland Journal* **16**: 64–76.

Scanlan, J.C., Mott, J.J., McKeon, G.M., Day, K.A. and Lawes, D. (1990). Predicting Outcomes of management decisions in grazed native grasslands. In: P.M. Dowling and D.L. Garden (Eds) '*Native Grass Workshop Proceedings*'. NSW Agriculture and Fisheries and Australian Wool Corporation, Dubbo, October 1990, pp 59–70.

Scanlan, J.C., Pressland, A.J., and Myles, D.J. (1996). Runoff and soil movement on mid-slopes in north-east Queensland grazed woodlands. *The Rangeland Journal* **18:** 33–46.

Schiller, A., Godfrey, J.S. and Meyers, G. (1997). A global ocean general circulation model for climate variability studies. CSIRO Marine Laboratories, Report 227.

Schiller, A., Godfrey, J.S., McIntosh, P. and Meyers, G. (1997). A Global Ocean General Circulation Model for Climate Variability Studies, CSIRO Division of Marine Research Report 227.

Scoccimarro, M., Mues, C. and Topp, V. (1995). Climate variability and farm risk. Australian Bureau of Agriculture and Resource Economics, Occasional Paper No. CV01/95, ABARE report to Land and Water Resources Research and Development Corporation.

Scoccimarro, Michelle (1996). Climate variability and on-farm economic performance–the national pattern. Proceedings of Managing with Climate Variability Conference 'Of droughts and flooding rains', 16–17 November 1995. Land and Water Resources Research and Development Corporation and Rural Industries Research and Development Corporation, Occasional Paper CV03/95.

Scott, J.M. (1995). Pasture management and stocking rate policies. In *A Users' Guide to Drought Feeding Alternatives*, University of New England (in press).

Scott, J.M. (1996). Managing for sustainable grazing on temperate high-rainfall pastures. Proceedings of Managing with Climate Variability Conference '*Of droughts and flooding rains*', 16–17 November 1995. LWRRDC Occasional Paper CV03/96, pp. 85–89.

Shao, Y. and Leys, J.F. (1997). Wind erosion assessment and prediction using dynamic models and field experiments. In 'Climate prediction for agricultural and resource management', Australian Academy of Science (in press).

Simpson, H.J., Cane, M.A., Herczeg, A.L., Zebiak, S.E. and Simpson, J.H. (1993). Annual river discharge in south-eastern Australia related to El Niño–Southern Oscillation forecasts of sea surface temperatures. *Water Resources Research* **29**, 3671–3680.

Simpson, H.J., Cane, M.A., Lin, S.K., Zebiak, S.E. and Herczeg, A.L. (1993). Forecasting annual discharge of River Murray, Australia, from a geophysical model of ENSO. *Journal of Climate* **6**, 386–391.

Smith, R. (1994). Australian vegetation watch. Final Report to the Rural Industries Research and Development Corporation. RIRDC reference No. DOL-1A.

Smith, R.C.G. (1995). Drought monitoring of the Australian continent by satellite. Final report to Land and Water Resources Research and Development Corporation, LWRRDC reference No. CEX1.

Smith, R.C.G., Adams, J. and Hick, P.T. (1994). Forecasting wheat yields from satellite observations. In Mapping resources, monitoring the environment and managing the future. Proceedings of the 7th Australasian Remote Sensing Conference, Vol. 2, 1–4 March, Melbourne.

Stafford Smith, D.M. and Foran, B.D. (1990). RANGEPACK: the philosophy underlying the development of a microcomputer-based decision support system for pastoral land management. *Journal of Biogeography* **17**: 541–546.

Stafford Smith, D.M. and Roan, B.D. (1992). An approach to assessing the economic risk of different drought management tactics on a South Australian pastoral sheep station. *Agricultural Systems* **39**: 83–105.

Stafford Smith, D.M., Clewett, J.F., Moore, A.M., McKeon, G.M. and Clark, R. (1994). *DroughtPlan Project Description.* DroughtPlan Working Paper No. 1, CSIRO Alice Springs. 10pp.

Stafford Smith, D.M., Clewett, J.F., Moore, A.M., McKeon, G.M. and Clark, R. (1996). *DroughtPlan. Full Project Report.* DroughtPlan Working Paper No 10, CSIRO Alice Springs/LWRRDC Occasional Paper Series CV01/97, Canberra. ca. 120pp.

Stafford Smith, M. (1995). DroughtPlan: developing strategies with graziers to manage with climate variability. *Proceedings of the LWRRDC Conference on Climatic Variability*, Canberra, Nov 1995.

Stafford Smith, M. and Clark, R. (1994). *DroughtPlan Decision Support Workshop Report.* DroughtPlan Working Paper No. 3, CSIRO Alice Springs. 13pp.

Stafford Smith, M. and Foran, B. (1992). An approach to assessing the economic risk of different drought management tactics on a South Australian pastoral sheep station. *Agricultural Systems* **39**, 83–105.

Stafford Smith, M. and McKeon, G.M. (1996). Assessing the historical frequency of drought events on rangelands grazing properties: Case Studies. Report to Bureau of Resource Sciences.

Stafford Smith, M., McKeon, G., Ash, A., Buxton, R. and Breen, J. (1996). Evaluating the use of SOI forecasts in north Queensland using the Herd-Econ/GRASP linked model. DroughtPlan Working Paper No. 9/LUCNA Working Paper No. 1, CSIRO Alice Springs, 50pp.

Stafford Smith, M., Milham, N., Douglas, R., Tapp, N., Breen, J., Buxton, R., and McKeon, G. (1995). Whole farm modelling and ecological sustainability: a practical application in the NSW rangelands. *Proc. Conf. ANZSEE.* pp.243–249.

Stafford Smith, M., Milham, N., McKeon, G., et al. (1995). Whole farm modelling and ecological sustainability: a practical application in the NSW rangelands. *Proc. Austr. NZ Soc. Ecological Economics Inaugural Conf.,* Coffs Harbour, Nov 1995. Pp.243–249.

Stephens, D.J. (1996). Objective criteria for drought exceptional circumstances—cropping areas. Report to the Bureau of Resource Sciences, Canberra, from Agriculture Western Australia, 74 pp.

Stephens, D.J., Walker, G.K. and Lyons, T.J. (1994). Forecasting Australian wheat yields with a weighted rainfall index. *Agricultural and Forest Meteorology* **71**, 247–263.

Stone, R., Nicholls, N. and Hammer, G.L. (1996). Frost in NE Australia: trends and influences of phases of the Southern Oscillation. *Journal of Climate* **9**(8), 1896–1909.

Stone, R.C. and Marcussen, T. (1994). Queensland producer requirements from seasonal climate forecast systems. Milestone report to LWRRDC.

Stone, R.C., Hammer, G.L. and Marcussen, T. (1996). Prediction of global rainfall probabilities using phases of the Southern Oscillation Index. *Nature* **384** (21), November 1996, pp. 252–255.

Stuth, J.W. and Stafford Smith, M. (1993). Decision support for grazing lands: an overview. In J. Stuth and B. Lyons (eds.), *Decision Support Systems for the Management of Grazing Lands,* UNESCO-MAB Book Series, pp. 1–35.

Thomas E.C., Gardner E.A., Littleboy M. and Shields P.J. (1992). A role for cropping systems models in land evaluation. *National Soils Conference, Australian Society of Soil Science Incorporated,* 19–23 April 1992, Adelaide.

Thomas E.C., Gardner E.A., Littleboy M. and Shields P.J. (1995). The cropping systems model PERFECT as a quantitative tool in land evaluation: An example for wheat cropping in the Maranoa area of Queensland. *Australian Journal of Soil Research* **33**:535–554.

Thompson, D., Jackson, D., Tapp, N., Milham, N., Powell, R., Douglas, B., Kennedy, G., Jack, E. and White. G. (1996). Analysing drought strategies to enhance financial viability. Final report to LWRRDC and RIRDC, 164 pp.

Walker, P. and Young, M. (1996). INSIGHT: a future-orientated and spatially-explicit modelling system for evaluation of land use alternatives. Report from the CSIRO Division of Wildlife & Ecology to the Rural Industries Research and Development Corporation.

White, B. (1995). Beating the odds: research on weather and farmer decisions. *Proceedings of the National Outlook Conference,* 7–9 February 1995, Australian Bureau of Agriculture and Resource Economics, Canberra, **2**: 10–17.

White, B. (1995). The value and accuracy of climate prediction for land management. *AIAS Occasional Publication: Drought Forum 1995,* Australian Institute of Agricultural Science

White, D.H. (1996). Accessing and brokering Government-based resources information through the Internet. *Proceedings of the Australian Accredited Agricultural Consultants (AAAC) Annual Conference* on 'Consulting in the new extension environment', 9 August 1996, Canberra.

White, D.H. (1997). Risk assessment and management: Case study—drought and risk. *Proceedings of the National Outlook Conference: Commodity markets and resource management,* 4–6 February 1997, Australian Bureau of Agriculture and Resource Economics, Canberra, pp. 98–103.

White, D.H. and Bordas, V. (editors) (1997). *Proceedings of a workshop on Indicators of Drought Exceptional Circumstances,* 30 September–1 October 1996, Bureau of Resource Sciences, Canberra (in press).

White, D.H. and Howden, S.M. (1991). The emerging role of decision support systems in managing for drought on Australian farms. *Proceedings of the International Conference on Decision Support Systems for Resource Management,* College Station, Texas, April 1991, pp. 129–132.

White, D.H. and Karssies, L. (1997). Australia's National Drought Policy: aims, analyses and implementation. *Proceedings of the World Water Congress,* 1–6 September, Montreal, Canada (in press).

White, D.H., Howden, S.M., Walcott, J.J. and Cannon, R.M. (1995). Estimating the extent and severity of drought. *Proceedings of the International Congress on Modelling and Simulation,* University of Newcastle, 28–30 November 1995, 2, pp. 255–259.

Willcocks, J.R., McKeon, G.M. and Day, K.A. (1991). Using Southern Oscillation Index to predict the growth of *Heteropogon contortus* pasture in south-east Queensland. In *Proceedings of Conference on Agricultural Meteorology,* Bureau of Meteorology, Melbourne. 17–19 July 1991. pp. 36–39.

Yet, J.D.S. (1994). Improved runoff prediction in pasture growth models. Project Report, Faculty of Engineering and Surveying, University of Southern Queensland.

Yet, J.Y., Silburn, M., Carroll, C., McKeon, G.M. and Willcocks, J. (1994). Improved prediction of soil moisture and run off in pasture models Proceeding of 8th *Australian Rangeland Conference*, Katherine, June 1994, p192–194.

Young, M.D., and Walker, P.A. (1996) Resources Futures Program—natural resources accounting and economic instruments. CSIRO Division of Wildlife and Ecology.

Young, R., Lau, L., Hutchinson, M., Hunt, B., Graham, N., Goddart, L., Duncalfe, F., Burrage, K., and McKeon, G. (1997). Integrating Advanced GCM Seasonal Climate Forecasts, Fine Resolution Spatial Systems, and Dynamic Web Visualisation for Sustainable Environmental Management, invited full length paper, refereed proceedings, *International Conference On Mission Earth: Modelling and Simulation For A Sustainable Global System*, Phoenix 12–15 Jan 1997, USA The Society for Computer Simulation Publication pp 43–51.

Zebiak, S.E. and Cane, M.A. (1987). A model El Niño/Southern Oscillation. *Monthly Weather Review* **115**, 2262–2278.

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