Australian Government
Cotton Research and
Development Corporation

Annual, Progress and Final Reports

REPORTS

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number:		**DAQ104C**
Annual Report:	☐	Due end of September
Progress Report:	☐	Due end of January
Final Report:	☑	Due 30 September (or within 3 months of completion of project)

Project Title: Using seasonal climate forecasts for more effective grain-cotton production systems

Project Commencement Date: 1 Jul 1999 **Project Completion Date:** 30 Jun 2005
Research Program: Farming Systems Agronomy

Part 2 – Contact Details

Administrator: Helen Kamel, Senior Planning Officer
Organisation: Department of Primary Industries and Fisheries
Postal Address: PO Box 241, Darling Heights, Q. 4350
Ph: 07 46315380 **Fax:** 07 46315378 **E-mail:** helen.kamel@dpi.qld.gov.au

Principal Researcher: Graham Harris, Senior Development Extension Officer
Organisation: Department of Primary Industries and Fisheries
Postal Address: PO Box 102, Toowoomba, Q. 4350
Ph: 07 46881559 **Fax:** 07 46881197 **E-mail:** graham.harris@dpi.qld.gov.au

Supervisor: Dr H Meinke, Program Leader
Organisation: Department of Primary Industries and Fisheries
Postal Address: PO Box 102, Toowoomba, Q. 4350
Ph: 07 46881378 **Fax:** 07 46881477 **E-mail:** holger.meinke@dpi.qld.gov.au

Researcher 2 Lexie Donald,Research Scientist
Organisation: Department of Primary Industries and Fisheries
Postal Address: PO Box 102, Toowoomba, Q. 4350
Ph: 07 46881200 **Fax:** 07 46881199 **E-mail:** alexis.donald@dpi.qld.gov.au

Signature of Research Provider Representative: ______________________________

CRDC FINAL REPORT

Using Seasonal Climate Forecasts for More Effective Grain-Cotton Production Systems

SUMMARY

The project has made significant contributions to further our understanding of causes and consequences of climate variability and climate change.

Scientifically it has resulted in the publication of 3 international journal papers in renown climate science journals (Journal of Climate, Climatic Change and Geophysical Research Letters), 1 chapter in a text book for agricultural students and practitioners (Principles of field crop production) and approximately 20 conference papers. This led to better targeted follow-on research as well as increased recognition by the rural sectors about the value of climate and agricultural systems science to rural industries.

From an industry view, the project has helped to improve the management of climate sensitive systems by

- quantifying impacts and current limits to predictability of low-frequency variability (decadal variability and climate change) in economic and environmental terms
- identifying the MJO as a major contributor to intra-seasonal (high-frequency) climate variability
- providing an operational prototype of an MJO-based forecast system that has already proven very popular with rural practitioners
- providing scientific input into the debate on climate change and its likely impacts. The project has helped to identify adaptation options and highlighted the need for industry to become proactive regarding their overall attitude to climate change.

It was clear from the outset that ENSO/SOI-type information already forms an integral part of decision making. Hence, the project concentrated on (a) low-frequency variability at decades or longer (including climate change) and (b) higher frequency variability at the interface between weather and climate:

Climate change

Climate change is already impacting on production systems. Global temperatures have increased, with 5 of the hottest years on record occurring since 1998. Minimum winter temperatures across many parts of the world are on the rise. In many places wheat is now sown earlier and maturity types have been adapted accordingly. Although these changes are rarely attributed to climate change, these autonomous adaptations in agricultural systems management are a consequence of a changing climate. Such autonomous adaptation should be supplemented by proactive adaptation. This requires policy frameworks that encourage proactive risk management strategies and farm managers who are willing to adapt. Proactive adaptation will be necessary to complement climate change mitigation efforts. Project

outcomes have been discussed with eg QFF, leading to the attached press release from November 2005 (Appendix 1).

The Madden-Julian Oscillation (MJO)

The MJO is a large-scale, tropical atmospheric anomaly that originates in the Indian Ocean and propagates eastward at intervals between 30 to 60 days. The MJO sits at the interface between synoptic weather forecasting and seasonal, ENSO-based climate forecasting (3-monthly to seasonal forecasting). The passage of the MJO often results in rainfall and lower temperatures in many parts of Australia. They also influence the onset and break activity of the Asian-Australian monsoon system. The ability to forecast the next MJO passage could significantly improve tactical climate risk management by influencing decisions in relation to sowing opportunity prediction, disease management, harvest scheduling, irrigation scheduling, product quality management and marketing. This research has established the basis for such a capability.

BACKGROUND

The combined value of grain/cotton production in north-eastern Australia is approaching $2 billion per annum. Recent experience has clearly shown the considerable benefits and future potential of seasonal forecasting in agricultural systems management (Hammer, 1997; Carberry et al., 1997; Meinke et al., 1998). Although these studies show that cotton rotations can be intensified, profits increased and erosion risks reduced, the technology has not been rigorously applied and incorporated into the decision making of grain/cotton systems. It is unlikely that this will happen without a coherent effort like the one proposed in this project although some case studies show possible gross margin increases of 15% and a reduction in the erosion risk of 25%. Consistent with GRDC's aim to improve growers' skills in managing production and price risks this project will develop, enhance and extend cropping systems management approaches that incorporate knowledge of climate variability and forecasting. Managing successfully in response to climate forecasting requires some understanding of the underlying principles by systems managers as well as guidance in how to best apply forecast information. In response to the considerable demand by farmers, farmer groups and other rural enterprises, this project will provide such information for the better management of dryland grain/cotton systems.

OBJECTIVES & ACHIEVEMENT

1. Model testing and problem identification:

Demonstrated APSIM's systems simulation capability using data from existing experiments (e.g. the Cotton CRC Farming Systems Trial, Warra) and consult with researchers, advisers and growers to determine the key issues and constraints governing their management strategies (ie. systems analysis). This was undertaken with the three case study farms examined. This entailed detailed economic characterisation of the farming system.

2. Current and potential use of climate information and case study definition:

We reviewed the existing seasonal climate forecasting approaches including the extended-period seasonal forecasting systems. From this it was decided to conduct scenario analysis for the case study districts using SOI, ENSO, IPO and the DCV indices. Preliminary evaluation of the MJO (40 day wave) as an intra-seasonal forecasting tool was also completed. A MJO website (www.apsru.gov.au/mjo) was established and promoted - it can be used to determine the current state of the MJO and the likely implication of this for likely rainfall response across Australia.

3. Climate Forecasting - develop a suite of current and improved forecasting technologies suitable for decision making in grain/cotton systems and implement them in APSIM:

Assessment of the profitability and sustainability of using the SOI, ENSO, IPO and the DCV indices to aid decision making in cotton-grain farming systems using APSIM. Additionally, a preliminary evaluation of the MJO as a tactical decision making tool in these cropping systems was completed - further research incorporating the MJO analysis within APSIM has the potential to enhance future tactical decision making in these cropping systems.

4. Simulation Analyses - Conduct and analyse simulation case studies and the optimisation of systems management taking account of financial and environmental risks (link through the GRDC project on cropping systems optimisation). Investigate and report on issues related to the vertical integration of the industries and quantify potential pay-offs that might be associated with such a move:

Simulation analyses completed for three geographically distinct locations in the Northern Grains Region – Breeza (Northern NSW), Dalby (Southern Queensland) and Emerald (Central Queensland). Simulations were used to assess the effect of climate variability at these locations, its effect on monoculture and opportunity cropping systems and the usefulness of a range of seasonal forecasting systems in maximising the profitability of cropping systems. Sustainability indicators (runoff, erosion loss and deep drainage) were determined for these alternative cropping systems.

5. Communication and information flow - Consider practical relevance by maintaining on-going dialogue with clients (or their representatives) with capacity to act on results. This will include investigating the adoptability of proposed changes in farming based on the objectives, external incentives and resource constraints of grain/cotton farmers. This project will maintain close links with extension staff, key farmer collaborators and staff in affiliated projects.

Whole farm economic analyses of the simulations for most appropriate cropping systems were developed in close consultation with collaborating growers and their consultants. This output was delivered via farm visits with collaborating growers to develop “case study” farm models and assess output from simulations.

6. Targeted provision of information, training activities and workshops - Develop and provide training modules on managing with climate variability to be presented at workshops and grower meetings. This will ensure that the entire industry will be able to benefit from this research even after the termination of this research project.

The simulation analyses indicated that none of the decadal and seasonal climate phenomena and forecasts examined in this project were sufficiently useful to aid a grower choose between alternative cropping systems in order to maximise profitability at any of the three case study locations. As a consequence there was little value to be gained in incorporating information on the seasonal forecasting indices on the choice between cropping alternatives. However preliminary research on the MJO has indicated that it may prove useful for tactical decision making – further research on this is needed before its incorporation into climate variability training models.

7. General provision of information: Continue the provision of general, climate related information - under special consideration of grain/cotton systems - in the general media (radio, rural press, newsletters) and through specific publications (eg. GROUNDCOVER, Cottongrower) currently provided as part of a LWRRDC/GRDC project (this project will terminate in 1999).

Opportunities have been taken to increase understanding of the MJO during the course of the project. The lack of usefulness of the seasonal forecasting indices limits their usefulness for extension. A MJO website has been created which provides real time information on the current phase of the MJO and the associated rainfall probabilities for locations throughout Australia (www.apsru.gov.au/mjo). This information is made available through the fortnightly Current Climate Note (produced by Dave McRae, DPI&F, Toowoomba). This publication is distributed electronically to approximately 500 subscribers, is available at www.apsru.gov.au/mjo and is published widely in the rural press. The target audience g included grain-grain farming enterprises, agribusinesses and policy makers in Australian cotton and grains industries.

METHODOLOGY

Incorporated within Appendices 2, 3 and 4.

RESULTS

See Appendix 5 for results summary – detailed results in Appendices 2, 3 and 4.

DISCUSSION

The project has clearly demonstrated the whole-farm profitability and sustainability benefits of the adoption of opportunity cropping systems compared with monocultural systems in the Northern Grains Region. In this project monoculture wheat, sorghum and cotton systems were tested using the existing climate record for three locations representing the geographic extent of the region (Breeza, Dalby and Emerald). Several indicators of climate variability at a range of time scales were explored as part of this project:

- the SOI Phase Forecast System, which indexes the El Nino / Southern Oscillation (ENSO)
- an index representative of decadal climate variability at 9-13 years (9y 13y DCV, decadal correlation between seas surface temperature anomalies and mean seas level pressure)
- the Interdecadal Pacific Oscillation (IPO) - combining the Pacific low frequency seas surface temperature indices
- interactions between ENSO and DCV

At shorter, intra-seasonal time scale research was initiated on the effect of the Madden-Julian Oscillation (40-day Wave) on rainfall occurrence across Australia.

The effect of the SOI Phase on the performance of monocultural cropping systems differs between geographic locations and crops. For monoculture wheat the SOI phase in April of the year of planting failed to discriminate between wheat cropping seasons at Breeza, although there was some separation in gross margins between SOI phases at planting at Dalby and Emerald - the negative SOI phase has a lower gross margin then the positive SOI phase. For monoculture sorghum the SOI phase prior to planting affected its performance at Breeza and Emerald (a positive SOI improved returns) but not at Dalby where there is usually sufficient rain to successfully produce sorghum in most years. For monoculture cotton a positive SOI phase prior to planting enhanced gross margins at all three locations. In opportunity sorghum-wheat systems the SOI phase prior to planting affected performance at Dalby and Emerald, but had no effect at Breeza. In the opportunity cotton and sorghum system at Emerald the performance of cotton was more reliable when the SOI phase was positive prior to planting.

The ENSO classification of years into La Nina or El Nino years showed:

- for wheat the chance of a negative gross margin was increased in El Nino years at all three locations
- for sorghum the chance of a negative gross margin was increased in El Nino years at all three locations
- cotton is less risky if planted in La Nina years, particularly at Emerald.
- the wheat-sorghum opportunity cropping system masks the effect of the ENSO classification on crop returns - the biggest impact of a El Nino year is greatest at Breeza with this cropping system
- the opportunity cropping cotton-sorghum system at Emerald performs significantly better then monoculture sorghum in La Nina years
- the opportunity cotton, sorghum and wheat system at Dalby is unaffected by the ENSO classification

At the decadal time scale, the 9y 13y DCV index showed that:

- a negative phase slightly reduced the risk of a negative gross margin for wheat at Breeza and Dalby (but no effect at Emerald) * a negative phase improved the performance of sorghum at Breeza and Emerald (but not at Dalby)
- a negative phase improved cotton returns at Breeza but had no effect at Dalby or Emerald
- a negative phase improved annual gross margins for opportunity sorghum and wheat at Emerald (no effect elsewhere)
- for opportunity cotton, sorghum and wheat system at Dalby a negative phase reduced the risk of a negative gross margin from 30% to 10% of years (compared to a positive index)

At a decadal/ interdecadal scale, the IPO index showed:

- sorghum at Emerald (the chance of a negative gross margin increases from 10% in negative indices years to 17% in positive indices years
- cotton at Breeza and Emerald (at Breeza the chance of a negative gross margin increases from 25% in negative indices years to 35% in positive indices years; at Emerald the chance of a negative gross margin increases from 35% in negative indices years to 50% in positive indices years)
- The IPO index was not significant for opportunity cropping systems.

Initial research on the Madden-Julian Oscillation indicated substantial value for tactical decision making at intra-seasonal time scales across the Northern Grains Region. Hence, the project concentrated heavily on MJO-based applications and the provision of relevant MJO information for the grain/cotton industries. This led to the establishment of a prototype WEB site (www.apsru.gov.au/mjo) and to a major publication on the global impact of the MJO (Donald et al., 2006).

AUSTRALIAN COTTON INDUSTRY IMPACT

The research demonstrated the value of an opportunity cropping system approach to the incorporation of raingrown cotton in a grain cropping system. It showed the benefit of considering the ENSO when looking to plant cotton in Central Queensland with the economic performance of cotton is significantly less risky when planted in a La Nina year. At Dalby the ENSO classification had no impact on the profitability of an opportunity cotton, sorghum and wheat cropping system.

At the decadal time scale, a negative 9y 13y DCV index improved cotton returns at Breeza but had no effect at Dalby or Emerald. For opportunity cotton, sorghum and wheat system at Dalby a negative phase reduced the risk of a negative gross margin from 30% to 10% of years (compared to a positive index). It appears that the 9y13y DCV index is of limited value assisting growers improve the profitability of raingrown cotton.

The insignificance of the IPO index to on opportunity cropping systems demonstrates their relative resilience to low rainfall patterns.
For the Australian cotton industry the research has clearly shown the economic and sustainability value of producing raingrown cotton in a opportunity cropping system

with grain crops. Further research is needed to examine the likely effect of climate change on this system and how best to maximise its performance. Further research on the MJO is needed to quantify its tactical decision making value in both raingrown and irrigated cropping systems.

PROJECT TECHNOLOGY

Not applicable- no commercially significant developments, patents etc.

RECOMMENDATIONS

Summary

Climate is one of many risk factors that managers of climate sensitive systems need to consider. In discussion with stakeholders, the project team identified that in addition to ENSO-based information at seasonal time scales, climate change information and probabilistic forecasts for tactical decision making at the 2-week to 2-months timescale as the most important climate-related issues to be addressed.

Scientifically, the most pressing issues that need to be addressed are:

a) agricultural scenario development that translate climate change projections into quantitative management responses (ie. which crops to grow where and how as the climate changes around us) and

b) interactions between intra-seasonal variability (MJO related variability) and seasonal variability associated with ENSO.

Details

a) Climate Change

The economy viability of agriculture in many parts of Australia could be at risk if climate change is ignored. We need to better understand the effects of climate change at a regional level and investigate the range of possible responses before making decisions about when, where and how individual producers and the industry as a whole need to adapt. This requires appropriate policy initiatives that are currently impaired by the lack of policy relevant scientific information at a regional level. We need to bridge this gap by providing quantitative information about the exposure to climate risk and the coping capacity of the affected rural and water sectors. For this we need detailed scenario analyses that quantify the likely outcomes of alternative response options.

The better understanding of climate change impacts at a regional level should be provided through a single point of truth arrangement to minimize the risk of inappropriate decisions and inconsistent planning due to climate change projections coming from various sources. This would increase the collective resilience to cope with climate extremes and climate change and assist rural enterprises on the path to sustained economic growth.

b) Intra-seasonal climate variability

Better quantification and predictions of the onset, duration and termination of the northern Australian wet season would provide critically important information for better decision-making across the agricultural enterprises (grain, cotton, sugar, horticulture, grazing) and, in fact, other sectors (health, infrastructure development, tourism etc). Similarly, in Southern regions, better quantification of wet and dry spell characteristics would improve tactical decisions (eg pest and disease control, planting and harvest operation, marketing). Building on existing forecast capabilities and new forecast capabilities as the ones created by this project (eg MJO and ENSO-based climate knowledge) further research should target the specific needs of rural enterprises and develop mechanisms by which rural practitioners can gain ready access to such knowledge. Further R&D is required to investigate the dynamic linkages between weather/climate phenomena at intra-seasonal timescales with ENSO-related climate variability.

The project led to the following on-going R&D activities:

1) New project funded by L&W Australia under their MCV Program: Improving Prediction of the Northern Australian Wet Season, start date: 1 Feb 2006

2) Major input into the recently intensified debate about climate change and possible adaptive responses by rural industries (eg. input into roundtable discussions with QFF- see Appendix 1).

3) Information and approaches developed by this project now provide significant input into several GRDC funded Farming Systems Project, particularly the Central and Western Farming Systems Projects.

PUBLICATIONS

See Appendix 6

Appendix 1

QUEENSLAND FARMERS' FEDERATION

MEDIA RELEASE *10 November 2005*

QFF MEMBERS

Australian Prawn Farmers Association

CANEGROWERS

Cotton Australia

Emerging Primary Industries Group
- Australian Ginger Growers
- Biological Farmers of Australia
- Flower Association of Queensland Inc
- Queensland Aquaculture Industries Federation
- Qld Olive Associations Group

Growcom

Nursery & Garden Industry Queensland

Qld Chicken Growers Association

Qld Dairyfarmers' Organisation

Qld Irrigators Council Association Inc

Qld Pork Producers Inc.

Rural sector must adapt to climate change

Queensland's rural sector recognises that it needs to adapt to a changing climate and is pleased that the State Government is starting to act with the release of a Climate Adaptation Discussion Paper today, according to the Queensland Farmers' Federation (QFF).

Queensland Farmers' Federation Chief Executive Officer John Cherry said the paper acknowledges that changes in Queensland's climate are happening and will continue to do so, and that to make the best of change, opportunities should be explored and progressed.

"To date, most debate about climate change been largely concerned with the reduction of greenhouse gases, with little attention paid to facilitating adaptation and even less attention paid to exploring and progressing opportunities that might exist" he said.

"Reducing greenhouse gases is important, but it is only one side of the coin"

"Research suggests Queensland's rainfall could fall as much as 15% by 2030, with rain falling in shorter, more intense periods. Temperatures could rise by up to 2 degrees by 2030, and up to 6 degrees by 2070.

"A changing climate has variable implications for Queensland's rural industry, depending on the exposure and sensitivity to changes in climate patterns, its adaptive capacity, adverse implications, and the potential to benefit.

"To truly address the problem, a response must encompass not just the reduction of greenhouse gases but also adaptation strategies driven by opportunities.

"Earlier this year, QFF co hosted with the Regional Groups Collective a forum on climate variability, and last month convened a rural industry roundtable on how best to adapt to a changing Queensland climate.

"Climate adaptation is considered by QFF an important issue which links to other key farming issues such as water, but could also affect consumers choice of food and their consumption habits.

'Like all changes, a changing climate brings both risks and opportunities. Those who better understand the changes can adapt effectively to avoid the risks and seize the opportunities. The smart ones plan and prepare" he said.

QFF will be putting togther a a repsonse to the dicussion paper over the coming months. It will likely focuss on how the State Government can best support rural industires to plan and position themsleves to the make the best of a changing climate, even afuture with less water than it has been in the past..

For further information: John Cherry 0408 066 105

Queensland Farmers' Federation Ltd. A.C.N. 055 764 488 A.B.N. 44 055 764 488
PO Box 12009 George St, Level 6, 183 North Quay, BRISBANE QLD 4003
Phone: 07 3837 4747 Fax: 07 3236 4100 Email: qfarmers@qff.org.au
Web Site: http://www.qff.org.au

APPENDIX 2

GRDC Project DAQ469/CRDC Project DAQ104C

Using Seasonal Forecasts for More Effective Grain-Cotton Production Systems

Climate variability, climate forecasts and grain-cotton production systems at Breeza

November 2005

Table of contents

1. Summary of results

In terms of the aspects of cropping systems management that we considered, the results of this work are:

- Dryland cotton at Breeza on a 190mm PAWC soil is a relatively risky cropping system.
- Decadal variation for dryland cotton at Breeza is two to three times greater than that shown by wheat grown over the same period. On nine occasions over the decadal sequences, dryland cotton would have equalled or outperformed wheat.
- The climate was much more favourable for cotton growing during the second half of the 20th century than the first half.
- None of the potential or existing forecasting systems tested here seem to have the capacity to change the perception by many dryland farmers at Breeza that cropping systems including dryland cotton are relatively more risky than alternative cropping systems.

2. Introduction

The purpose of this report is to:

- Identify known sources of climate variability that may impact on farming systems common to the Liverpool Plains at Breeza, and
- Test the common dryland farming systems at Breeza for response to the known sources of climate variability
- Estimate the benefits available to farm managers at Breeza of responding to forecasts for the various sources of climate variability.

Forecasts that may identify the more **favourable climate sequences** for **the growing of dryland cotton** will be the main focus of this report.

The climate records of Breeza (Breeza records 1890 to 2003, Rainman version 4.3) will be used in the analysis of climate variability.

The Liverpool Plains farming district of northern NSW is seen as a reliable and profitable broadacre dryland-farming district that has enjoyed a relatively stable climate. It is also considered suitable for the growing of dryland cotton.

The Breeza district was mostly developed for dryland farming activities after the 1940's with the subdivision of some of the larger grazing properties for soldier settlement schemes. Much of the better cultivation soil has therefore been farmed for at least 50 years.

3. Climate variability

3.1 Potential sources of climate variability at Breeza

Rainfall variability in Australia (and northern NSW) is only partially explained by the El Nino – Southern Oscillation phenomenon (ENSO). Some of the other climate phenomena that combine with an inherently unpredictable chaotic component of climate to produce "climate variability" are identified in Table 1.

Table 1 Known climate phenomena and their return intervals (frequency) that contribute to rainfall variability in Australia (From Meinke and Stone 2004)

Name and/or Type of Climate Phenomena	*Reference*	*Frequency (approx. in years)*
Madden-Julian Oscillation, Intra-seasonal (MJO or ISO)	Madden and Julian (1972)	0.1 – 0.2
SOI phases based on El Niño – Southern Oscillation (ENSO), Seasonal to inter-annual	Stone *et al.* (1996)	0.5 – 7
Quasi- biennial Oscillation (QBO)	Lindesay (1998)	1 – 2
Antarctic Circumpolar Wave (AWC), inter-annual	White (2000b)	3 – 5
Latitude of Sub-tropical ridge, Inter-annual to decadal	Pittock (1975) Vines (1974)	10 – 11
Interdecadal Pacific Oscillation (IPO)	Zhang *et al.* (1997) Power *et al.* (1999)	13+
or Decadal Pacific Oscillation (DPO)	Tourre and Kushnir (1999) Mantua *et al.* (1997) Allan (2000)	13 – 18
Multi-decadal Rainfall Variability	Allan (2000)	18 – 39
Interhemispheric Thermal Contrast (secular climate signal)	Folland *et al.* (1998)	50 – 80
Climate change	Timmerman *et al.* (1999) Kumar *et al.* (1999)	???

3.2 Climate phenomena to be tested at Breeza

3.2.1 SOI phase forecast system

Variation in seasonal rainfall over much of northern and eastern Australia has been related to the El Nino and Southern Oscillation (ENSO) phenomena (McBribe and Nicholls (1983)). The monthly Southern Oscillation (SOI) is a key indicator of ENSO and can correlate significantly with rainfall in subsequent months.

The SOI phase forecast system is a probabilistic rainfall forecast system based on defined phases of the Southern Oscillation. (Stone & Auliciems (1992), Stone *et al.* (1996)) A variety of dryland cropping systems have been tested for response to the SOI phase forecast system described by Stone *et al* (1996)

3.2.2 ENSO classification

An ENSO classification provided by Potgieter (Potgieter *et al.* 2003) has been used to test relationships between the ENSO phenomena and cropping system results at Breeza.

Potgieter *et al.* (2003) derived El Nino and La Nina events in the period 1901-2002 using a classification system based on the **combination** of Extended Reconstructed Sea Surface Temperatures ERSST 18 and Troup SOI10 data sets. (See Appendix 1 for the classification of individual years)

Using the Sea Surface Temperature (SST) time series, a year was classified as El Nino if the 5-month running mean was greater than or equal to 0.5 for 6 or more months between April and December 19. Using the SOI time series, a year was classified as El Nino if the 3-month running mean was less than or equal to -5.5 for 6 or more months between April and

December 20. The La Nina classification was the opposite in sign of both the El Nino classifications for SST's and SOI's.

The threshold value for the classification of El Nino years based solely on SST or SOI yielded near 25% occurrence for each. Combining both classification systems resulted in 24 El Nino years and 22 La Nina years in the 102 years used in this analysis. See Smith *et al.* (2003), Trenberth KE (1997) and Ropelewski (1987) for the derivation of the base climate indices.

3.2.3 9y 13y DCV Index

Meinke *et al.* (2003) described correlations between global, low frequency sea surface temperature (SST) anomalies and seasonal rainfall in the tropics and subtropics, the North Atlantic region, India, northern Africa and Australia.

For their study they used factor scores from time series based on Empirical Orthogonal Function (EOF) analyses of (a) near-global SST and Mean Sea Level Pressure (MSLP) data (4 time series band pass filtered for significant frequencies) and (b) Pacific SST data alone (1 series).

The four frequencies for the combined SST and MSLP analysis were (i) 2.5 to 8.0 years representing the ENSO timescale; (ii) 9 to 13 years or decadal timescale; (iii) 13 to 18 years or inter-decadal timescale and (iv) 18 to 39 years or multi-decadal timescales (Allan 2000).

Meinke *et al.* (2003) report in addition to the traditional ENSO signal only "phenomena operating on decadal (9 to 13 years) and interdecadal (13 to 18 years) time scales produce significant modulations of annual terrestrial rainfall. The greatest and most coherent low frequency effect is evident at the decadal (9 to 13 years) timescale".

The frequency of the 9 to 13 years or decadal timescale index is graphed in Figure 1. The index will be referred to as the **9y 13y DCV** index in this report.

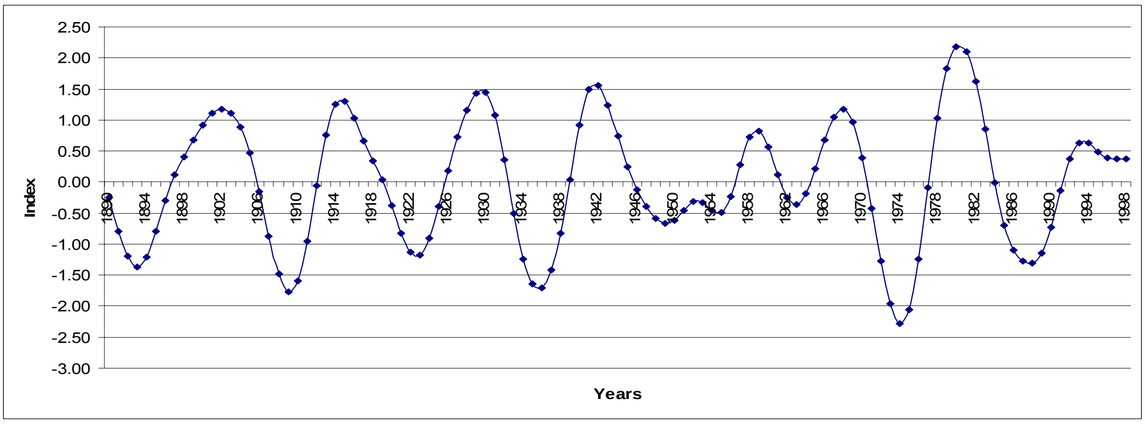


Figure 1 Graph of Decadal Climate Variability 9y 13y index values

Meinke *et al.* (2003) found that the decadal frequency domain (9y 13y DCV index) *had most affect in central eastern Australia during the January to March period*. When index values are negative, rainfall in this period may be enhanced. When index values are positive, rainfall values in this period could be suppressed.

Other research has shown that indices of decadal climate variability corresponded with variations in soil water drainage. (Keating *et al.* 2003)

Climate scientists have also proposed that climate phenomena occurring at decadal to multi-decadal timescales can modify ENSO leading to the enhancement of ENSO impacts.

(Kleeman and Power (2000), Meehl *et al.* (2001)) Enhancement in this case means that dry periods are expected to be dryer and wet periods are expected to be wetter when the correct alignments of the longer-term climate phenomena and ENSO occur.

An example of this enhancement may have been the La Nina events of the early 1970's that coincided with a negative phase of the 9y 13y DCV index. Considerable flooding and above average rainfalls were encountered by eastern Australia during this period.

3.2.4 Interdecadal Pacific Oscillation

Power *et al.* (1999) found that many of the Pacific Low Frequency SST based indices are similar and can be combined into what is collectively known as the Inter-decadal Pacific Oscillation (IPO).

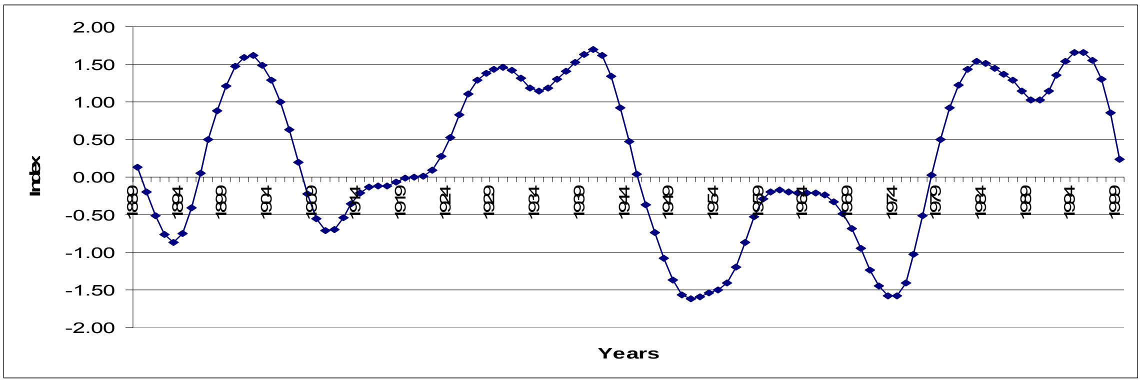


Figure 2 Inter-decadal Pacific Oscillation phase values

Meinke *et al.* (2003) found that there was no statistical relationship between annual rainfall and the phase value of the IPO. They did find a significant relationship between the phase value of the IPO index and January to March quarter rainfall. Similar to the 9y 13y DCV index, when IPO values are negative rainfall in this period may be enhanced and when IPO values are positive rainfall values in this period could be suppressed.

3.3 Climate variability at Breeza

3.3.1 Monthly rainfall recorded at Breeza

Table 2 Monthly rainfall recorded at Breeza composite (Australian Rainman version 4.3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	72	61	47	39	41	43	41	39	39	53	59	65	600
Median	54	45	30	32	32	34	32	31	32	50	48	63	604
Standard deviation	62	56	48	35	35	34	34	32	29	37	44	41	165
Highest on record	313	238	241	169	178	190	193	154	120	154	217	193	1,133
Lowest on record	0	0	0	0	0	0	0	0	0	1	1	0	258
Mean rain days	6	5	4	4	5	6	6	6	5	6	6	6	65
No. of years	120	120	120	120	120	119	119	119	119	119	119	119	119

Median monthly rainfall at Breeza is less variable than Emerald and more reliable during the autumn and winter months than Dalby. Median monthly rainfalls for Emerald, Dalby and Breeza are shown in figure 3.

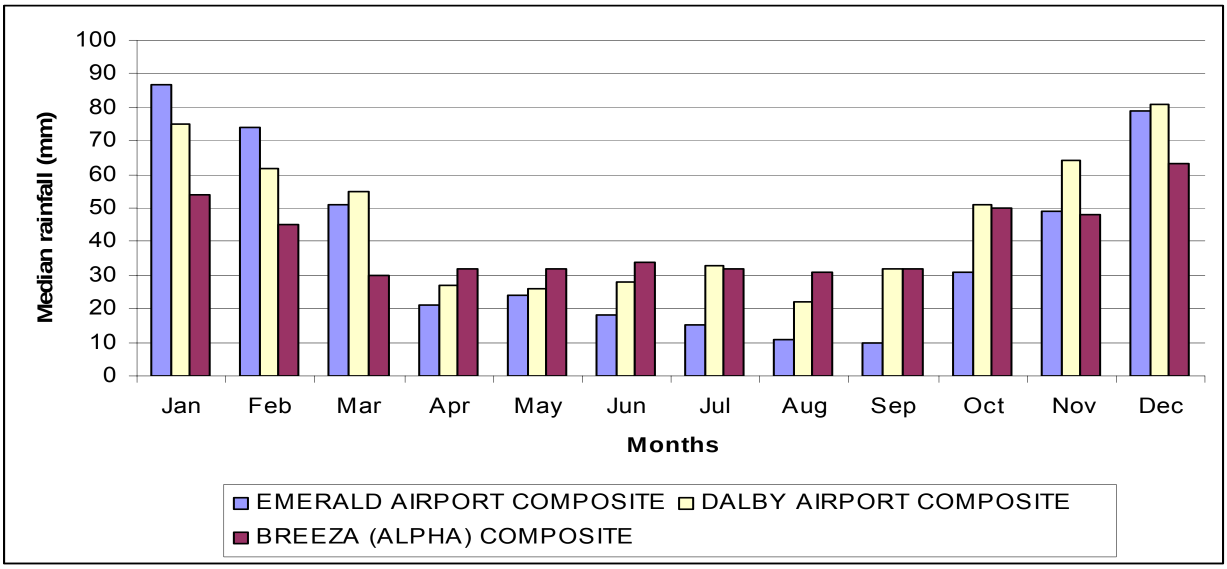


Figure 3 Median monthly rainfalls for Emerald, Breeza and Warra. (Australian Rainman version 4.3)

3.3.2 Droughts calculated on Breeza composite rainfall

Drought has been quantified in a number of ways. Some processes rely on dividing the rainfall observations into deciles. Kinninonth et al (2000) suggested that if the observed precipitation total for the preceding three months falls within the lowest decile of the historical distribution of 3-month totals, then the region is considered to be "drought affected".

Rainman (Clewett et al (2003)) defines drought (or severe rainfall deficits) as a 12-month period that receives less rain than in the driest 10% of calendar years. A severe drought is classified on the basis of the driest 5% of years for each 12-month period. A moderate drought is classified as the second driest 5% of years. A drought ends when rainfall records fall into the wettest 10% of years. Droughts may start in any month. Total number of droughts in the 120 years from 1883 to May 2003 equals 22 (Table 3).

Table 3 Drought periods for Breeza (Australian Rainman version 4.3)

Drought	Period	Duration (months)	Total rainfall (mm)	% of time in severe drought
1	Dec 1884 to Nov 1885	12	377	0
2	Sep 1887 to Mar 1889	19	672	25
3	Jul 1900 to Mar 1903	33	1,000	50
4	Aug 1905 to Jul 1906	12	371	0
5	Apr 1914 to Oct 1916	31	991	5
6	Jan 1918 to May 1920	29	801	72
7	Mar 1922 to Dec 1923	22	687	9
8	Dec 1924 to Jan 1926	14	446	0
9	Oct 1926 to Sep 1927	12	358	0
10	Jul 1928 to May 1930	23	746	8
11	Sep 1931 to Aug 1932	12	391	0
12	Oct 1938 to Dec 1940	27	792	63
13	Apr 1941 to Jun 1942	15	406	100
14	Jan 1944 to Dec 1944	12	348	0
15	Jul 1945 to Jun 1947	24	703	85
16	Jun 1964 to Apr 1966	23	755	50
17	Oct 1971 to Sep 1972	12	386	0
18	Feb 1974 to Jan 1975	12	352	0

19	Feb 1980 to Jan 1981	12	295	100
20	Nov 1981 to Apr 1983	18	688	57
21	Apr 1994 to Aug 1995	17	433	33
22	Nov 2001 to Feb 2003	16	599	0

3.3.3 ENSO frequency

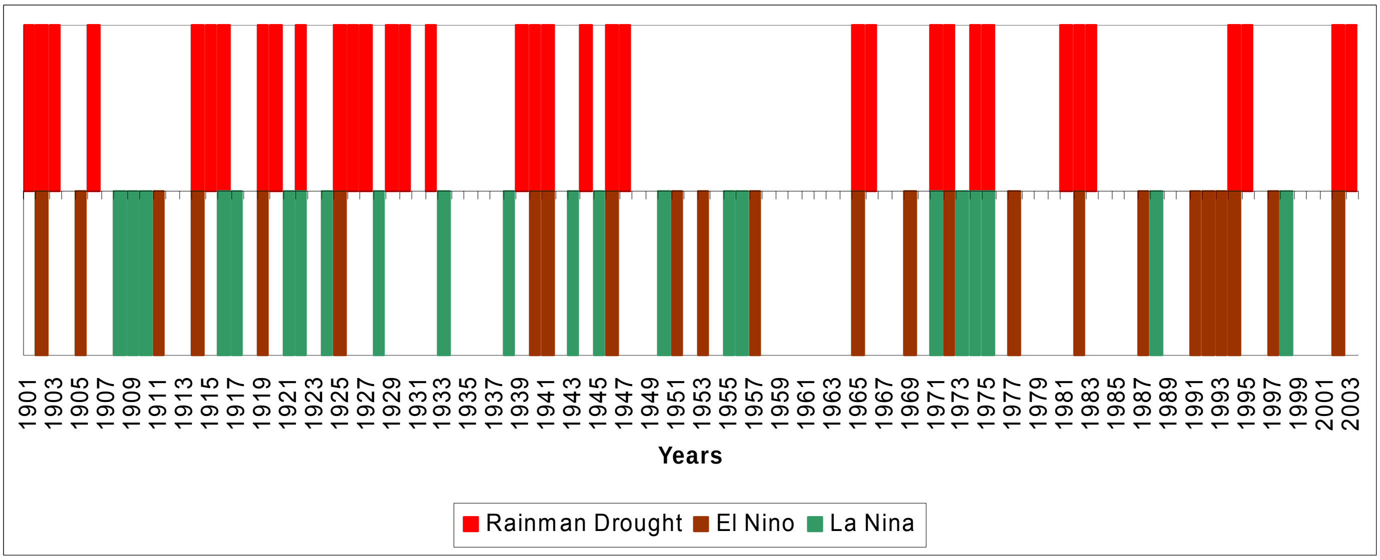


Figure 4 Frequency of El Nino and La Nina events since 1901 at Breeza (Potgieter *et al.* 2003) plus drought (Rainman 4.3)

The classification system provided by Potgieter (2003) indicates that there have been 22 La Nina events from 1902 to the end of 2003 at an average frequency of one every 4.5 years (Figure 4). For the 27-year period since 1976 there have only been two. The frequency of La Nina events from 1902 to 1975 was one every three to four years.

The years classified as drought years by Rainman version 4.3 (Clewett *et al.* 2003) and the years classified as El Nino by Potgieter *et al.* (2003) do not always coincide (Figure 4).

3.3.4 ENSO trends

The frequency of El Nino and La Nina per thirty-year period has varied markedly since 1902. (Figure 5) Over this time period the El Nino phenomena has become much more frequent and the La Nina phenomena has become much more infrequent.

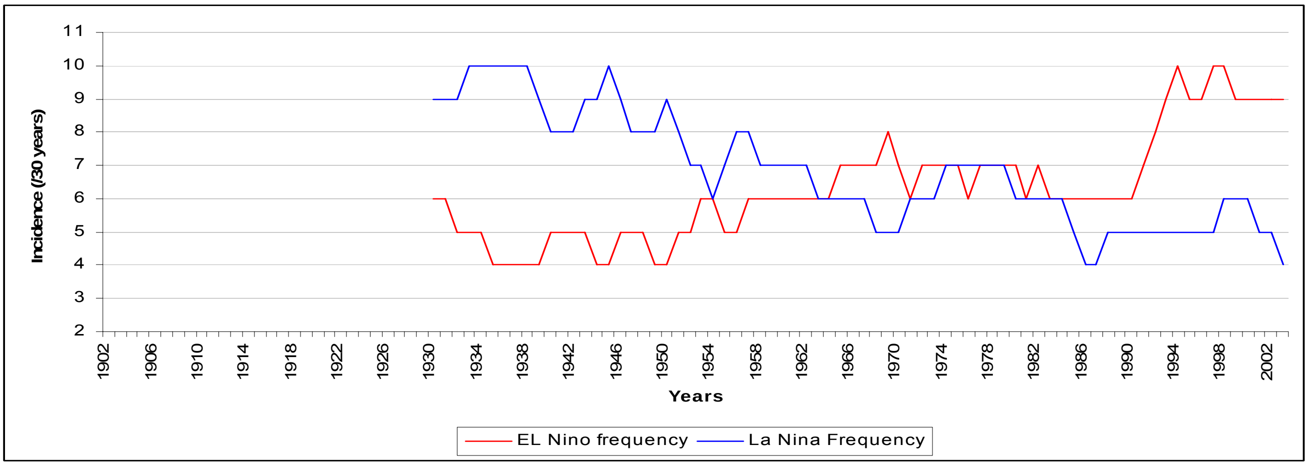


Figure 5 30 year frequency of El Nino and La Nina based on classification of Potgieter *et al.* (2003)

3.3.5 Rainfall trends at Breeza

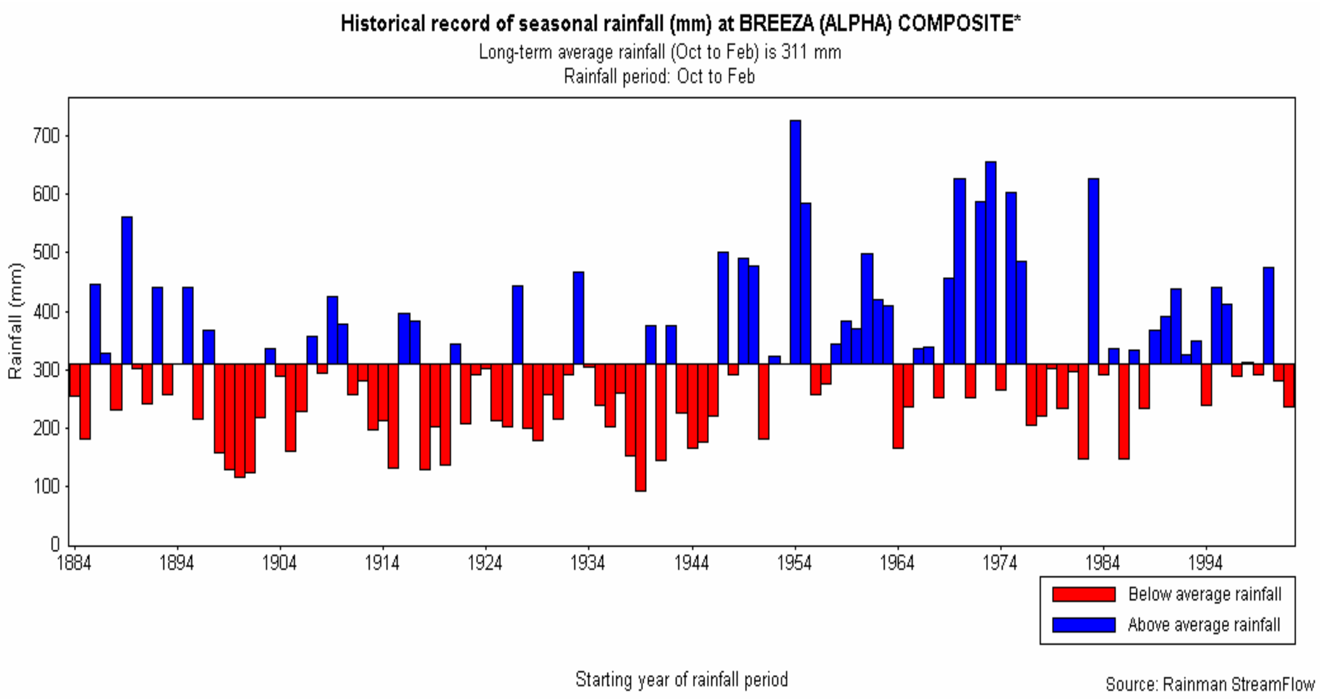


Figure 6 Seasonal rainfalls for summer cropping at Breeza (source Rainman 4.3)

Breeza summer cropping rainfall shows considerable variability but indicates that summer rainfall has been above average more often than not since the middle 1940's.

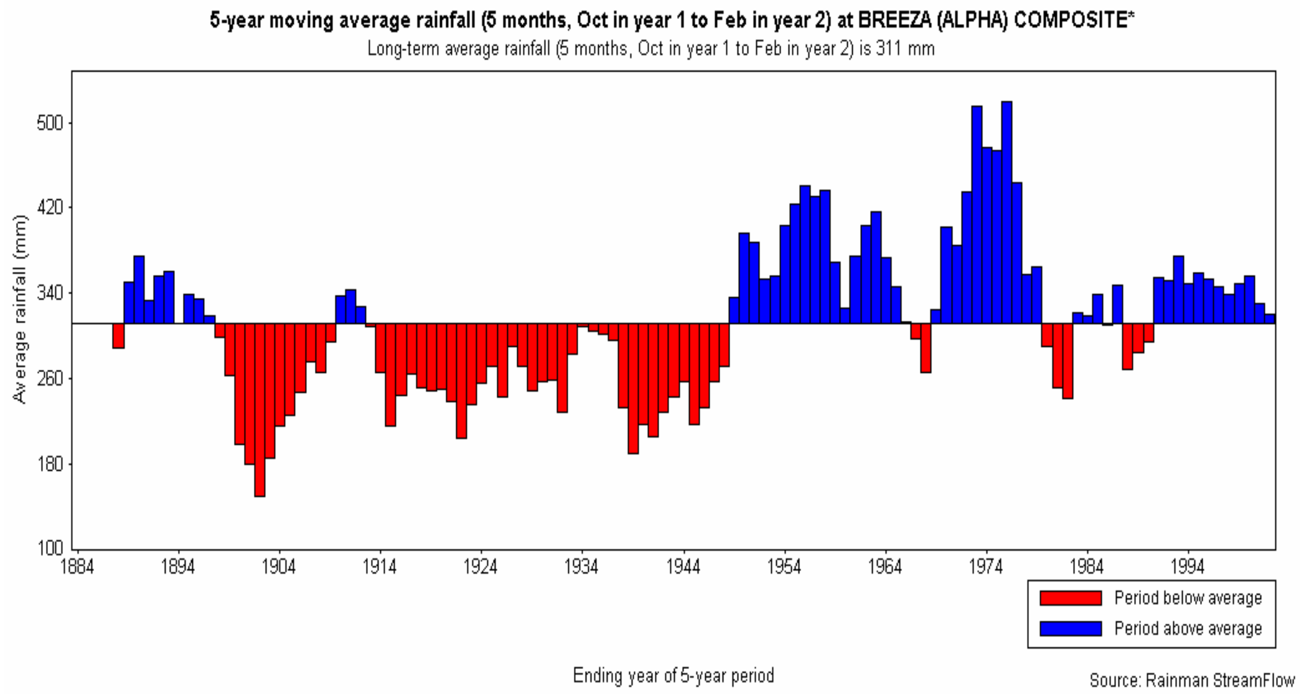


Figure 7 5-year moving average summer cropping rainfall at Breeza (source Rainman 4.3)

A five-year moving average for summer rainfall at Breeza shows a significant increase in summer cropping rainfall reliability during the second half of the 20th Century.

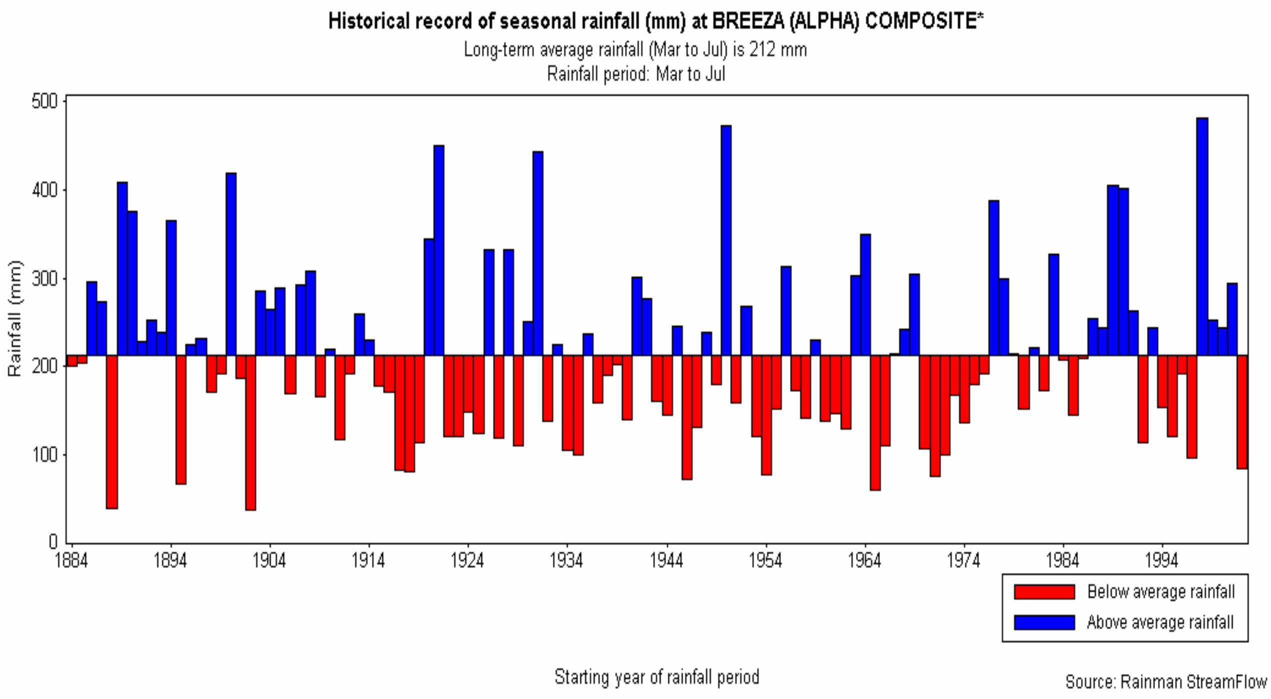


Figure 8 Winter cropping rainfall at Breeza (source Rainman 4.3)

Above average and below average years seem to be more equally spaced for winter cropping activities at Breeza.

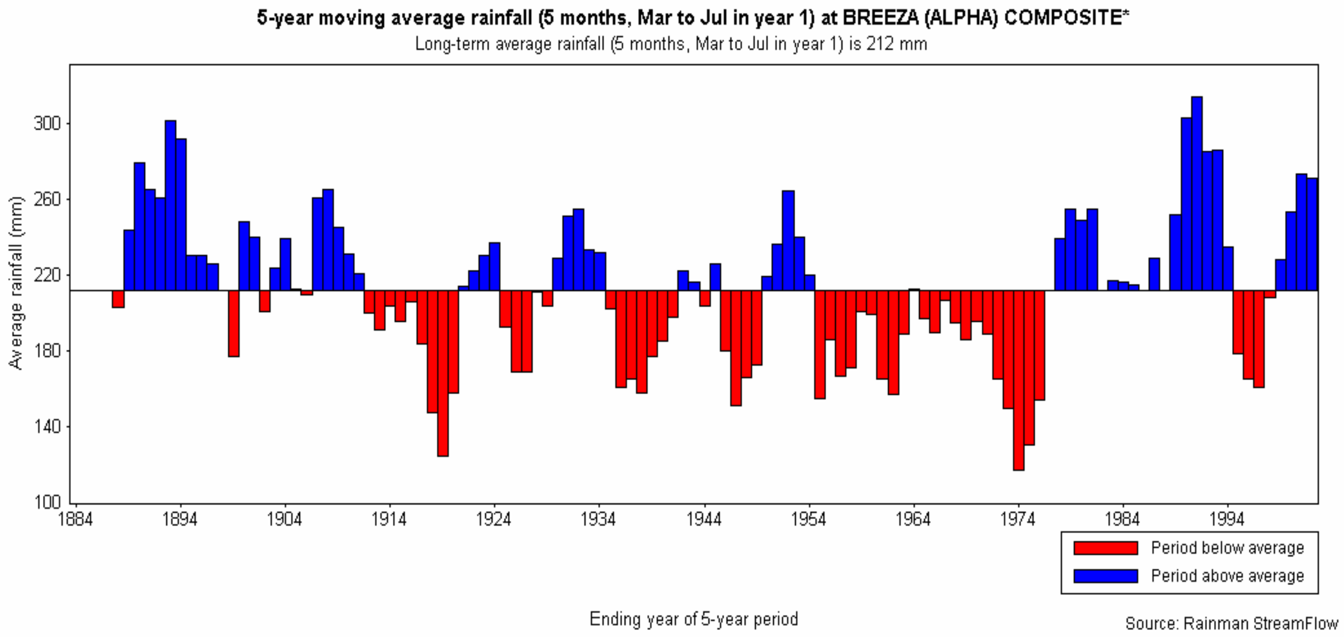


Figure 9 5-year moving average winter cropping rainfall at Breeza (source Rainman 4.3)

Breeza encountered periods during the early part of the 20th Century when both summer cropping and winter cropping rainfall were both below average. This does not seem to have happened in the second part of the 20th Century.

4. Climate variability and cropping system success

Rainfall amount is not the only determinant of plant growth. Starting soil water, temperature, planting dates, rainfall intensity and rainfall timeliness will strongly influence crop yield.

Simulation models can integrate all these effects in a physiologically meaningful way to indicate the impact of climate variability on cropping system success.

The benefits of simulating cropping systems to consider impact of climate variability can be listed as:

- Climate and management effects on cropping systems can be integrated in a meaningful way
- It is a cost effective alternative to field experimentation
- A large number of combinations can be assessed
- Inter-relationships between sustainability, resilience and productivity of cropping systems can be assessed
- A predictive capacity can be developed for agricultural system outcomes, that is, relationships can be quantified in probabilistic terms.

4.1 APSIM model

APSIM is a daily time step model that mathematically reproduces the physical processes taking place in a cropping system. This calculation of daily outcomes within the model allows the collection of cropping system outputs on a time basis and/or event basis.

APSIM can be run for any number of days up to the total length of suitable climate records.

Cropping systems modelled in APSIM can:

- respond accurately to rainfall incidence and effectiveness;
- reflect soil water balance over time;
- calculate dates for events and time spans between events,

to generate expected crop yields and cropping frequency for the climate period modelled.

When this information is combined with farm economic data, the financial impacts of alternative management systems can be related to specific sequences of climatic events or states of the farming system.

For example, the annual gross margin for each cropping system can incorporate variable fallow costs that respond to the amount of rainfall and the number of days of the fallow period between crops.

Fallow costs relating to specific crops can also be included along with variable fertiliser costs that responded to the efficiency of soil N use by the cropping system.

The costs of crops that are planted and then fail or have yield significantly reduced by seasonal conditions can also be accounted for.

In this way the costs associated with the cropping system can be made to respond to the type of crops grown, the intensity of the cropping system and the climatic conditions encountered by the cropping system.

There are some limitations to this modelling approach.

- APSIM has to be configured specifically for each location.
- APSIM plants crops on a single day with an even plant establishment plus optimal plant population and spacing.
- APSIM crops are grown without significant weed or insect competition and do not suffer harvest losses or frost damage.
- APSIM crops and rotations respond only to the crop sequence characterised during model initiation. They do not respond over time to changing price relationships or the timeliness of alternative farming systems.

The limitations of APSIM need to be remembered when the results of simulations are being interpreted.

5 Climate forecasts and Breeza cropping systems

5.1 Monoculture wheat

Wheat has been the dominant crop in both area planted and tons produced in Northern NSW and for this reason it will be used as a benchmark for alternative cropping systems in this analysis.

5.1.1 Wheat yield and protein

The long term farming history of the Liverpool plains means that most cropping soils currently have a low residual fertility after any individual cereal crop. This low soil fertility together with the potentially high level of soil water storage used in our analysis (190mm PAWC) means that correct fertiliser rates have to be applied for optimum yields and protein content to be achieved.

The impact of climate variability, especially the response to better seasons, will be reduced if soil nitrogen and not soil water limits crop yield.

To test the response of wheat grown at Breeza to both soil nitrogen and soil water, a number of simulations of APSIM were undertaken with fertiliser N applied at different rates. For all runs the initial soil fertility was set at 35kg N per ha.

Nitrogen fertiliser was applied at three separate rates.

1. A fixed rate of 40 kg N per hectare per crop planted.
2. A variable rate that applied fertiliser N so that available soil N was 100 kg N per hectare at planting, or
3. A variable rate that applied fertiliser N so that available soil N was 150 kg N per hectare at planting.

Another scenario that showed the impact of unlimited soil N on potential yield was also simulated.

The total yield per decade for each of these fertiliser or fertility scenarios is shown in figure 10 for 22 overlapping decades since 1890. The last decade beginning 1995 has only eight cropping opportunities completed in this analysis.

Conditions under which wheat could be planted by the model were set to mimic the current expectations of Breeza farmers. The planting window opened in the third week of May and closed at the end of July. For a planting to occur, stored soil water had to be at least 75mm and 25mm of rain had to occur over the previous 20 days. The soil surface also had to be sufficiently dry for the planting operation to take place. Crops were planted in sequence to show the impact on soil water and soil N on the potential yield of crops grown under continuous cropping conditions at Breeza.

During the first half of the climate record, wheat yield generally showed an unremarkable response to fertiliser N. For example, in the decades beginning 1910 and 1935, increasing the amount of soil N available at planting by 50% increased the total yield for the respective decades by only 0.6% and 0.1%. Water not soil N obviously limited yield during these decades. During the second ½ of the climate record all decadal yields were increased by at least 20% and normally by more than 25% with a similar application of fertiliser. During this period the yield was limited more by N than water.

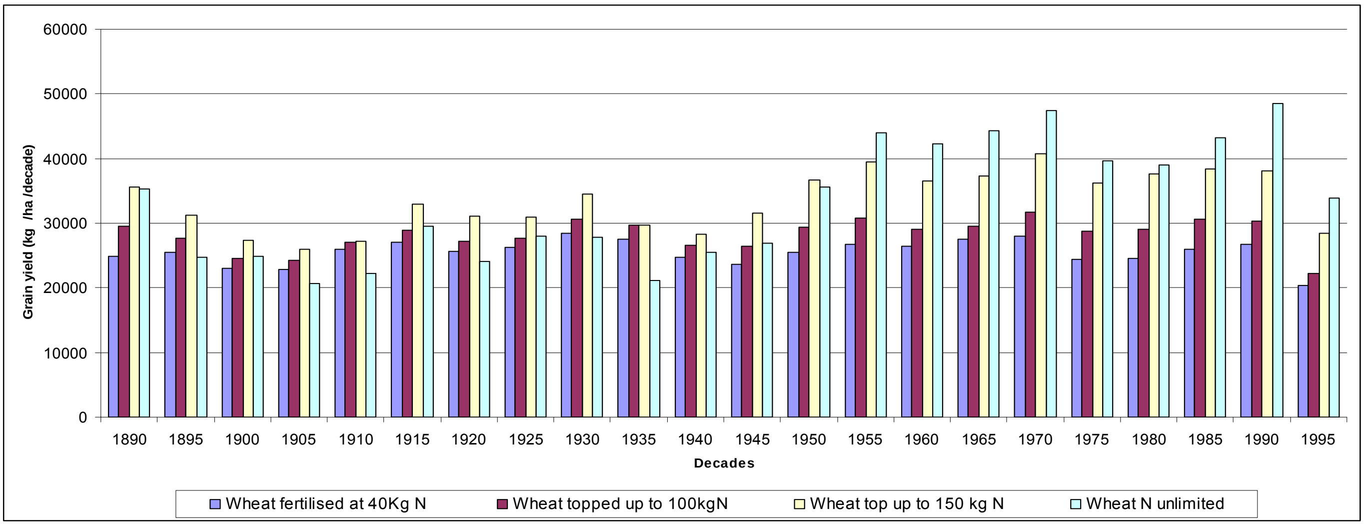


Figure 10 Modelled yields and cropping frequency for monoculture wheat at Breeza for planting years 1890 to 2003 on a 190mm PAWC soil

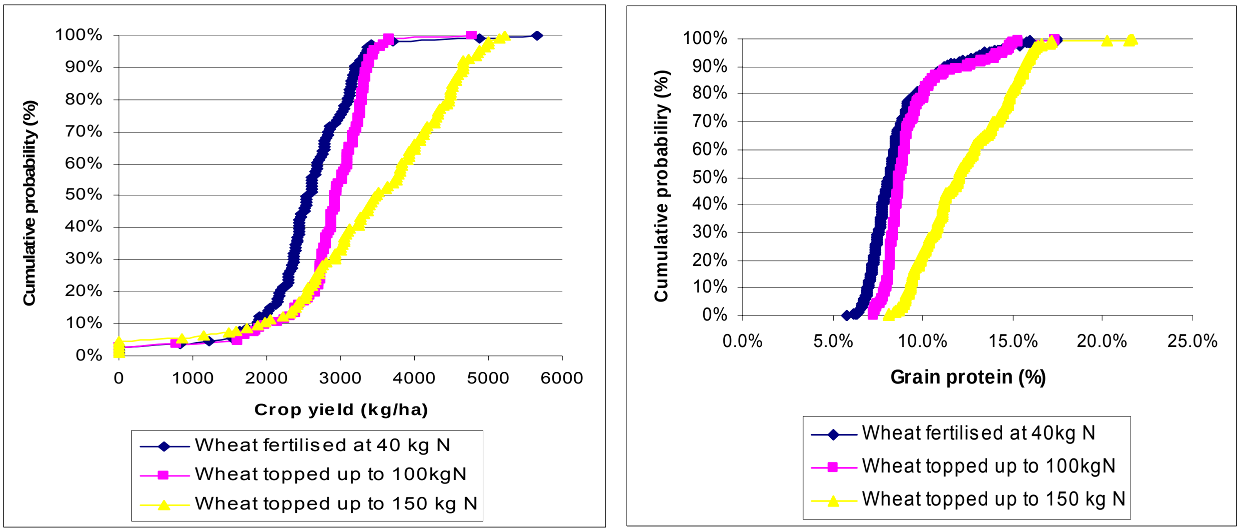
The yield response to having unlimited N is slightly different. (Figure 10) The generally dryer decades earlier in the century had lower total decadal yields than the fertilised scenarios. This is thought to be the impact of wheat crops with unlimited N producing greater amounts of dry matter and drying out the soil profile. This occasionally prevented the planting of the next crop. The number of years in which wheat was not planted was double for the unlimited N scenario compared to the 150 kg N scenario. Many of these extra years occurred early in the climate record.

Although the unlimited N scenario in unrealistic, the more than doubling of potential decadal yields shown during the last 50 years of the analysis compared to the first 50 years indicates much mo Grain yield exceeded 3.5 t/ha in 50% of years when soil N was topped up to 150 kg N at planting. (Figure 11a) Few yields above 5 t/ha have been generated due to the planting conditions chosen, the variety planted and the cropping system modelled.

The modelled cropping system grew crops in sequence and relied upon the antecedent and contemporary climate conditions for the success of the crop. Other wheat cropping scenarios that missed a greater number of planting opportunities achieved wheat yields above 6 tonnes per hectare with occasional yields greater than 8 tonnes per hectare. The scenario modelled placed the ceiling on yields, not the APSIM model.

re soil water became available for grain production in this region over the latter period.

This analysis will use the 150 kg N fertiliser strategy to test the value of responding to a climate forecast at Breeza.



(a) (b)

Figure 11 Distribution for monoculture wheat yields (a) and grain protein (b) at Breeza for all years 1890 to 2002

The distribution of grain protein indicates that the 150 kg N fertiliser strategy also impacted significantly on grain protein. (Figure 11b)

The response of modelled grain protein to extra fertiliser (Figure 11b) and the relationship between modelled grain yield and modelled grain protein % (Figure 12) seem to reflect industry expectations.

Overall the outcomes for the modelled wheat cropping system are seen as reflecting the expected range of outcomes for a zero till continuous wheat farming system at Breeza.

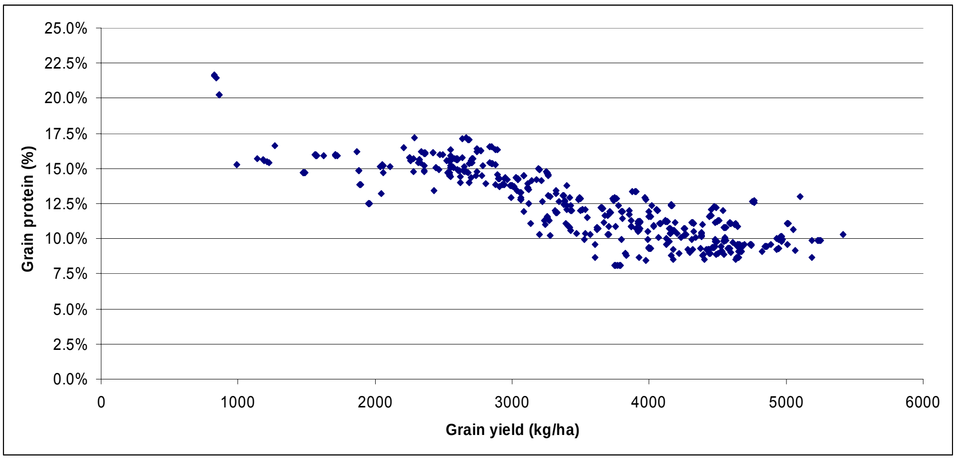


Figure 12 Relationship between modelled yield and modelled grain protein for wheat grown at Breeza on a 190mm PAWC soil fertilised so that 150 kg N was available at planting

5.1.2 Wheat gross margin

Modelled yields and proteins produced by the planting and fertilising scenario can be used to generate gross margins for the years 1890 to 2002. Costs and returns have been held constant at current prices for the entire climate record.

Table 4 On farm wheat prices and protein premiums selected for Breeza analysis

Protein %	**$ /ton on farm**
2.00%	$145.00
3.00%	$145.00
4.00%	$145.00
5.00%	$145.00
6.00%	$145.00
7.00%	$145.00
7.50%	$145.00
8.00%	$145.00
8.50%	$145.00
9.00%	$145.00
9.50%	$145.00
10.00%	$160.00
10.50%	$162.50
11.00%	$165.00
11.50%	$167.50
12.00%	$170.00
12.50%	$172.50
13.00%	$180.00
13.50%	$182.50
14.00%	$185.00
14.50%	$187.50
15.00%	$190.00

At the on farm prices chosen, a gross margin greater than $350 per ha could have been expected in 50% of years (Figure 13). Wheat prices have varied between $90 and $350 per ton on farm in the past decade. This range of values for price should also be remembered when cropping systems are being compared.

Negative gross margins were produced in about 5% of years by monoculture wheat on a 190mm PAWC soil at Breeza (Figure 13).

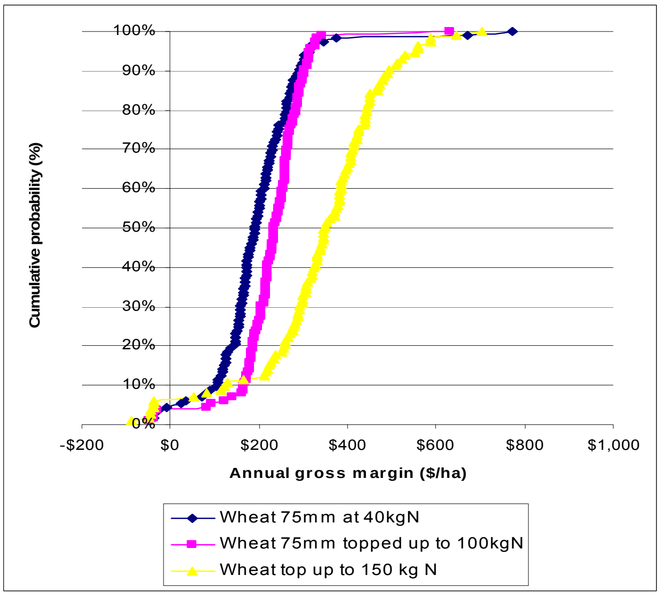


Figure 13 Distribution for modelled monoculture wheat annual gross margins at Breeza on a 190mm PAWC soil.

Modelled annual gross margins for dryland wheat production at Breeza have fallen below the median about fourteen times since 1960 or about 32% of times. (Figure 14) This is half the long-term expectation. For the first 50 years from 1890 wheat gross margins were below the long term median 64% of times. (Data not shown) This indicates wheat growers at Breeza have experienced significantly less variability due to climate since 1960 than their modelled counterparts would have in the first part of the century.

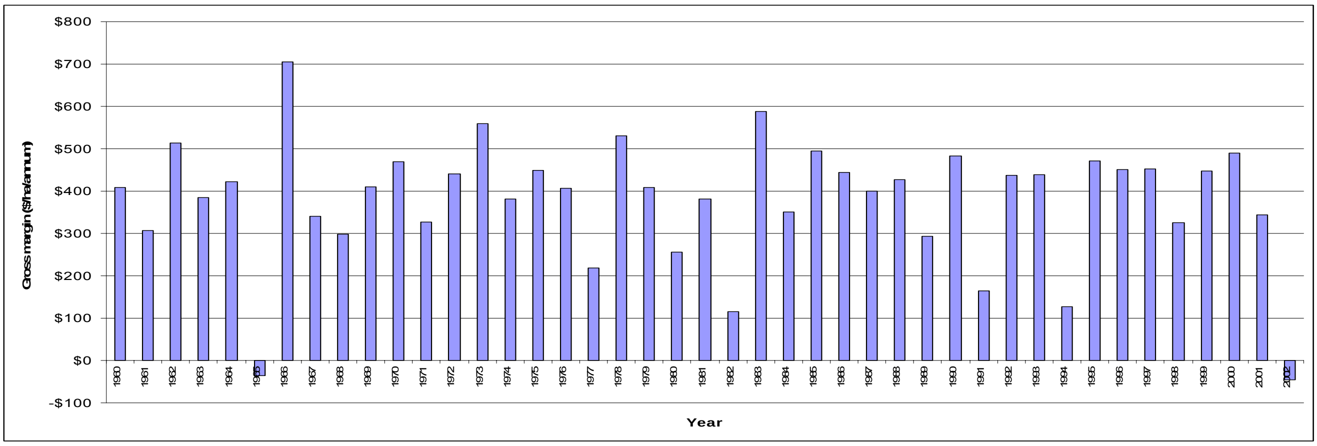


Figure 14 Annual gross margins for modelled monoculture wheat yields at Breeza on a 190mm PAWC soil (1960 to 2002 harvest years).

Decadal gross margins are the total annual gross margin for each decade beginning in 1890 and continuing to 1995. Each total figure shown in figure overlaps the previous by five years. The decade beginning 1995 contains eight cropping season not ten.

The total gross margin for any decade can vary by up to 25% around the median value for the total period modelled due to the impact of climate. (Figure 15) Note that the total gross margin for each decade overlaps by five years and therefore tends to smooth out some of the decadal fluctuations in returns.

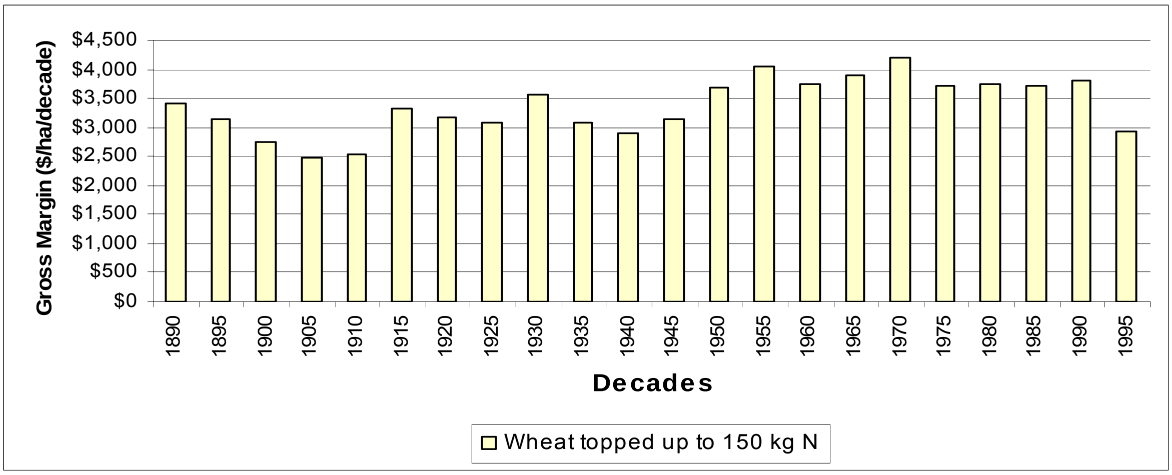


Figure 15 Total gross margins by decade for monoculture wheat at Breeza.

The variability in decadal performance is driven by the prevailing climate with some constraints applied by the fertiliser strategy and the farming system chosen. Both of these constraints tend to dampen the variability in returns due to climate. Farm managers who used higher fertiliser rates and or longer fallows would experience a greater variability in returns.

The wheat cropping system at Breeza is unable to use all of the extra water available from a wetter than average climate sequence. A considerable amount of the additional water is lost as drainage. (Figure 16)

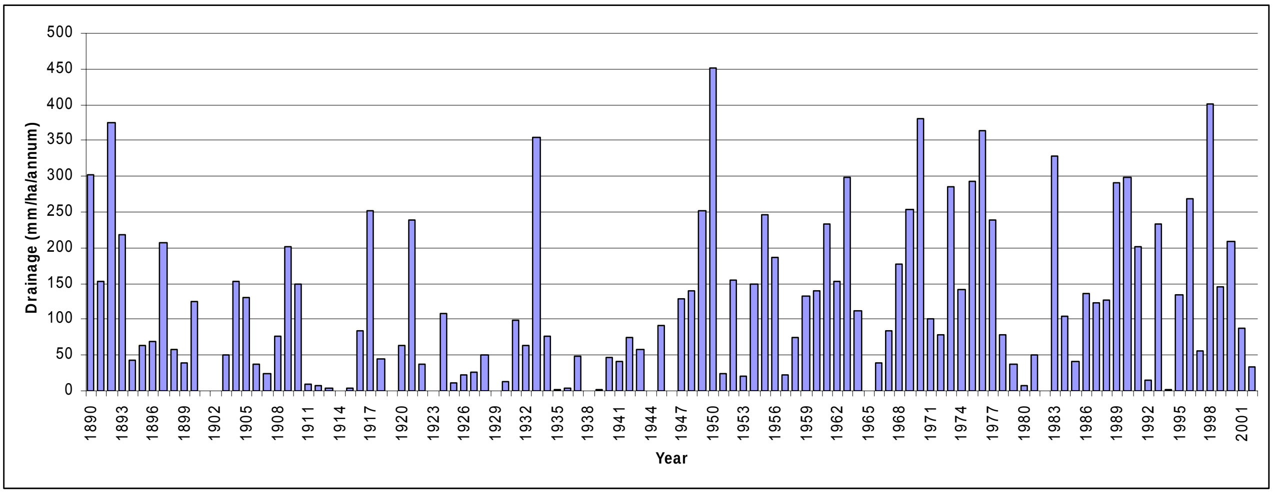


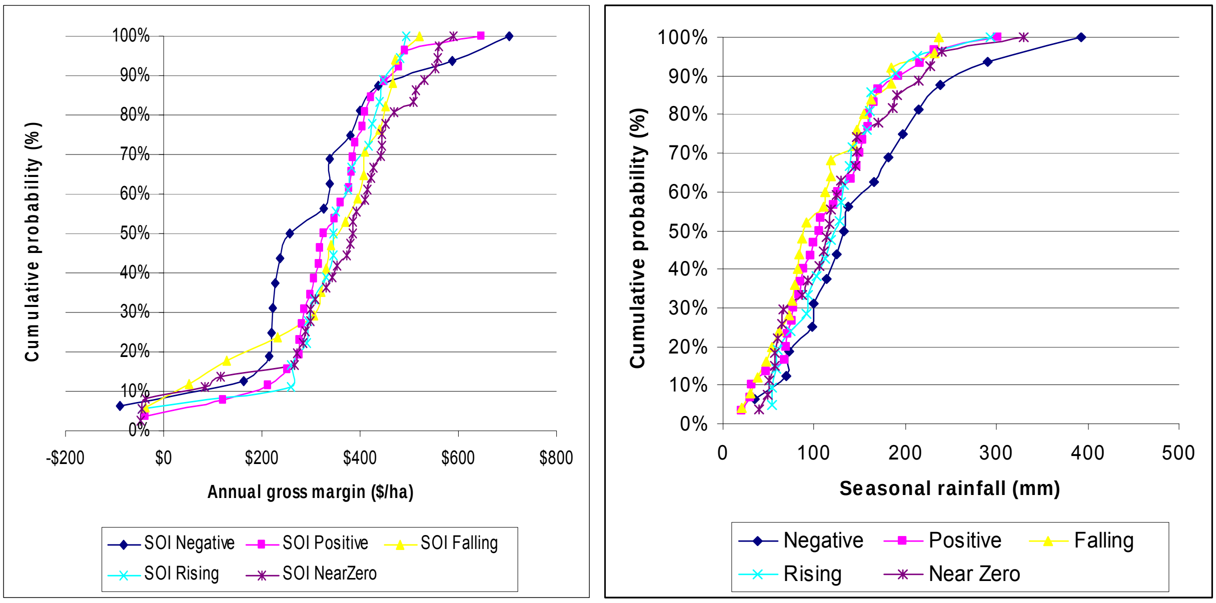
Figure 16 Modelled annual drainage for a monoculture wheat cropping system at Breeza (1890 to 2002)

5.1.3 Monoculture wheat response to climate phenomena at Breeza

SOI phase

The SOI phase is the most likely forecast tool that a farmer intending to plant wheat at Breeza will have available to support decisions about how the crop is managed. Most of these management decisions will have to be made prior to the crop being planted which means that the SOI phase at the end of April will be the phase most likely to be used in the decision making process.

Rainman 4.3 finds that that the phase of the SOI in April at Breeza is statistically unable discriminate seasonal rainfall in the months of May, June and July. (Figure 17b)



(a) (b)

Figure 17 Monoculture wheat distribution of annual gross margin at Breeza on a 190mm PAWC soil separated on the basis of the SOI phase in April of the year of planting

Dryland wheat planted at Breeza in those years with a SOI negative phase in April possibly shows a lower, but not significantly lower, potential gross margin in about 40% of years. (Figure 17a) The SOI phase in April of the year of planting does not discriminate between wheat cropping seasons at Breeza. There is no statistical difference between the gross margin distributions.

ENSO classification

Annual gross margins for dryland wheat production at Breeza were separated on the basis of the ENSO classification of the year of planting (Figure 18). (Note: ENSO classifications are for calendar years not seasons)

The cropping results for wheat planted in El Nino years are significantly different to the range of outcomes expected in years classified as La Nina or Other years. The chance of suffering a negative gross margin increases from 2% of years in La Nina and Other years to about 25% in El Nino years. The modeled median gross margin falls by about 45% from La Nina and Other years to El Nino years.

Unfortunately there is currently no way of forecasting El Nino years at a time when cropping decisions are being made for wheat at Breeza.

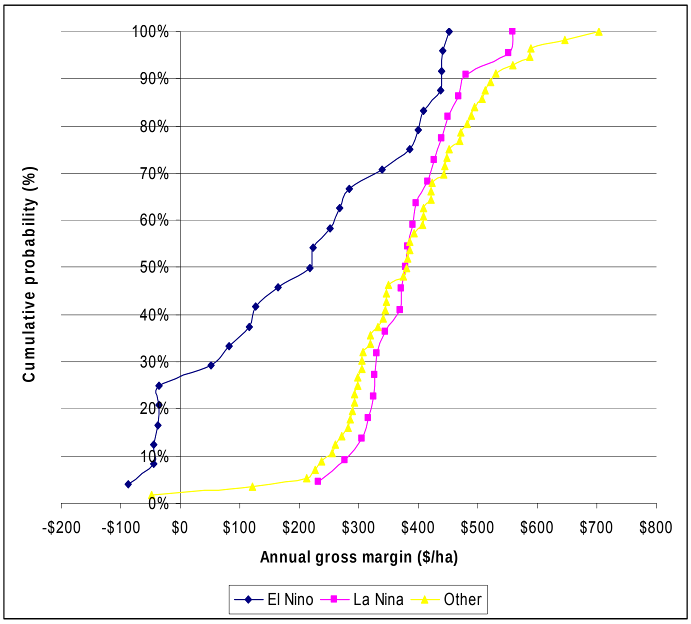


Figure 18 Annual gross margins for monoculture wheat production at Breeza separated on the basis of ENSO classification of the year of planting.

9y 13 y DCV Index and IPO

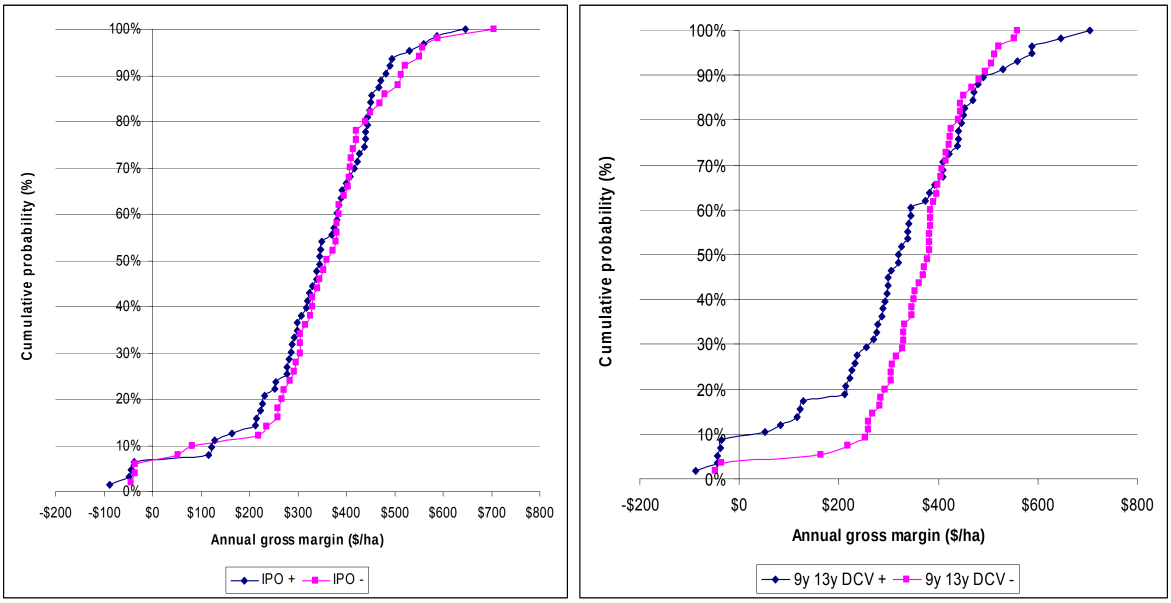
To test whether wheat production at Breeza responded to the different phases of the 9y 13y DCV index or the IPO, annual gross margins were separated on the basis of the value of the index in January of the year of planting.

The January value was chosen for convenience. As the index values vary at decadal or multi-decadal timescales, the value for the index in any month for the planting year could have been chosen and the outcome expected to remain the same.

The wheat cropping systems at Breeza show no response to the phase of the IPO. (Figure 19a)

The 9y 13y DCV index indicates that the chance of suffering a negative gross margin increases slightly from about 3% of years when the index has a negative (-) value to about 10% of years when the index has a positive (+) value. (Figure 19b) The median gross margin also improves with the negative phase of the 9y 13y DCV from $320 per ha per annum to about $380 per ha per annum.

The gross margin for the negative phase of the index will potentially be better than the gross margin for the positive phase of the index in about 65% of years. Conversely, the positive phase of the index produces annual gross margins that equal or exceed those of the negative phase of the index in 35% of years. (Figure 19b)

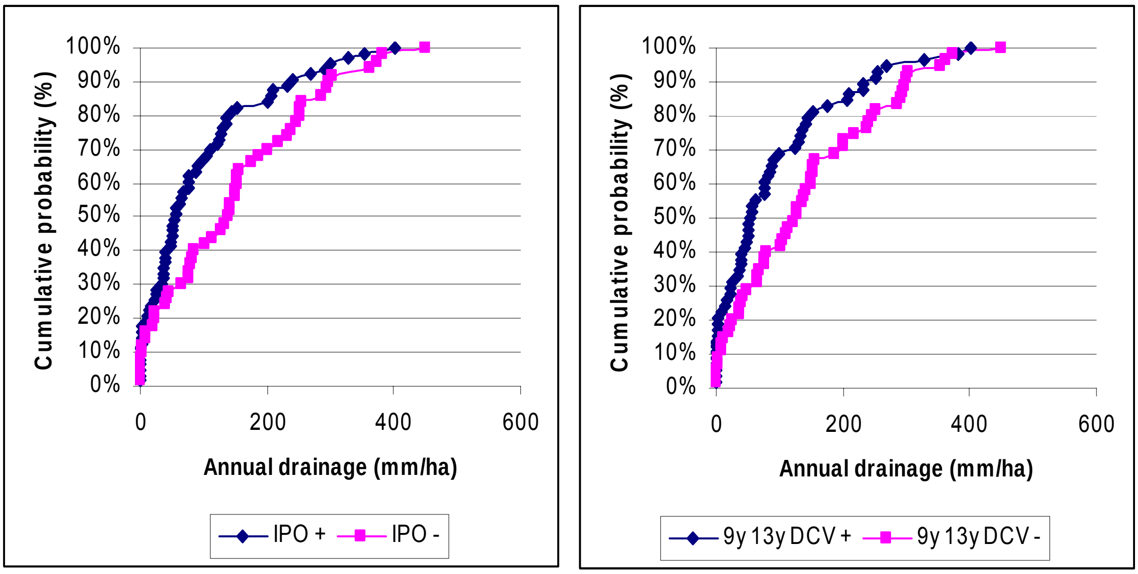


(a) (b)

Figure 19 Distribution of annual dryland wheat gross margins for the (a) IPO and (b) the 9y 13y decadal index

The 9y 13y decadal index shows a statistically significant difference between the gross margin distributions.

Gross margins are not the only indicator of climate impact on wheat at Breeza. The total drainage per annum under each phase of the IPO and the 9y 13y DCV index has also been compared at Breeza. (Figure 20)



(a) (b)

Figure 20 Distribution of annual drainage under wheat at Breeza for the (a) IPO and (b) the 9y 13y decadal index

As shown in previous reports, (See the Dalby report) monoculture wheat has a capacity to store excess rainfall but seems generally unable to use it all in crop production. Rainfall is enhanced by both the negative phase of the IPO and the negative phase of the 9y 13y DCV index at Breeza but much of this extra rainfall may be lost to the wheat cropping system as drainage. Very little shows up in improved gross margins.

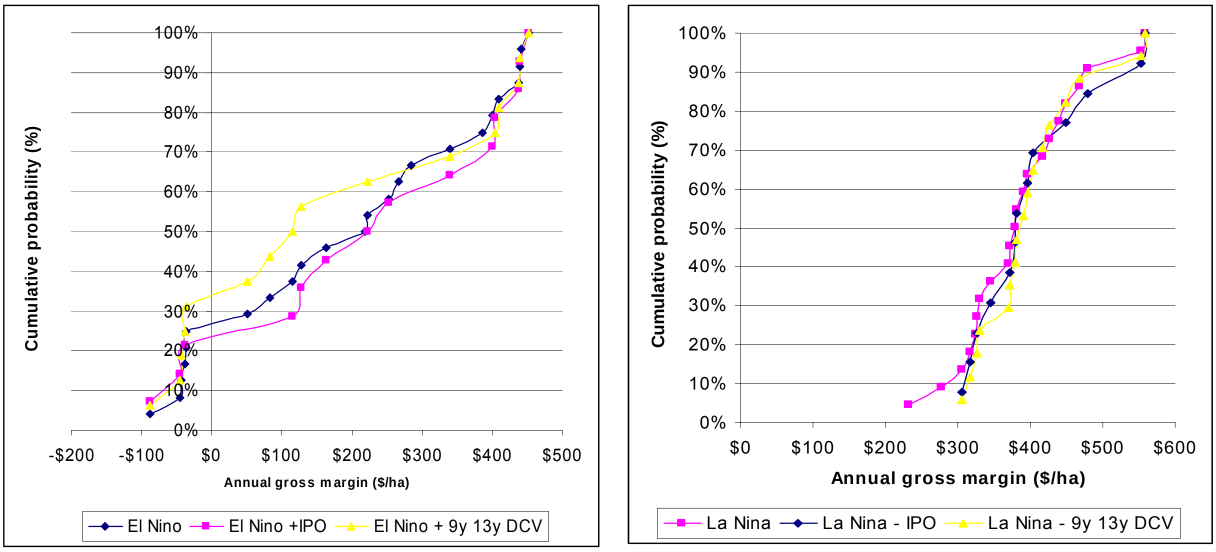
Interactions between ENSO and DCV indices at Breeza

Meinke *et al.* (2003) found a relationship between the phase values of the decadal indices and the ENSO phenomena. They found that El Nino years may have had their impact enhanced during the positive phases of the decadal indices. La Nina years may have also been enhanced during the negative phases of the decadal indices.

The distribution of annual gross margin for wheat at Breeza was not significantly impacted for those years when an El Nino lined up with the years in the positive phase of the IPO. (Figure 21a)

Those years that coincided with both an El Nino and the positive phase of the 9y 13y DCV index showed a reduction in median potential gross margin of about $100 per hectare (Figure 21a) when compared to all El Nino years. The chances of a negative gross margin also increased from 24% of years for all El Nino years to 35% of years for those El Nino years that coincided with the positive phase of the 9y 13y DCV index.

No significant impact on wheat gross margins was shown for those years classified as La Nina and coincide with the negative phase of the IPO or the 9y 13y DCV index. (Figure 21b)



(a) (b)

Figure 21 Distributions for monoculture wheat annual gross margin at Breeza on a 190mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

Summary of monoculture wheat

Even though wheat growing at Breeza is currently seen as very reliable and low risk, climate variability has had a significant impact on the potential profitability of the wheat cropping system at Breeza over the past 113 years.

The El Nino classification, the positive phase of the 9y 13y DCV index and the combination of the positive phase of the 9y 13y DCV index and the El Nino phenomena identify a set of years when the performance of wheat can be significantly reduced.

A cropping system based on summer fallows and winter wheat growing at Breeza appears unable to respond very well to climate periods with enhanced rainfall. This may lead to water being lost from the cropping system as drainage or runoff.

5.2 Monoculture cotton

Dryland cotton can be planted as an alternative for winter crops at Breeza. The summer season is targeted instead of the winter season.

The traditional planting window for cotton starts in early October but farm managers will generally not plant until a significant amount of soil water has been stored during the fallow and a sound planting rain received.

Dryland cotton was planted in our simulations if 75mm of soil water was stored, 15mm of rain was received and the cotton window was open. This planting rule ensured that cotton was planted in 90% of years and allowed climate variability to be more fully expressed in the gross margin calculations than if a more restrictive set of rules were applied.

5.2.1 Modelled cotton yields

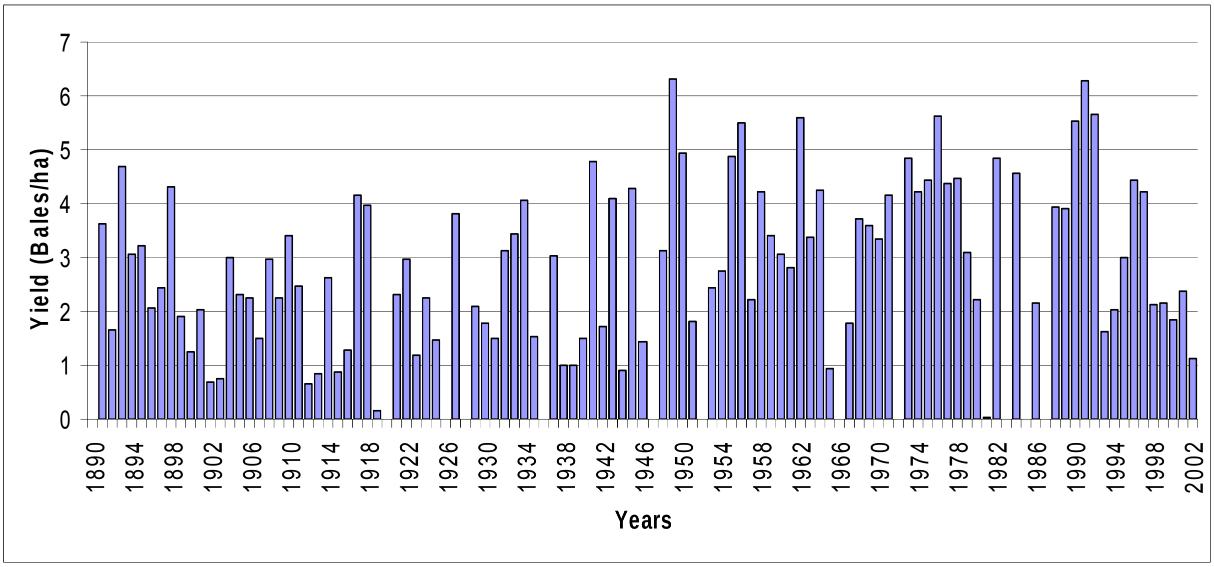


Figure 22 Modelled yields for dryland cotton at Breeza for the plant years from 1890 to 2002 grown on a 190mm PAWC soil

Annual modelled cotton yields show considerable variation around the median. Yields in the second half of the 20th century have a higher median than those of the first half of the 20th century. The frequency of missed planting opportunities and failed crops appear to be fairly consistent across the century.

When cotton crops were successfully established, APSIM produced a median yield of about 2 to 2.25 bales per ha. (Figure 23) A farm manager would need to employ suitable weed, insect and harvest management to achieve these yields. The top 10% of years produced yields between 4 to 6 bales per ha.

Even though our planting rules may have led to more modelled crops being planted over time than would have been actually planted in the paddock crops, we believe that our modelling accurately reflects the potential cropping frequency and crop yields of a properly managed zero till dryland cotton cropping system in this environment.

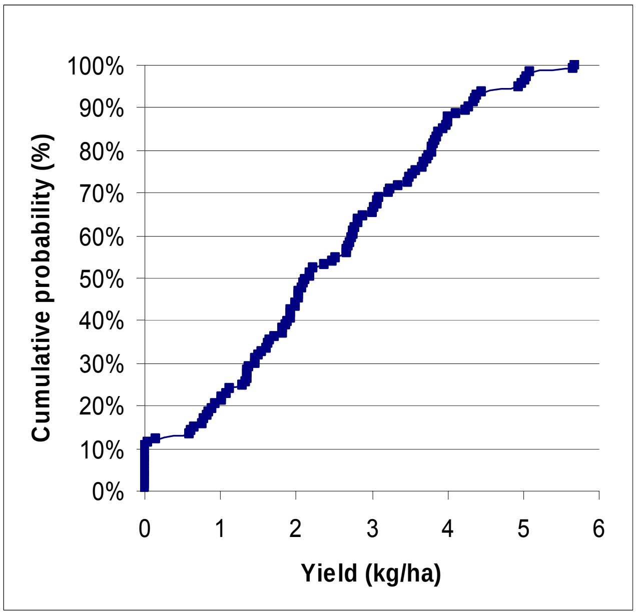


Figure 23 Distribution for monoculture cotton yields at Breeza.

5.2.2 Modelled cotton drainage

Modelled drainage from monoculture cotton at Breeza responds significantly to the increased rainfall of the second half of the 20th century. (Figure 24)

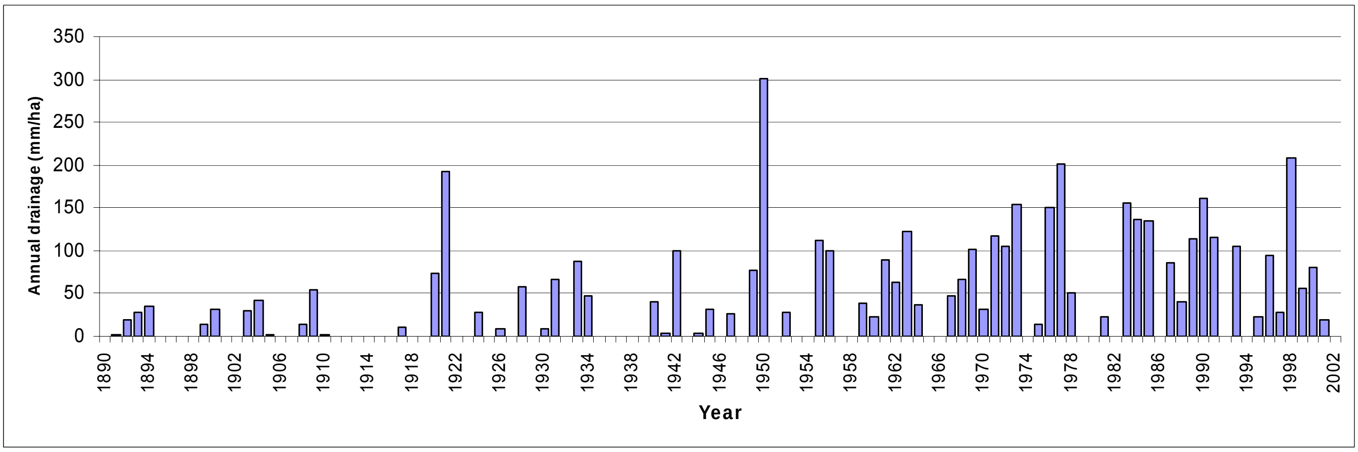


Figure 24 Drainage modelled by APSIM for monoculture cotton at Breeza (1890 to 2002)

Monoculture cotton at Breeza responds to increased rainfall partly by increasing yield (Figure 22) but also partly by losing some of the extra water through drainage or runoff. (Figure 24)

5.2.3 Cotton gross margins

Cotton gross margins are calculated with an average selling price of $500 per bale ex gin with current growing costs applied across all years.

The variable selling prices and different growing costs of the past would have obviously produced different (real) results for cotton growers who actually grew the crops during the years modelled. It must be remembered that the purpose of the modelling exercise is to reflect the impact of past climate variability on potential returns, not to reflect the past returns of existing dryland cotton producers.

Negative annual gross margins for cotton are produced by missed cropping opportunities as well as by crops that are planted, incur high growing costs then suffer a low yield or fail.

In about 30% of years more funds would have been spent on growing dryland cotton at Breeza than were earned. (Figure 25) The top 20% of years produce gross margins of greater than $700 per hectare and up to $1500 per hectare at the prices and costs selected. Wheat growing at the same location would have been more reliable and profitable in 60% of years.

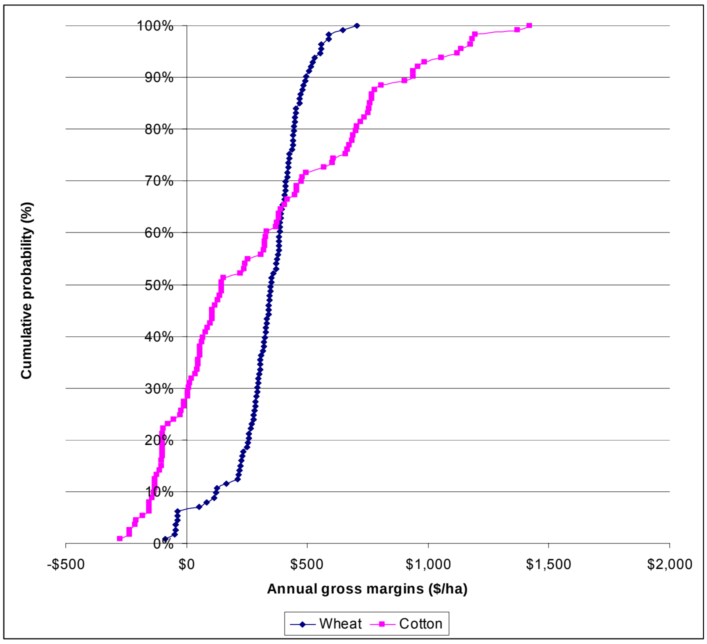


Figure 25 Distribution for monoculture cotton and wheat gross margins at Breeza on a 190mm PAWC soil.

The total gross margin for each decade is the sum of the annual gross margins for the same period. When a crop is missed or has a low yield, the annual gross margin can be a negative value thereby reducing the total gross margin for the decade.

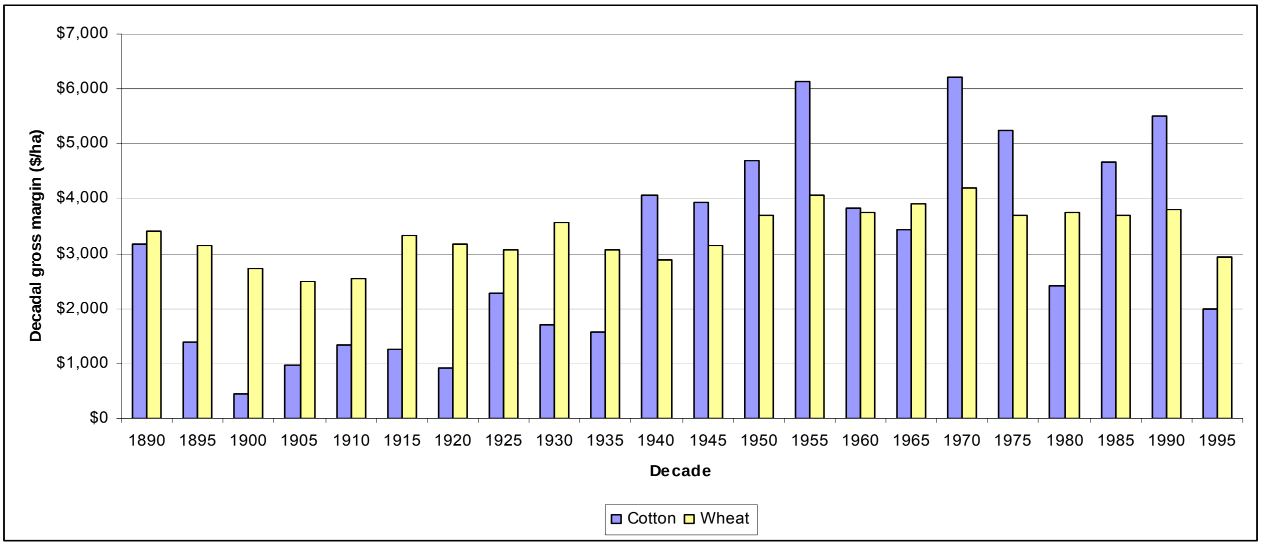


Figure 26 Decadal gross margins for dryland cotton and dryland wheat production at Breeza on a 190mm PAWC soil

All of the decadal variability shown is driven by the prevailing climate. (Figure 26) Note that the totals for the decade beginning in 1995 only contain eight harvest periods.

Decadal variation for dryland cotton at Breeza is two to three times greater than that shown by wheat grown over the same period. On nine occasions over the decadal sequences, dryland cotton would have equalled or outperformed wheat.

The climate was much more favourable for cotton growing during the second half of the 20th century than the first half.

5.2.4 Monoculture cotton response to climate phenomena at Breeza

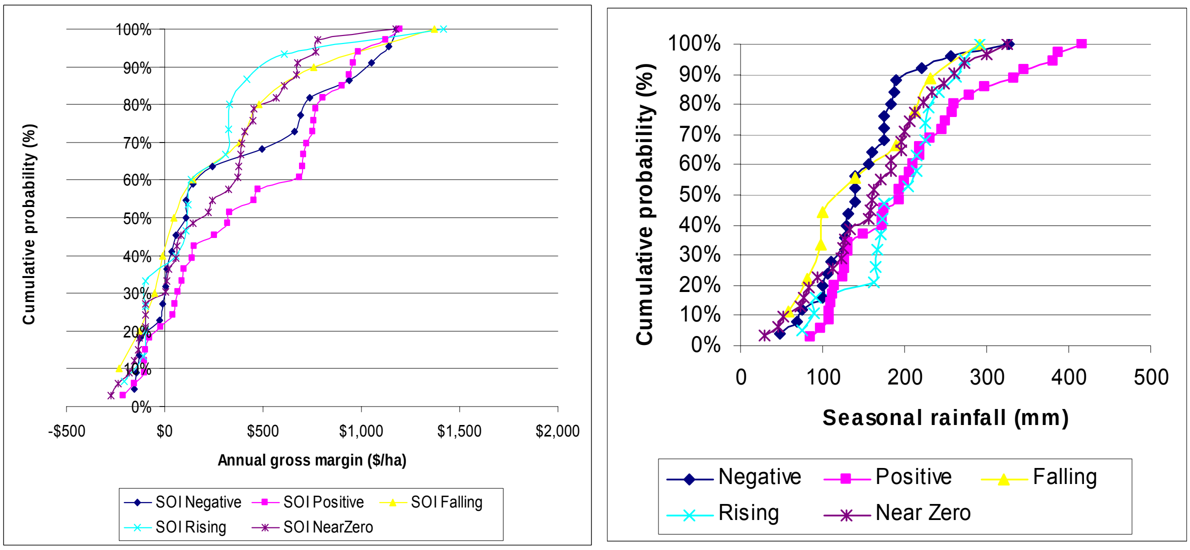
SOI phase

Annual gross margins for dryland cotton production at Breeza have been separated based on the phase of the SOI in September of the planting year (Figure 27a). Seasonal rainfall has also been separated on the basis of the SOI phase in September. (Figure 27b)

Rainman 4.3 indicates that rainfall for the October, November, and December period may be significantly impacted if the negative or rising phases of the SOI occur in September, although this may not be a skilful forecast.

The SOI positive phase prior to cotton planting doubles the median gross margin of dryland cotton at Breeza and halves the chance of suffering a negative gross margin when compared to the other phases of the SOI at the same time of the year. The SOI positive phase has a statistically significant impact on gross margins.

These differences between seasonal rainfall forecasts based on the SOI phase and cropping system outcomes based on the SOI phase are not unexpected. The cropping system gross margins have the capacity to respond to rainfall prior to planting as well as rainfall that falls within the crop. The extended planting window of the cropping system also buffers the impact of a rainfall deficit early in the planting window.

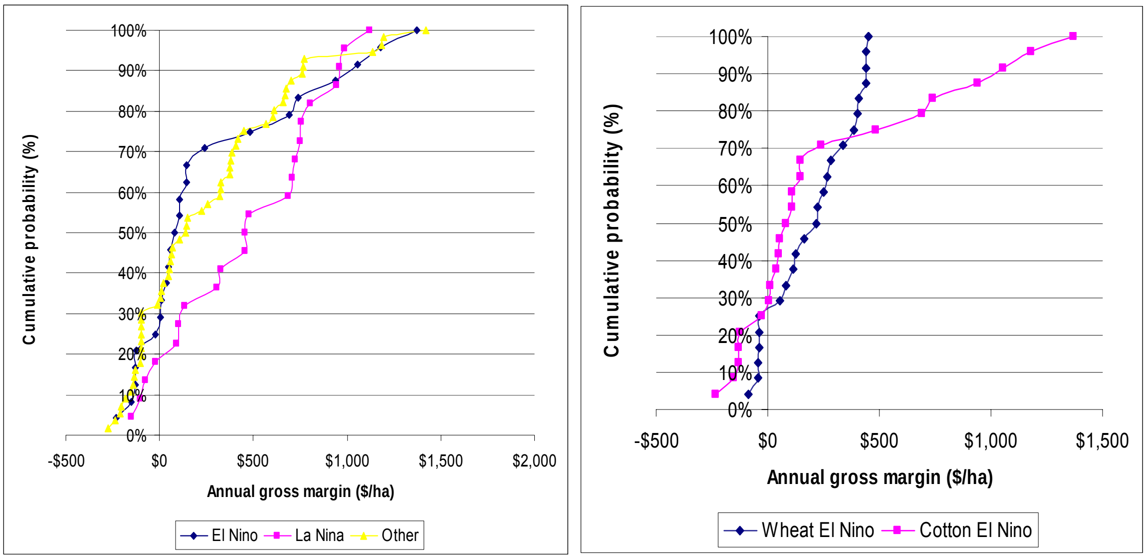


(a) (b)

Figure 27 Dryland cotton gross margin distributions at Breeza on a 190mm PAWC soil separated on the basis of the SOI phase in September of the year of planting (a). Seasonal rainfall at Breeza separated on the basis of the SOI phase in September (b)

ENSO classification

Annual gross margins for dryland cotton production at Breeza were separated on the basis of the ENSO classification in the year of planting (Figure 28).



(a) (b)

Figure 28 (a) Annual gross margins for monoculture cotton production at Breeza separated on the basis of ENSO classification of the year of planting. Figure 28(b) Annual gross margins for cotton and wheat at Breeza in El Nino years

Climate variability arising from ENSO has a noticeable impact on the potential profitability of dryland cotton production at Breeza. (Figure 28a) The median gross margin of modeled cotton is improved by about 300% in years classified as La Nina compared to the modeled gross margin for years classified as Other or El Nino. Conversely, little difference between the ENSO classifications would be noticed in about 60% of years.

Even though planting cotton into an El Nino year would not appear very encouraging, the decision to plant wheat earlier in the year is not so clear-cut. (Even if a forecast for El Nino was available and there was no trade off in the time of receipt of income.) A committed cotton grower would point to the improved payoff of cotton over wheat in 30% of years and a committed wheat grower would point to the lower risk and improved reliability of wheat over cotton. (Figure 28b) Neither would be expected to change their cropping intentions if they had advanced knowledge of the ENSO classification for the year.

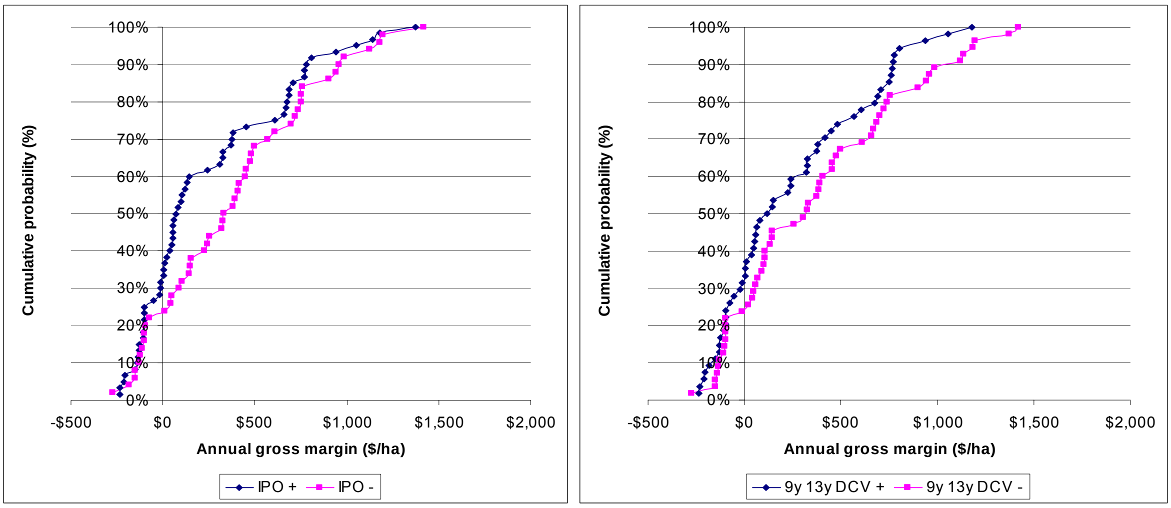
9y 13 y DCV Index and IPO

To test whether dryland cotton production at Breeza responded to the different phases of the 9y 13y DCV index and IPO, annual gross margins were separated on the basis of the value of the index in January of the year of harvest.

Cotton gross margins show a response to the phase of the IPO. (Figure 28a) Dryland cotton at Breeza shows a median gross margin of about $70 per ha in positive IPO years (+) and a median gross margin of $330 per ha in negative IPO years (-).

The chance of dryland cotton at Breeza suffering a negative gross margin increases from about 25% of years when the IPO index has a negative (-) value to 35% of years when the IPO index has a positive (+) value.

The phase value of the 9y 13y DCV index also seems to differentiate annual cotton gross margins at Breeza with the median gross margin improving by about 100% in the years that coincide with the negative value of the phase (Figure 29b)

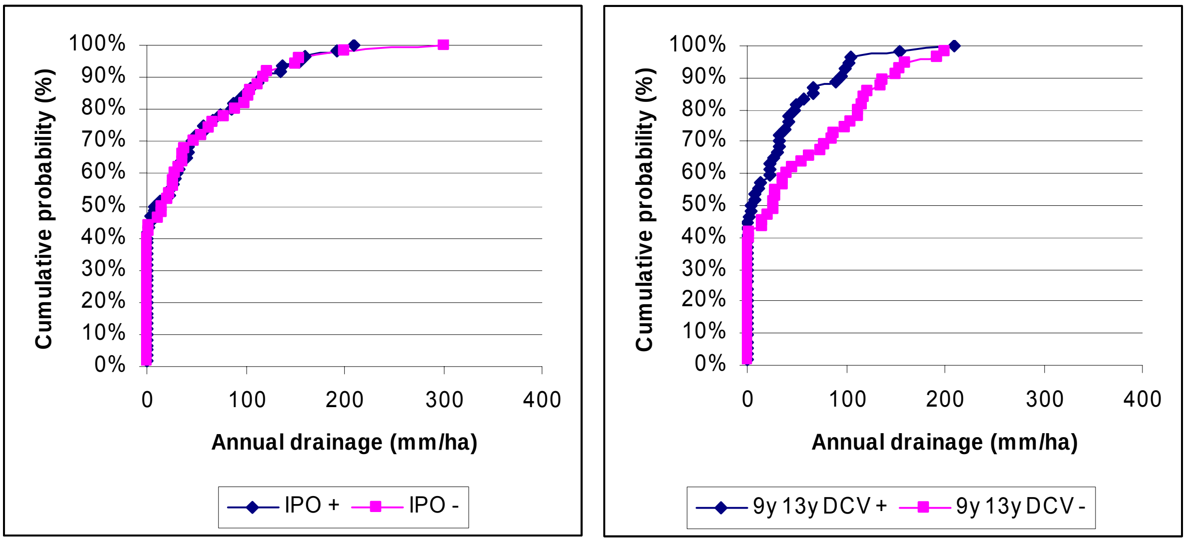


(a)

(b)

Figure 29 Distribution of annual dryland cotton gross margins for the (a) IPO and (b) the 9y 13y decadal index

Drainage under monoculture cotton at Breeza is significantly less than that experienced under monoculture wheat. (Figure 30)



(a) (b)

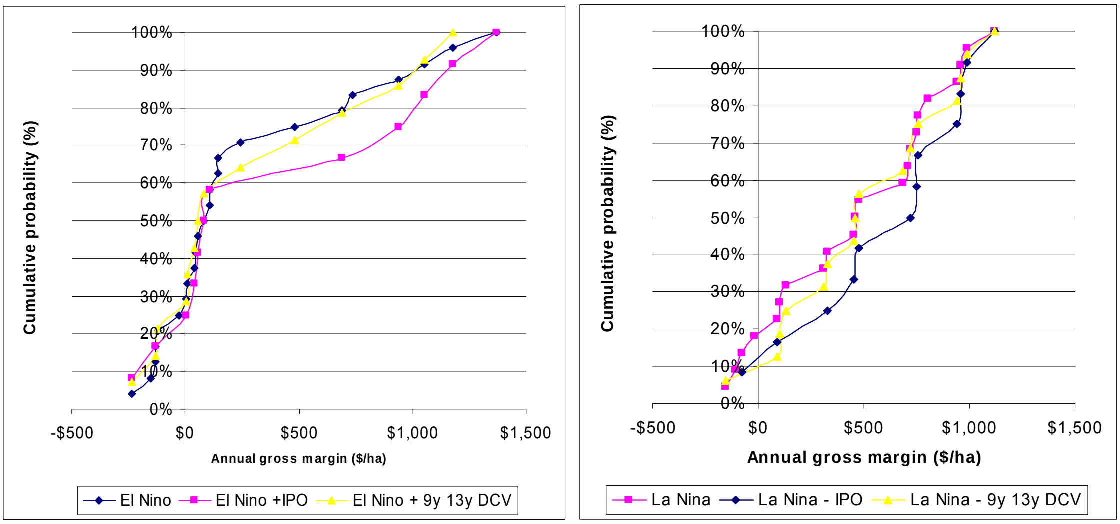
Figure 30 Distribution of annual drainage for cotton at Breeza for the (a) IPO and (b) the 9y 13y decadal index

Cotton seems to show a capacity to use favourable rainfall periods identified by the IPO negative phase to produce yield and not runoff. This would align with the expectation that the IPO negative phase enhances January to March rainfall – the main growing period for the cotton crop at Breeza.

Interactions between ENSO and DCV indices at Breeza

The impact of an El Nino year on cotton production at Breeza is not significantly modified by the El Nino year coinciding with the positive phase of either decadal index. (Figure 31a)

La Nina years that happen during the negative phase of the IPO have their median gross margins increased by about 50% when compared to all La Nina years. (Figure 31b)



(a) (b)

Figure 31 Distributions for monoculture cotton annual gross margin at Breeza on a 190mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

The differences identified are not large enough or sufficiently frequent to bring about a change of management by a wheat grower at Breeza.

5.2.5 Using climate phenomena to swap between wheat and cotton

A number of climate phenomena showed a significant impact on the potential performance of cotton and wheat.

An existing wheat producer at Breeza will probably only change from the relative stability of wheat production to the greater variability of cotton production if a forecast of a climate phase or phenomena provided a significant chance of improvement in returns without a significant increase in the risks of incurring a loss.

A wheat producer at Breeza has an opportunity in May to plant wheat or fallow through to cotton later in the year.

If the decision were to be based on the SOI phase at the end of April, the expected distribution for each phase of the SOI at this time can only be compared to the all years' expectation for cotton. (Figure 32) This is due to the SOI phase in April showing no skill in predicting rainfall during the following summer at Breeza (Rainman 4.3).

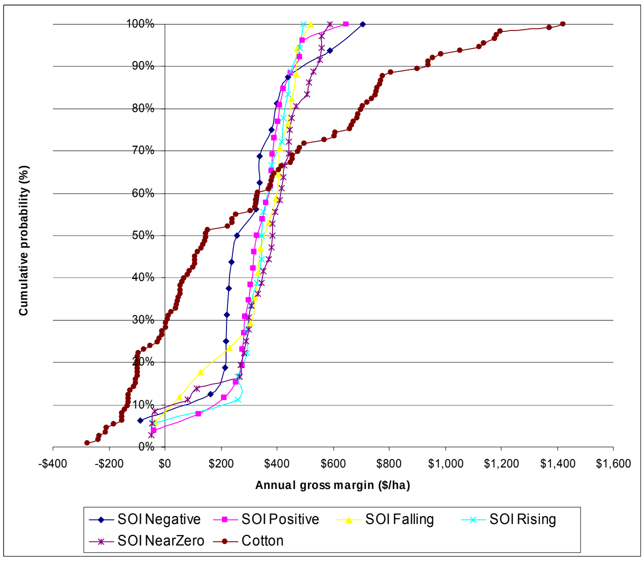


Figure 32 Dryland cotton and wheat annual gross margins at Breeza on a 190mm PAWC soil

The phase value of the SOI in April does not appear provide sufficient impact on wheat production to change the relationships between wheat and cotton production. Even in a year when the SOI is negative in April at Breeza, cotton production will be both significantly more risky and potentially more profitable than wheat. (Figure 32)

The SOI phase forecast system does not provide useful information for the decision to alternate between wheat and cotton and would not be used to change between wheat and cotton production at this location.

Wheat production during El Nino years is dramatically impacted. If a farm manager had a forecast available for this ENSO phenomenon in April, a decision could be considered to hold off for cotton production later that year.

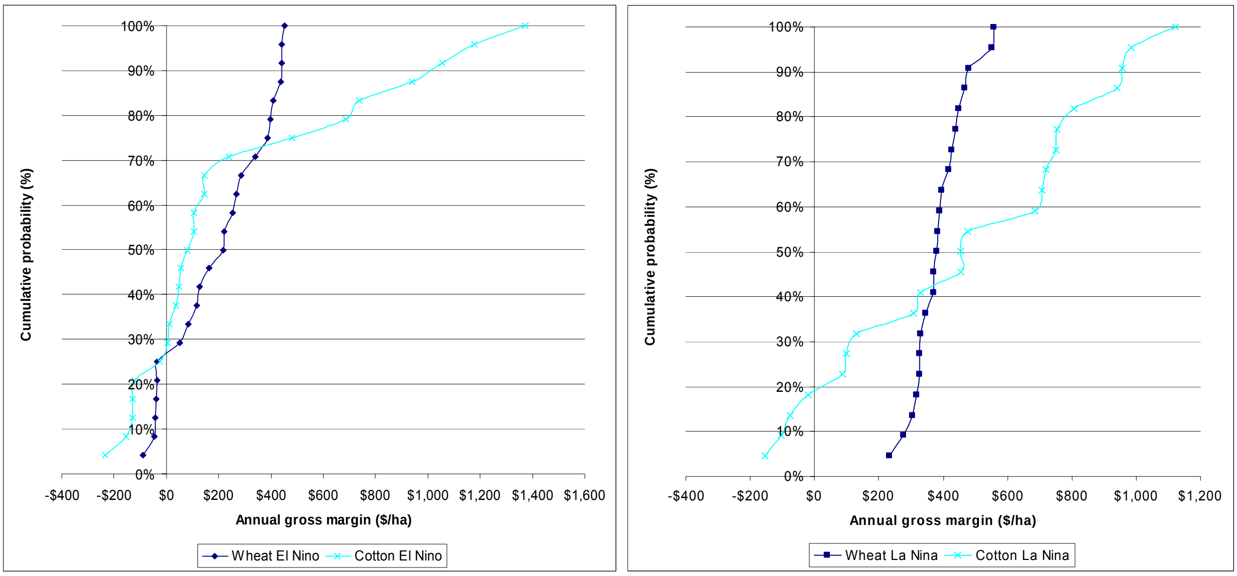
As the El Nino forecast would apply to the whole year, the production of cotton planted at the end of the El Nino year has to be compared to wheat planted and harvested in an El Nino year.

Farm managers could choose to not plant wheat and hold off until later in the year for cotton production during El Nino years but this is unlikely for two reasons.

Firstly, wheat will still outperform cotton in about 70% of such years and holding off to plant cotton could mean that an extended fallow could be needed to get back into wheat production. Occasionally two wheat crops, not one, will be foregone to plant one cotton crop leading to a quite low probability that the wheat farm business would be better off planting cotton in El Nino years.

La Nina years show a similar pattern to the all years distributions for these two crops. Cotton retains the ability to be both very profitable and incur significant losses. Wheat shows a high level of reliability and very little risk. It is unlikely that a wheat farmer would use a forecast of the La Nina phenomena to change his cropping system to cotton.

Even though the impacts of the climate phenomena can be significant for both wheat and cotton cropping systems at Breeza, we cannot show that this information would be useful in swapping between cotton and wheat.



(a) (b)

Figure 33 Wheat and cotton modelled annual gross margins for El Nino (a) and La Nina (b) years at Breeza.

5.3 Monoculture sorghum

Sorghum can be successfully grown at Breeza and also represents a substitute for wheat production.

5.3.1 Sorghum yields

Conditions under which sorghum could be planted by the model were set to mimic the current expectations of Breeza farmers. The planting window opened after the last week of October and closed in the second week of January.

For a planting to occur stored soil water had to be at least 75mm and 15mm of rain had to occur over the previous twenty days. The soil surface also had to be sufficiently dry for the planting operation to take place. These conditions were met in more than 80% of years.

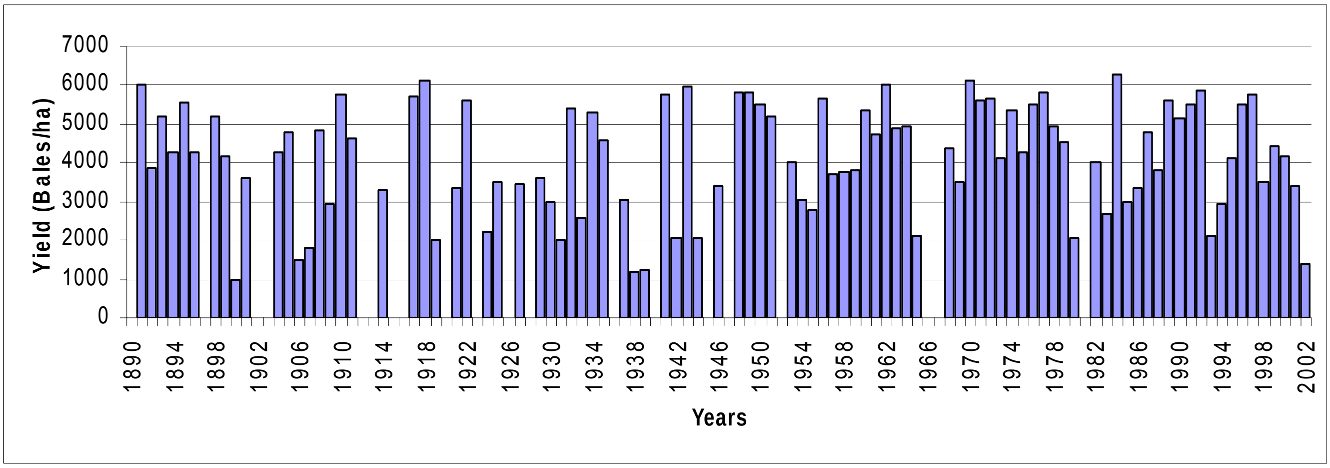


Figure 34 Modelled yields and cropping frequency for monoculture sorghum at Breeza for planting years 1890 to 2002 on a 190mm PAWC soil

Sorghum shows a similar pattern to cotton in that the productivity of the cropping system is improved in the second part of the 20th century compared to the first part. During the first half of the modelled period 14 sorghum crops were missed and only 5 were missed during the second half of the modelling period.

Sorghum is not planted or fails to produce a yield more often than cotton over the time period modelled.

This difference between the two cropping system is thought to be due to the slight differences in planting windows chosen for cotton and sorghum and the maturity date of the sorghum variety chosen. The sorghum window opens after the cotton window and closes about two months later than cotton. This planting window allowed sorghum to be planted late in some dry years occasionally leading to a failed crop.

The distribution of sorghum yields (Figure 35) indicates a median yield of about 3.8 tons/ha with yields above 6 t/ha fairly rare due to the constraints applied by the modelling process.

Breeza district farmers who had longer fallows (a lower cropping frequency) would show paddock yields potentially above these levels.

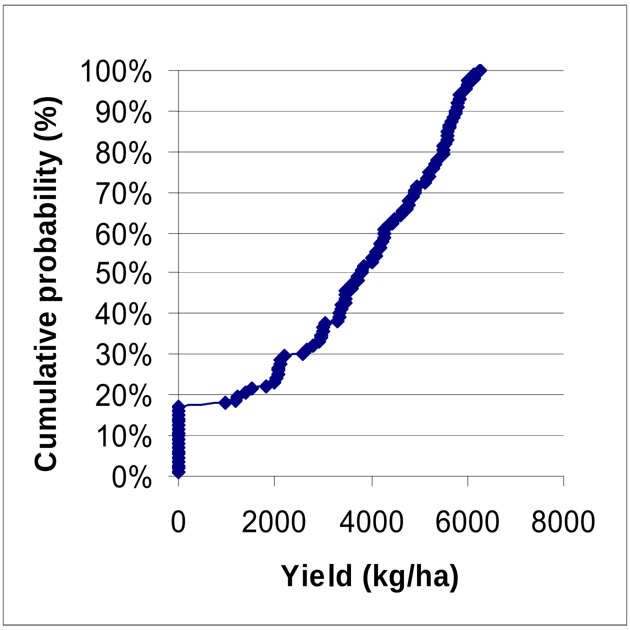


Figure 35 Distribution for monoculture sorghum yields at Breeza for all years 1890 to 2002

5.3.2 Sorghum gross margin

Modelled yields produced by the traditional planting window can be used to generate gross margins for the years 1890 to 2002. Costs and returns have been held constant at current prices for the entire climate record.

An average selling price of $140 per ton on farm was chosen for sorghum and at this price a gross margin greater than $300 per ha could have been expected in 50% of years (Figure 36). Sorghum prices have varied between $90 and $300 per ton on farm in the past decade. This range of values for price should also be remembered when cropping systems are being compared.

Negative gross margins were produced in about 20% of years by monoculture sorghum on a 190mm PAWC soil at Breeza (Figure 36). Sorghum is less reliable than wheat but less risky than cotton.

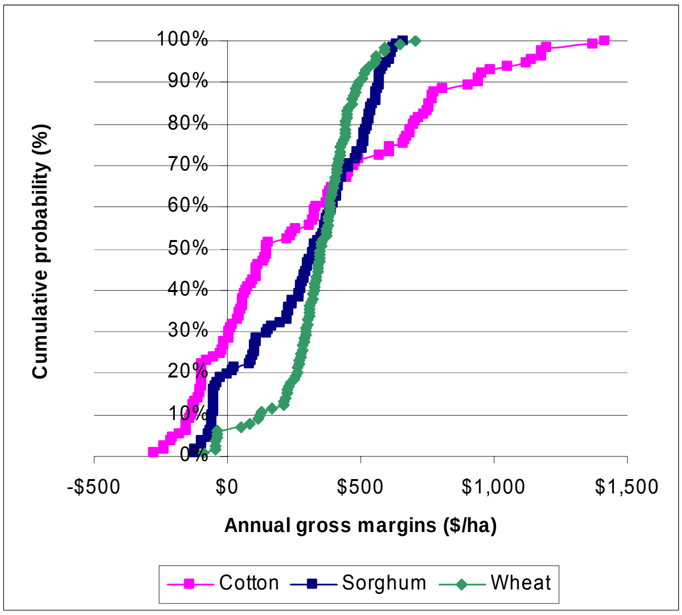


Figure 36 Distribution for modelled monoculture sorghum, cotton and wheat annual gross margins at Breeza on a 190mm PAWC soil.

The modelled annual gross margin for dryland sorghum production at Breeza has been below the long-term median in 25% of the years from 1952 to 2001. (Figure 37) Negative gross margins have been suffered in 6% of those years. Conversely, negative gross margins were suffered in 30% of years in the period 1890 to 1951 and the long-term median was only exceeded on 39% of occasions.

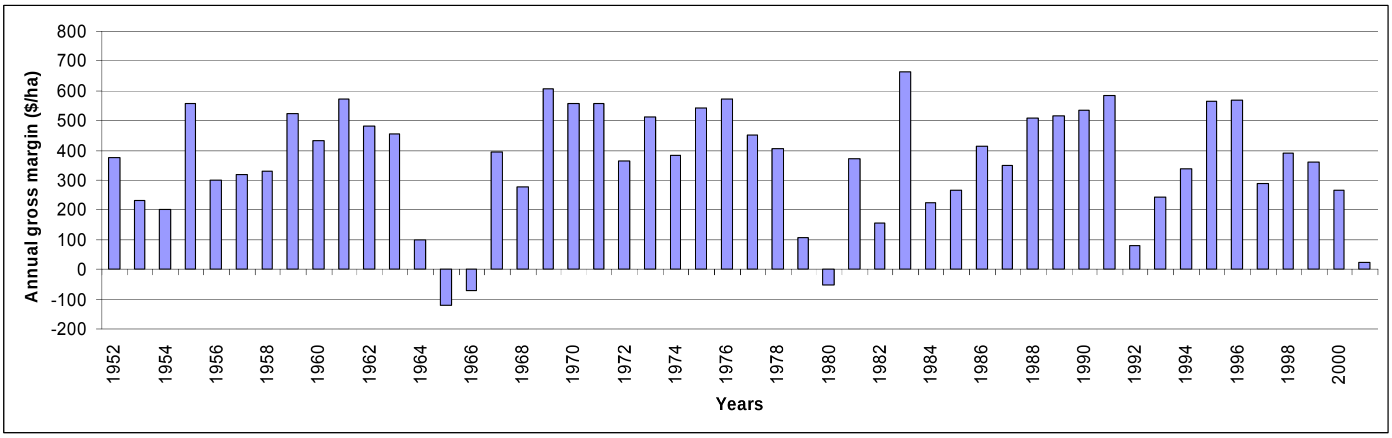


Figure 37 Plant year gross margins for modelled monoculture sorghum yields at Breeza on a 190mm PAWC soil (1952 to 2001 plant years).

Decadal gross margins for sorghum can vary by up to 50% around the median value for the total period modelled. (Figure 38) Note that the total gross margin for each decade overlaps by five years and therefore tends to smooth out some of the decadal fluctuations in returns.

All of the variability shown in the decadal gross margins is driven by the prevailing climate. The median gross margin for sorghum production from 1940 to 1990 effectively doubled when compared to the period from 1895 to 1935. Note that the total for the decade beginning in 1995 only contains eight harvest periods.

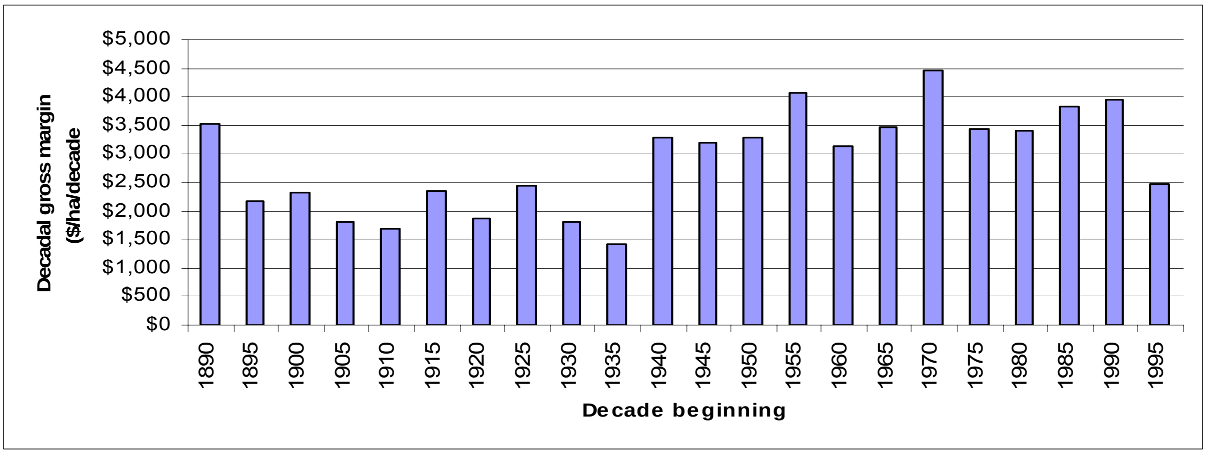
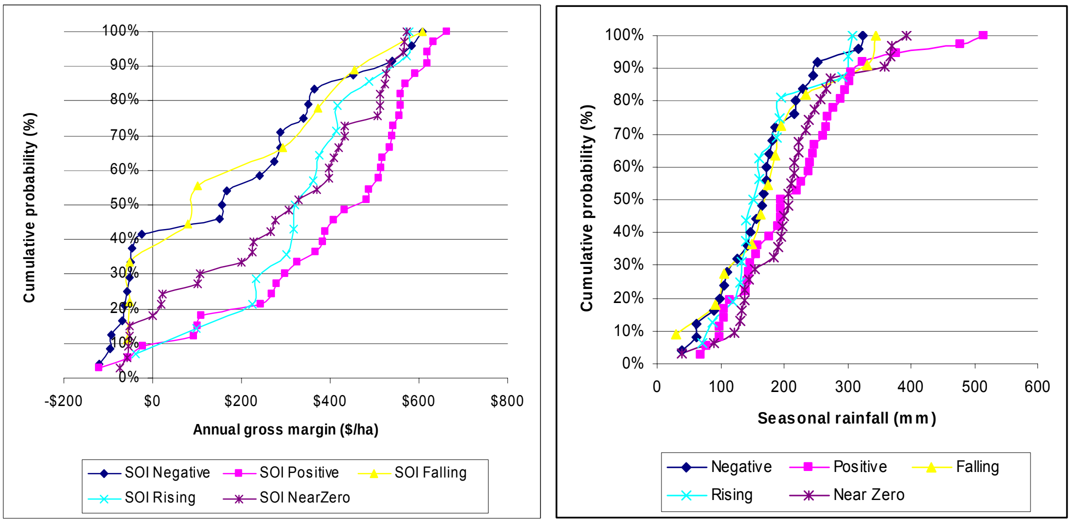


Figure 38 Total gross margins by decade for monoculture sorghum at Breeza.

5.3.3 Monoculture sorghum response to climate phenomena at Breeza

SOI phase

The SOI phase is the most likely forecast tool that a farmer intending to plant sorghum at Breeza will have available to support a decision.



(a) (b)

Figure 39 (a) Dryland sorghum distributions of annual gross margin at Breeza on a 190mm PAWC soil separated on the basis of the SOI phase in September of the year of planting and (b) November to January seasonal rainfall at Breeza separated on the basis of the phase of the SOI in October (Source Rainman 4.3).

Dryland sorghum planted at Breeza in those years with a SOI falling or negative phase in October shows an increased risk of suffering a negative gross margin. (Figure 39a) The years that had a SOI positive phase in September appear to be a relatively reliable and profitable set of years in which to grow sorghum.

Rainman 4.3 indicates that rainfall for the November, December and January period is not significantly impacted by the phase of the SOI in October.

The differences between seasonal rainfall forecasts based on the SOI phase and cropping system outcomes based on the SOI phase are not unexpected. The cropping system gross margins have the capacity to respond to increased or decreased rainfall prior to planting as well as the amount and effectiveness of rainfall that falls within the crop. In this case the marginal nature of the sorghum cropping system in this district tends to accentuate the reasonably small real differences in seasonal rainfall.

ENSO classification

Sorghum is generally planted in November or December of one year and harvested in the first half of the following year. An ENSO in the year of planting is the most likely ENSO event able to be forecast. (Note: ENSO classifications are for calendar years not seasons and depend upon climate events that prevail generally in the middle to second half of the calendar year)

Annual gross margins for dryland sorghum production at Breeza were separated on the basis of the ENSO classification of the year of planting (Figure 40).

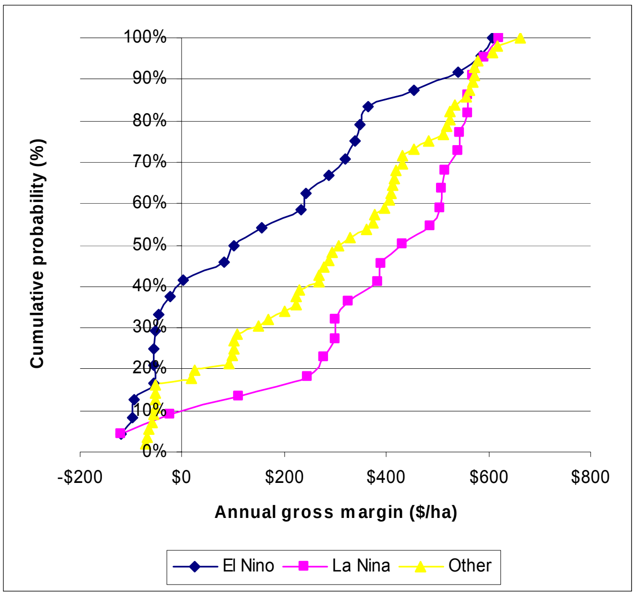
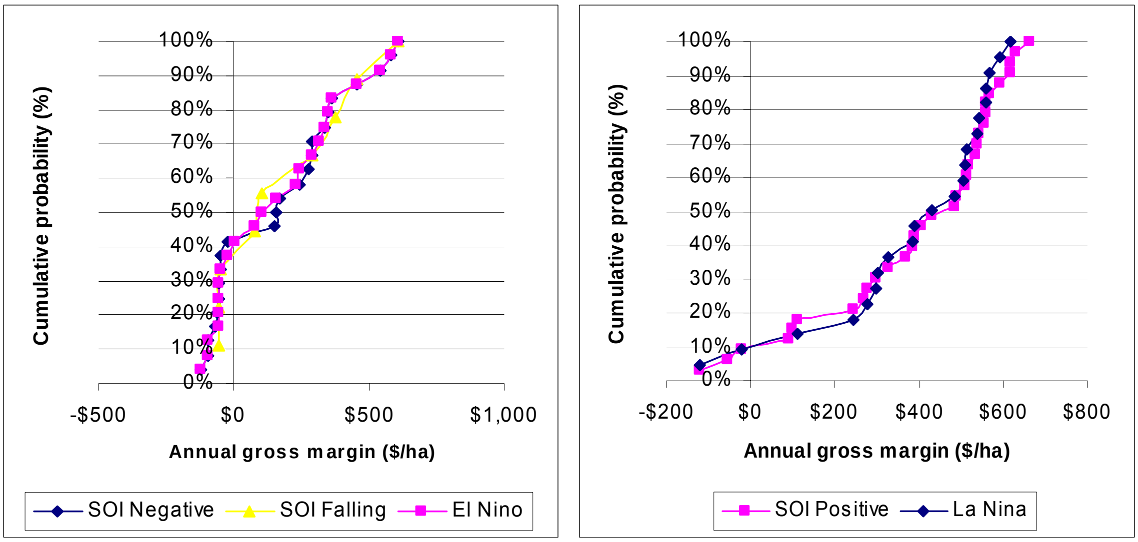


Figure 40 Annual gross margins for monoculture sorghum production at Breeza separated on the basis of ENSO classification of the year of planting.

Climate variability arising from an ENSO event in the year that a sorghum crop is planted has a significant impact on sorghum gross margins. The impact in El Nino years is similar to that in SOI negative or falling years. (Figure 41a) The impact in La Nina years is also similar to that experienced in SOI positive years. (Figure 41b)

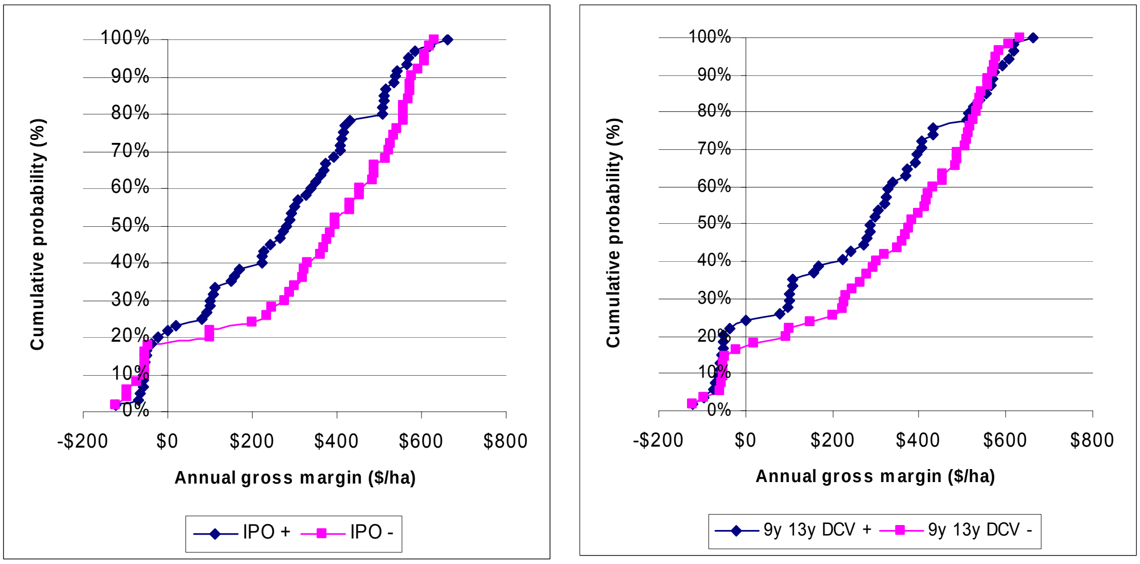


(a) (b)

Figure 41 Annual gross margins for sorghum at Breeza separated on the basis of the El Nino and SOI negative in October classifications (a) and the La Nina and SOI positive in October classifications

9y 13 y DCV Index and IPO

To test whether dryland sorghum production at Breeza responded to the different phases of the 9y 13y DCV index and IPO, annual gross margins were separated on the basis of the value of the index in January of the year of harvest. The January value was chosen for convenience. As the index values vary at decadal or multi-decadal timescales, the value in any month could have been chosen and not changed the outcome.



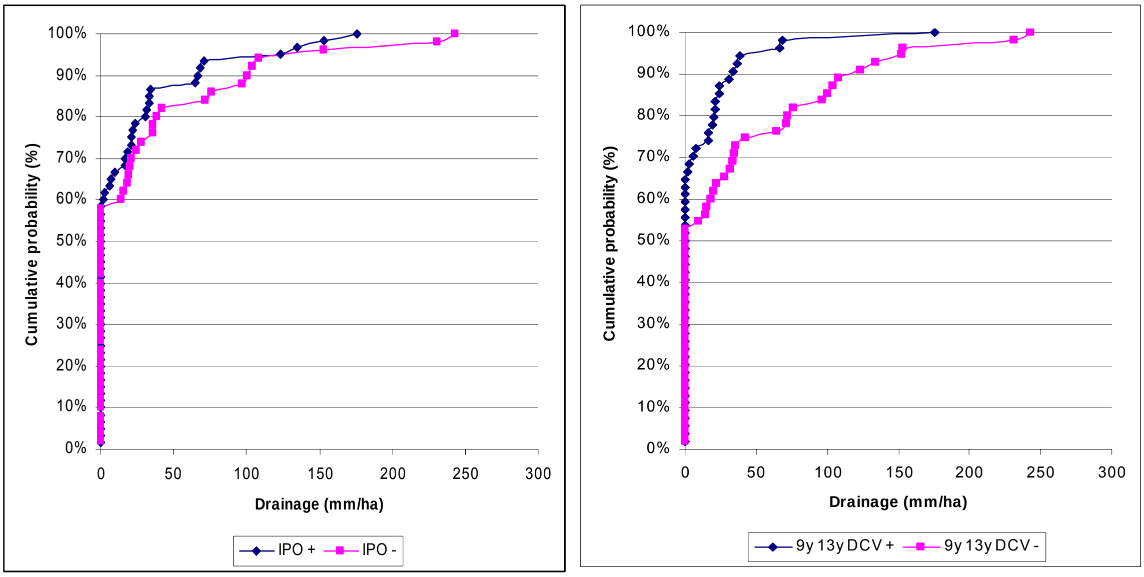
(b) (b)

Figure 42 Distribution of annual dryland sorghum gross margins at Breeza for the (a) IPO and (b) the 9y 13y decadal index

The IPO index shows the same level of riskiness for sorghum production at Breeza in both phases of the index but improves the median gross margin by 25% in those years that had a negative value for the index. (Figure 42a)

The 9y 13y DCV index indicates a slight increase in the chance of suffering a negative gross margin when the index has a positive (+) value and an improved median gross margin when the index has a negative value.

The sorghum monoculture cropping system modelled also significantly reduced water lost out of the system when compared to the monoculture wheat cropping system. (Figure 43)



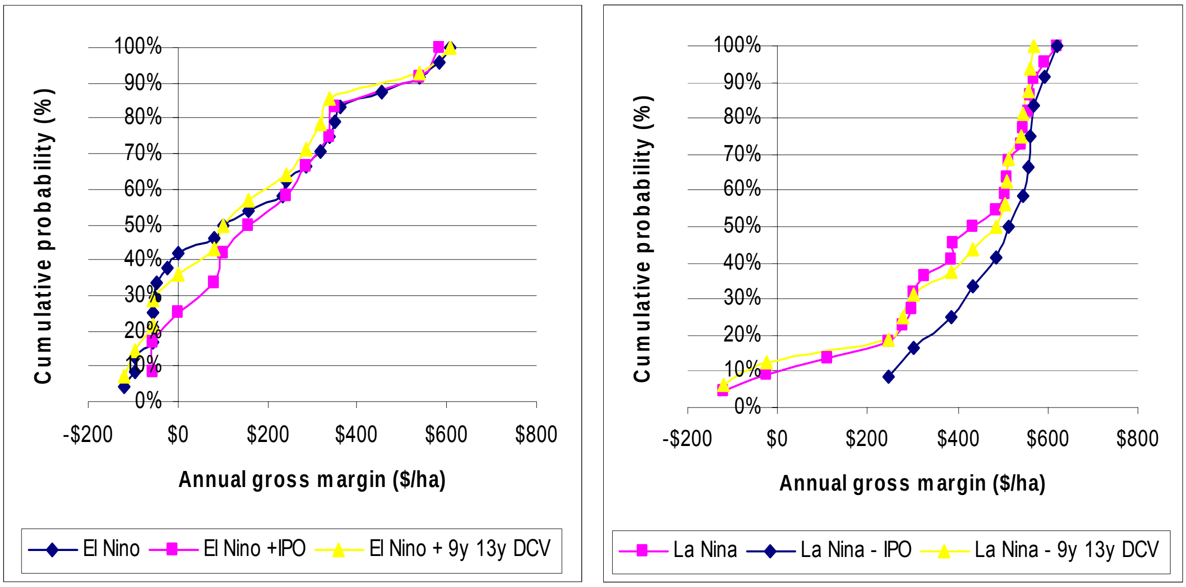
(a) (b)

Figure 43 Distribution of annual drainage for sorghum at Breeza for the (a) IPO and (b) the 9y 13y decadal index

Interactions between ENSO and DCV indices at Breeza

Meinke *et al.* (2003) found a relationship between the phase values of the decadal indices and the ENSO phenomena. They found that El Nino years may have had their impact enhanced during the positive phases of the decadal indices. La Nina years may have also been enhanced during the negative phases of the decadal indices.

The distribution of annual gross margin of sorghum was not significantly affected by El Nino or La Nina events if the phase value of either the 9y 13y DCV index or IPO is negative or positive respectively (Figure 44 a, b).



(a) (b)

Figure 44 Distributions for monoculture sorghum annual gross margin at Breeza on a 190mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

5.3.4 Using climate phenomena to swap between sorghum and cotton

A farm manager at Breeza who is interested in swapping between cotton and sorghum will consider the varying outcomes for each cropping system that arise from the climate phenomena tested. A farm manager will make a change from one cropping system to the other if the alternative cropping system is not expected to be significantly more risky and is also expected to significantly improve returns.

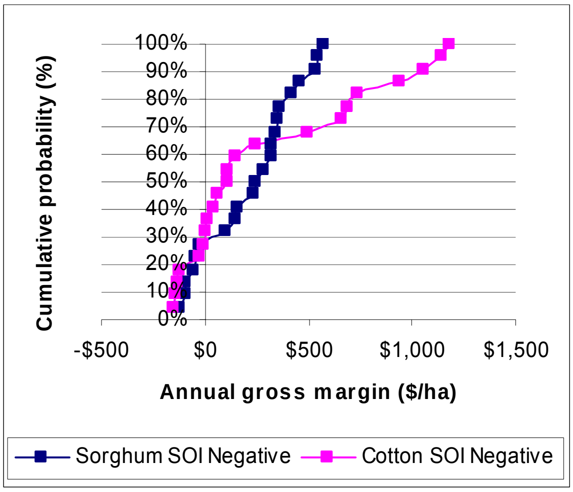
A number of climate phenomena showed a significant impact on the potential performance of sorghum and cotton at Breeza.

The gross margins of each cropping system have been separated on the basis of the SOI phase in September to test whether useful information for cropping system decisions could be found.

A farm manager at Breeza who wanted to make a choice between cotton and sorghum at Breeza based on the SOI phase forecast system would most likely use the phase of the SOI in September for both cotton and sorghum.

The SOI phase in September shows some skill in predicting rainfall during the following three months at Breeza with the SOI negative phase and the SOI rising phase both showing a significant impact on rainfall (Rainman 4.3). The SOI phase in September is the last forecast available prior to the cotton planting decision being undertaken.

The SOI rising phase is possibly the only SOI phase likely to impact upon a committed cotton grower. (Figure 45d) A committed sorghum grower will not find any help in the SOI phase forecast system for a choice between these two crops at this time as cotton retains its inherently risky nature in all phases of the forecast system when compared to sorghum.


Cumulative probability (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-$500
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$500
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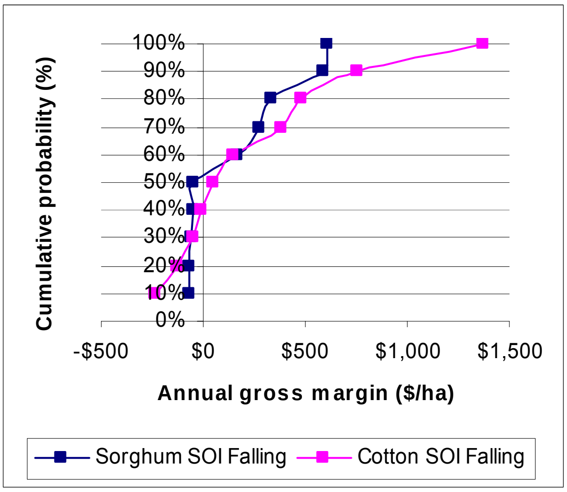
$1,500
Annual gross margin ($/ha)
Sorghum SOI Negative
Cotton SOI Negative

(a)


Cumulative probability (%)
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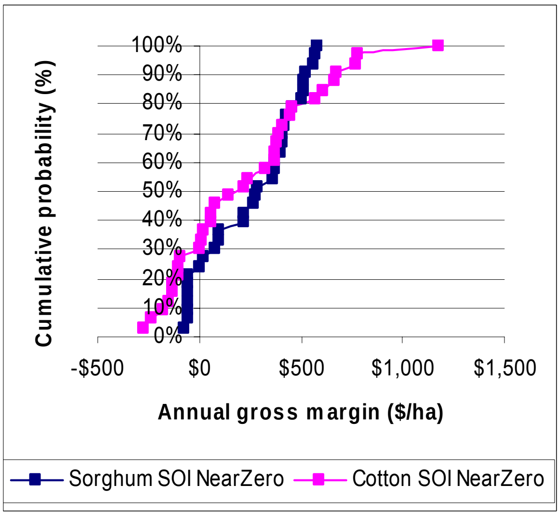
Annual gross margin ($/ha)
Sorghum SOI Falling
Cotton SOI Falling

(b)


Cumulative probability (%)
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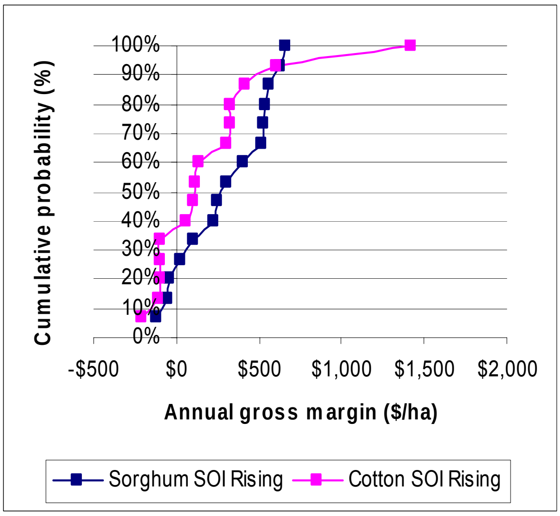
Annual gross margin ($/ha)
Sorghum SOI NearZero
Cotton SOI NearZero

(c)


Cumulative probability (%)
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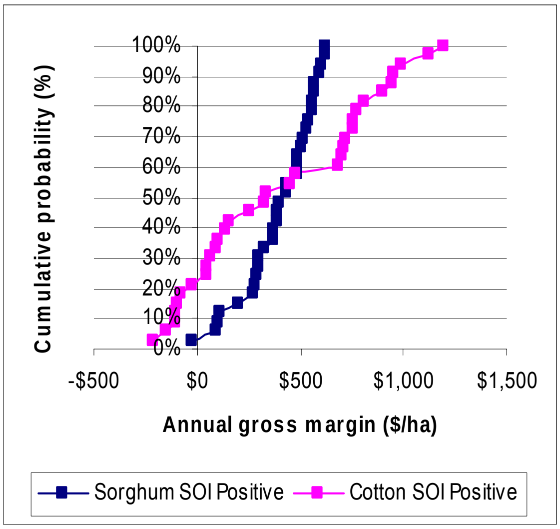
$1,500
$2,000
Annual gross margin ($/ha)
Sorghum SOI Rising
Cotton SOI Rising

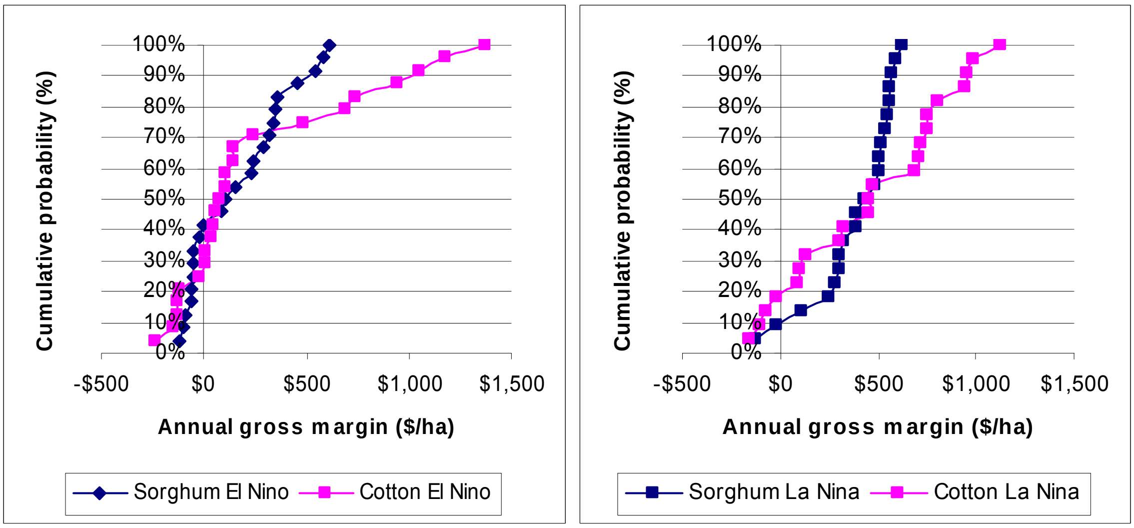
(d)


Cumulative probability (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-$500
$0
$500
$1,000
$1,500
Annual gross margin ($/ha)
Sorghum SOI Positive
Cotton SOI Positive

(e)

Figure 45 Dryland cotton and sorghum annual gross margins at Breeza on a 190mm PAWC soil separated on the basis of the phase of the SOI in September

Sorghum production during El Nino years is dramatically impacted. If a farm manager had a forecast available for this ENSO phenomenon in September, a decision could be considered to plant cotton or hold off for sorghum production later that year.



(a) (b)

Figure 46 Sorghum and cotton modelled annual gross margins for El Nino (a) and La Nina (b) years at Breeza.

Farm managers could choose to plant cotton and not hold off for sorghum later in the year if an EL Nino was forecast for the year of planting. (Figure 46a) There is a reasonable chance (30%) of significantly improving on the sorghum gross margin. There is also a reasonable chance (20%) of significantly higher losses for planting cotton than planting sorghum. Over the 113 year period modelled, the producer who selected sorghum in El Nino years would have achieved a median gross margin for El Nino years of $15 per ha greater than the producer who selected cotton.

La Nina years show a similar pattern to the all years distributions for these two crops. Cotton retains the ability to be both very profitable and incur significant losses. Sorghum shows a relatively high level of reliability and less risk than cotton. It is unlikely that a sorghum producer would use a forecast of the La Nina phenomena to change his cropping system to cotton even though the reliability of cotton is improved in this forecast. The median gross margin for cotton in La Nina years is only $23 per hectare better than the median gross margin for sorghum and the chances of making a loss are about double with the cotton decision compared to the sorghum decision.

Both cotton and sorghum show a fairly poor level of performance in planting years classified as El Nino. A Breeza farm manager may consider not making the choice between cotton and sorghum and holding the paddock over to wheat production in the following winter. The median gross margin for sorghum and cotton would have to be significantly lower than the potential gross margin for wheat for this decision to be considered.

Not planting sorghum or cotton in an El Nino year and holding off for a wheat crop in the year following an El Nino event may significantly improve the financial performance of a paddock potentially available for sorghum of cotton production. (Figure 47)

The wheat versus sorghum or cotton decision is not as low risk as it looks at first glance. The wheat gross margins would depend upon a forward price forecast of at least 12 months and there may be considerable expenses incurred in weed control over the summer months if the summer crop is not planted. Even so, a marginal planting opportunity in an El Nino plant year for sorghum or cotton may encourage the farm manager to hold over for wheat. When a good planting opportunity arises for cotton in an El Nino year, many farm managers may still find it a reasonable bet.

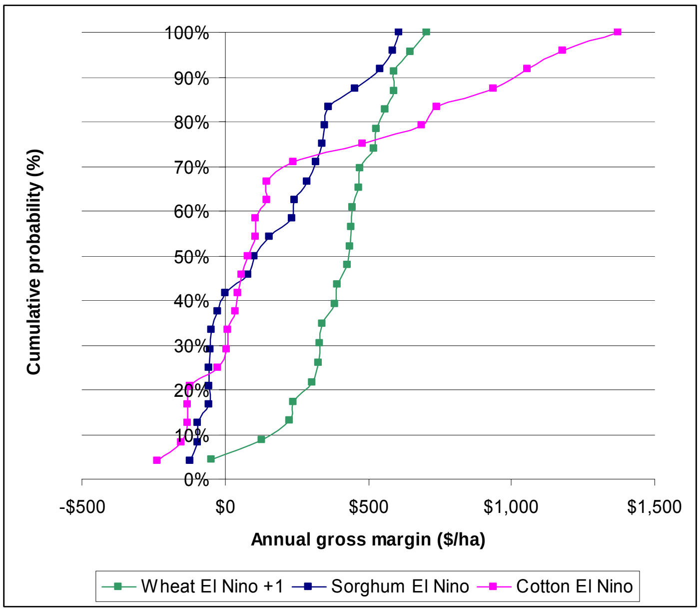


Figure 47 Cotton and sorghum gross margins for years where an El Nino coincides with planting compared to wheat gross margins for the year after an El Nino event

5.4 Opportunity cropping sorghum and wheat

Opportunity cropping sorghum and wheat is a cropping system designed to maximise cereal planting opportunities over any period of time.

This cropping system has been modelled on the basis that planting opportunities for either wheat or sorghum were to be taken when the planting window was open and rainfall plus stored soil water conditions were met.

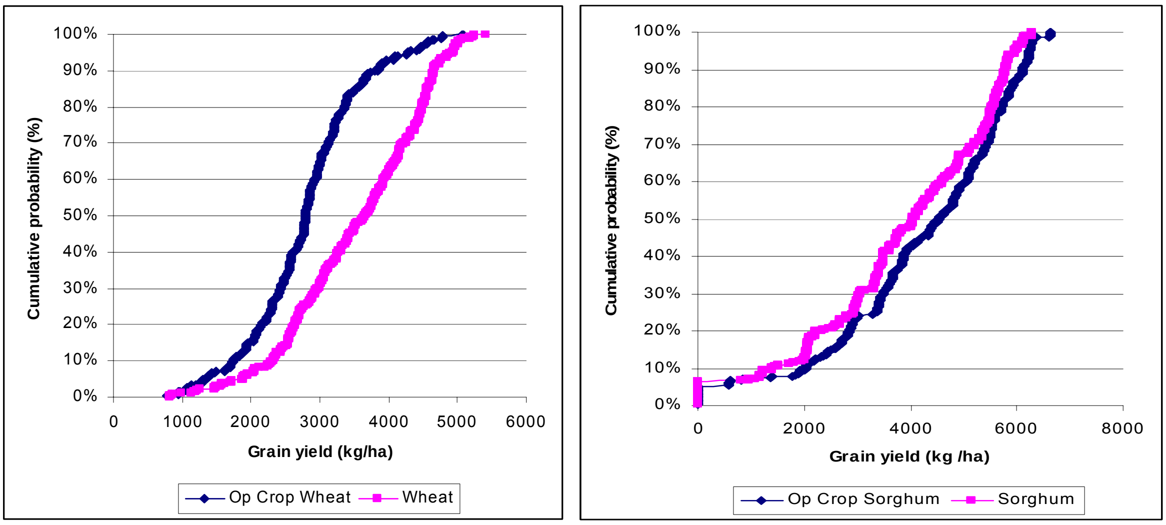
The planting window and planting criteria for both wheat and sorghum were maintained as for the monoculture analyses.

5.4.1 Crop yields

The modelled median yield for wheat grown within opportunity cropping sorghum and wheat is reduced by about 1 tonne/ha when compared to the median yield for monoculture wheat. (Figure 48a) Most of this reduction would be due to the reduced water status of the soil at wheat planting.

Modelled sorghum yields for sorghum grown within opportunity cropping sorghum and wheat show a potential improvement in most years compared to modelled monoculture sorghum yields. (Figure 48b) This potential improvement is probably due to the "self – selection" of the more favourable sorghum years by the opportunity cropping system.

Sorghum was planted a lot less frequently in the opportunity cropping system than the monoculture system and it is possible that some of the years not planted to sorghum in the opportunity cropping system were lower performing years in the monoculture system.



(a) (b)

Figure 48 Distribution of wheat yield (a) and sorghum yield (b) on a 190mm PAWC soil at Breeza. Cropping systems modelled are monoculture wheat, monoculture sorghum and opportunity cropping sorghum and wheat.

5.4.2 Grain protein

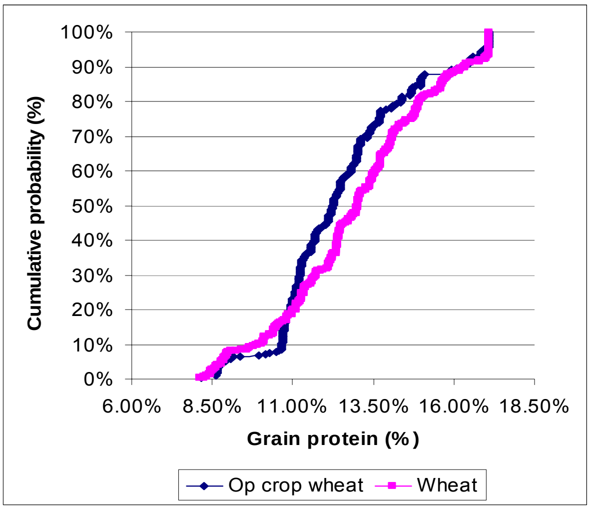


Figure 49 Distribution for grain protein in wheat at Breeza on a 190mm PAWC soil.

The median wheat protein percentage for wheat grown in the opportunity cropping system is reduced by about 1.5% when compared to the protein percent expected for monoculture wheat. (Figure 49) This reduction is probably due to the higher cropping frequency of opportunity cropping tending to reduce the available soil nitrate for protein production in wheat (at the level of N input used).

5.4.3 Gross margins

Modelled opportunity cropping wheat and sorghum produced negative annual gross margins in about 10% to 15% of years. (Figure 50) This is slightly less than cotton and slightly more than sorghum. Wheat remains the most reliable cropping system at Breeza and potentially has the highest median gross margin.

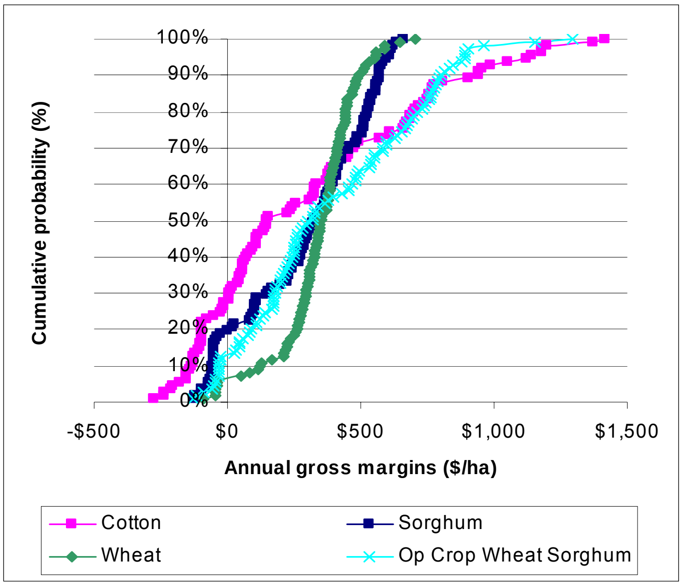


Figure 50 Cumulative distributions for Cotton, Sorghum, Wheat and opportunity cropping wheat and sorghum on a 190mm PAWC soil at Breeza

Opportunity cropping performs significantly better than monoculture wheat on about seven occasions and significantly worse than monoculture wheat on about five occasions. The remaining eleven decades show little difference between the cropping systems. (Figure 51)

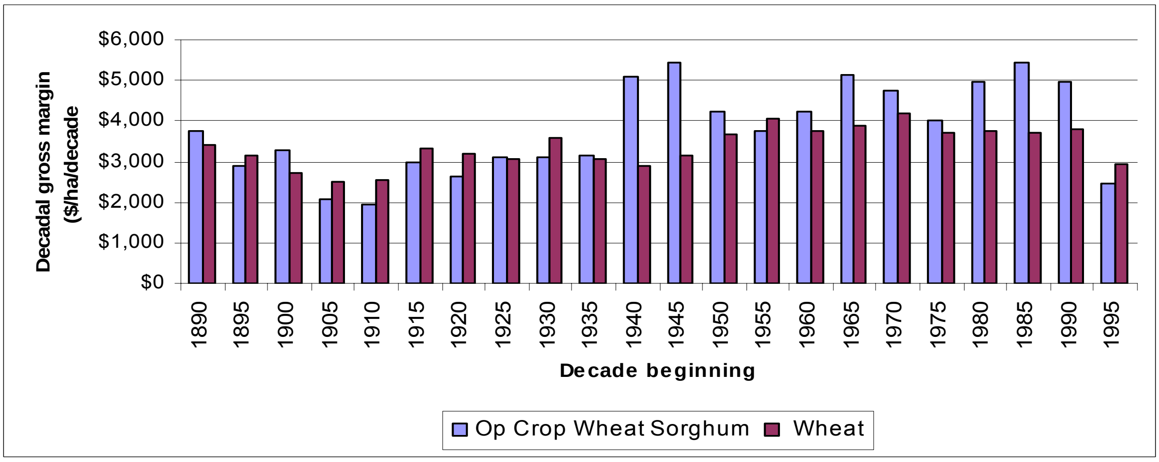


Figure 51 Modelled decadal gross margins for monoculture wheat and opportunity cropping wheat and sorghum at Breeza on a 190mm PAWC soil

Opportunity cropping has generally outperformed monoculture wheat since the decade beginning 1940.

5.4.4 Opportunity cropping sorghum and wheat response to climate phenomena at Breeza

SOI phase

Annual gross margins for opportunity cropping wheat and sorghum gross margins at Breeza were separated on the basis of the phase of the SOI in April of the winter cropping season (Figure 52).

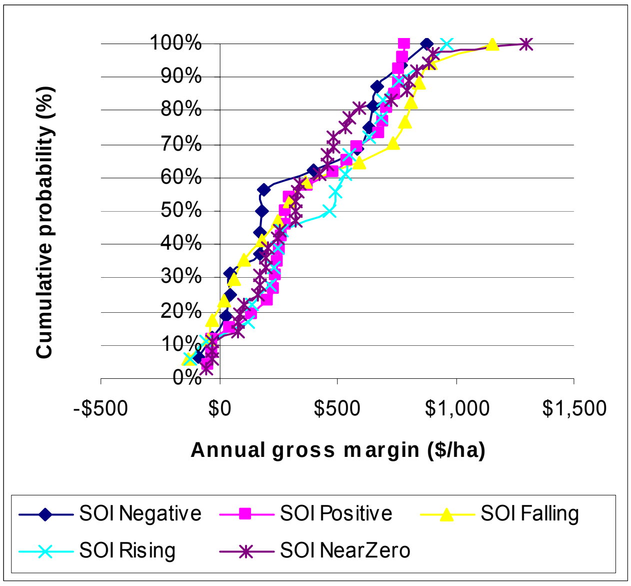


Figure 52 (a) Opportunity cropping gross margin distributions at Breeza on a 190mm PAWC soil separated on the basis of the SOI phase in April of the year of planting.

No phase of the SOI in April has a significant impact on the outcomes for opportunity cropping wheat and sorghum at Breeza.

ENSO classification

Annual gross margins for modeled opportunity cropping at Breeza were separated on the basis of the ENSO classification in the year of planting (Figure 53).

Suffering an El Nino in the year of planting of the opportunity cropping systems impacts significantly on the outcomes for the cropping system.

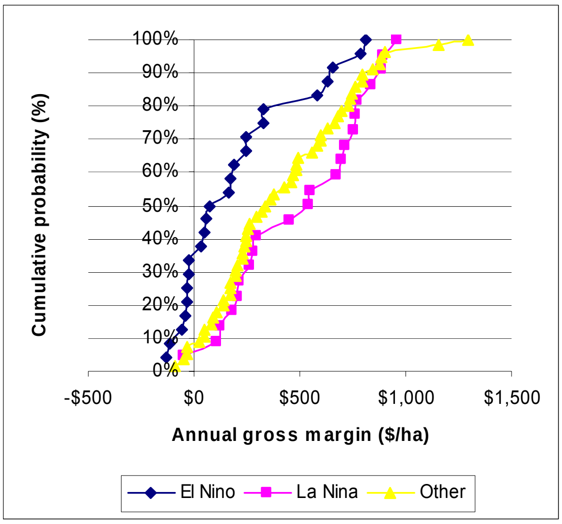
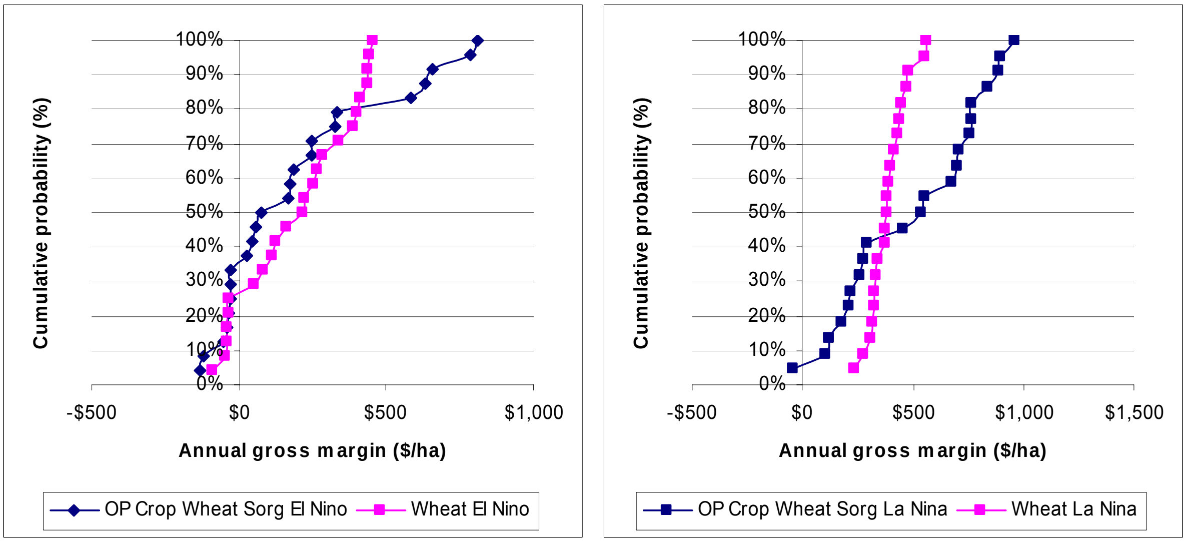


Figure 53 Annual gross margins for opportunity cropping wheat and sorghum at Breeza separated on the basis of the ENSO classification of the year of planting.

The availability of a forecast for ENSO events earlier in the year may reduce the riskiness of opportunity cropping systems at Breeza. (Figure 54a)



(a) (b)

Figure 54 Annual gross margins for opportunity cropping of wheat and sorghum and monoculture wheat production at Breeza separated on the basis of ENSO classification of the year of planting (a) El Nino years and (b) La Nina years.

Maintaining a wheat monoculture in El Nino years may reduce the chance of a loss in opportunity cropping systems by about 25%. (Figure 54a) The median annual gross margin for El Nino years may be improved by about $140 per ha if the choice to reduce cropping intensity is made.

It is not clear from this analysis whether the potentially lower annual gross margins in El Nino years in opportunity cropping systems are due to the impact of additional crops planted prior to the El Nino event or the taking of a summer cropping opportunity at the end of an El Nino year.

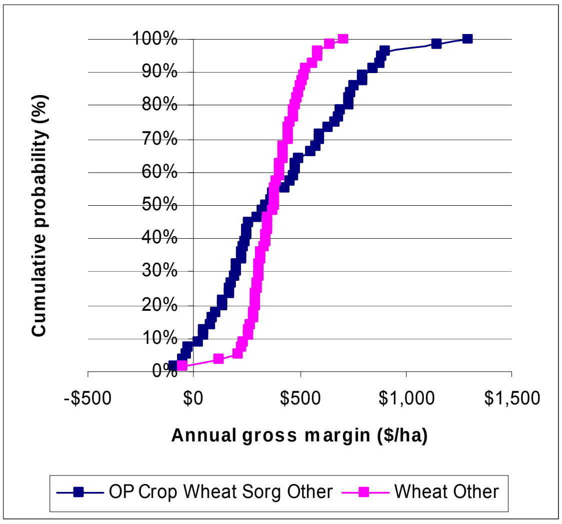
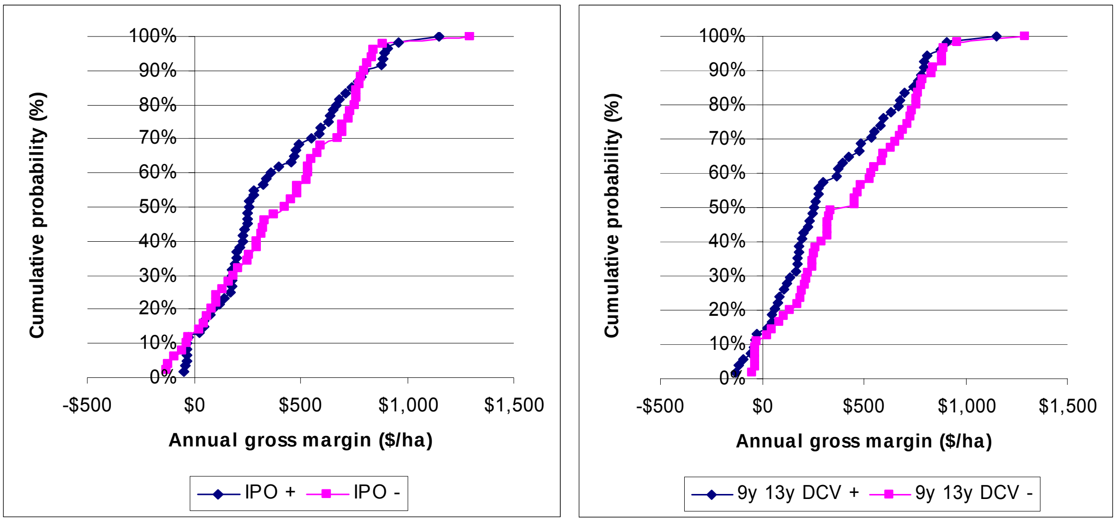


Figure 55 Annual gross margins for opportunity cropping of wheat and sorghum and monoculture wheat production at Breeza separated on the basis of the Other ENSO classification of the year of planting

Opportunity cropping of wheat and sorghum at Breeza is less reliable and generally less profitable than monoculture wheat in all classifications of the ENSO phenomena. It appears that incorporating summer crops into this winter dominant cropping system has a much bigger impact on the profitability and reliability of the winter crop than the summer crop leading to an overall reduction in the potential profitability of the opportunity cropping system compared to the monoculture wheat cropping system.

9y 13 y DCV Index and IPO

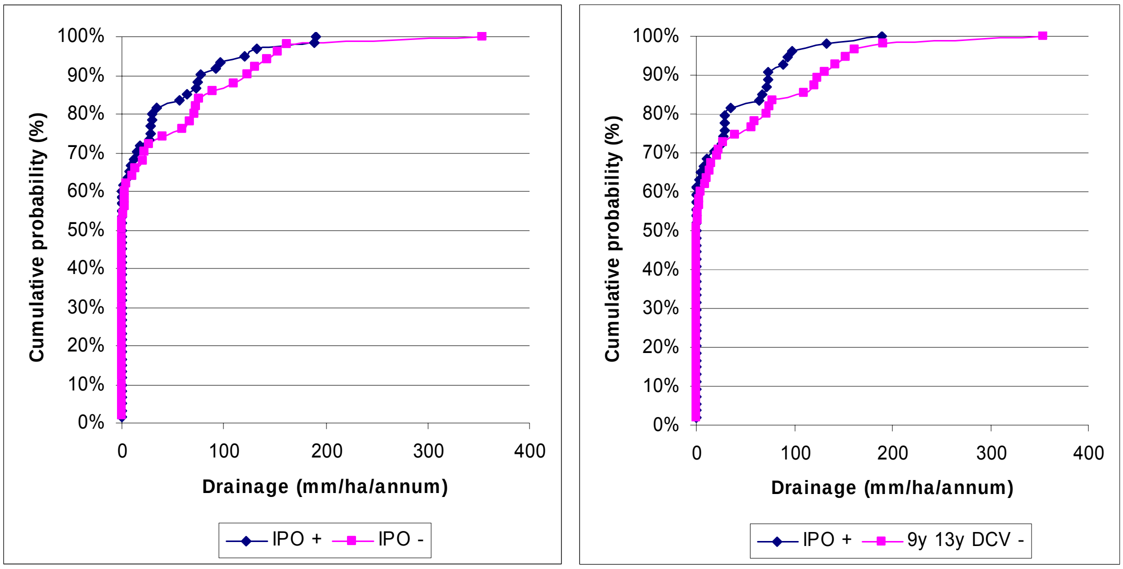
To test whether opportunity cropping of sorghum and wheat at Breeza responded to the different phases of the 9y 13y DCV index and IPO, annual gross margins were separated on the basis of the value of the index in January of the year of harvest (Figure 55).



(a) (b)

Figure 56 Distribution of annual opportunity cropping wheat and sorghum gross margins for (a) the IPO and (b) the 9y 13y decadal index

Both decadal indices show a separation of the annual gross margins for opportunity cropping wheat and sorghum. Knowledge of the phase of either decadal index would not add value to decisions about cropping intensity, as the underlying relationships between the cropping systems do not significantly change.



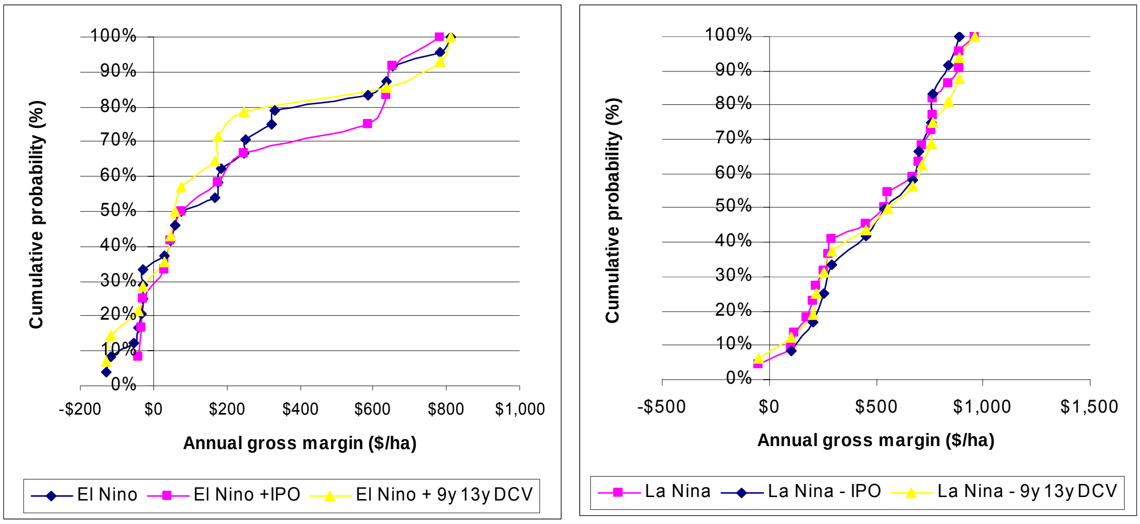
(a) (b)

Figure 57 Distribution of annual drainage under opportunity cropping wheat and sorghum at Breeza on a 190mm PAWC soil

The potential drainage under cropping system at Breeza is significantly reduced compared to monoculture wheat cropping systems. (Figure 56) Wetter periods still show increased drainage suggesting that not all of the additional water available during such periods is being captured and used by the cropping system.

Interactions between ENSO and DCV indices at Breeza

There is no altered impact of El Nino or La Nina events on opportunity cropping activities at Breeza if the phase value of either the 9y 13y DCV index or IPO is negative or positive respectively (Figure 57 a and b).



(a) (b)

Figure 58 Distributions for opportunity cropping wheat and sorghum annual gross margin at Breeza on a 190mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

5.4.5 Summary of opportunity cropping sorghum and wheat

Opportunity cropping systems at Breeza do show an economic advantage over less intensive wheat cropping systems in about 50% of years. Many of these years have occurred in the last half of the 20th Century.

None of the climate phenomena or climate forecasts tested here seem to be able to clearly identify when the decision to include extra summer crops in the wheat cropping system would consistently improve returns and reduce risk.

6 Discrete Years for Climate Indices

6.1 Discrete years for the 9y 13 y DCV index

The 9y13y DCV Index has been broken into periods when the index was above zero and periods when the index was below zero. The cut of and start dates were chosen as close as possible to the date at which the 9y13y DCV index changed its sign value. Table 5 shows these dates.

Table 5 Start and finish dates for phase values 9y 13y DCV index

Start	**Finish**	**Index sign**	**Years**
1-01-1890	31-12-1896	-	7
1-01-1897	31-12-1905	+	9
1-01-1906	31-12-1911	-	6
1-01-1912	31-12-1918	+	7
1-01-1919	31-12-1925	-	7
1-01-1926	31-12-1931	+	6
1-01-1932	31-12-1939	-	8
1-01-1940	31-12-1945	+	6
1-01-1946	31-12-1956	-	11
1-01-1957	31-12-1960	+	4
1-01-1961	31-12-1964	-	4
1-01-1965	31-12-1969	+	5
1-01-1965	31-12-1976	-	7
1-01-1977	31-12-1983	+	7
1-01-1984	31-12-1990	-	7
1-01-1991	31-12-1998	+	8
		Total	109

6.2 Discrete years for the IPO index

Table 6 Start and finish dates for phase values IPO DCV index

Start	Finish	Index sign	Years
1-01-1890	31-12-1895	-	6
1-01-1896	31-12-1907	+	12
1-01-1908	31-12-1919	-	12
1-01-1920	31-12-1944	+	25
1-01-1945	31-12-1977	-	33
1-01-1978	31-12-1998	+	21
		Total	109 years

Note –01/01/1945 to 31/12/1977 was truncated to 30 years in the analysis.

6.3 Discrete years for the ENSO classification

Table 7 ENSO classification (Potgieter *et al.* 2003)

El Nino years	La Nina years	Other years
1902	1908	1901
1905	1909	1903
1911	1910	1904
1914	1916	1906
1919	1917	1907
1925	1921	1912
1940	1922	1913
1941	1924	1915
1946	1928	1918
1951	1933	1920
1953	1938	1923
1957	1943	1926
1965	1945	1927
1969	1950	1929
1972	1955	1930
1977	1956	1931
1982	1971	1932
1987	1973	1934
1991	1974	1935
1992	1975	1936
1993	1988	1937
1994	1998	1939
1997		1942
2002		1944
		1947
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		1986
		1989
		1990
		1995
		1996
		1999

		2000
		2001

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APPENDIX 3

GRDC Project DAQ469/CRDC Project DAQ104C

Using Seasonal Forecasts for More Effective Grain-Cotton Production Systems

Climate variability, climate forecasts and grain-cotton production systems at Dalby

November 2005

Table of contents

1. Summary of results

The purpose of this report is to:

- identify the performance of alternate farming systems under varying climate systems at Dalby in south east Queensland
- quantify the potential benefits available to Dalby region dryland cropping farm managers from responding to actual or potential climate forecasts that occur at a range of time scales.

The overall modelling project is about estimating the impact of climate variability from the recent past on potential future returns. It is not about the past returns of existing Dalby region dryland cotton and grain producers.

Specifically we sought to answer the question:

Can the profitability, economic efficiency and resource risk management of dryland grain/cotton systems at Dalby be significantly improved through the effective use of seasonal climate forecasts and quantification of climatic variability?

Previous projects have considered the impact of a variety of indices of climate variability on rainfall patterns and found that the measured impacts of indices of decadal climate variability on rainfall were:

- Seasonal rainfall and soil water drainage responded to some indices of decadal climate variability.
- A relationship between the intensity of ENSO events and the phase of the IPO or DCV pattern was detected.
- Some scope may exist for responsive cropping systems to take strategic advantage of observed climate variability.

In terms of the aspects of cropping systems management that we considered, the results of this work are:

- Dryland cotton at Dalby on a 190mm PAWC soil is a relatively risky cropping system.
- None of the potential or existing forecasting systems tested here seem to have the capacity to change the perception by many dryland farmers at Dalby that cropping systems including dryland cotton are relatively more risky than alternate cropping systems.
- Where the decision to go dryland cotton farming requires the purchase of some specialist cotton machinery, such an investment in dryland cotton production equipment based on a climate forecast would not be profitable unless:
    - the investment was small,
    - the advantage was very large,
    - the forecast was very reliable.
- Tested climate forecasts may be used by existing dryland cotton producers at Dalby to reduce dryland cotton production when the forecast increased the chances of a loss in cotton production. This assumption may be unreliable as there still remains a reasonable upside for dryland cotton production in all forecasts and the basic expectations, risk preferences and choices of dryland cotton producers would probably remain unchanged.

- Price spikes for cotton relative to sorghum may change planting intentions for mixed cotton and sorghum producers but this does not change the underlying value of the climate forecasts tested.

2. Introduction

Climate variability is seen as having significant impacts on the profitability, efficiency and resource risks of dryland grain/cotton farming systems. Studies of the benefits of seasonal climate forecasting on tactical responses in farming systems have shown the potential for intensification in rotations, increased profits and reduced erosion risks. (See Hammer 1996, Meinke et al 1998, Carberry et al 2001)

This project has used simulation modelling combined with simple farm economic tools to consider the benefits of management strategies that incorporate climate forecasts into rotation management, crop selection and cropping intensity.

2.1 Questions to be answered

1. Can the profitability, economic efficiency and resource risk management of dryland grain/cotton systems be significantly improved through the effective use of seasonal climate forecasts and quantification of climatic variability?
2. Can indices of decadal climate variability (DCV) provide opportunities to manage grain cotton cropping systems more profitably?

In general, managers can respond to a climate signal or forecast within a farming system by:

- Varying the inputs applied to a crop, for example
    - Variety sown
    - Fertiliser rate
    - Planting date
    - Seeding rate
- Varying the crop sown, for example
    - Cotton or sorghum
    - Wheat or barley
- Varying the cropping season targeted, for example
    - Summer versus winter
- Varying the intensity of cropping, for example
    - Opportunity cropping versus fixed rotations
- Varying the proportion of the property planted to different cropping systems

This analysis considers the impact of responding to the variables of crop sown, cropping intensity and cropping season specifically for some dryland cotton farming systems and their alternates at Dalby in southern Queensland.

The potential benefits of varying inputs and cropping intensity in response to a seasonal climate forecast have previously been investigated. (See Hammer et al 1996, Hammer et al 2001, Meinke et al 2001)

2.2 What has been done previously?

Extracts from the final report of Climate Variability in Agriculture Project - *Can decadal climate variability (DCV) be predicted? (*Reference Number QPI44)

Extract 1

Several tentative conclusions can be drawn from these results:

1) *DCV at the 9 – 13 year time scale is evident in the simulated drainage component of a wheat – fallow – wheat system.*
2) *The frequency of a drainage event occurring is generally higher in 'low' DCV years (eg. Wallumbilla, 70% vs. 40%, respectively).*
3) *Difference between high and low DCV years are more pronounced in the summer rainfall dominated environments (Southern Queensland to Central NSW). This result is congruent with our global rainfall analysis in the previous section where we showed the strongest effect of DCV on Eastern Australian rainfall during OND and JFM. This is also the period that coincides with the fallow period (and hence low water use periods) in the simulations, leading to increased incidence and amount of drainage.*
4) *This might provide an opportunity to strategically intensify rotations at locations most affected by drainage. It clearly is an area of research that requires additional research to address the emerging and pressing problems in our agricultural systems.*

Extract 2

As for the IPO (Interdecadal Pacific Oscillation - Power et al 1999), JFM rainfall resulted in the highest fsr value affecting predominantly Queensland, South Africa, Mexico and SW USA. Autumn rainfall in Australia (AMJ) does not appear to be impacted by DCV. Winter rainfall (JAS) for Northern and Central NSW appears to be somewhat affected and spring rainfall (OND) in South Australia, Southern NSW, Victoria and Tasmania appears to be modulated at these time scales.

Extract 3

For their study, Keating et al. (2001) only used post 1957 rainfall data, because this is the only data source that provides simulation ready, daily climate data with good spatial coverage. This limits the interpretive value for issues at decadal time scales and beyond and a more detailed analysis should focus on stations for which long-term climate records (100 years +) are available. Here we only report on results from the wheat – fallow – wheat rotations. Keating et al. (2001) investigated a range of possible rotations differing in intensity and crops used. Clearly, this will have significant impact on the amount of drainage and forecasts based on DCV might offer a way to identify rotations and management options that are profitable as well as sustainable. This should be the focus of the next phase of research.

Extract 4

Part II: Effect of DCV on global rainfall distributions

Previous research has shown that a negative (positive) IPO or DCV pattern enhances (weakens) any ENSO related rainfall variability in many parts of Australia (Meinke et al., 2000).

2.3 Summary of previous work

Measured impacts of indices of decadal climate variability on rainfall were:

- Seasonal rainfall and soil water drainage responded to some indices of decadal climate variability.
- A relationship between the intensity of ENSO events and the phase of the IPO or DCV pattern was detected.
- Some scope may exist for responsive cropping systems to take strategic advantage of observed climate variability.

3. Current work

Case studies have been completed at four sites to consider the impact of climate variability arising from two decadal indices and one ENSO classification on dryland cropping systems. The SOI phase system of forecasting (Stone and Auliciems (1992)) has also been applied to some of the cropping systems to test its capacity to identify opportunities to alter the crop sown in the next season or intensify cropping activities.

The two indices of decadal climate variability assessed are the IPO as described by Power et al (1999) and the 9y 13y index described by Meinke et al (2003). Potgieter provided the ENSO classification. (Potgieter et al 2003)

The four sites studied are:

- Emerald in Central Queensland
- Dalby / Warra in South East Queensland
- North Star in Northern New South Wales
- Gunnedah / Breeza in Central Northern New South Wales

The sites move from highly summer dominant rainfall in the north down to a balance of summer and winter rainfall.

Climate stations at these locations have greater than 100 years of reliable records for daily rainfall and temperature.

Cropping systems analysed at each location were:

- Monoculture sorghum
- Monoculture cotton
- Monoculture wheat
- Opportunity cropping cotton, sorghum and wheat
- Opportunity cropping sorghum and wheat
- Opportunity cropping cotton and sorghum
- Fixed rotation cotton and sorghum

These cropping systems represent the major alternatives available for summer and winter cropping windows at the four sites and were chosen for their ability to highlight any benefits that may arise from responding to marginal differences in seasonal or decadal water supply.

The monoculture cropping systems were included to represent low intensity summer and winter based cropping systems.

The opportunity cropping systems were included because of their potentially greater responsiveness to the water supply available to the cropping system.

One fixed rotation of summer crops was included to indicate the relative performance of a rotational cropping system that may not respond immediately to the prevailing climate or water supply but could represent a more typical/traditional approach to incorporating cotton with its perceived greater riskiness into dryland farming systems.

The planting rules for the fixed cotton sorghum rotation indicate that if a crop is not planted when expected the fallow period will extend to the next crop in the rotation. Fixed planting rules occasionally lead to lengthy fallow periods in environments with variable climates but may increase the reliability of the crops planted. This trade off can be considered by the inclusion of this fixed rotation cropping system.

The cropping systems simulation model APSIM was used in combination with whole-farm economic analyses to assess the economic response of these cropping systems to climatic variability.

Outputs generated for each cropping system were:

- Yield by year (1890 to 2003) and cumulative distribution of yield
- Cumulative distribution of wheat protein
- Gross margin by year (1890 to 2003)
- Total gross margin by decade, overlapping at half decade intervals
- Investment return by decade, overlapping at half decade intervals
- Distribution of annual returns
- Cumulative distribution of annual gross margin (1890 to 2003)
- Cumulative distribution of crop gross margin by climate variability index
- Marginal return on capital invested in changing cropping systems (where applicable).
- Drainage, runoff and soil loss by year and decade.

Cropping systems are compared in pairs or to monoculture cotton or monoculture sorghum production and this report contains only those outputs thought to be relevant to the analysis.

3.1 Modelling Processes

3.1.1 APSIM model

APSIM is a daily time step model that mathematically reproduces the physical processes taking place in a cropping system. This calculation of daily outcomes within the model allows the collection of cropping system outputs on a time basis and/or event basis.

APSIM can be run for any number of days up to the total length of suitable climate records.

The ability of cropping systems modelled in APSIM to:

- respond accurately to rainfall incidence and effectiveness;
- reflect soil water balance over time;
- generate dates for events and time spans between events;

is the critical reason for using a dynamic crop simulation model to generate expected crop yields and cropping frequency.

When this information is combined with representative whole farm models, the economic impacts of alternate management systems can be related to specific sequences of climatic events or states of the farming system.

For example, the annual gross margin for each cropping system had variable fallow costs that responded to the amount of rainfall and the number of days of the fallow period between crops.

Fallow costs relating to specific crops were included along with variable fertiliser costs that responded to the efficiency of soil N use by the cropping system.

The costs of crops that were planted and then failed or had the yield significantly reduced by seasonal conditions were also matched to cropping system outcomes.

In this way the costs associated with the cropping system were made to respond to the type of crops grown, the intensity of the cropping system and the climatic conditions encountered by the cropping system.

There are some limitations to this modelling approach.

- APSIM has to be configured specifically for each location.
- APSIM plants crops on a single day with an even plant establishment plus optimal plant population and spacing.
- APSIM crops are grown without significant weed or insect competition and do not suffer harvest losses or frost damage.
- APSIM crops and rotations respond only to the crop sequence characterised during model initiation. They do not respond over time to changing price relationships or the timeliness of alternate farming systems.

The limitations of APSIM need to be remembered when the results of simulations are being interpreted.

3.1.2 Model farm approach

The outputs of APSIM have been incorporated into whole farm models and used to generate two types of outputs. Firstly, as outputs arranged in time sequence to construct relatively simple cash flow and investment budgets. Secondly, as outputs used to construct annual gross margins and arranged as probability distributions.

Investment budgets are constructed for time periods up to thirty years and generally allow for at least one investment cycle for farm plant and equipment.

The economic analysis seeks to inform the managers of cropping systems as to the possible range of economic and financial outcomes arising from the major cropping system choices and responses to climate indices available to them.

3.2 Climate indices tested

Meinke et al (2003) described correlations between global, low frequency sea surface temperature (SST) anomalies and seasonal rainfall in the tropics and subtropics, the North Atlantic region, India, northern Africa and Australia.

For their study they used factor scores from time series based on empirical orthogonal function (EOF) analyses of a) near-global SST and MSLP data (4 time series band pass filtered for significant frequencies) and b) Pacific SST data alone (1 series).

The four frequencies for the combined SST and MSLP analysis were (i) 2.5 to 8.0 years representing the ENSO timescale; (ii) 9 to 13 years or decadal timescale; (iii) 13 to 18 years or inter-decadal timescale and (iv) 18 to 39 years or multi-decadal timescales (Allan 2000).

The frequency of the 9 to 13 years or decadal timescale is graphed in figure 1. The index will be referred to as the 9y 13y DCV index in this report. All cropping systems will be tested for response to the phases of this index.

3.2.1 9y 13y DCV Index

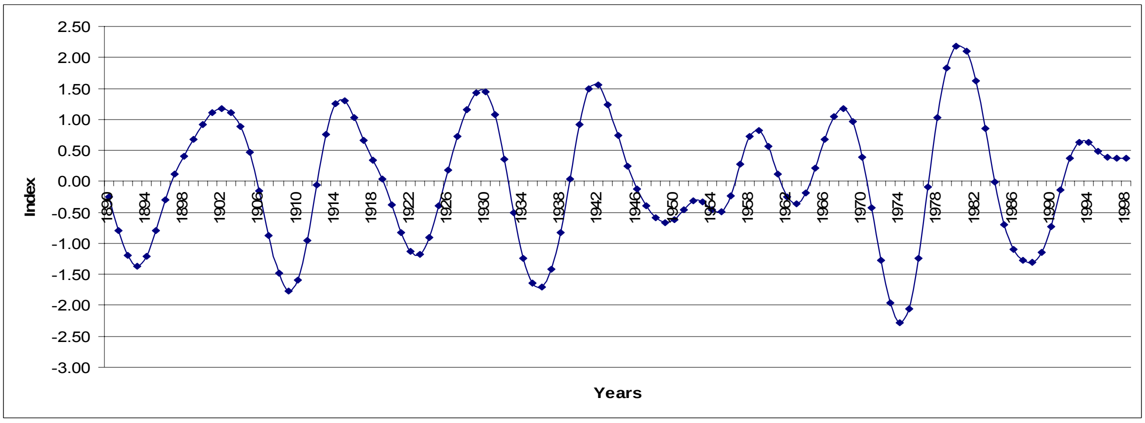


Figure 1 Graph of Decadal Climate Variability 9y 13y index values

3.2.2 Interdecadal Pacific Oscillation

Power et al (1999) found that many of the Pacific Low Frequency SST based indices are similar and can be combined into what is collectively known as the Inter-decadal Pacific Oscillation (IPO).

Cropping systems will also be tested for response to the phase values of this index.

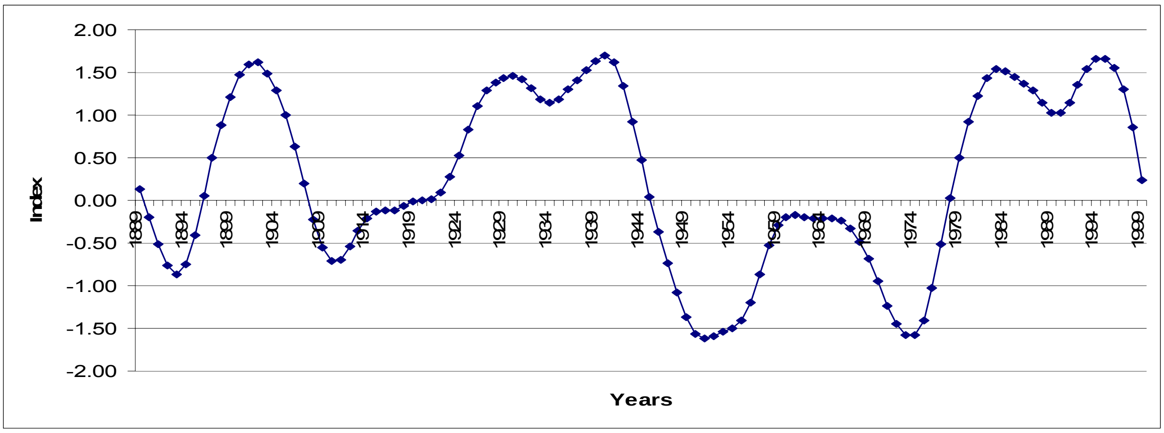


Figure 2 Inter-decadal Pacific Oscillation phase values

3.2.3 ENSO classification

El Nino and La Nina events in the period 1901-2002 were derived by Potgieter et al (2003) using a classification system based on the combination of extended reconstructed SST (ERSST) 18 and Troup SOI10 data sets. (See Appendix 1 for the classification of individual years under this classification)

Using the SST time series, a year was classified as El Nino if the 5-month running mean was greater than or equal to 0.5 for 6 or more months between April and December 19. Using the SOI time series, a year was classified as El Nino if the 3-month running mean was less than or equal to -5.5 for 6 or more months between April and December 20. The La Nina classification was the opposite in sign of both the El Nino classifications for SST's and SOI's.

The threshold value for the classification of El Nino years based solely on SST or SOI yielded near 25% occurrence for each. Combining both classification systems resulted in 24 El Nino years and 22 La Nina years in the 102 years used in this analysis. See Smith et al (2003), Trenberth KE (1997) and Ropelewski (1987) for the derivation of the base climate indices.

3.2.4 SOI phase forecast system

The SOI phase forecast system is a probabilistic rainfall forecast system based on defined phases of the Southern Oscillation. (Stone & Auliciems (1992), Stone et al (1996)) This forecast system is currently available for application by farm managers unlike the other various classification systems and indices tested for response in this project.

The annual gross margins for all monoculture cropping systems have been tested for response to the phase of the SOI in the month prior to the planting window opening. Opportunity cropping systems have been tested for to response to the phase of the SOI in July/August of the year prior to the calculation of the annual gross margin.

3.3 Property Investment at Dalby

The chosen characteristics for the model property at Dalby are as follows:

- 1000 ha total size of property
- 900 ha cultivation
- $2,500 / ha value for land and fixed improvements = $2,500,000
- Opening plant and equipment value for a property that can grow cotton is $510,250 (See appendix 1 for details of farm plant and equipment)
- The capital cost of setting up to grow dryland cotton is $32,500.

In this analysis, properties that do not have a capacity to grow dryland cotton (those that only grow grain crops) do not own the scuffler, a module builder or the boll buggies. This reduces the current value of farm plant to $478,250. (See appendix 1 for details)

- Soil – very deep, self-mulching grey vertosol, 190mm PAWC
- Rainfall – summer dominant, 660mm median rainfall
- Farming system – zero till where possible
- Farm overhead expenses $87,500 per annum. Farm overhead expenses represent the fixed costs of operating the farm business. (See appendix 1 for details)

Cotton growing is expected to incur additional labour costs compared to cereal cropping systems and these costs have been estimated on a per hectare basis and included in the cotton variable costs of production. (See appendix 1 for details)

- The owner manager of the property is paid a return of $60,000 per annum for management skills and labour.
- No debt is held by the business at the beginning of each simulation.

The example property is considered to be a high quality property that is equipped with modern farming equipment highly suited to the low tillage farming system at hand. The manager is also considered to have the skills and experience to manage the cropping systems modelled with a similar degree of timeliness and success to that captured in the model.

The property and its management are considered to be very capable of producing dryland cotton in this environment, something that properties with lesser management, equipment, financial resources or shallower soils may not be able to do with the same level of success.

The property is also considered to have the most likely overall configuration for responding successfully to a climate forecast.

4. Cropping System Analysis

4.1 Cotton monoculture cropping systems

4.1.1 Cotton Yields

Figure 3 indicates the cumulative distribution of cotton yields that could be expected at Dalby on this soil under the farming conditions modelled.

This distribution was achieved after modelled yields produced by APSIM were compared to trial results for dryland cotton production and farmer expectations. After some discussion, it was decided that an across the board reduction in modelled yields by 20% would better reflect the expected outcomes for dryland cotton production at Dalby.

Using this modified distribution of yields we expect that monoculture cotton cropping farming systems will fail to plant in about 15% of years due to a lack of a planting rain or stored soil water but will exceed 3.25 bales per hectare in 50% of years planted.

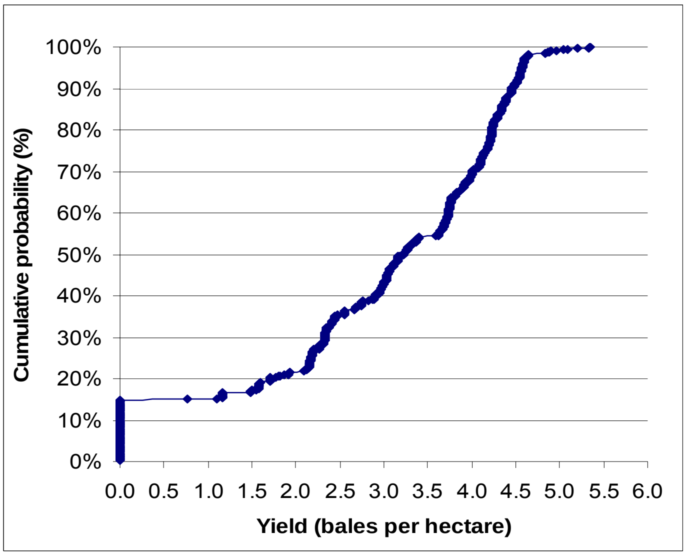


Figure 3 Distribution for monoculture cotton yields at Dalby – all years 1890 to 2003

Figure 3 shows the modelled yields for the harvest years from 1976 to 2003.

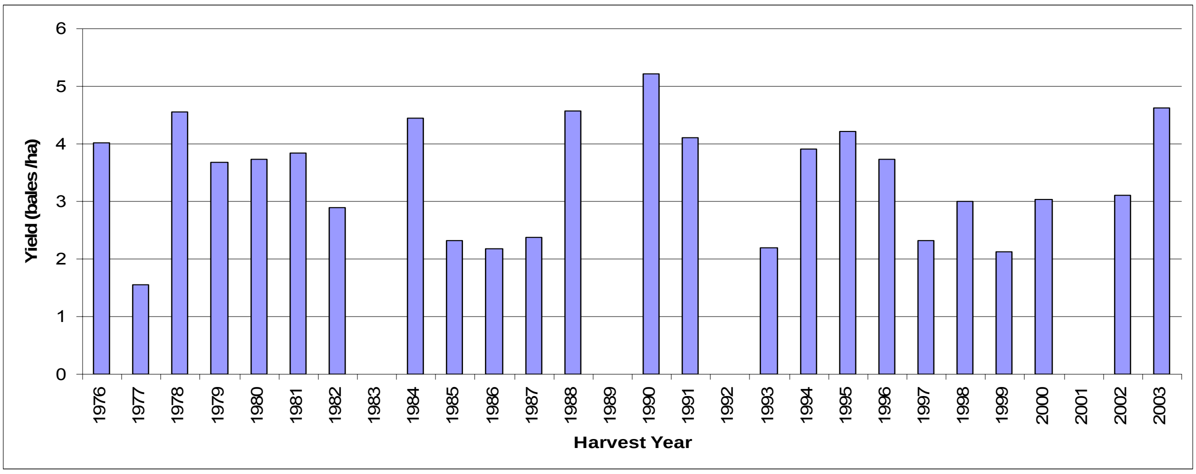


Figure 4 Cotton yields as modelled for Dalby 190mm PAWC soil by APSIM (1975 to 2002 plant years, 1976 to 2003 harvest years)

Modelled yields match up fairly consistently with yields achieved in paddock scale trials carried out over recent seasons and reflect the variable seasonal conditions of the past 25 years quite well.

4.1.2 Cotton gross margins

Figure 5 shows the cumulative distribution of annual gross margins for the harvest years from 1891 to 2003.

The gross margins are calculated with an average selling price of $475 per bale ex gin with current growing costs applied across all years. (See appendix 1 for growing costs)

The variable selling prices and different growing costs of the past would have obviously produced different real results for cotton growers who actually grew the crops during the years modelled. It must be remembered that the purpose of the modelling exercise is to reflect the impact of past climate variability on potential returns, not to reflect the past returns of existing dryland cotton producers.

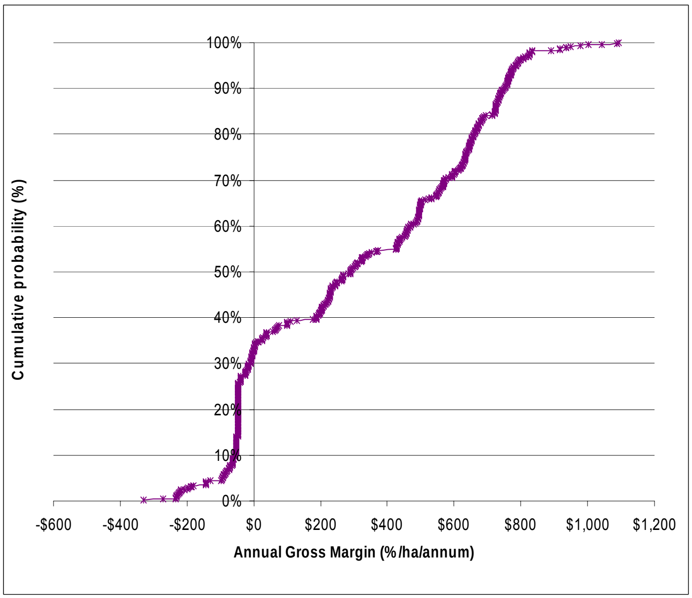


Figure 5 Distribution for monoculture cotton gross margin at Dalby

Negative annual gross margins are produced by missed cropping opportunities and by crops that are planted and then fail. In about 35% of years more funds would be spent on growing dryland cotton at Dalby than are earned. The top 20% of years produce gross margins of greater than $700 per hectare at the prices and costs selected.

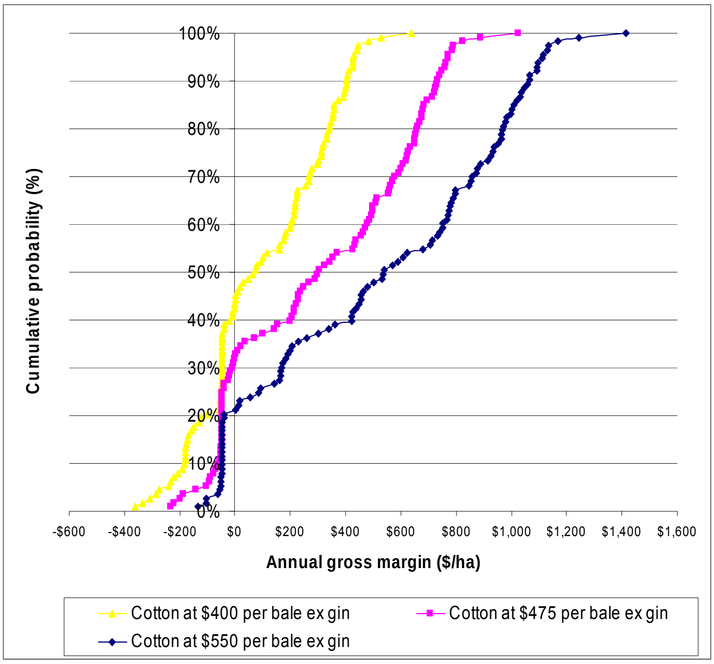


Figure 6 Distribution for monoculture cotton gross margin at Dalby at three separate prices per bale (ex gin)

Figure six above indicates the potential gross margins for monoculture cotton at a range of prices ex gin. Higher prices still have a reasonable expectation of low and negative gross margins. Low prices show dryland cotton production as very risky.

Future annual gross margins for dryland cotton production at Dalby could fall somewhere between -$350 per ha and +$1400 per ha. We have used an ex gin price of $475 per bale for the remainder of our analysis to simplify the graphs and to make variability due to climate more identifiable. The full range of possible prices should be remembered throughout the analysis.

Figure seven (below) shows the annual gross margins for dryland cotton production at a price of $475 per bale ex gin from 1976 to 2003 harvest years.

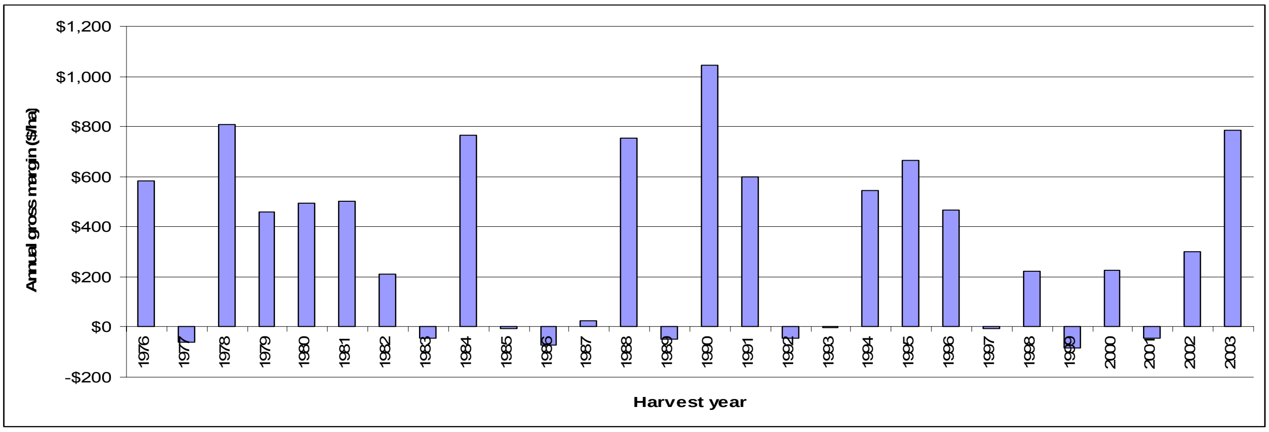


Figure 7 Harvest year gross margins modelled from 1976 to 2003 for dryland cotton at Dalby on a 190mm PAWC soil

The variability of monoculture cotton production at Dalby is also apparent in figure seven. Ten of the twenty-eight years of the sequence produce a negative gross margin. About the same number of years produce a gross margin of greater that $500 per hectare. At current prices this would be quite a profitable crop and relatively more profitable that the alternate cereal crops at their current expected production costs and price ranges.

Few if any dryland cotton producers would attempt to grow dryland cotton over their whole property at the frequency shown in figure seven because of the variability of returns. The monoculture cropping system has been included at this cropping frequency as it requires large amounts of stored soil water and in crop rainfall to be successful at this location and is therefore likely to show a response to a favourable climate sequence that provides extra rainfall for cropping.

Figure eight indicates the decadal variability of gross margin returns from dryland monoculture cotton growing at Dalby. The total of annual gross margins for any decade can vary by up to 50% around the median value for the total period (113 years) modelled.

The total gross margin for each decade is the sum of the annual gross margins. When a crop is missed or has a low yield, the annual gross margin can be a negative value and reduce the total gross margin for the decade.

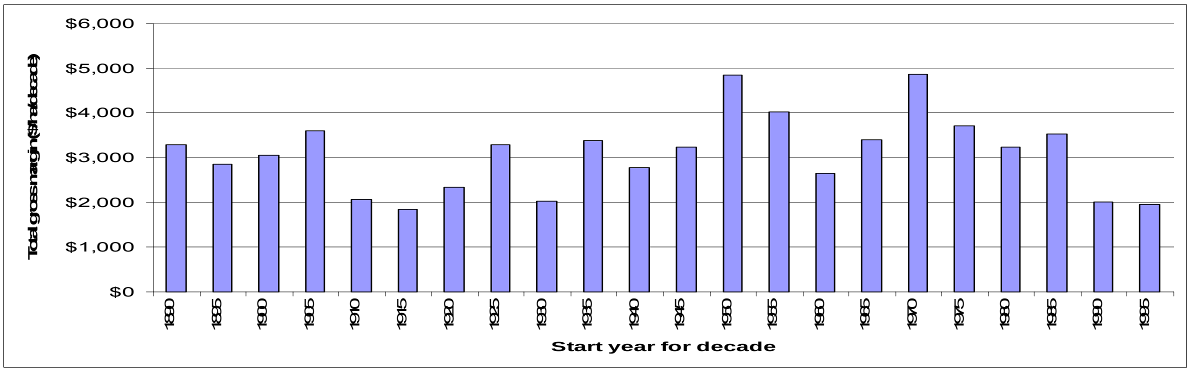


Figure 8 Total gross margins by decade for monoculture cotton at Dalby

Note that the total gross margin for each decade overlaps by five years and therefore tends to smooth out some of the decadal fluctuations in returns. The total for the decade beginning in

1995 only contains eight harvest periods and if good cropping conditions are received in late 2003 and 2004 then the total for this decade could be significantly improved.

All of the variability shown in figure seven is driven by the prevailing climate. At current costs and returns, the poor climatic result for dryland cotton growing encountered in the decade from 1990 to 2000 would have been encountered in about 25% of the previous decades since 1890.

4.1.3 Return on cotton investments

Annual return

Figure nine shows that a farming business at Dalby that specialised in growing dryland cotton could expect to lose money on funds invested in about 40% of years. Annual returns above 10% could be expected in 40% of years.

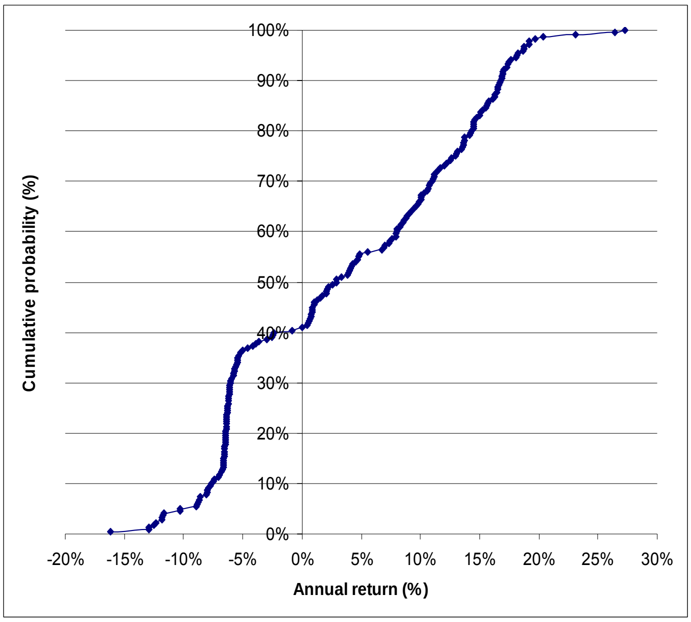


Figure 9 Annual return on capital invested for a dryland cotton property at Dalby

Internal Rate of Return

Although figure eight indicates the highly variable annual returns that could be suffered by a specialist dryland monoculture cotton grower and is a measure of the riskiness of the cropping system, it is probably better to consider a return on investment that is calculated over a longer period of time than one year as a measure of the potential success or failure of investing in cotton production. Most farming investments last at least a decade and will tend to receive some favourable and unfavourable weather patterns over that longer period of time.

The internal rate of return (IRR) is a measure that captures the flows of capital, income and costs into and out of a business over the period of the investment. We calculated the IRR for an investment in monoculture cotton at Dalby for 22 overlapping decades of climate history since 1890. Each decade began with the same level of investment and then received income and paid costs as the prevailing climate dictated. At the end of the decade the farm investment was sold and the return calculated. The percentage return calculated represents the average return on capital invested over the period.

Figure ten shows the IRR for specialist dryland monoculture cotton producers over twenty-two investment decades since 1890. The variation is due entirely to differences in climate encountered by the farm business within each decade. Prices are held at $475 per bale ex gin.

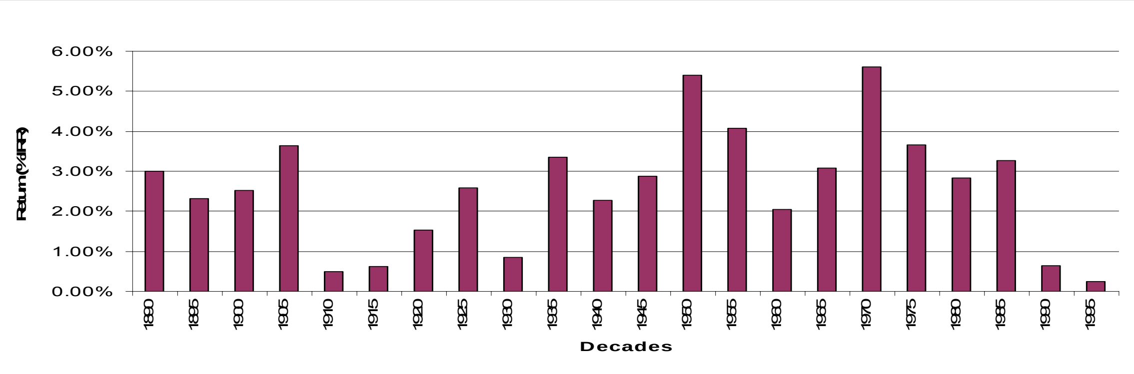


Figure 10 Variation in decadal returns for a dryland cotton property investment at Dalby

Figure ten shows the range of decadal returns on capital available from an investment in dryland cotton production at Dalby. These returns are not directly comparable to investment returns available elsewhere as they have not been adjusted for the effect of inflation or the cost price squeeze. The returns can be compared to each other across decades and to other cropping systems with returns calculated the same way to show the impact of climate variability.

No negative returns on capital are shown as the calculation of IRR tends to be buffered by the value of land and machinery included in the calculation.

The most favourable climate period for investing in dryland cotton at Dalby (i.e. the one providing the best return on investment when all non climate factors are held constant) was the decade from 1970 to 1980. Note again that the return for the period from 1995 only contains eight harvest years. The decades beginning 1950 and 1970 were 25% better in relative terms than any other decade.

Dryland cotton production developed and rapidly expanded during the period from 1970 to 1990 in southern Queensland. The consistency of return on investment for dryland cotton production shown by the four overlapping decadal investment periods that cover the years from 1970 to 1990 has not been matched over the previous recorded climate period. The performance expectation of dryland cotton producers in southern Queensland may prove be a little high if we experience a similar range of climate in the future as we have in the past.

Sustainability Indicators

The sustainability indicators output from APSIM can be compiled to provide a comparison between decades for individual cropping system and a comparison between modelled cropping systems over a number of decades.

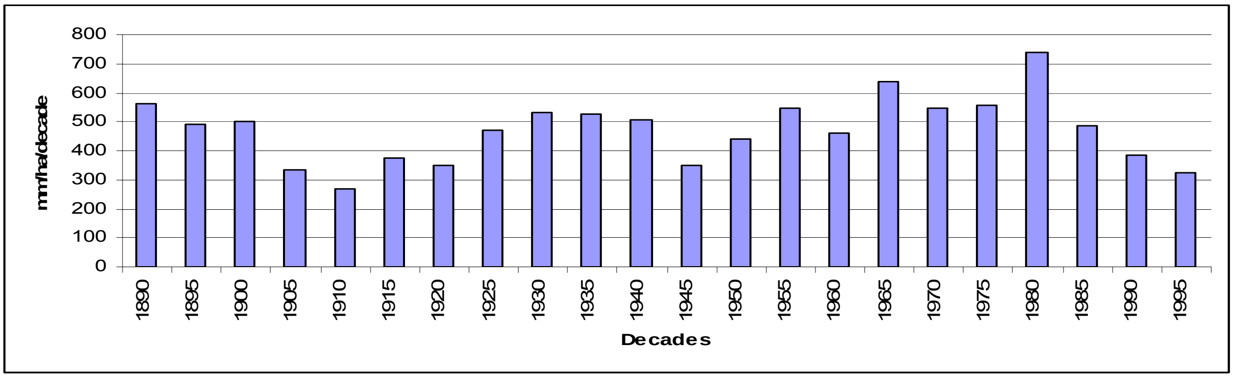


Figure 11 Total modelled runoff per decade at Dalby from monoculture cotton grown on a 190mm PAWC soil

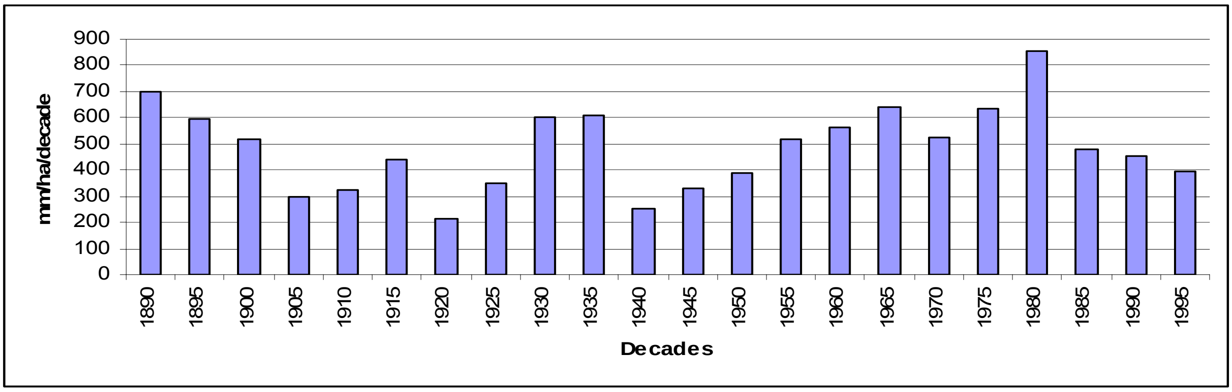


Figure 12 Total modelled drainage per decade at Dalby from monoculture cotton grown on a 190mm PAWC soil

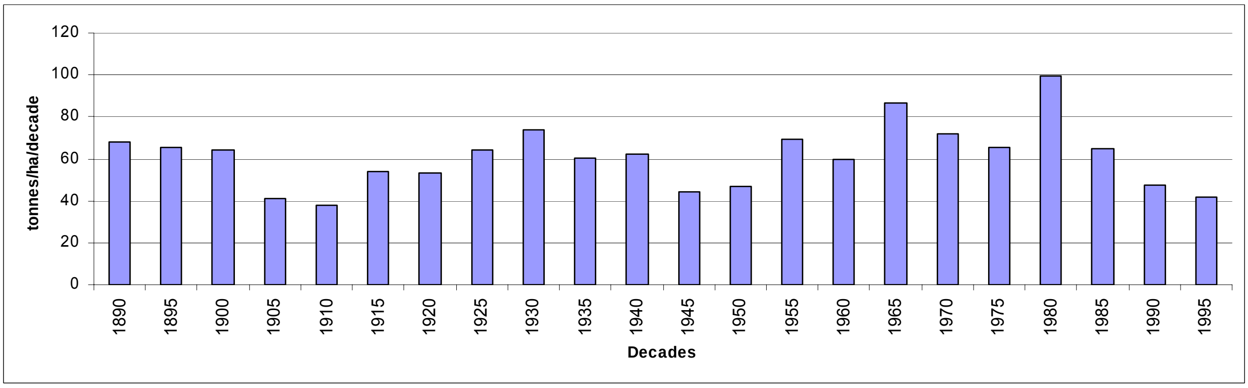


Figure 59 Total modelled soil loss per decade at Dalby from monoculture cotton grown on a 190mm PAWC soil

It is interesting to note that the decade beginning in 1980 indicates a significantly higher level of runoff, drainage and soil loss for monoculture cotton production than for any other decade.

Figure fourteen shows the modelled soil loss on an annual basis from 1975 to 2002. The APSIM output indicates that four years in the 1980's had potential soil loss that was greater than 10 tonnes per ha.

This suggests that this monoculture cotton farming system on this soil may not trap the available water from some rainfall events even though the farming system is low tillage in nature. This inability to trap the available rainfall may not make monoculture cotton as responsive to higher rainfall input from a favourable climate cycle as previously hoped.

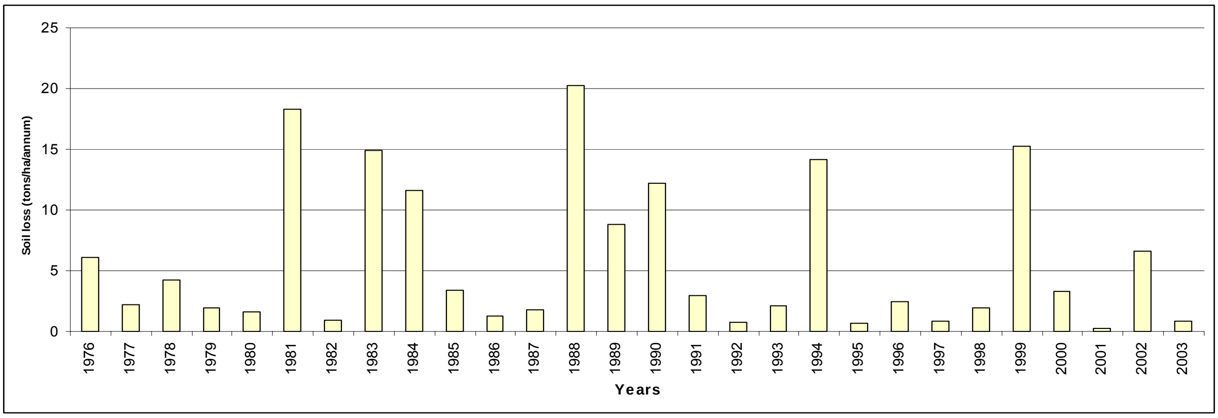


Figure 14 Modelled annual soil loss for monoculture cotton at Dalby on a 190mm PAWC soil (1975 to 2003)

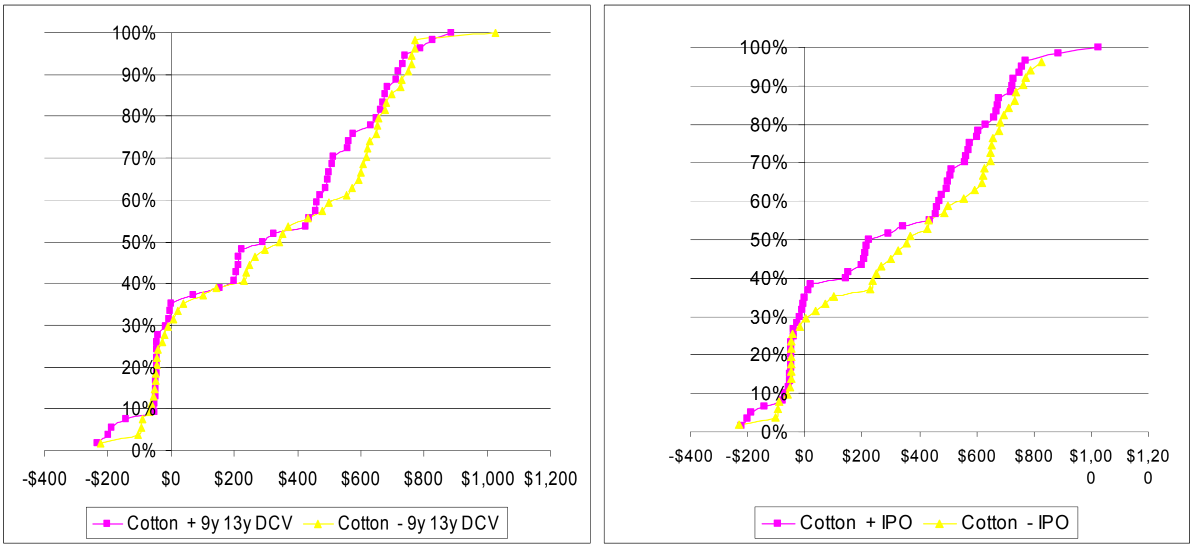
4.1.4 Climate signals and monoculture cotton at Dalby

Decadal Climate Variability (DCV) Indices

To test whether dryland cotton production performed differently in different phases of the various climate indices the annual gross margins for dryland cotton production at Dalby were separated on the basis of the value of the DCV index in January of the year of harvest.

Generally cotton would have been planted in September or October of the previous year. The 9y 13y DCV index has values calculated up to and including 1998 and the IPO index has values calculated up to and including 1999.

Values for these indices are only available for the past and cannot currently be predicted. They will be used in this analysis as if they could be acted upon in advance, allowing a value to be placed on giving the indices a predictive capacity.



(d) (b)

Figure 15 Distribution of annual dryland cotton gross margins for the 9y 13y decadal index (a) and the IPO index (b).

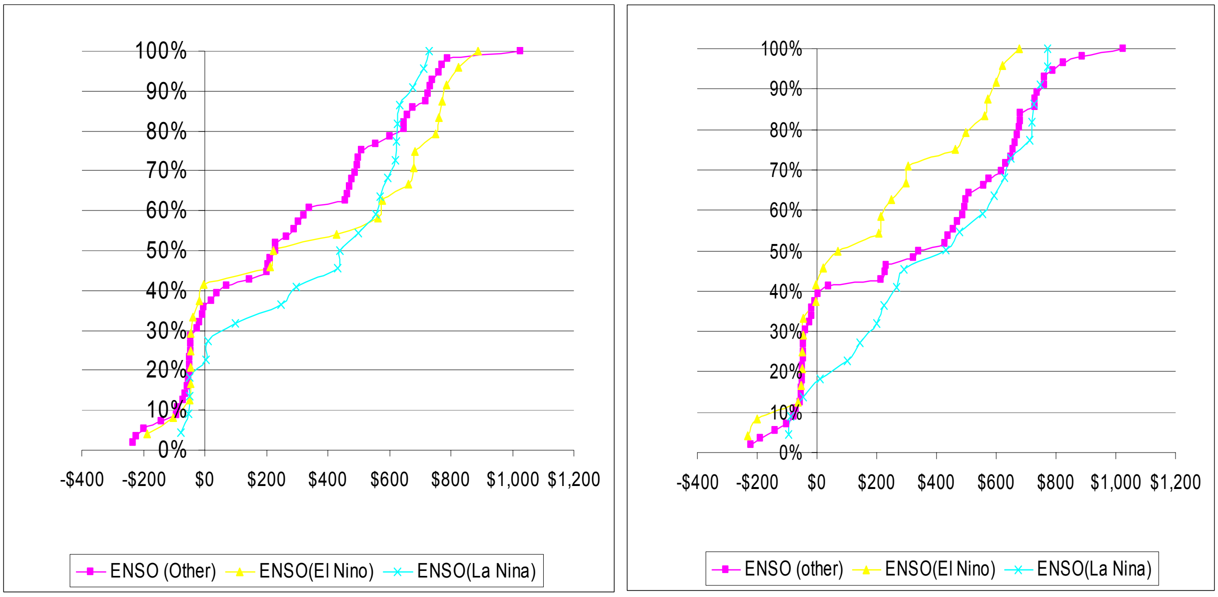
The median annual gross margin for dryland cotton production in years with a positive (+) 9y 13y DCV index is $307 per ha. Years with a negative (-) 9y 13y DCV index have a median gross margin of $347 per ha. Both phases of the index show a high percentage of years when a negative gross margin would be suffered.
The IPO index shows a median gross margin of $256 per ha in positive years (+) years and a median gross margin of $354 per ha in negative (-) years.

The IPO index also indicates that the chance of suffering a negative gross margin increases from about 30% of years when the index has a negative (-) value to 40% of years when the index has a positive (+) value.

ENSO classification

Annual gross margins for dryland cotton production at Dalby were separated on the basis of the ENSO classification in the year of planting (Figure 16a) and also on the basis of the ENSO classification in the year of harvest (Figure 16b).

Generally cotton is planted in September or October of the one year and harvested in the first half of the following year. The ENSO classification provided by Potgieter et al (2003) has values calculated from 1901 up to and including 2002.



(a) (b)

Figure 16 Distribution of annual dryland cotton gross margin for ENSO classification years. Figure (a) Plant year ENSO vs. harvest year GM and figure (b) harvest year ENSO vs. harvest year GM.

The ENSO classification in the year of planting would not be known until after cotton planting but does not offer great predictive capacity.

For example suffering an El Nino in the year of planting slightly increases the chances of producing a negative gross margin but such crops go on to potentially outperform crops planted in La Nina years 40% of the time. Crops planted in La Nina years will potentially outperform crops planted in the other two classifications in about 30% of years but have similar performance in the remaining 70% of years.

The largest impact on dryland cotton production at Dalby seems to occur when an El Nino year coincides with a harvest year.

The occurrence of an "El Nino" event in the year of harvest of a dryland cotton crop at Dalby produces a median gross margin of $137 per hectare. A year classified as "other" produces a median annual gross margin of $383 per hectare and a year classified as "La Nina" produces an annual gross margin of $455 per hectare. Unfortunately this knowledge of how the year is classified is not currently available until December of the year of harvest, some months after the crop has been harvested.

SOI phase

Dryland cotton gross margins were separated on the basis of the phase of the SOI in July / August of the year of planting. The SOI phase is the most likely forecast tool that a farmer intending to plant cotton will have available to support a decision.

Australian Rainman (version 3.3) finds that the only statistically significant phase of the SOI in July August is the consistently negative phase and that is only for rainfall from September to November.

There is no predictive skill provided by the July August phase of the SOI for rainfall over longer periods of the summer beginning in September or periods later in the summer.

Figure seventeen shows the separation of annual gross margins for dryland cotton production at Dalby based on the phase of the SOI in August of the planting year.

The outcomes for dryland cotton planted in those years with a SOI negative phase in July August of the planting year is largely identical to the other four phases in about 70% of years but different to three others in about 30% of years. This variation in cropping outcomes has been shown in other studies to have a value in tactical decisions. (Hammer et al 1996, Hammer et al 2001,Carberry et al 2001)

In terms of riskiness, a distribution that shows a 45% to 50% chance of receiving a negative gross margin (SOI falling, SOI negative) and a 60% chance of being less than $250 per ha may make a decision maker think twice about the alternatives to dryland cotton production in the following summer, even though the remainder of the distribution shows a similar range of outcomes as other phases of the SOI in August.

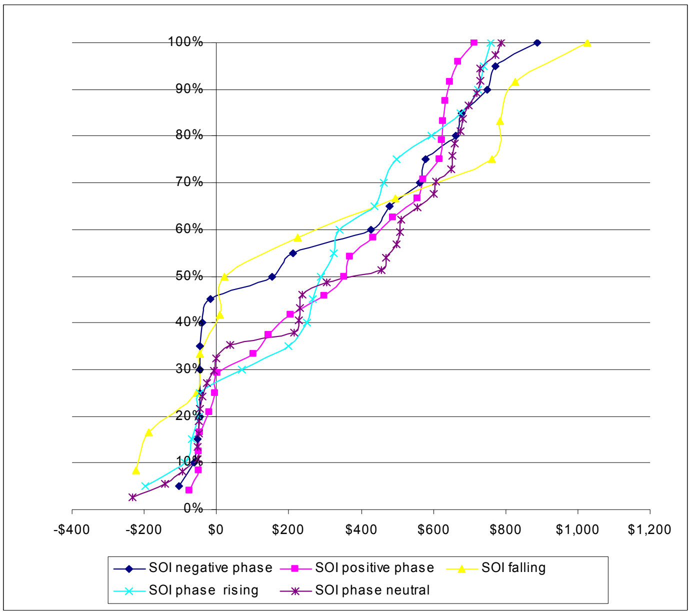


Figure 17 Dryland cotton distributions at Dalby on a 190mm PAWC soil separated on the basis of the SOI phase in July August of the year of planting.

Crop yields or gross margins produced by a crop model like APSIM that incorporates rainfall effectiveness may show a different level of response to a forecast system when compared to the response shown to raw rainfall figures.

4.2 Monoculture sorghum cropping systems

Dryland sorghum is a crop that can be planted as a substitute to dryland cotton production over the summer rainfall period at Dalby. Cotton growers can substitute sorghum for cotton at the beginning of each season on the basis of a seasonal forecast. Sorghum growers may face an investment in additional plant and equipment before cotton can be successfully produced.

4.2.1 Sorghum yields

Figure 18 indicates that monoculture sorghum is a very reliable cropping system at Dalby on a 190mm PAWC soil that is fallowed over winter. In 50% of years grain yield is expected to exceed 4.5 tonnes per ha. Yields above 6.5 tonnes per ha have not been generated in this analysis due to the planting conditions chosen and the variety planted. A variety that matured later in the season may have generated some higher yields but would have shown lower cropping reliability.

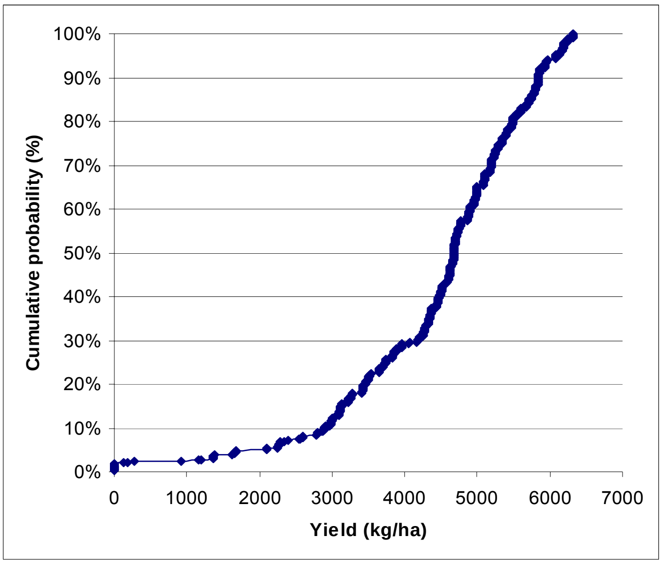


Figure 18 Distribution for monoculture sorghum yields at Dalby –all years 1890 to 2003

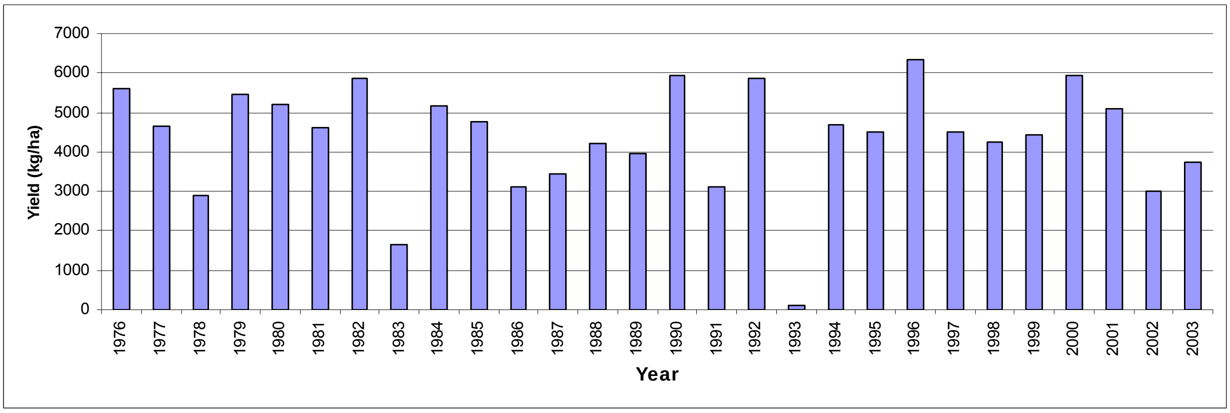


Figure 19 Monoculture sorghum yields as modelled for Dalby 190mm PAWC soil by APSIM (1975 to 2002 plant years, 1976 to 2003 harvest years)

Individual sorghum yields for the harvest years from 1976 to 2003 show a greater degree of reliability than the yields for monoculture cotton shown previously. Note that the years 1977, 1982, 1987, 1991, 1992, 1993, 1994 and 2002 are classified as El Nino years by the classification of Potgieter et al (2003). The impact of an El Nino occurring in a harvest year has not been consistent on sorghum yields over this period.

4.2.2 Sorghum gross margin

Negative gross margins will be produced in about 10% of years by monoculture sorghum on a 190mm PAWC soil at Dalby. An average selling price of $130 per ton on farm was chosen for sorghum and at this price gross margins greater than $400 per ha can be expected in 50% of years. Sorghum prices have varied between $90 and $300 per ton on farm in the past decade. This range of values for price should also be remembered when cropping systems are being compared.

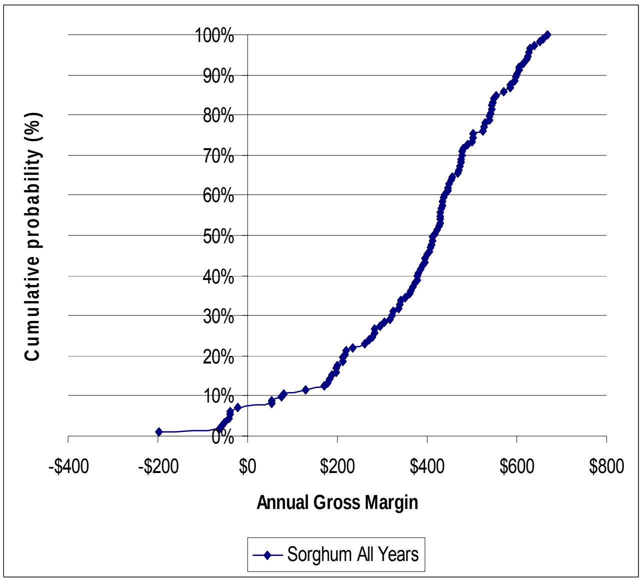


Figure 20 Distribution for monoculture sorghum gross margins at Dalby on a 190mm PAWC soil

4.2.3 Sustainability Indicators

Sorghum generally shows lower levels of runoff, similar levels of drainage and lower soil loss when compared to monoculture cotton. Most of this difference could be attributed to the higher cropping frequency of sorghum compared to cotton.

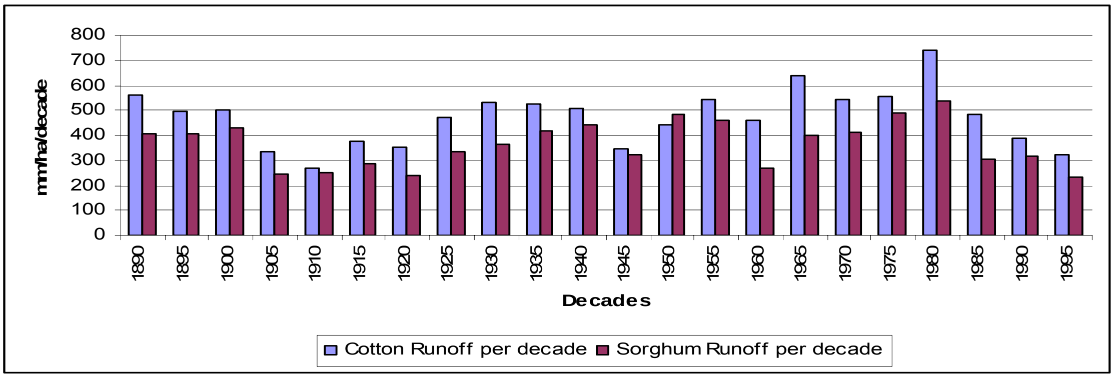


Figure 21 Total modelled runoff per decade at Dalby from monoculture cotton and monoculture sorghum grown on a 190mm PAWC soil

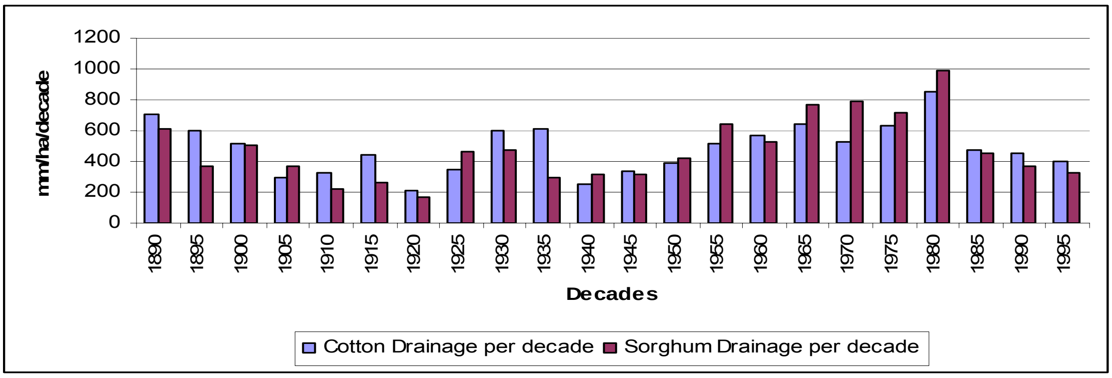


Figure 22 Total modelled drainage per decade at Dalby from monoculture cotton and monoculture sorghum grown on a 190mm PAWC soil

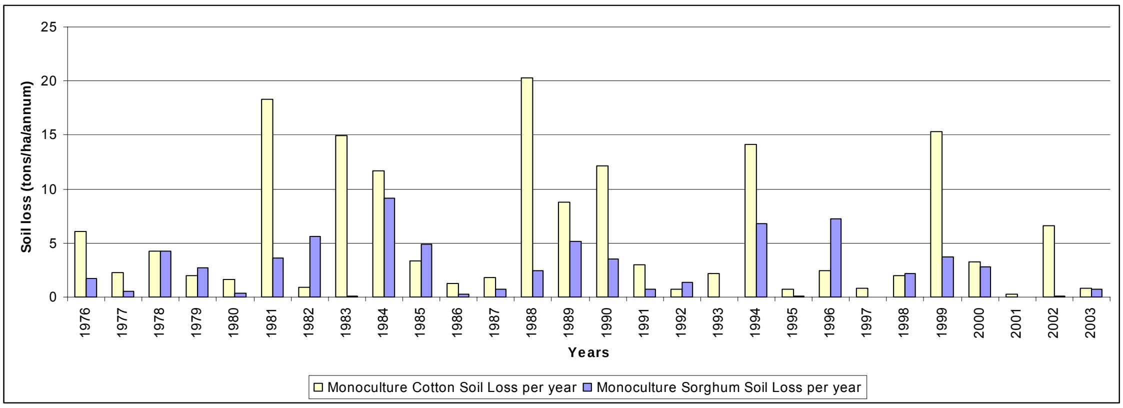


Figure 23 Modelled annual soil loss for monoculture cotton and monoculture sorghum at Dalby on a 190mm PAWC soil

It is interesting that the model predicts that monoculture sorghum will occasionally have a higher potential soil loss within individual years than monoculture cotton.

4.2.4 Climate signals and monoculture cotton and sorghum at Dalby

Figure 24 shows the distribution for of annual gross margin for monoculture dryland cotton and monoculture dryland sorghum production at Dalby on a 190mm PAWC soil.

The expected trade off between dryland cotton and sorghum production in this environment is clearly shown. The negative gross margin for cotton in about 30% of years and better returns for cotton than sorghum in about 40% of years would concur with the expectations of many farm managers in this region.

An increase in the cotton price relative to the sorghum price would not change the underlying comparison between the distributions (or their relative riskiness). With a cotton price increase, the years that cotton relative to sorghum would payoff and the value of the payoff would increase but the percentage of years that cotton would generate a loss would reduce only slightly.

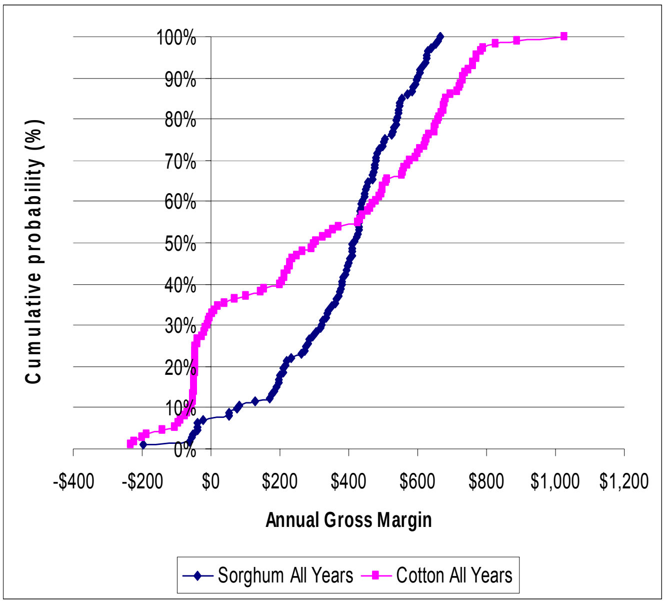


Figure 24 Distribution of annual dryland cotton and sorghum gross margins at Dalby in all years

Existing dryland farming operations in the Dalby district that have the capacity to grow either cotton or sorghum will have previously developed individual approaches to the amount of each crop they incorporate into their farm plan.

Farm managers who prefer sorghum because of the perceived riskiness of cotton will not alter their view of cotton production unless a climate forecast alters the relationship between the distributions for cotton and sorghum to make cotton production significantly less risky and more likely to pay better than sorghum.

Farm managers who prefer cotton because of the chance of a greater payoff will not alter their cotton production strategies unless a climate forecast provides a significantly different view of possible outcomes than those they currently hold.

Figure 25 compares the individual decadal returns calculated as IRR from monoculture cotton or monoculture sorghum at Dalby on a 190mm PAWC soil. It is notable that some decades show dominance by cotton whilst some show dominance by sorghum at the prices and costs selected.

This indicates that the economic performance of these two summer crops has been driven by slightly different temporal distributions of rainfall within the summer cropping window.

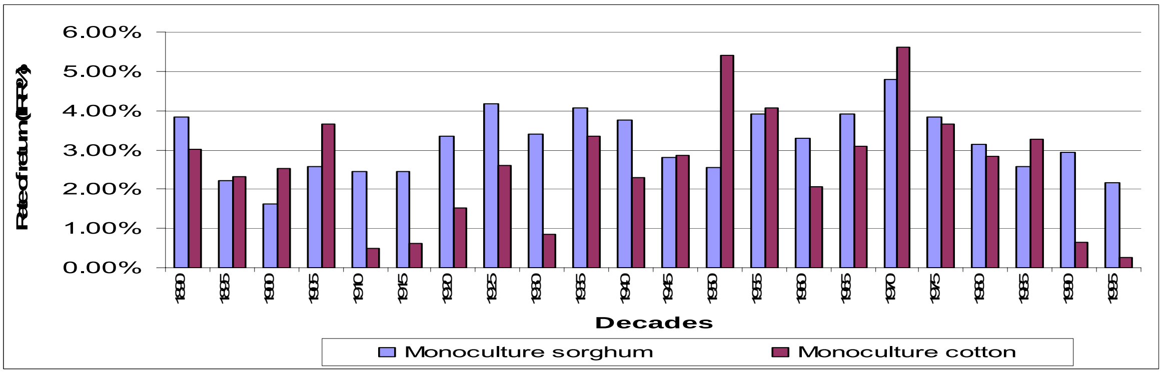


Figure 25 Decadal investment returns for monoculture cotton farming systems at Dalby

The capacity to pick the time to be in cotton or sorghum would improve the overall economic performance of the farming system, especially when higher cotton prices prevailed.

The decision to go cotton farming may not be as simple as we have so far portrayed for many producers who currently only have the capacity to successfully grow cereal crops. Quite often the incorporation of dryland cotton production into a cropping system requires the purchase of some specialist cotton machinery. The nature and cost of the machinery will vary from property to property but if dryland cotton is to be produced on a regular basis over a number of years some specialist machinery is normally purchased. In this analysis we have assumed the purchase of $32,000 worth of extra equipment. This will allow dryland cotton to be produced across the entire example property if necessary.

Figure 26 indicates the marginal profitability of investing in dryland cotton production at current costs and prices for a farm business that currently successfully grows monoculture sorghum in a zero till farming system.

The Net Present Value figure represents the value that accrues to a sorghum producer who purchases an additional $32,000 in capital equipment and chooses to grow dryland cotton instead of dryland sorghum. The variation in returns is driven by the different response to the temporal distribution of rainfall by the two summer crops.

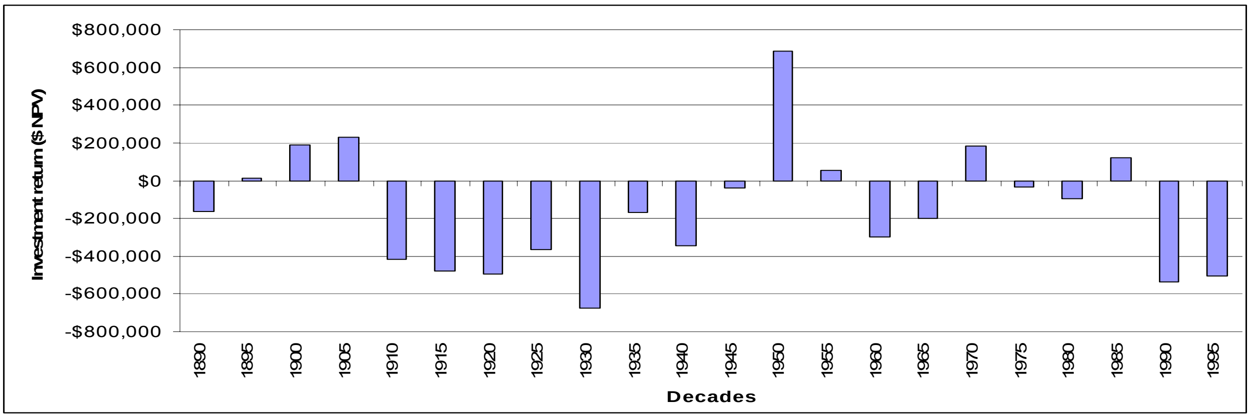


Figure 26 Present value of investing in cotton production at current costs and returns

Investing in the capacity to produce dryland cotton instead of dryland sorghum would have been beneficial in about 30% of decades at current costs and returns. The remaining 70% of years generated a net loss on the investment of up to $600,000 when compared to maintaining the sorghum production system. The chance of suffering a loss of more than $200,000 from choosing the cotton investment over maintaining the sorghum system is about 50%.

To calculate these returns we have looked at the extreme case of substituting all dryland sorghum with dryland cotton to fully utilise our investment in plant to gain the best return on extra capital invested.

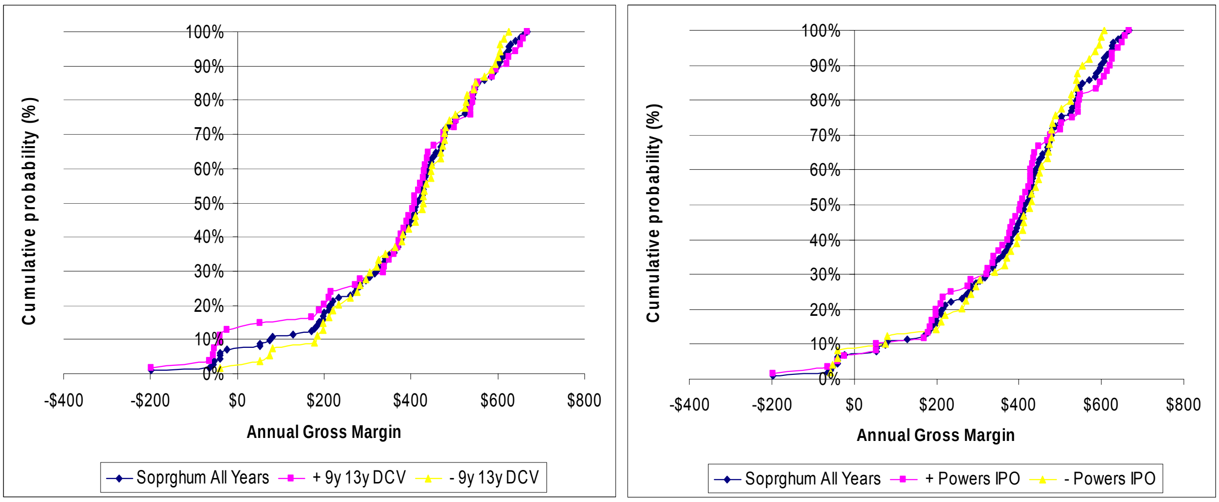
In the real world, cropping areas would be altered at the margin with only some dryland cotton substituted for dryland sorghum. The potential benefits of investing in the more risky dryland cotton production system would be reduced but the potential downside of investing would also be mitigated. Capital costs could also be reduced but the overall benefits of a scaled down investment would be expected to show the same patterns of winning and losing on the investment indicated in figure 26.

Investing in a capacity to produce dryland cotton and then swapping into and out of dryland cotton on the basis of a decadal or seasonal climate forecast would also reduce the benefits of an investment in dryland cotton production that has a life longer than one decade. That is, you have to be producing dryland cotton to get the benefits of investing in a capacity to produce dryland cotton. Periods spent not producing dryland cotton will dilute returns.

Decadal Climate Variability (DCV) Indices

Figure 27 compares the annual gross margin distributions for sorghum production at Dalby grouped under the phase values of the 9y 13y DCV index and the IPO.

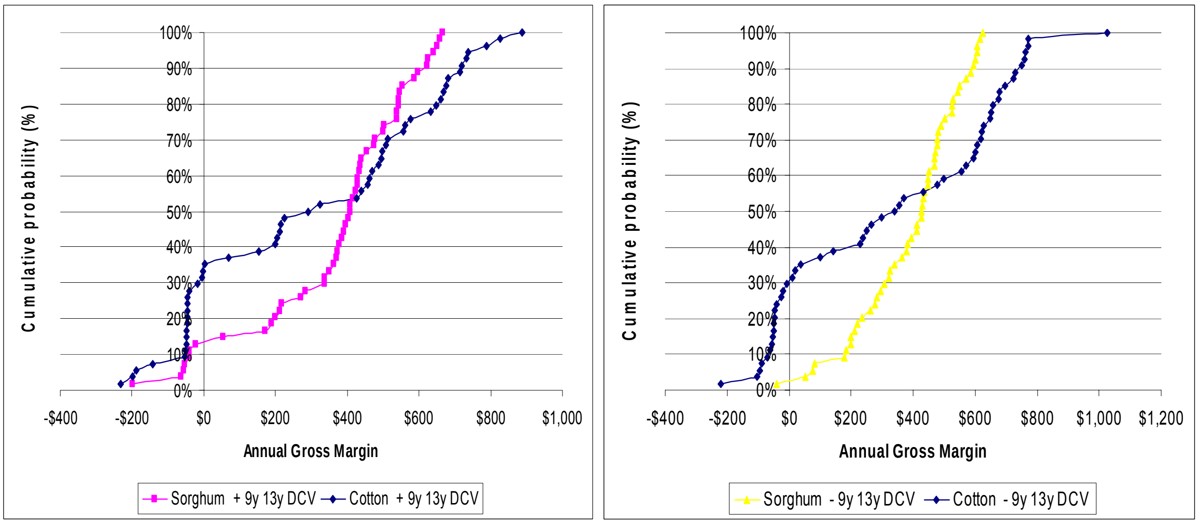
Figure 27a indicates a slight improvement in the reliability of sorghum production in negative (-) 9y 13y DCV index years compared to positive (+) 9y 13y DCV index years.



(a) (b)

Figure 27 Distribution of annual dryland sorghum gross margins for the 9y 13y DCV index (a) and the IPO index (b)

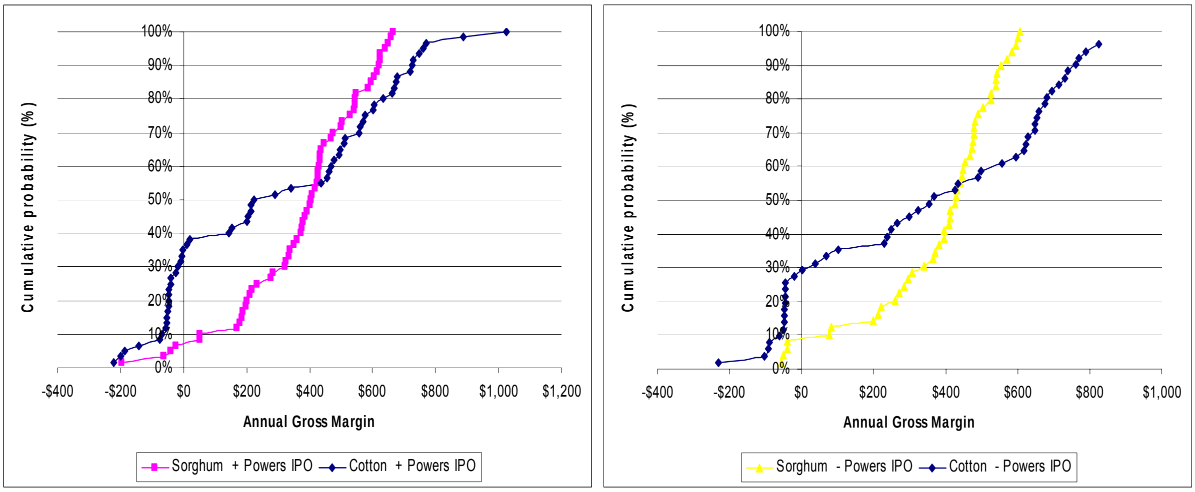
Figure 28 compares the distributions for cotton and sorghum production at Dalby grouped under the different phase values of the 9y 13y DCV index.



(a) (b)

Figure 28 Distribution of annual dryland cotton and sorghum gross margins for the positive (+) phase 9y 13y DCV index (a) and negative (-) phase of the 9y to 13y DCV index (b)

Figure 30 compares the distributions for cotton and sorghum production at Dalby grouped under the different phase values of the IPO index.



(a) (b)

Figure 29 Distribution of annual dryland cotton and sorghum gross margins for the positive (+) phase of the IPO index (a) and negative (-) phase of the IPO index (b)

As stated previously, farm managers who can produce both dryland cotton and dryland sorghum will have already made a choice between these crops based on an individual risk preference combined with their expected outcomes for the crops. A seasonal forecast will only bring about a change in a cropping pattern if it provides sufficient information to change the expected outcome of the decision maker. How much the expected outcome has to change depends upon the individual risk preference of the decision maker.

In this analysis we do not use formal measures for incorporating risk preferences into an assessment of the likelihood of a cropping system change arising from a change in expected outcome. We will use a simple method of comparing the relationship between the forecast distributions to the relationship between the all-years distributions and considering the likelihood of change.

Figures twenty-eight and twenty-nine show that the expected relationship between the distributions does not really change with the different phase values of either climate index when compared to the all years' distribution for these crops shown in figure twenty-three.

On this basis it is hard to see any value being attached to knowing in advance the phase value of the 9y 13y DCV or the IPO index when choosing between these two monoculture crops at this location. Neither of the DCV indices tested excludes sufficient low yielding years to help in making decisions.

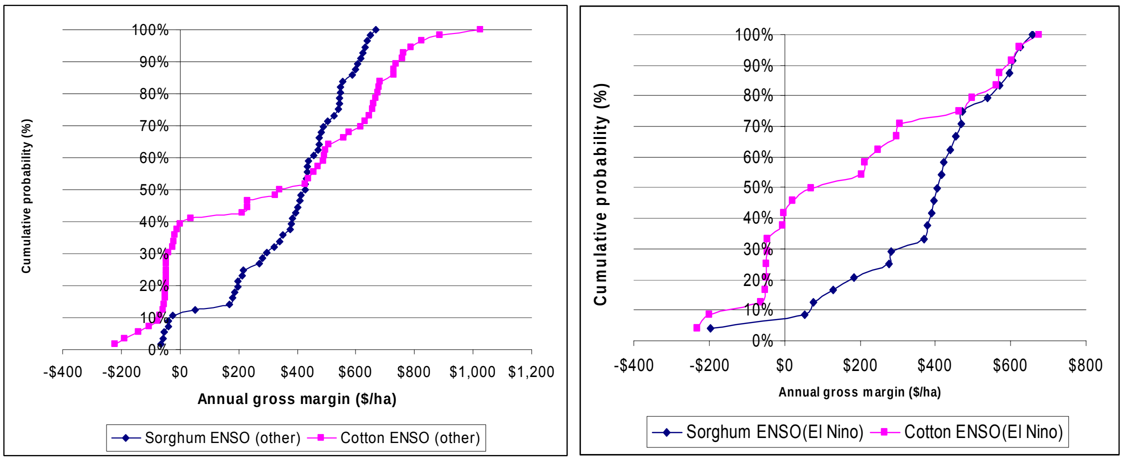
An improvement in the price paid for cotton relative to sorghum could change planting intentions at the margin for producers who have both crops in their farm plan but this is unrelated to the value of knowing in advance the state of either of these DCV indices as the relationships between the all years distribution and the phase distributions would not change in a relative sense due to a price relationship change.

That is, price changes that favour cotton production over sorghum production would not change significantly the relationship between the distributions in those years when cotton performs poorly in terms of yield.

The value of the payoff would improve for cotton in those years that cotton was successfully grown but the underlying riskiness of cotton compared to sorghum would basically remain. Riskiness in this case is expressed in terms of the chances of making a loss and the total variance of returns.

ENSO classification

Dryland cotton and sorghum production are compared below on the basis of the ***harvest*** year ENSO classification.



(a) (b)

Figure 30 Distribution of annual dryland cotton and sorghum gross margins for the ENSO classification "Other" (a) and the ENSO classification "El Nino" (b)

Knowledge of the harvest year ENSO classification would lead to no change of crop management in years classified as "Other" compared to the all years decision.

It is likely that dryland cotton production would be foregone in El Nino years due to the significant chance (45% of years) of a negative gross margin and being out performed by dryland sorghum in 80% of El Nino years.

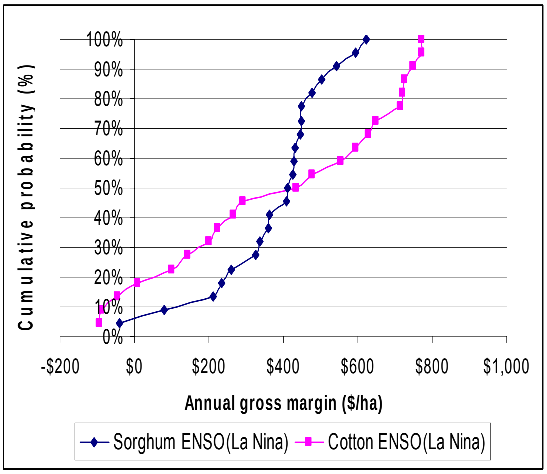


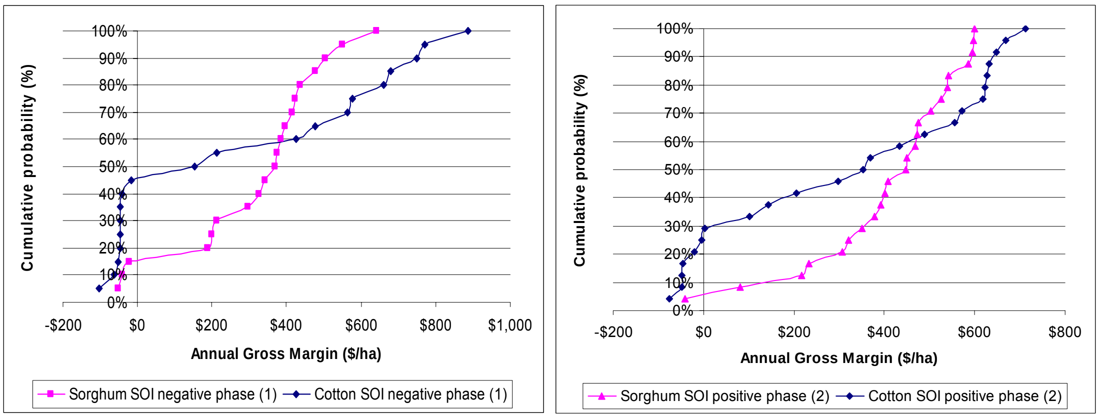
Figure 31 Distribution of annual dryland cotton and sorghum gross margins for the ENSO classification "La Nina"

Some managers may be tempted to move from sorghum to cotton if they knew a La Nina was imminent as the chances of a loss on cotton production are halved in La Nina years when compared to cotton production in years with the Other ENSO classification.

Even so, perfect knowledge of the harvest year ENSO classification in advance would only produce an expected value benefit of $20 per ha per annum at current costs and prices for the swap from sorghum to cotton. This is without allowing for the cost of any extra capital equipment that may be required to efficiently produce cotton.

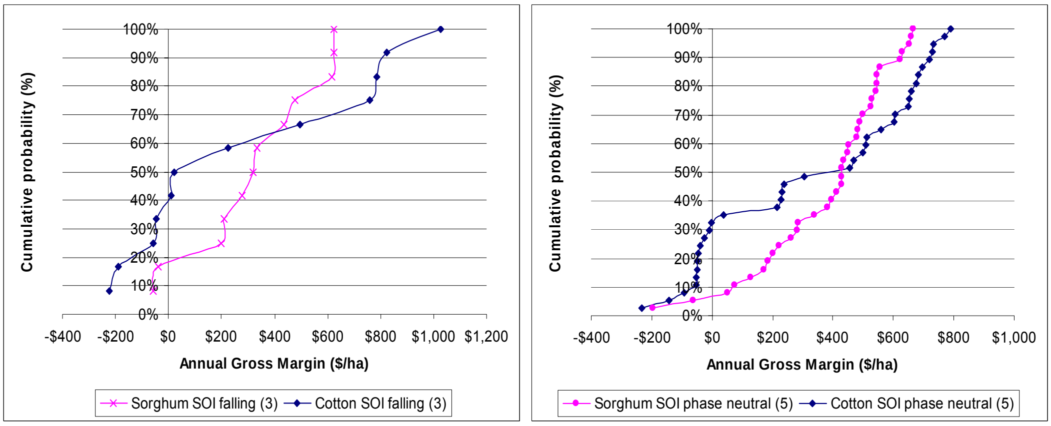
SOI phase

Dryland cotton and sorghum production are compared below on the basis of the SOI phase in August of the ***plant*** year.



(a) (b)

Figure 32 Distribution of annual dryland cotton and sorghum gross margins for the SOI negative phase in August (a) and the SOI positive phase in August (b)



(a) (b)

Figure 33 Distribution of annual dryland cotton and sorghum gross margins for the SOI falling phase in August (a) and the SOI neutral phase in August (b)

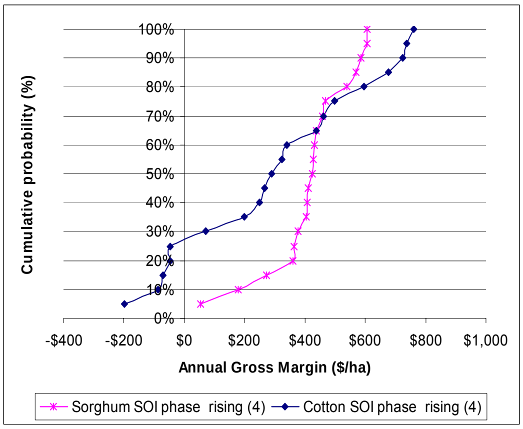


Figure 34 Distribution of annual dryland cotton and sorghum gross margins for the SOI rising phase in August

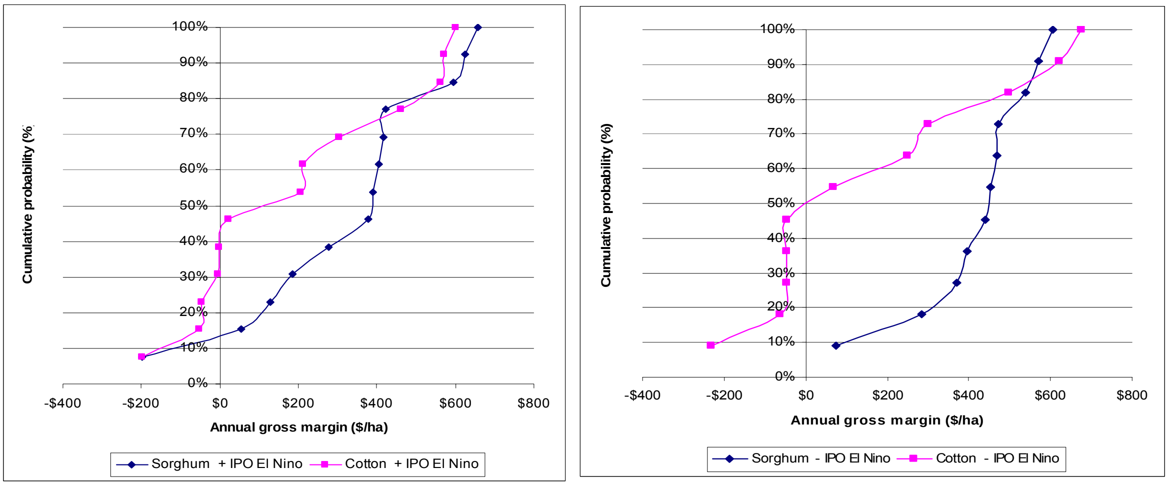
Knowledge of the SOI phase in August does not offer sufficient additional information to alter the choice already made based on knowledge of the all years' distribution.

Interactions between ENSO and DCV indices

Previous work has found that years classified as El Nino or La Nina seemed to have their impact enhanced during the negative (-) phase of the IPO index. (Meinke et al 2003)

The question to be considered here is "does the interaction of ENSO and IPO years change the distribution of risks and returns sufficiently to alter management decisions based on the all years expectation?"

Figure 35 shows the distributions for cotton and sorghum gross margins during **El Nino** years that correspond with the positive (+) phase of the IPO (a) and the negative (-) phase of the IPO (b).



(a) (b)

Figure 35 Distributions for annual gross margin at Dalby on a 190mm PAWC soil in El Nino years separated by the phase of the IPO index

Figure 36 shows the distributions for cotton and sorghum gross margins during **La Nina** years that correspond with the positive (+) phase of the IPO (a) and the negative (-) phase of the IPO (b).

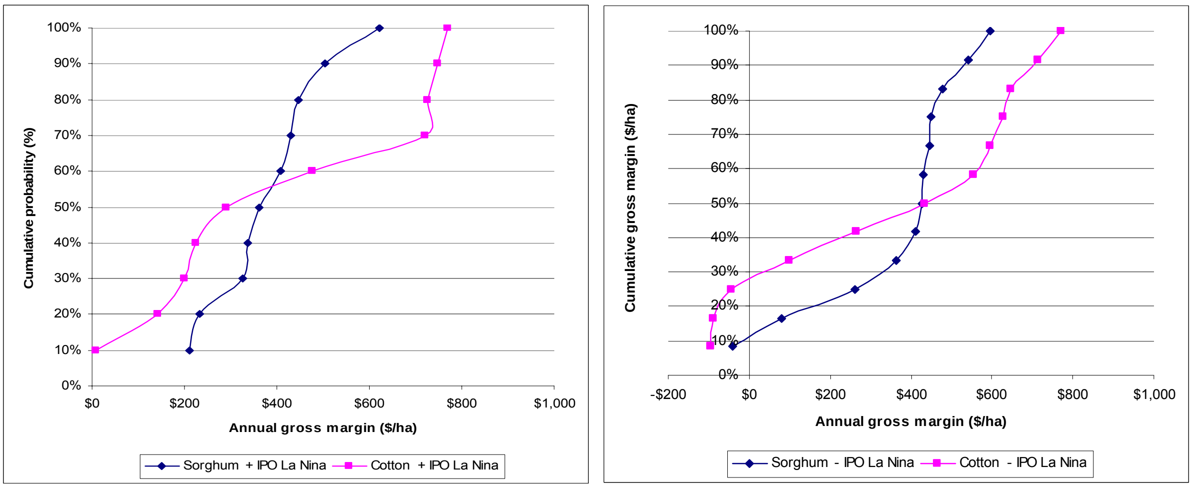
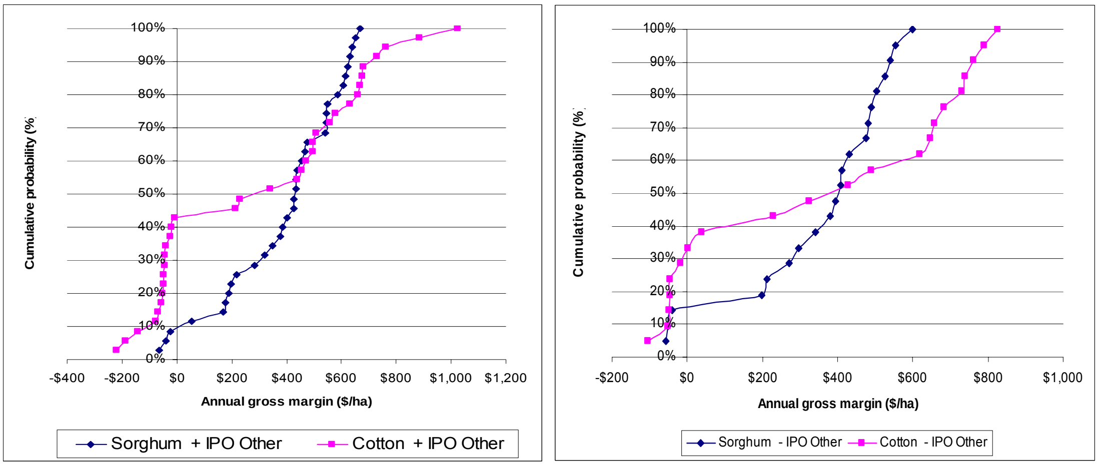


Figure 36 Distributions for annual gross margin at Dalby on a 190mm PAWC soil in La Nina years by the phase of the IPO index

Figure 37 shows the distributions for cotton and sorghum gross margins during **Other** ENSO years that correspond with the positive (+) phase of the IPO (a) and the negative (-) phase of the IPO (b).



(a) (b)

Figure 37 Distributions for annual gross margin at Dalby on a 190mm PAWC soil in Other ENSO years by the phase of the IPO index

Separation of the IPO index phases by the ENSO classification would not alter the view previously held by an existing sorghum producer and may reduce the enthusiasm of a cotton producer.

Focussing on climate events that have a low frequency during our climate history highlights another two issues.

Firstly if an event occurs regularly one year in every five to seven years, an investment to take advantage of that event would not be profitable unless the investment was small and the advantage was very large, predictable and unlikely to be taken advantage of by other potential investors.

Secondly if the event has a high incidence in a particular decade but has long time periods between events, the investor could be waiting a considerable period of time to again use the investment strategy. The payoff from investing in the high incidence but low frequency event would also have to be quite significant.

Table 7 below indicates the frequency of La Nina and El Nino years during negative (-) phases of the IPO.

- IPO **El Nino**	**- IPO** **La Nina**
1911	1908
1914	1909
1919	1910
1946	1916
1951	1917
1953	1950
1957	1955
1965	1956
1969	1971
1972	1973
1977	1974
	1975

Table 7 Incidence of El Nino and La Nina years during the negative (-) phase of the IPO

Table one indicates that some interactions of indices occur in "clumps". Even if the clumps of La Nina years were perfectly predictable and cotton was clearly superior in economic performance, an investment in a year equivalent to 1971 to take advantage of a forecast could be problematic. Only four of the next ten years have the favourable classification and the investor could wait up to 33 years (1917 to 1950) before they could act on the next similar occurrence of the interaction of the IPO index and the ENSO classification.

The time period to the next incidence of a climate event that an investment relies upon to be profitable can be critically important - even if the event can be predicted with certainty. For instance, what is the value of knowing the winners of the 2030, 2032 and the 2034 Melbourne Cup today?

Summary of cotton and sorghum monocultures

Farm managers have a pre-existing view of dryland cotton and sorghum production based on their risk preferences and expectations that we believe coincide with the modelled distributions of annual gross margin shown in figure 23.

We have investigated decadal and seasonal climate signals to see if we could provide forecasts that would change this view – namely shifting production from dryland sorghum to dryland cotton.

At this location it appears that an existing dryland sorghum producer would gain insufficient extra knowledge from any of these climate classifications or forecasts to change the summer crop sown.

Existing dryland cotton producers could alter planting areas at the margin and reduce dryland cotton production when the forecast or indicator increased the chances of a loss but even this assumption may be unreliable as there still remains a reasonable upside from dryland cotton production and their basic expectations and risk preferences would probably remain unchanged.

Cotton price is not going to have a big effect on an existing sorghum producer due to the underlying riskiness of cotton when compared to sorghum. Price spikes for cotton relative to sorghum may change planting intentions for mixed cotton and sorghum producers but this does not change the underlying value of the climate forecast.

4.3 Wheat monoculture cropping system

Monoculture wheat is an alternate cropping system to both monoculture sorghum and monoculture cotton at Dalby although it targets a different season.

4.3.1 Wheat Yields

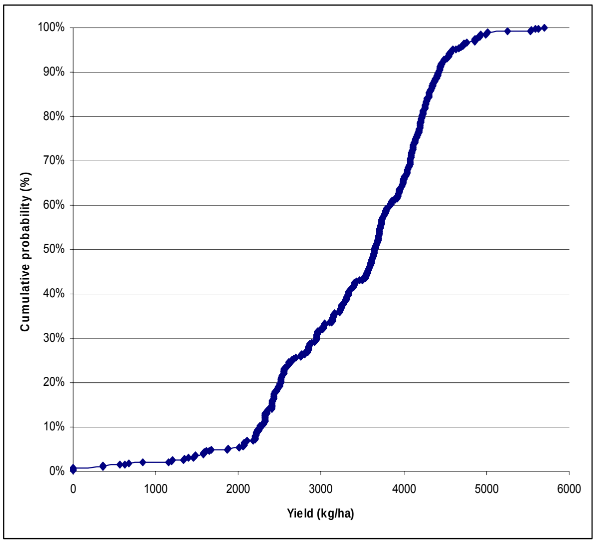


Figure 38 Yield for monoculture wheat grown on a 190mm PAWC soil at Dalby

4.3.2 Wheat Protein

Wheat is a very reliable crop when grown after a summer fallow at Dalby. The fertiliser strategy chosen for this analysis may occasionally limit wheat yield and protein content should be suppressed in higher yielding years.

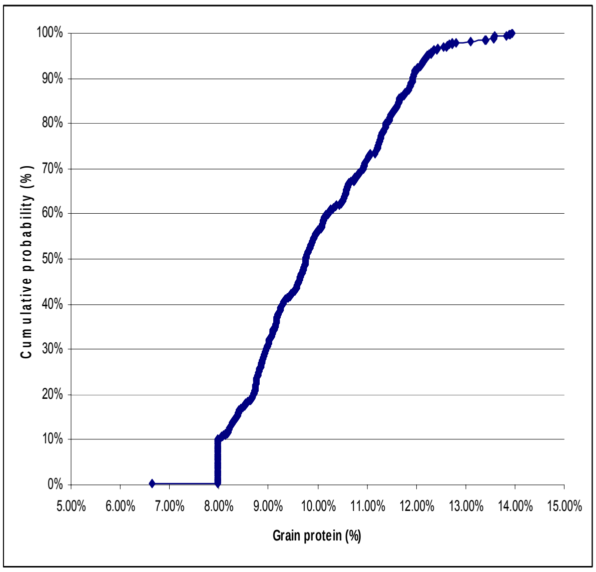


Figure 39 Grain protein for monoculture wheat grown on a 190mm PAWC soil at Dalby

A median value of less than 10% for grain protein in modelled wheat could be due to the constraint applied by the fertiliser strategy at this reliable and high yielding site.

The low level of soil N at the beginning of each simulation tends to highlight the fertiliser constraint on wheat protein but this is expected to be the case on many similar soils that have been farmed for some time.

The model may be underestimating grain protein slightly as well.

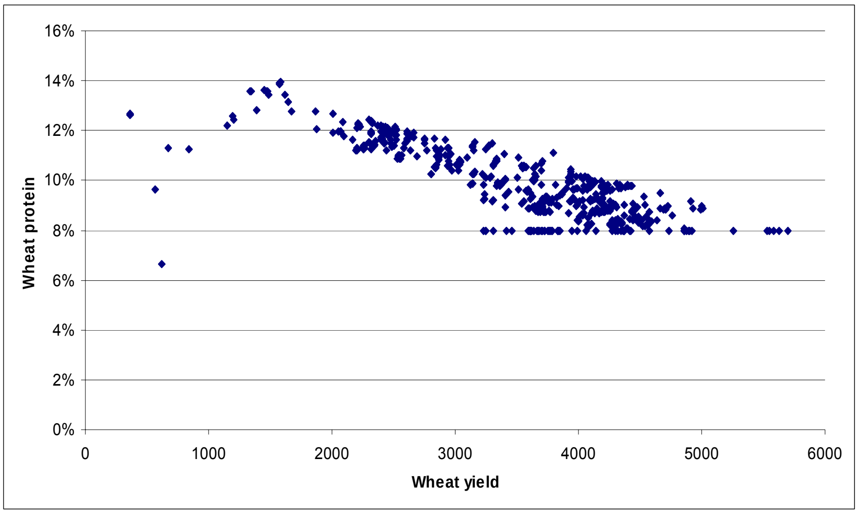


Figure 40 Relationship between modelled grain protein percent and grain yield on a 190mm PAWC soil at Dalby (APSIM IWHEAT module)

Figure 40 shows that once wheat yields exceed about 3 tonne per hectare (about 70% of years at this site) protein percent is generally below 10%. The model does not show proteins below 8% in such years.

4.3.3 Wheat gross margins

Wheat prices have been increased slightly above current market expectations for low protein grades to compensate for the slight underestimation in the wheat model of wheat protein. The gross margins and economic analysis of wheat should then be comparable in a relative sense to the cotton and sorghum analysis.

	Wheat Price	
Protein %	**$ /ton on farm**	
7.00%	$150.00	
7.50%	$150.00	
8.00%	$150.00	
8.50%	$150.00	
9.00%	$150.00	
9.50%	$150.00	Feed
10.00%	$160.00	ASW 10
10.50%	$162.50	
11.00%	$165.00	
11.50%	$167.50	
12.00%	$180.00	AH (12%)
12.50%	$182.50	
13.00%	$190.00	PH (13%)
13.50%	$192.50	
14.00%	$205.00	PH (14%)
14.50%	$207.50	
15.00%	$210.00	

Table 8 Estimated on farm wheat price at Dalby

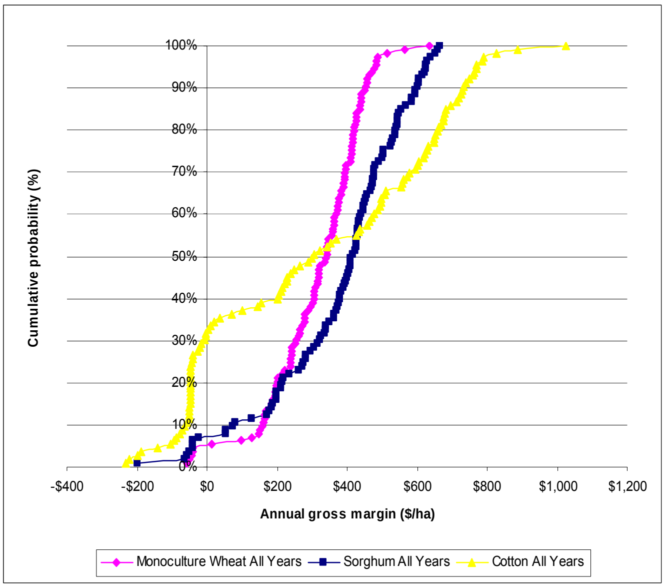


Figure 41 Distribution of annual dryland monoculture cotton; sorghum and wheat gross margins at Dalby on a 190mm PAWC soil, all years

Modelled dryland wheat at Dalby on a 190mm PAWC soil is slightly more reliable than sorghum but is out performed by both cotton and sorghum in a majority of years. Wheat also outperforms cotton in 50% of years. We would expect a similar distribution of outcomes for annual gross margins to be achievable by low till farmers at Dalby who had very competent precision planters for summer crops and sound timeliness in farm operations.

4.3.4 Sustainability Indicators

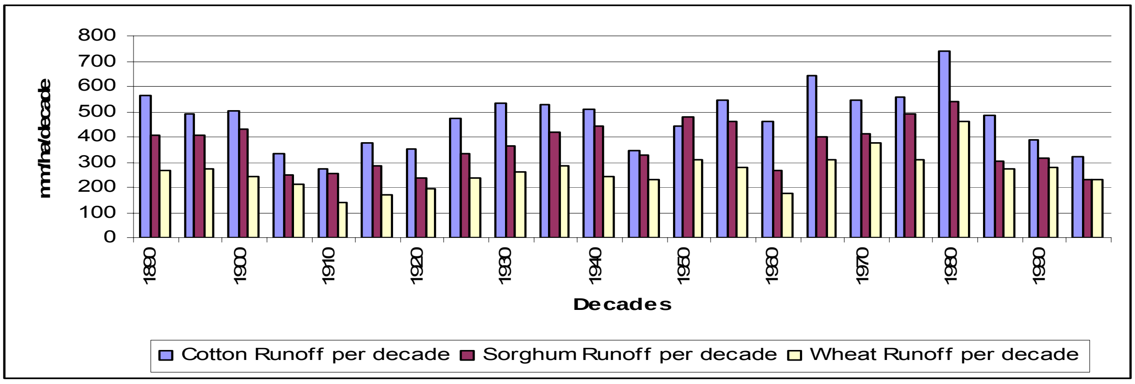


Figure 42 Total modelled runoff per decade at Dalby from monoculture cotton, monoculture sorghum and monoculture wheat grown on a 190mm PAWC soil

Monoculture wheat suffers less potential runoff when compared to monoculture cotton and monoculture sorghum. All simulations begin with 1.5 ton of crop residue per hectare. Residue levels are then calculated by APSIM on a daily basis and reported as the simulation progresses.

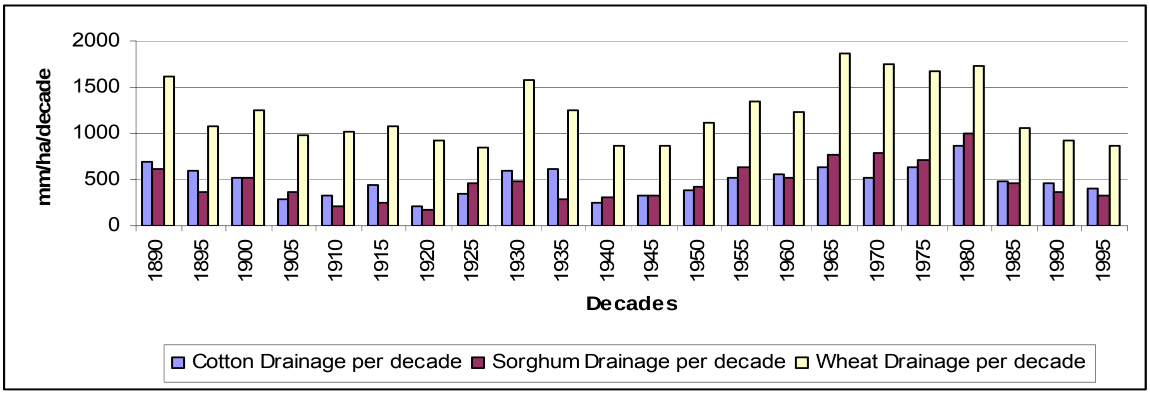
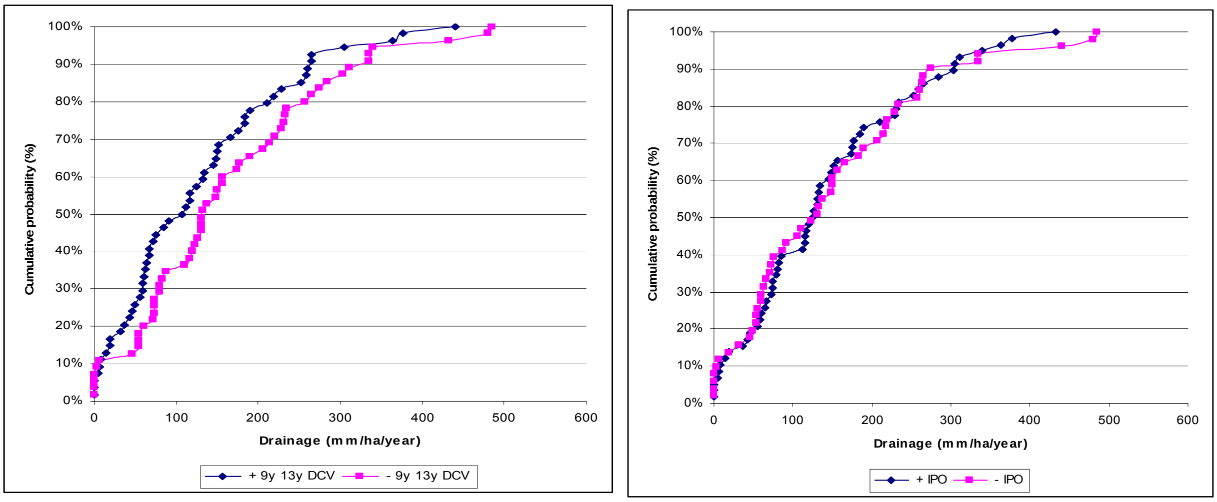


Figure 4360 Total modelled drainage per decade at Dalby from monoculture cotton, monoculture sorghum and monoculture wheat grown on a 190mm PAWC soil

Modelled wheat drainage exceeds the modelled drainage from cotton and sorghum in all decades. In many decades it is more than double that of the other two crops.



(a) (b)

Figure 44 Distribution for annual drainage for monoculture wheat at Dalby on a 190mm PAWC soil. (a) 9y 13y DCV index and (b) IPO index.

Figure 44 indicates a response to drainage in wheat by the phases of the 9y 13 y DCV index. Expected drainage increases by about 30% in years that have a negative phase value compared to years that have a positive phase value. The phase values of the IPO index do not make a distinction between potential drainage levels for the different phases of the IPO index.

This suggests that this monoculture wheat cropping system is unable to use the extra water stored during favourable climate sequences even though it largely prevents it from running off (figure 42) and causing soil loss (figure 45) when compared to the alternate monoculture cropping systems.

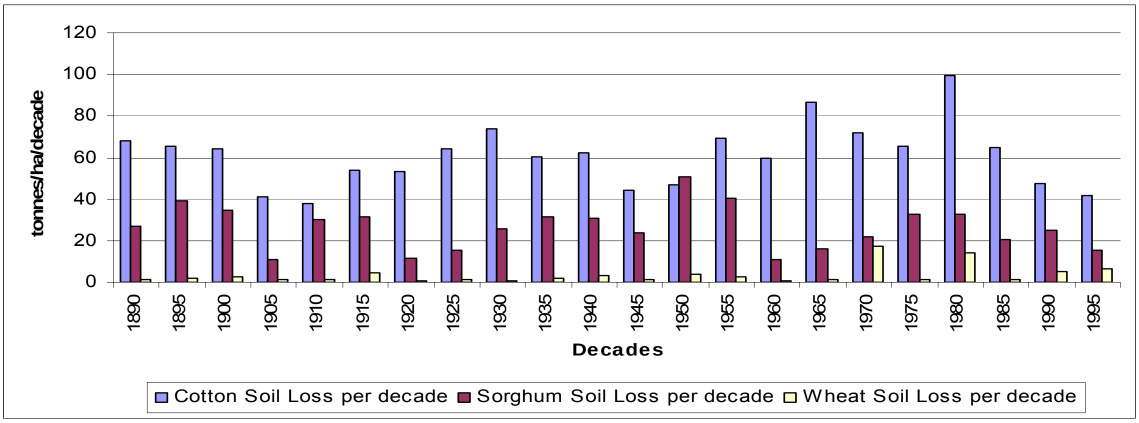


Figure 45 Total modelled soil loss per decade at Dalby from monoculture cotton, monoculture sorghum and monoculture wheat grown on a 190mm PAWC soil

Modelled soil loss is predicted to be less with zero till monoculture wheat cropping systems than the level modelled for monoculture cotton and sorghum cropping systems.

4.3.5 Climate signals and monoculture wheat at Dalby

The gross margin distributions for the monoculture cropping systems together with the expected investment returns shown below suggest that an existing dryland cotton or sorghum farmer would not switch to monoculture wheat production for economic reasons.

This is even though wheat outperforms sorghum on nine out of twenty two occasions at the prices and costs chosen.

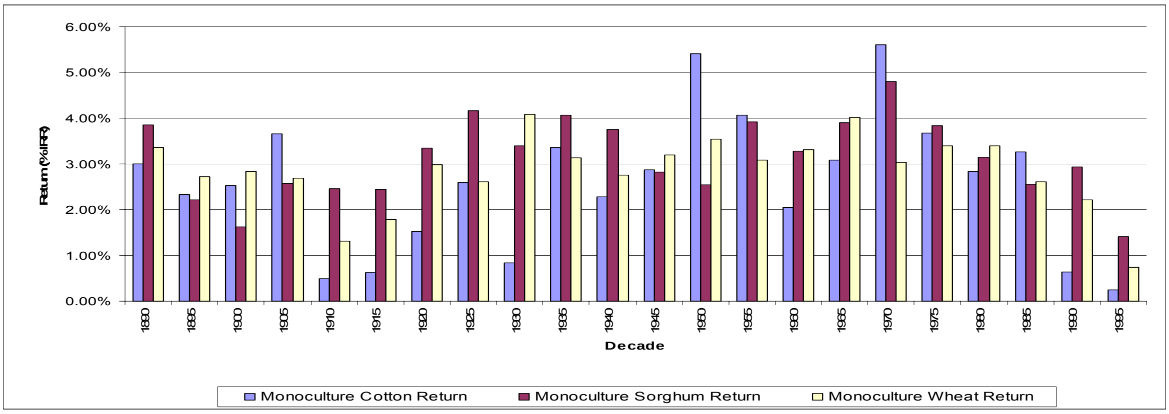
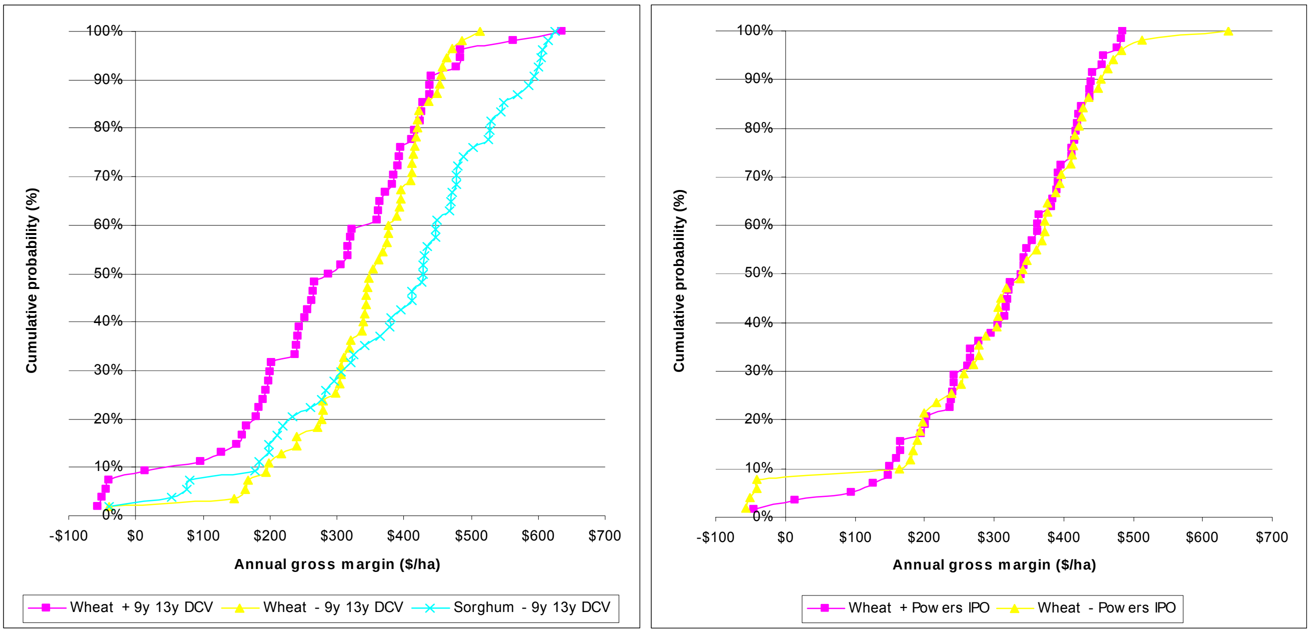


Figure 46 Decadal Investment returns for monoculture cotton sorghum and wheat

Existing producers who prefer wheat are unlikely to swap to dryland cotton or sorghum production because of the higher production costs of the summer crops together with the greater risk of negative gross margins. Existing wheat producers would also quote such things as the price history of wheat compared to sorghum, the ease of establishment of wheat compared to sorghum or cotton and the different weed and disease pressure of the winter cereal.



(a) (b)

Figure 47 Distribution of annual gross margin for wheat and sorghum by the 9y 13y DCV index (a) and IPO index (b)

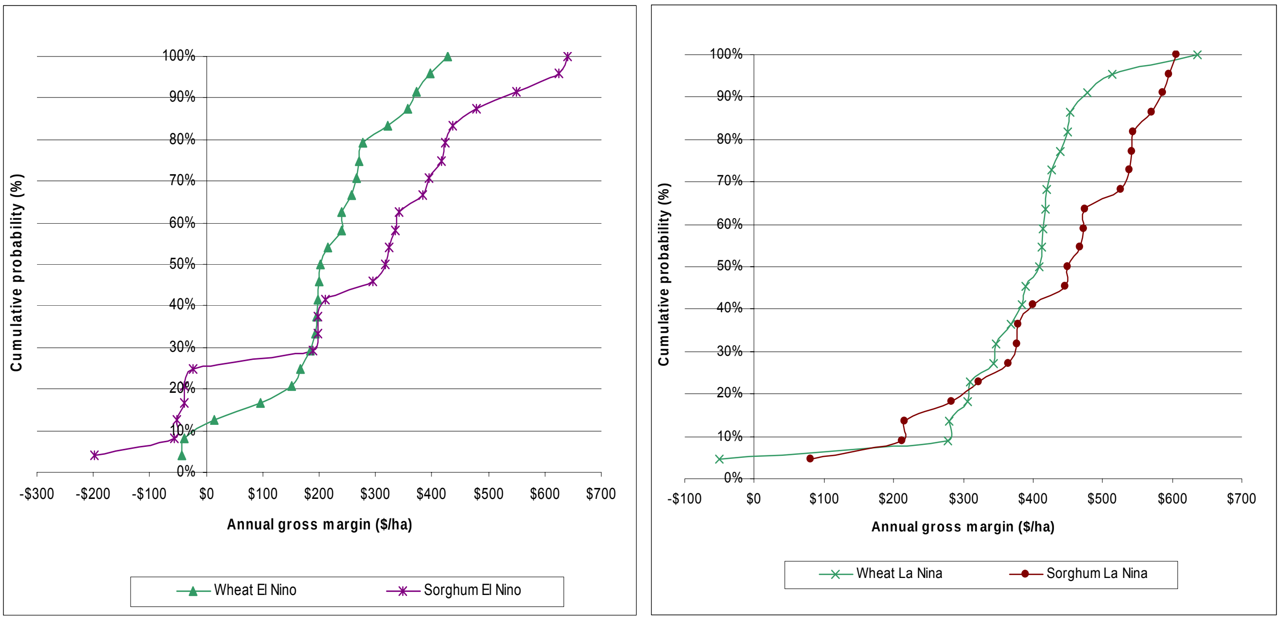
Wheat annual gross margin shows a response to the phases of the 9y 13y DCV index. (Figure 47) Wheat becomes a much more reliable crop and improves its median annual gross margin from $290 to $350 per ha in the negative phase of the 9y 13y DCV index compared to the positive phase of the 9y 13y DCV index.

The response of sorghum under the negative (-) phase of the 9y 13y DCV index has been overlaid to show that sorghum would be preferred to wheat in 70% of years classified this way.

It is unlikely that a sorghum or cotton producer would gain any consistent benefit by swapping production to wheat during the negative (-) phase of the 9y 13y DCV index. Wheat producers would look at the largely unchanged relative riskiness of sorghum and cotton and retain their production strategy.

The IPO index shows no response.

ENSO classification



(a) (b)

Figure 48 Wheat and Sorghum annual gross margins at Warra classified by ENSO. (a) El Nino year (b) La Nina years

Figure 48 shows that advanced knowledge of the ENSO classification does not offer sufficient extra insight to change the intentions of wheat or sorghum producers.

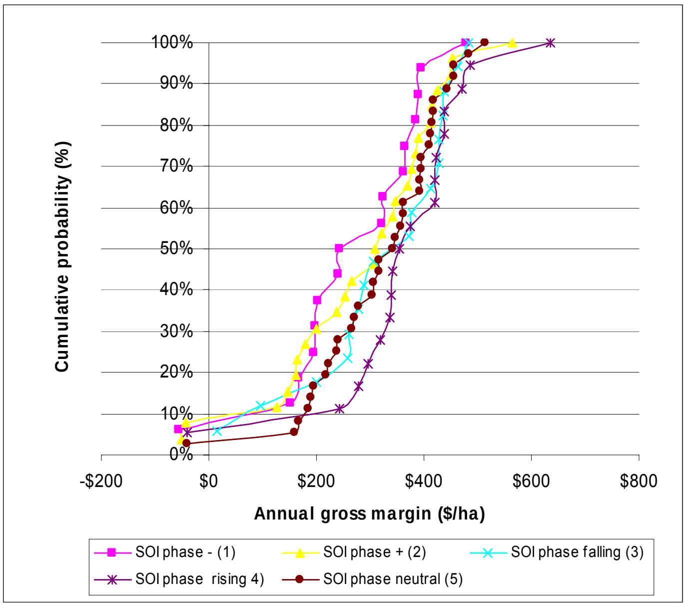


Figure 49 Wheat annual gross margins at Warra classified by SOI phase prior to planting

The SOI phase forecasting system shows some separation of wheat gross margins. These differences have a value when used to fine tune the inputs applied to a winter cropping system. (See Hammer 1996)

The SOI phase forecasting system may not provide insight into the choice between a summer and winter cropping system as the phase changes during the year. The SOI phase system may indicate a reduced or increased median gross margin for wheat production but this phase may not apply to a sorghum planting opportunity later in the year.

The more usual way to compare short-term wheat and sorghum production decisions using the SOI phase at wheat planting would be as follows:

- calculate the distribution of gross margins for wheat using the expected yields and proteins for the SOI phase prior to planting wheat combined with the expected wheat prices,
- calculate the distribution for sorghum yields based on the all years expectations,
- apply a range of prices that reflects the extra sorghum price uncertainty associated with the time span between sorghum and wheat opportunities when combining sorghum yields and prices to create sorghum gross margins,
- discount the sorghum gross margins by the amount of the opportunity cost of foregoing the earlier receipt of wheat income by the farming business.

The discounted sorghum gross margin distribution can then be compared to the SOI phase adjusted wheat gross margin distribution to assist in making the choice.

This process would only apply when there is an expected price spike for wheat compared to the sorghum price. At the current price and yield relationship between wheat and sorghum, sorghum would be the preferred cereal crop on this soil type at this location. This longer-term decision is made after considering the all years' distribution for each crop.

4.3.6 Summary of wheat

Wheat monoculture responds to the 9y 13y DCV index, the ENSO classification and the SOI phase forecast system but these responses are unlikely to assist producers with the cropping system decisions that we are considering here. At current prices sorghum outperforms wheat in 70% to 80% of similarly classified years and swapping the cropping system in response to any of the climate signals tested is unlikely to produce an ongoing benefit.

As wheat and sorghum prices have a fairly stable basis relationship - they tend to move in the same direction at about the same time, this relationship is expected to continue over the longer term.

Swapping between cotton and wheat production on the basis of a decadal or seasonal index or classification would confront the same challenge as swapping between cotton and sorghum. The underlying riskiness of cotton in all climate indices would make it unlikely for a wheat producer to use the index as the basis for a decision to swap between the crops.

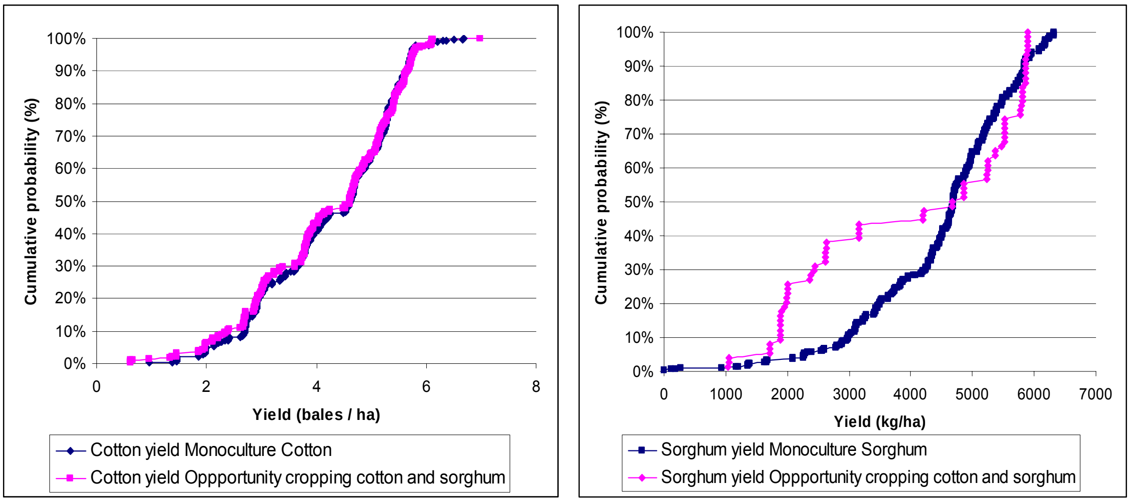
4.4 Cotton and sorghum opportunity cropping

4.4.1 Crop yield

Cotton and sorghum opportunity cropping combines the crops of cotton and sorghum in a cropping system where sorghum is not planted until after the cotton planting window has closed and cotton has not been planted.

The cropping system tries to maximise the planting opportunities for cotton but not lose potential income in the 15% of years that cotton is expected to miss its planting window under the conditions of monoculture cotton dryland farming on a 190mm PAWC soil at Dalby. Planting sorghum into these missed cotton opportunities will change the water balance for subsequent cotton crops.

The impact of this change in water balance on cropping systems economics or cropping system response to climate signals is to be considered here.



(a) (b)

Figure 50 Yield distributions for years planted for sorghum (a) and cotton (b) when farmed as a monoculture or as an opportunity crop with each other

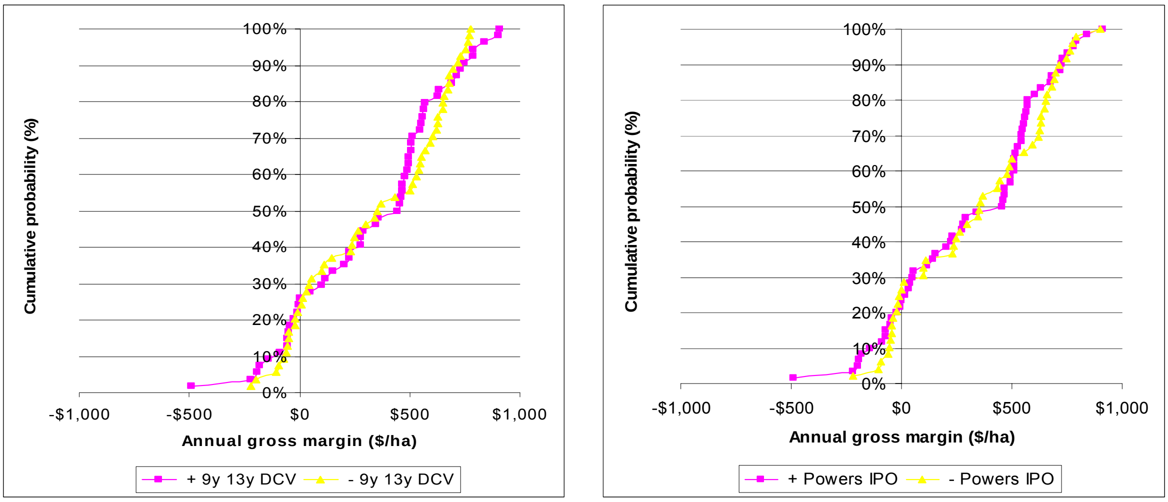
Modelled cotton yields show little response to the changed cropping system and maintain a very similar cropping frequency under both opportunity cropping cotton and sorghum and monoculture cotton.

Modelled sorghum yield potential is lower than the monoculture sorghum distribution in about 50% of the years that it is planted after a cotton opportunity is missed. This could be due to a lower starting PAW status at planting and or lower in-crop rainfall.

Producers who took the opportunity to plant sorghum after the cotton window closed would only marginally change the number of expected cotton crops grown in any decade compared to the number grown under monoculture cotton conditions. They would increase the intensity of their cropping system by growing about one to two sorghum crops each decade.

Monoculture sorghum growers would plant slightly more total crops that the cotton/sorghum opportunity cropper but this may only be an extra 1 to1.5 crops per decade on average.

4.4.2 Gross margins



(a) (b)

Figure 51 Opportunity cropping cotton and sorghum gross margins at Dalby on a 190mm PAWC soil. Phases of the 9y 13y DCV index (a) and phases of the IPO index (b)

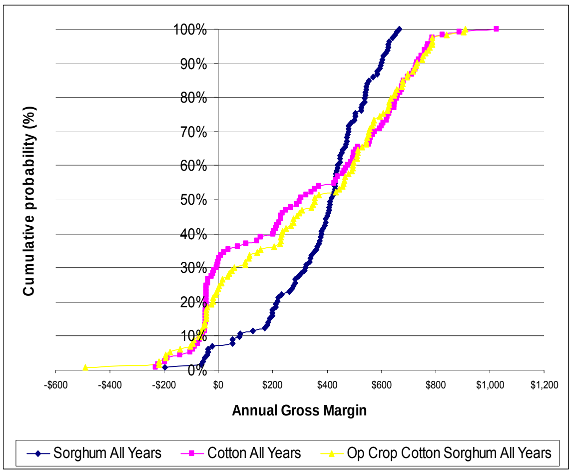


Figure 61 Annual gross margin distribution for opportunity cropping cotton and sorghum compared to monoculture cotton and monoculture sorghum on a 190mm PAWC soil at Dalby

Opportunity cropping of cotton and sorghum will potentially have fewer years that produce a negative gross margin than monoculture cotton due to its higher cropping frequency but will only perform better than monoculture sorghum in about 50% of years.

4.4.3 Investment returns

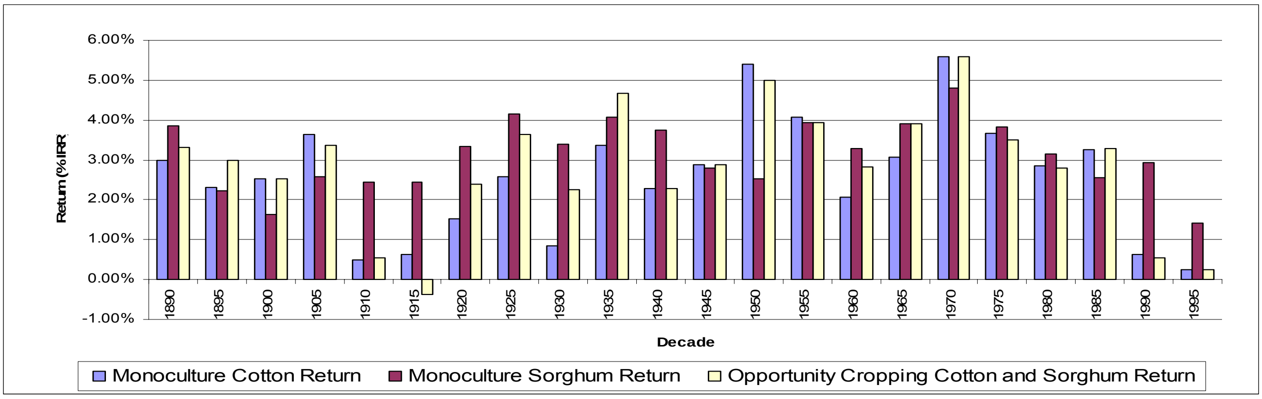


Figure 53 Investment returns for Cotton and sorghum cropping systems at Dalby on a 190mm PAWC soil

Existing cotton producers would have their profitability increased in about seven decades, maintained in about eight decades and reduced in the remaining six if they opportunity cropped sorghum after the cotton planting window closed.

Existing sorghum producers would be unlikely to change to cotton sorghum opportunity cropping due to the perception of riskiness they hold concerning cotton production. This attitude would see their sorghum business out perform the alternate cotton business in ten of the decades modelled. This reflects the distribution of outcomes provided by the analysis of annual gross margins.

4.4.4 Sustainability indicators

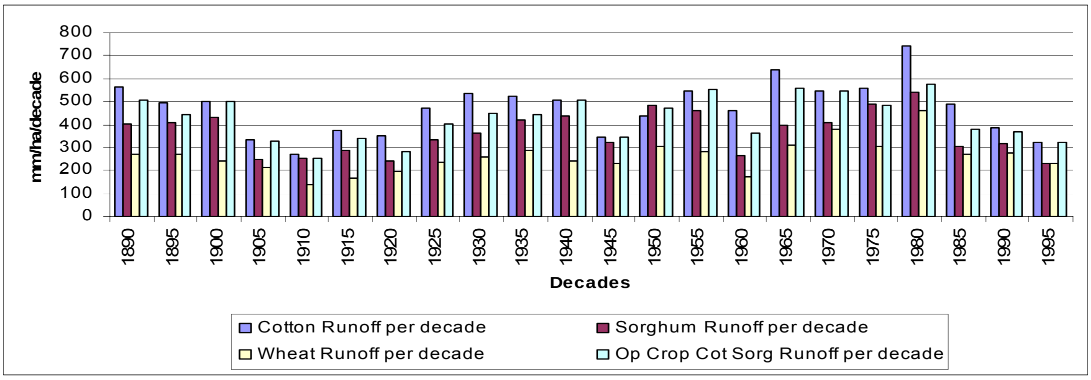


Figure 54 Modelled runoff for cropping systems at Dalby on a 190mm PAWC soil

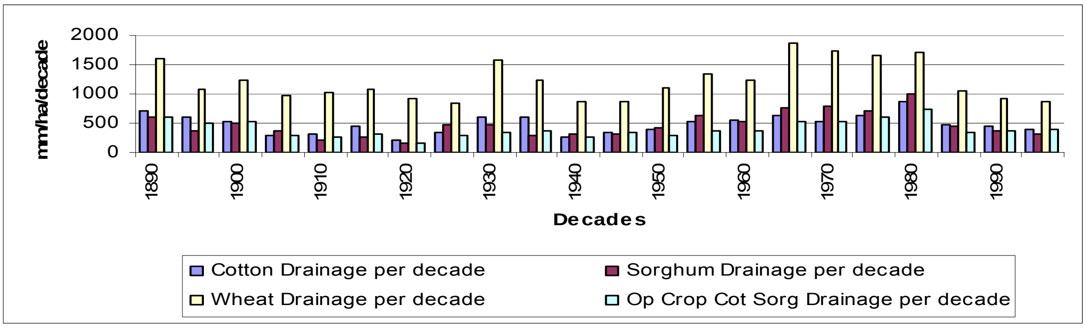


Figure 55 Modelled drainage for cropping systems at Dalby on a 190mm PAWC soil

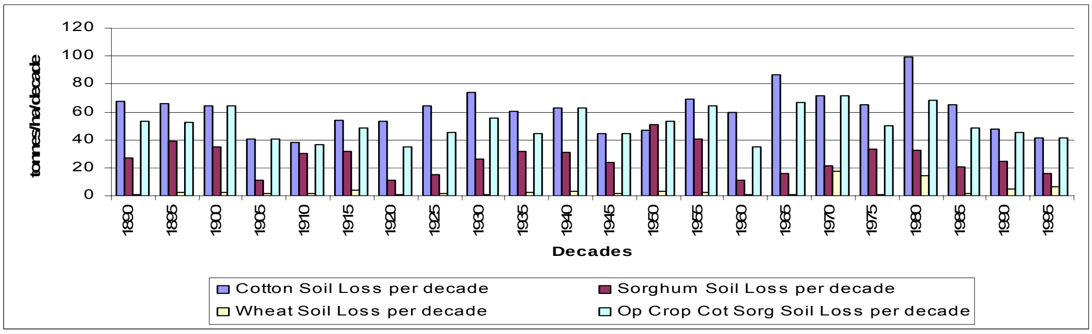


Figure56 Modelled soil loss for cropping systems at Dalby on a 190mm PAWC soil

The slightly greater cropping intensity of the opportunity cotton sorghum system compared to the monoculture cotton system provides only a small impact on the environmental indicators.

4.4.5 Summary of opportunity cropping cotton and sorghum

Opportunity cropping cotton and sorghum would be preferred by monoculture cotton producers because the potential profitability of their cotton cropping system is enhanced through a reduction in production risk without a reduction in outcomes in the better cotton years.

Existing monoculture sorghum and wheat producers are unlikely to change because the riskiness of switching to cotton production has only been marginally reduced by the incorporation of sorghum as an opportunity crop.

Decadal climate variability indices and ENSO classifications do not help in reducing the riskiness of switching from sorghum or wheat to cotton/sorghum opportunity cropping.

4.5 Fixed rotation cotton and sorghum

Fixed rotation cotton and sorghum combines the crops of cotton and sorghum on the basis that the crops follow each other in sequence. If a planting opportunity for a crop is missed the opportunity to plant another crop is not taken until the next summer when the next crop in sequence is planted.

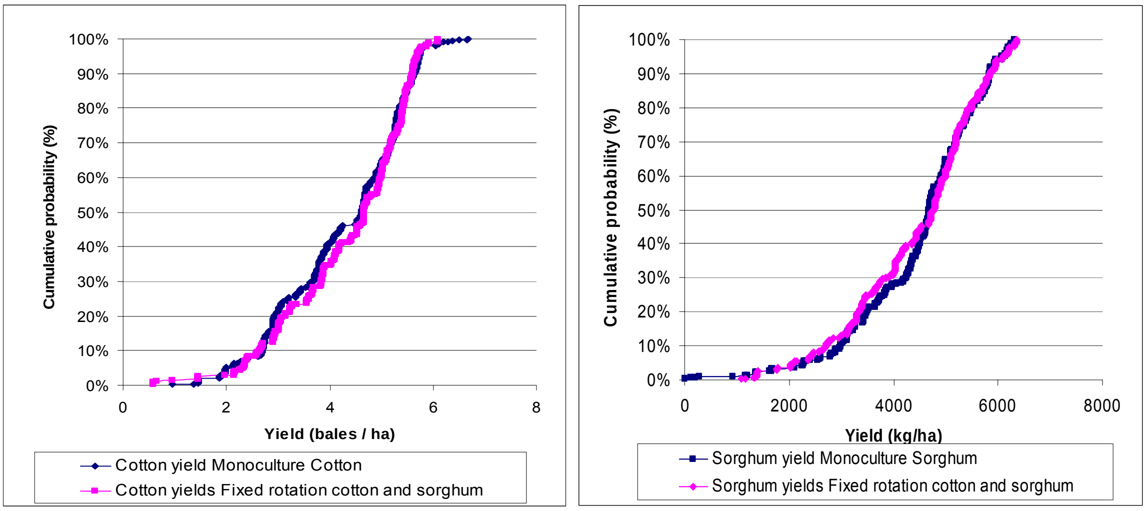
The difference between this cropping system and the monoculture cropping systems of either cotton or sorghum is that cotton is followed by sorghum and that crop is then followed by cotton again whereas cotton follows cotton in monoculture cotton and sorghum follows sorghum in monoculture sorghum.

The fixed rotation of cotton and sorghum cropping systems attempts to manage the available water differently to both monoculture cotton and monoculture sorghum. Many farm managers see cotton as an extractive crop that may have a higher yield reliability every second year when followed by sorghum compared to planting a cotton crop every year.

On a whole farm basis, one half of the property would be planted to cotton each year while the other half would be planted to sorghum. The crops would reverse paddocks in subsequent years.

This crop management approach is also expected to reduce the risk associated to planting the whole property to cotton at one time.

4.5.1 Crop yields



(a) (b)

Figure 57 Yield distributions for years planted for cotton (a) and sorghum (b) when farmed as a monoculture or fixed rotation with each other

Modelled cotton yield potential is slightly increased by growing the crop in a fixed rotation with sorghum. Modelled sorghum yield potential is slightly decreased by growing the crop in a fixed rotation with cotton. In both cases the difference is slight.

If a planting opportunity is received for either cotton or sorghum the yield potential is largely unaffected by whether cotton or sorghum was the previous crop grown. Although the available starting soil water for a sorghum or cotton crop can impact on yield outcomes, the differences to starting soil water brought about by the nature of the previous summer crop are slight.

4.5.2 Gross margins

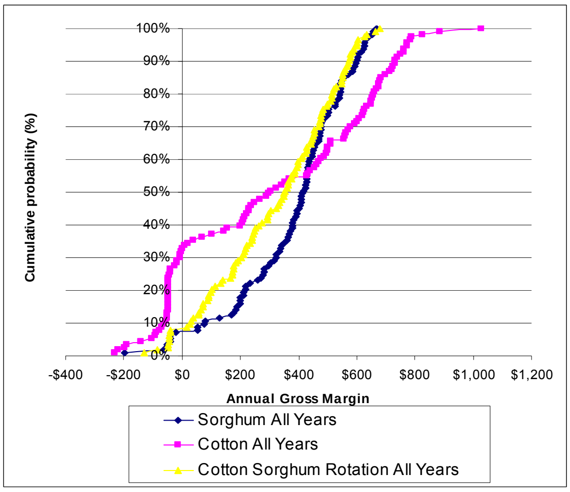
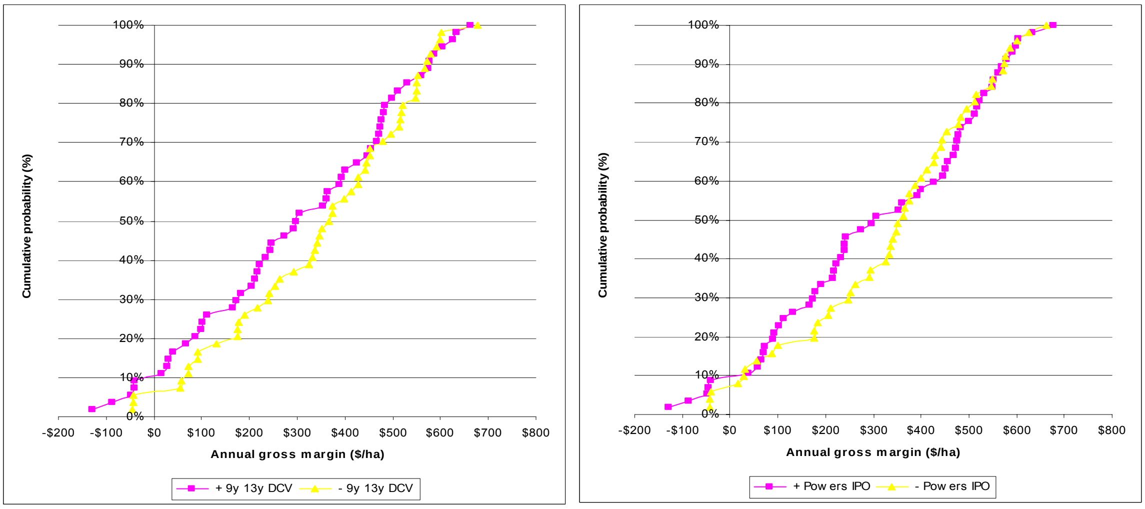


Figure 58 Annual whole farm gross margin distribution for fixed rotation cotton and sorghum compared to monoculture cotton and monoculture sorghum on a 190mm PAWC soil at Dalby

The fixed rotation reduces the riskiness associated with monoculture cotton production but also reduces the reliability associated with sorghum production. The fixed rotation also under performs monoculture cotton in those years that cotton excels.



(a) (b)

Figure 59 Fixed rotation cotton and sorghum gross margins at Dalby on a 190mm PAWC soil. Phases of the 9y 13y DCV index (a) and phases of the IPO index (b)

The slight response to the decadal climate signal would not change the value for an accurate forecast of the index as previously explained.

4.5.3 Investment returns

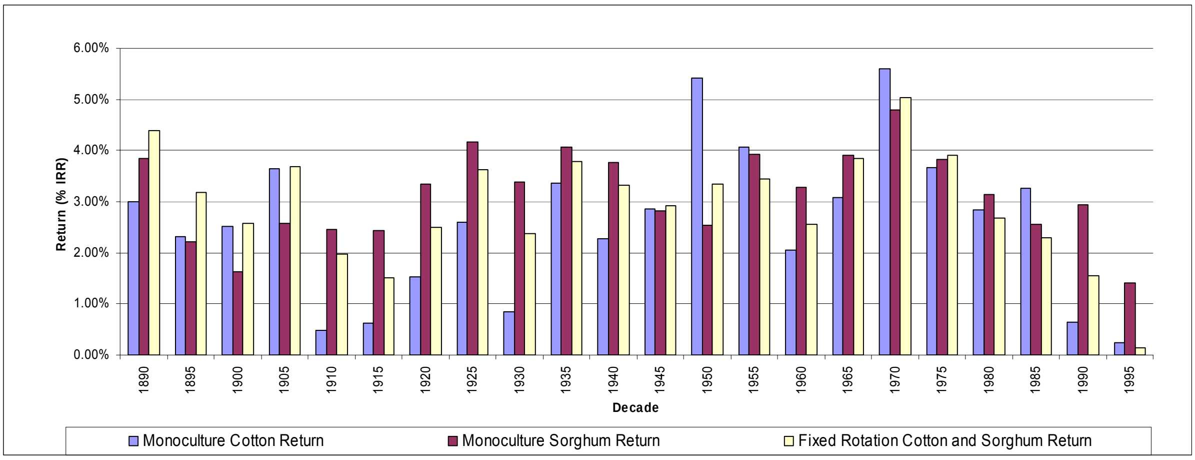


Figure 60 Investment returns for cotton and sorghum cropping systems at Dalby on a 1190mm PAWC soil

Fixed rotation cotton and sorghum out performs monoculture sorghum on six occasions and under performs it on thirteen occasions.

Fixed rotation cotton and sorghum out performs monoculture cotton eleven occasions and under performs it on four occasions. The remainder show no real difference between cropping systems.

4.5.4 Sustainability indicators

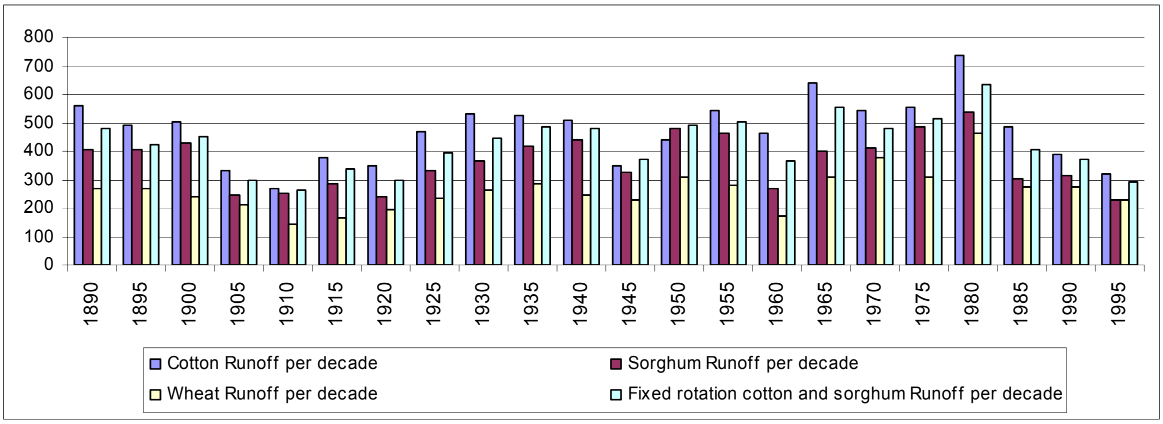


Figure 61 Modelled runoff for cropping systems at Dalby on a 190mm PAWC soil

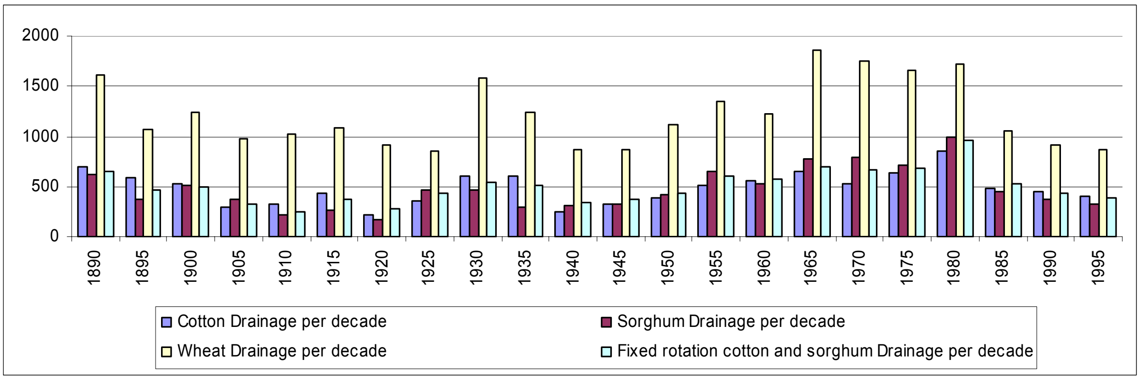


Figure 62 Modelled drainage for cropping systems at Dalby on a 190mm PAWC soil

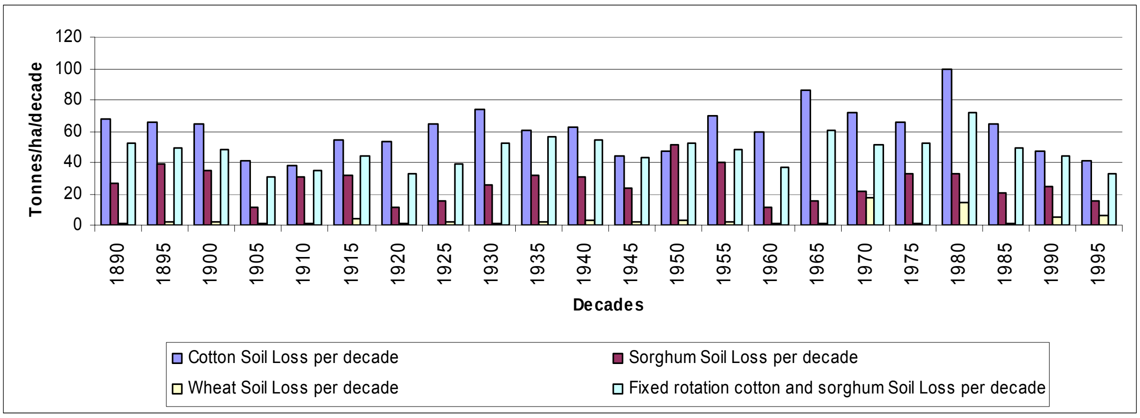


Figure 63 Modelled soil loss for cropping systems at Dalby on a 190mm PAWC soil

The inclusion of cotton in a rotation seems to increase the potential for soil loss above that predicted for monoculture sorghum or monoculture wheat.

4.5.5 Summary of fixed rotation cotton and sorghum

Applying a fixed rotation of cotton and sorghum to a suitable dryland cropping property at Dalby does not improve the potential profitability of that property above that expected for monoculture sorghum production. The rotation also tends to reduce the reliability of returns compared to sorghum in lower performing years.

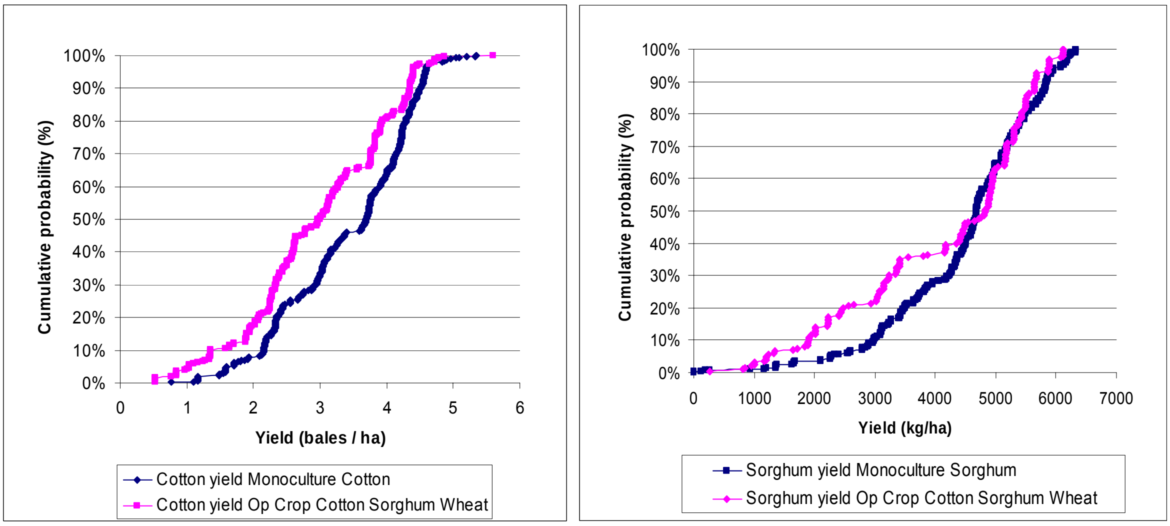
The fixed rotation of cotton and sorghum does reduce the riskiness of monoculture cotton production but also limits the potential benefits of concentrating on monoculture cotton in years with a high yield potential.

No climate signal tested appears capable of changing these relationships.

4.6 Opportunity cropping cotton sorghum and wheat

Opportunity cropping cotton sorghum and wheat is a cropping system designed to maximise cropping opportunities over any period of time. Planting opportunities for any of the three crops are taken when the conditions are met without references to crop sequence.

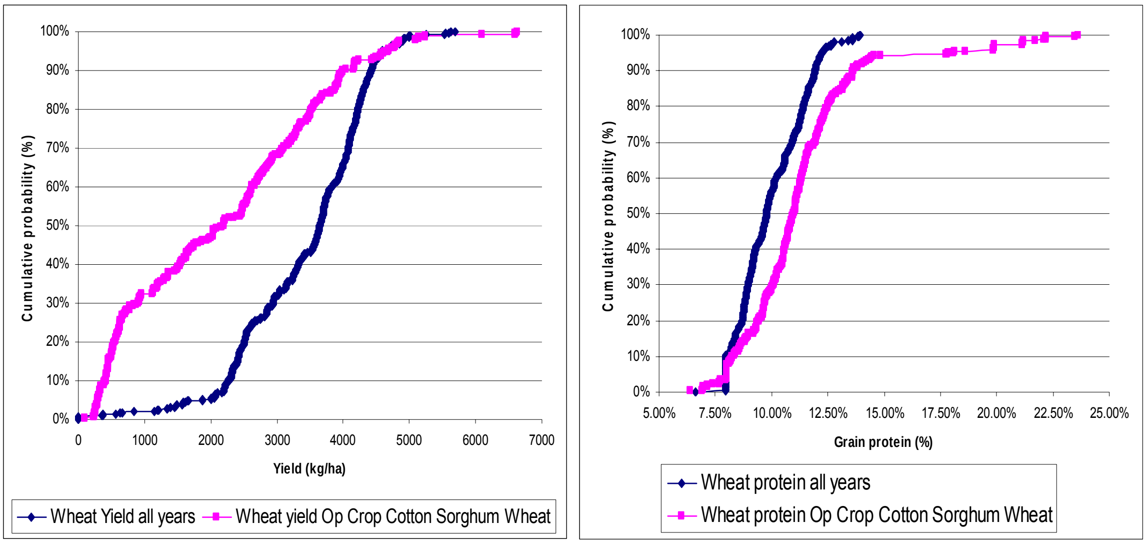
4.6.1 Crop yields



(a) (b)

Figure 64 Cumulative distribution for cotton yield (a) and sorghum yield (b) grown for monoculture and opportunity cropping cotton sorghum and wheat at Warra on a 190mm PAWC soil

The median yield of cotton crops is reduced by about .7 bales per ha in those years that it is planted in the opportunity cropping cotton sorghum and wheat farming system when compared to those years that it is planted in monoculture cotton. Yield potential for sorghum crops grown within the opportunity cropping cotton sorghum and wheat cropping system is lower in about 50% of years when compared to sorghum yield in monoculture sorghum.



(a) (b)

Figure 65 Cumulative distribution for wheat yield (a) and wheat protein (b) for monoculture cropping and opportunity cropping cotton sorghum and wheat at Dalby on a 190mm PAWC soil

Potential median wheat yield is reduced by one and a half tonnes per hectare when it is grown within the opportunity cropping cotton sorghum and wheat cropping system and median wheat protein is increased by about 1% when compared to the potential yields and proteins available for the monoculture wheat system.

4.6.2 Cropping frequency

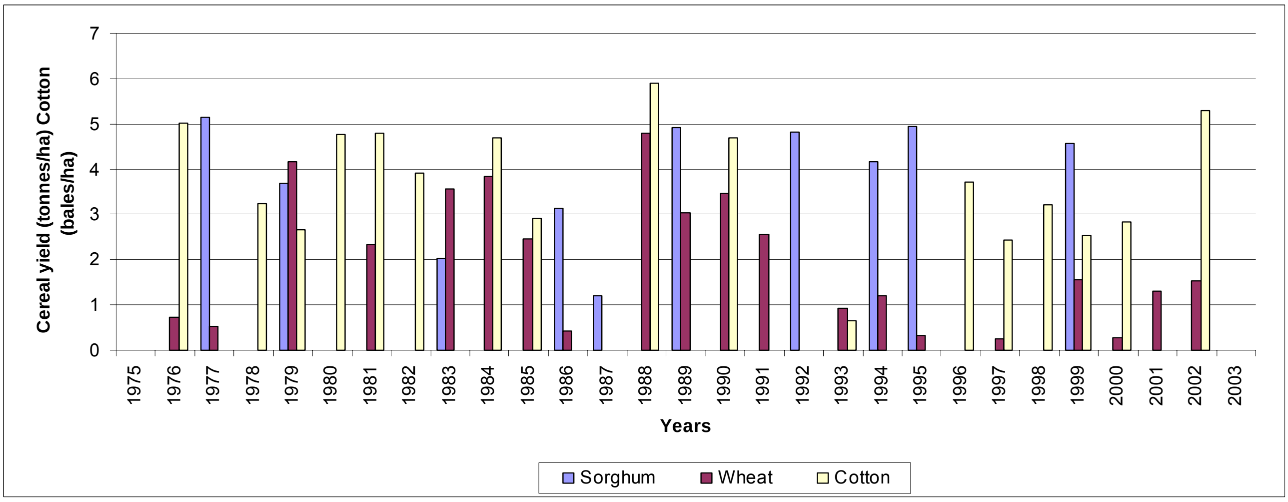


Figure 66 Cropping frequency for opportunity cropping cotton sorghum and wheat on a 190mm PAWC soil at Dalby from 1975 to 2003

Over any 30-year period we would expect about 15 – 17 cotton crops, 8 – 10 sorghum crops and about 15 – 20 wheat crops. Figure 66 indicates that taking an opportunity crop sometimes leads to a loss (1995) and sometimes leads to a win (1988, 1999 or 2002).

4.6.3 Gross margins

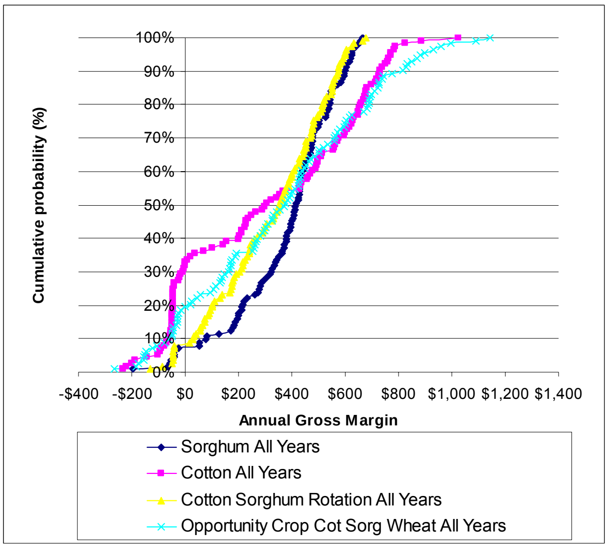
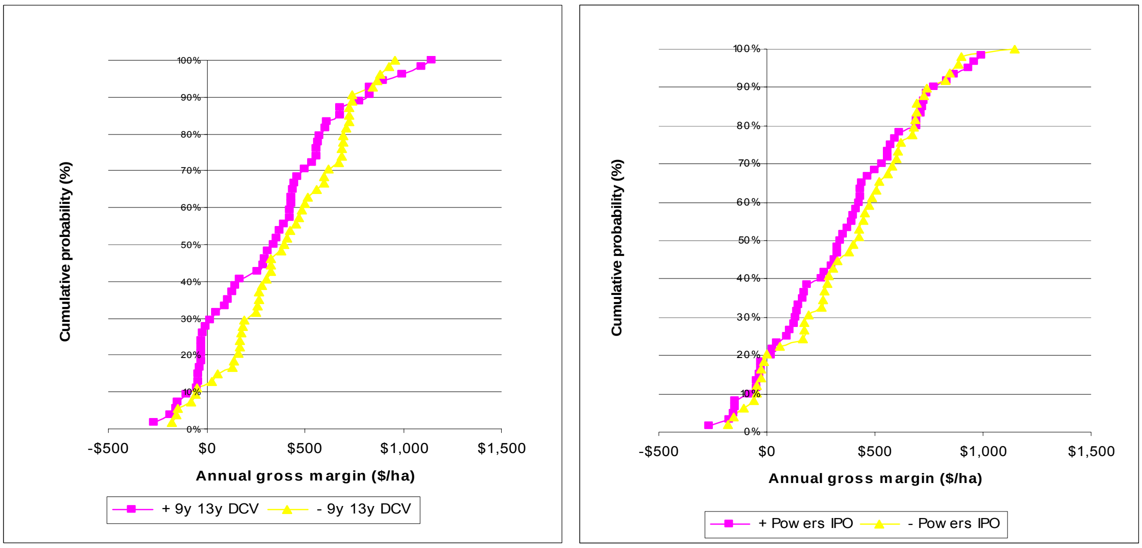


Figure 67 Cumulative distribution for monoculture and opportunity cropping gross margins on a 190mm PAWC soil at Dalby

Figure 67 indicates that opportunity cropping cotton sorghum and wheat is a trade off between the reliability of wheat and sorghum and the riskiness of cotton. This intense cropping system will outperform all others in the top 20% of years but is more risky that all others in the bottom 10% of years. Monoculture sorghum out performs it in 50% of years.

Perusal of the simulated output over a number of decades reveals that wheat is often double cropped after cotton into fairly dry soil and yields are suppressed accordingly (figure 65a). Wheat protein is slightly enhanced (by 1% in 50% of years) due to the constrained water conditions brought about by cropping intensity. (Figure 65b)



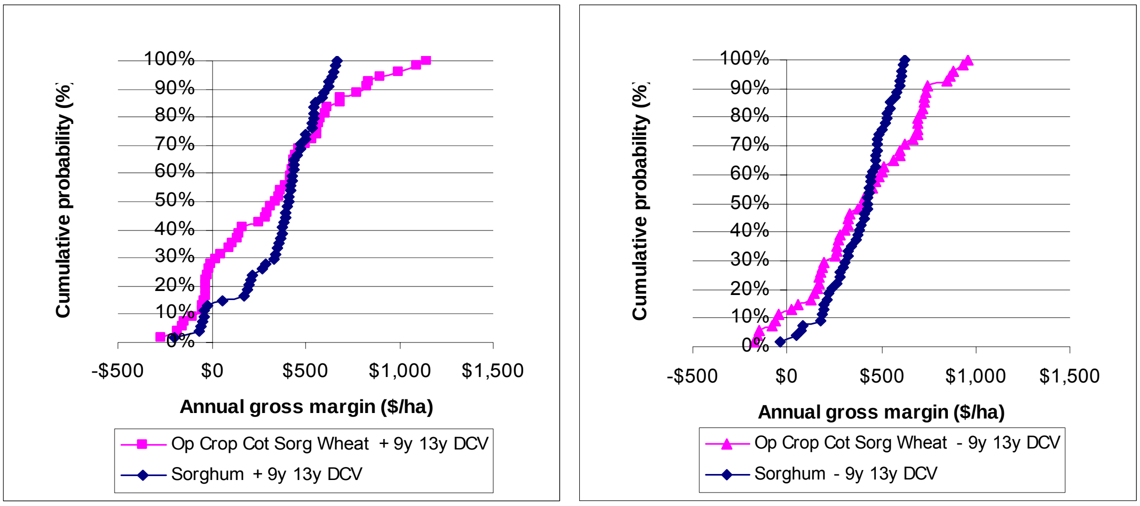
(a) (b)

Figure 69 Cumulative gross margin distribution for opportunity cropping cotton sorghum and wheat at Dalby on a 190mm PAWC soil. 9y 13y DCV index (a) and IPO index (b)

4.6.4 Climate signals and opportunity cropping cotton, sorghum and wheat at Dalby

Decadal Climate Variability Indices

Figure 68 (a) does reveal some differentiation between phases of the 9y 13y DCV climate signal.



(a) (b)

Figure 62 Cumulative gross margin distribution for opportunity cropping cotton sorghum and wheat and monoculture sorghum at Dalby on a 190mm PAWC soil. Positive phase of the 9y 13y DCV (a) and negative phase of the 9y 13y DCV (b)

Monoculture sorghum dominates or equals opportunity cropping cotton sorghum and wheat in 70% of years that the 9y 13y DCV index is positive.

Figure 69 (b) indicates that an existing sorghum grower is unlikely to change to opportunity cropping cotton sorghum and wheat as monoculture sorghum still outperforms or has the same potential performance as opportunity cropping cotton sorghum and wheat in 55% of years that have a negative (-) phase for the 9y 13y DCV index.

ENSO Classification

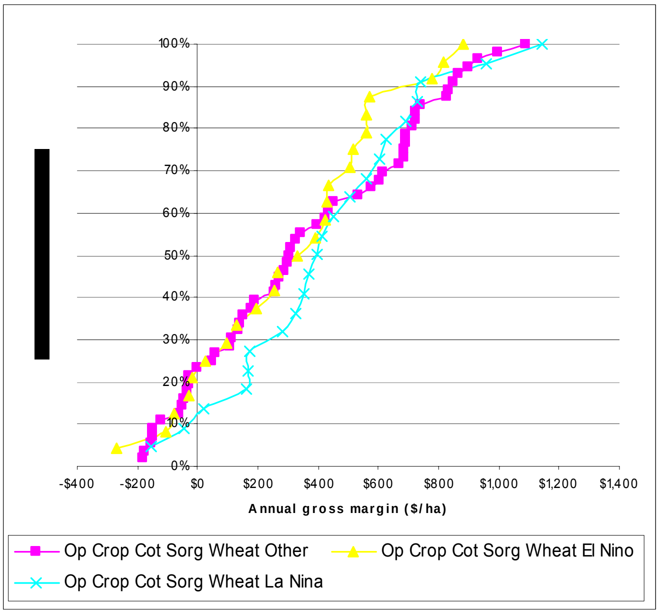
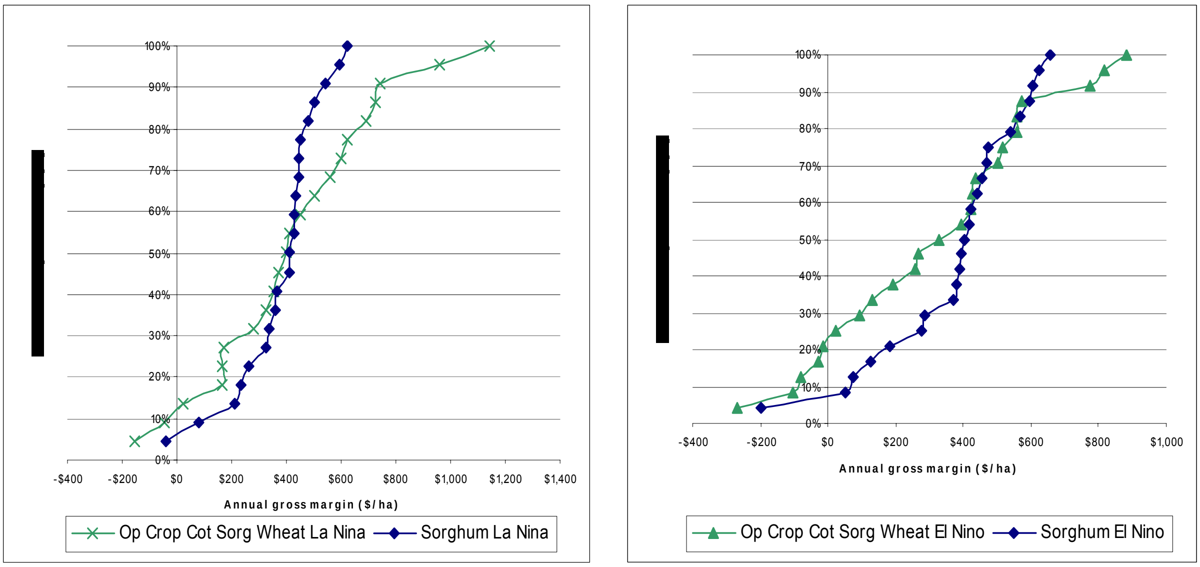


Figure 70 Opportunity cropping cotton sorghum and wheat annual gross margins at Warra classified by ENSO.

Figure 70 shows some advantage for this intense cropping system in years that are classified as La Nina.



(a) (b)

Figure 71 Opportunity cropping cotton sorghum and wheat annual gross margins plus monoculture sorghum annual gross margins at Warra classified by ENSO. (a) La Nina years and (b) El Nino years

Figure 71 indicates little reason to expect monoculture sorghum producers to swap to the more intense opportunity cropping cotton sorghum and wheat cropping system during a year that was classified as either an El Nino or a La Nina.

Investment returns and the IPO index

Figure 72 shows the investment returns for opportunity cropping cotton sorghum and wheat graphed against the **inverse** of the IPO index.

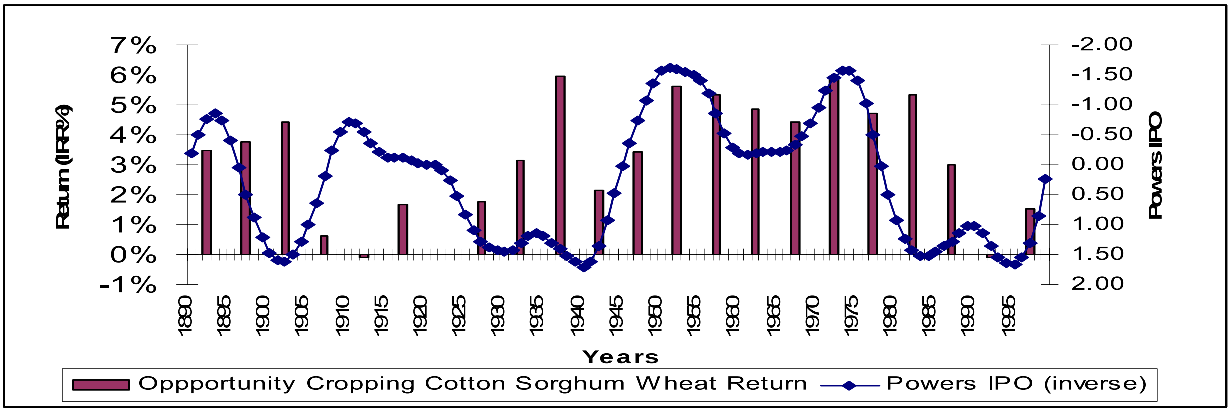


Figure 72 Investment returns for opportunity cropping cotton sorghum and wheat at Dalby on a 190mm PAWC soil compared to the inverse index values for the IPO.

Figure 72 provides some insight into why the IPO provides such a poor differentiation for modelled cropping system gross margins when they are separated on the basis of the value of the index.

The period from 1945 to 1977 exhibits a negative signal for the IPO thereby possibly enhancing rainfall prospects. This increased rainfall potential is mirrored by the increased relative economic performance of the high frequency cropping system.

Unfortunately the cropping system performs well in the 1930's when the index is positive and performs poorly in the period from 1910 to 1920 when the index is negative.

This poor fit between the phase of the signal and the performance of the cropping system significantly impacts on the capacity of the IPO index to identify periods when the change to a higher intensity cropping system will be acceptably more profitable than the alternate lower intensity cropping system.

4.6.5 Investment returns

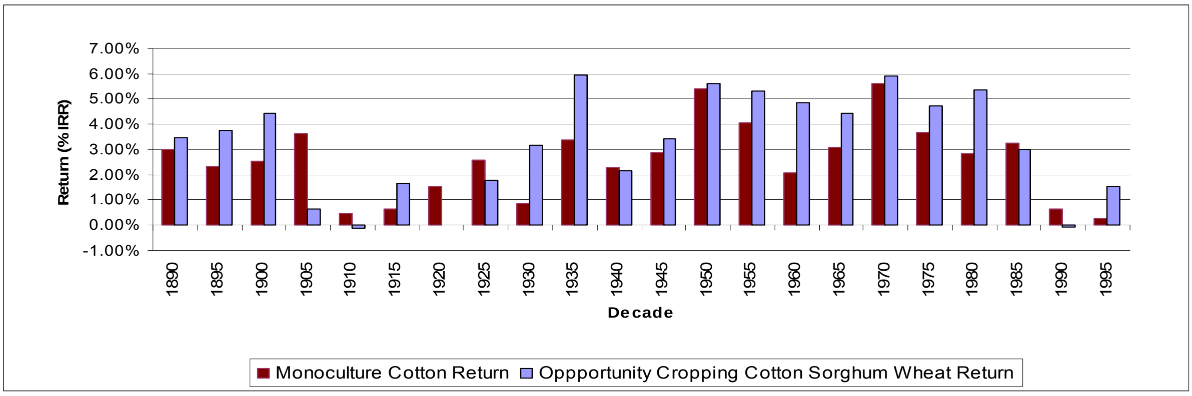


Figure 73 Investment returns for monoculture cotton and opportunity cropping cotton sorghum and wheat at Dalby on a 190mm PAWC soil

Monoculture cotton performs as well as or better than opportunity cropping cotton sorghum and wheat in about 50% of the investment decades modelled. These investment returns have not been adjusted for the extra effort that may be involved in planting, harvesting and growing the additional crops involved in opportunity cropping cotton sorghum and wheat.

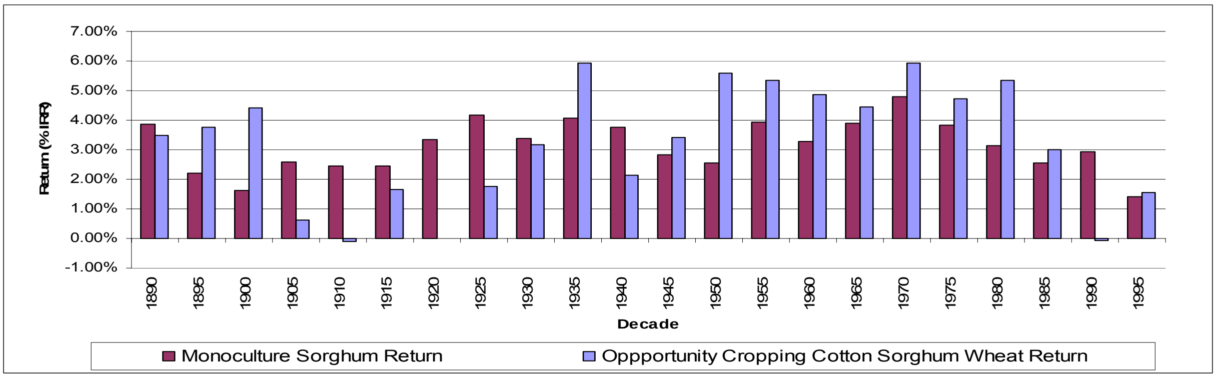


Figure 74 Investment returns for monoculture sorghum and opportunity cropping cotton sorghum and wheat at Dalby on a 190mm PAWC soil

Existing monoculture sorghum producers are unlikely to convert to opportunity cropping cotton sorghum and wheat because of the additional risk of loss, the extra effort required and the lack of any clear benefit.

4.6.6 Sustainability indicators

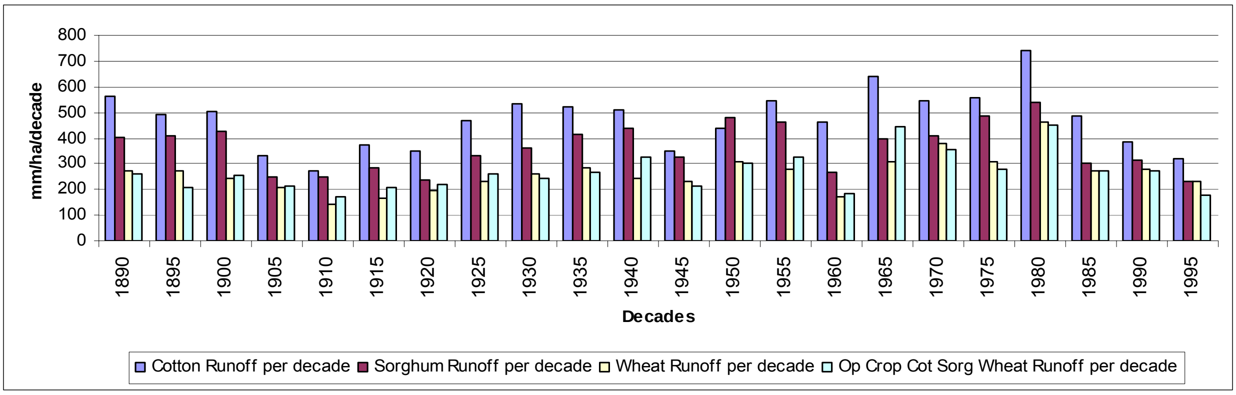


Figure 75 Modelled runoff for cropping systems at Dalby on a 190mm PAWC soil

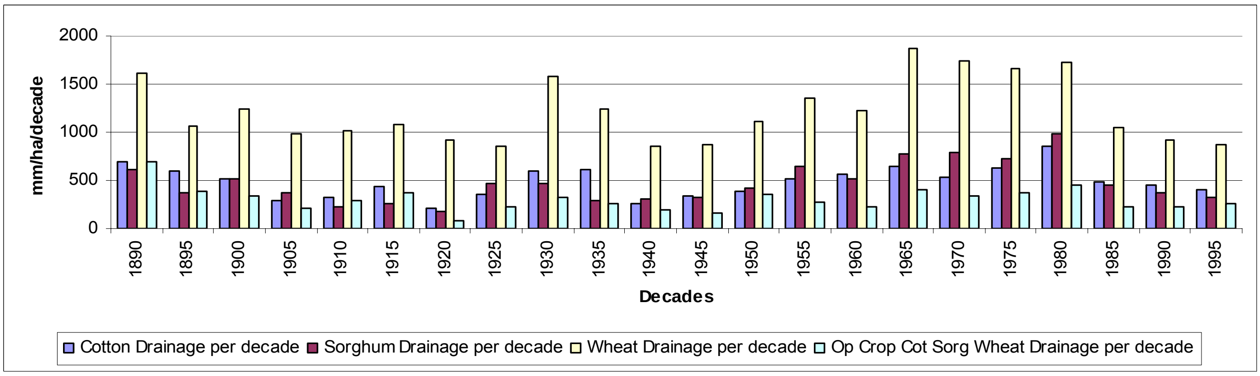


Figure 76 Modelled drainage for cropping systems at Dalby on a 190mm PAWC soil

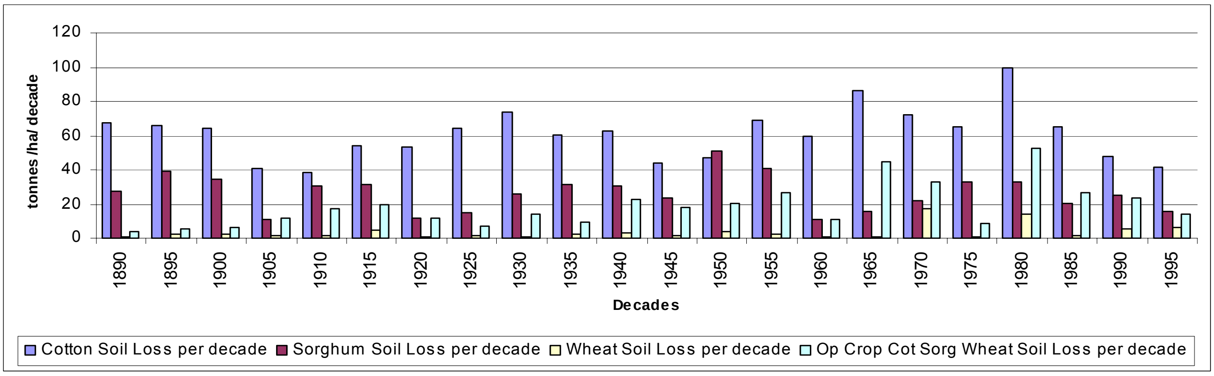


Figure 77 Modelled soil loss for cropping systems at Dalby on a 190mm PAWC soil

Including cotton in a cropping system seems to impact on soil loss but taking opportunity crops seems to reduce runoff and drainage.

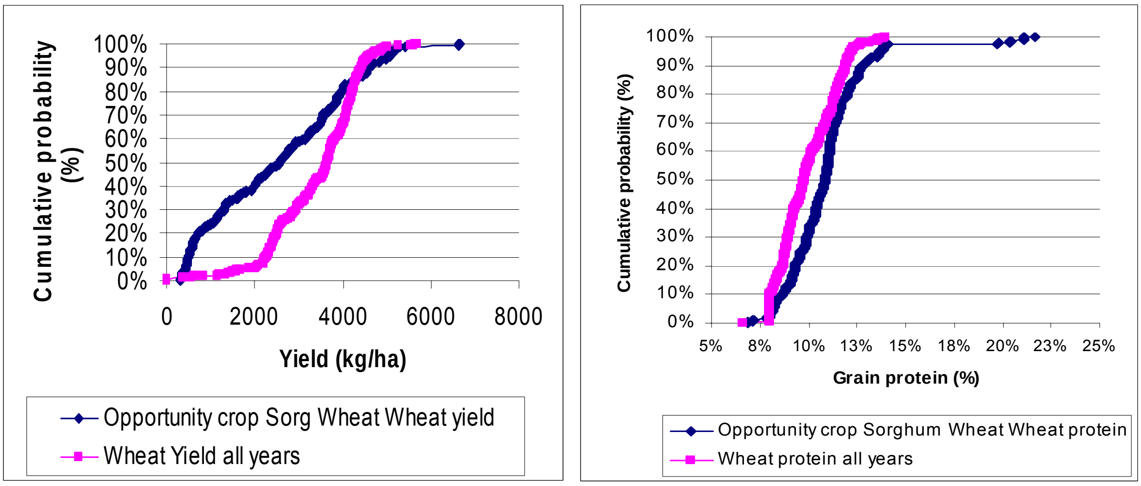
4.6.7 Summary of opportunity cropping cotton sorghum and wheat

Increasing the intensity of a cropping system that includes dryland cotton without a useful climate forecast system does not improve the economic performance or reduce the riskiness of the modelled farm business.

4.7 Opportunity cropping sorghum and wheat

Opportunity cropping sorghum and wheat is a cropping system designed to maximise cropping opportunities over any period of time without incurring the added risk of dryland cotton production. Planting opportunities for either wheat or sorghum can be taken when the planting window is open plus rainfall and stored soil water conditions are met.

4.7.1 Crop yields



(a) (b)

Figure78 Distribution of wheat yield (a) and wheat protein (b) on a 190mm PAWC soil at Dalby. Cropping systems modelled are monoculture wheat and opportunity cropping sorghum and wheat.

The modelled median yield for wheat grown within opportunity cropping sorghum and wheat is almost halved when compared to the median yield for monoculture wheat. This is due to the increased cropping frequency of the opportunity cropping farming system. The median wheat protein of wheat grown in the opportunity cropping system is increased by 1% when compared to the protein percent expected for monoculture wheat. This increase is probably due to the increased chances of water stress in wheat production under the opportunity cropping system.

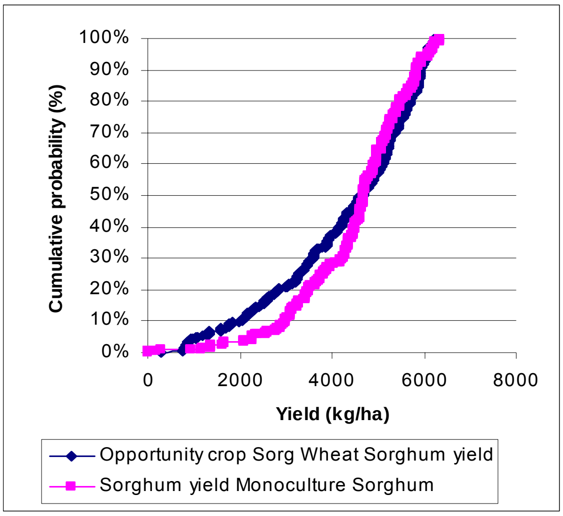


Figure79 Distribution for sorghum yield at Dalby on a 190mm PAWC soil.

Modelled sorghum yields for sorghum grown within opportunity cropping sorghum and wheat show a potential reduction in about 50% of years compared to modelled monoculture sorghum yields.

4.7.2 Cropping frequency

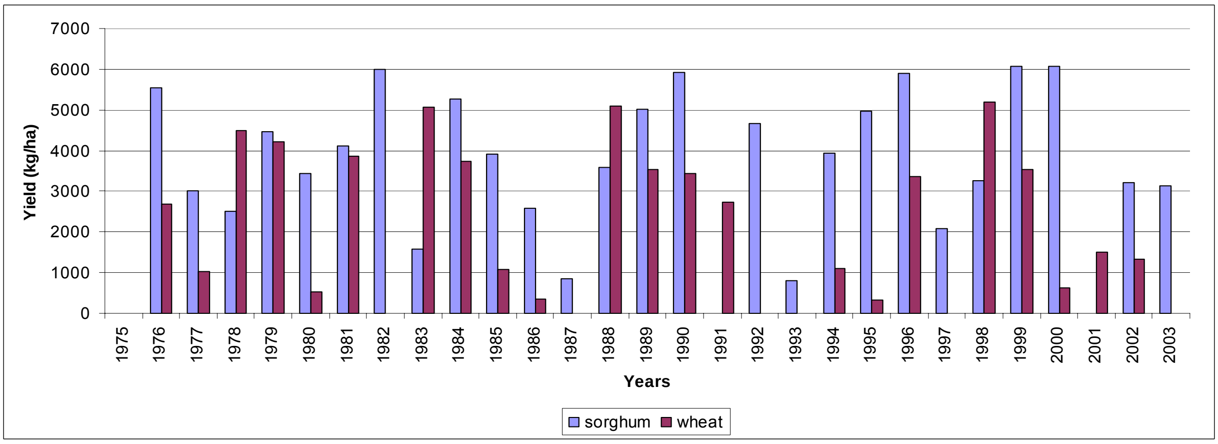


Figure 80 Cropping frequency and modelled yields for opportunity cropping sorghum and wheat at Dalby on a 190mm PAWC soil. 1975 to 2003 harvest years

The cropping frequency shown in figure 80 is typical of much of the climate sequences modelled for Dalby since 1890. On average about 75% more crops could expect to be sown over a 30-year cropping period under this cropping system when compared to monoculture wheat and monoculture sorghum.

The number of crops sown and then "failing" seems to increase slightly compared to either monoculture sorghum or monoculture wheat. On average about 10% of the crops sown could be considered to be "failures" although this measurement could be open to discussion and redefinition.

4.7.3 Gross margins

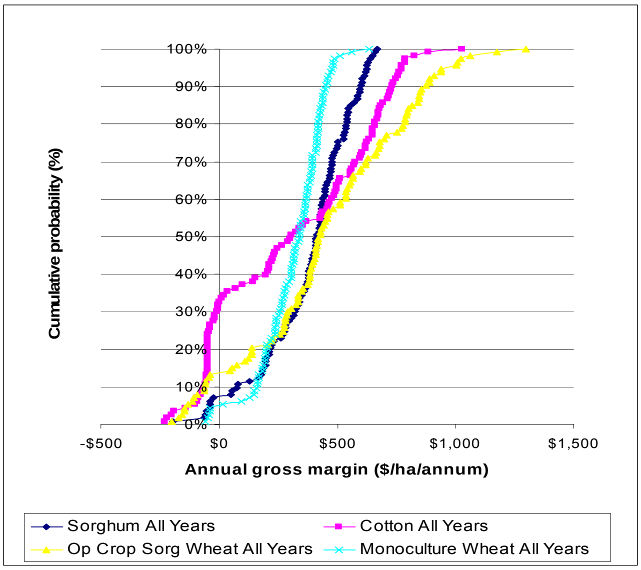


Figure 81 Cumulative distribution for monoculture and opportunity cropping gross margins on a 190mm PAWC soil at Dalby

Opportunity cropping sorghum and wheat is not as reliable as either monoculture wheat or monoculture sorghum and will produce negative gross margins in about 10% to 15% of years. It has the potential to outperform or equal the performance of either cereal monoculture in about 80% of years.

Opportunity cropping sorghum and wheat is less risky that any of the cotton production systems and probably will outperform them in at least 50% of years.

4.7.4 Sustainability indicators

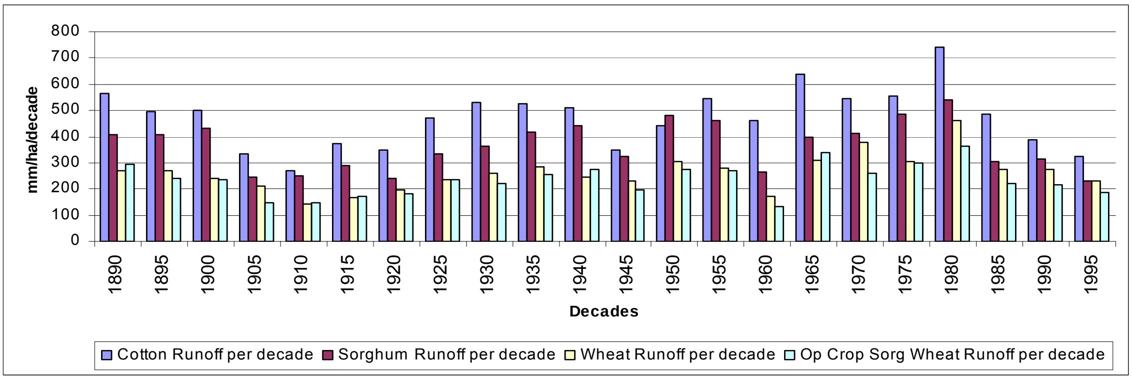


Figure 82 Modelled runoff for opportunity cropped sorghum and wheat on a 190mm PAWC soil at Dalby

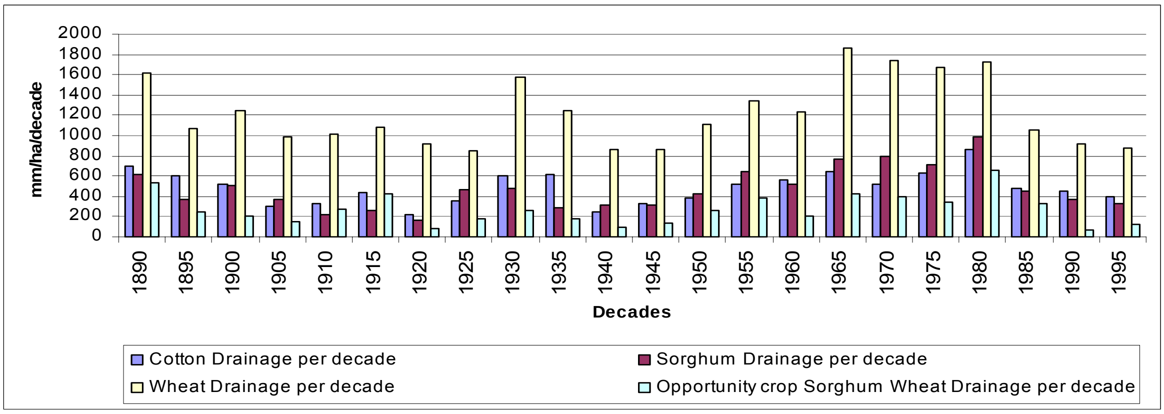


Figure 83 Modelled drainage for opportunity cropped sorghum and wheat on a 190mm PAWC soil at Dalby

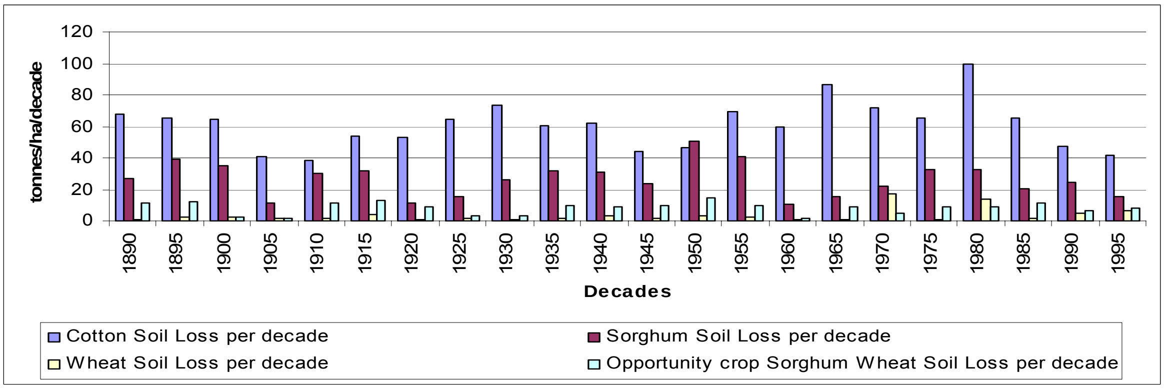
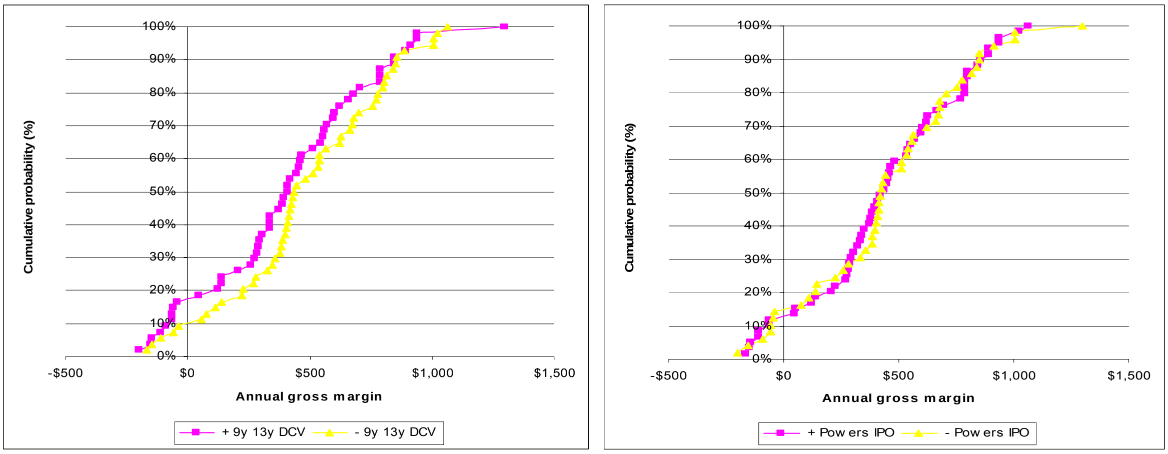


Figure 84 Modelled soil loss for opportunity cropped sorghum and wheat on a 190mm PAWC soil at Dalby

Opportunity cropped sorghum and wheat holds runoff at comparable levels to other cereal cropping systems; reduces potential drainage in most climate sequences and holds potential soil loss at consistently low levels.

4.7.5 Climate signals

Decadal Climate Variability Indices



(a) (b)

Figure 85 Cumulative gross margin distribution for opportunity cropping sorghum and wheat at Dalby on a 190mm PAWC soil. 9y 13y DCV index (a) and IPO index (b)

Opportunity cropping sorghum and wheat shows a small response to the 9y 13y DCV index.

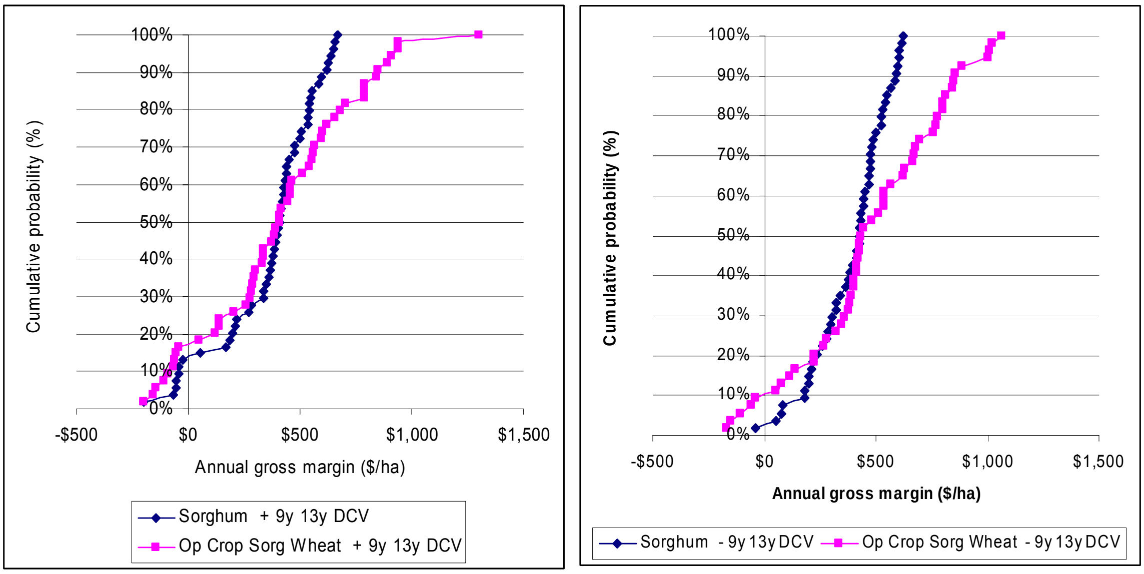


Figure 86 Distribution of annual gross margin for opportunity cropping sorghum and wheat and monoculture sorghum separated on the basis of the positive phase (a) and the negative phase (b) of the 9y 13y DCV index.

The slight response of opportunity cropping sorghum and wheat to the 9y 13y DCV index encouraged consideration of the trade off with monoculture sorghum and the phases of the index. Insufficient differences exist between the potential outcomes to use this index as a criterion for choosing between the cropping systems.

ENSO classification

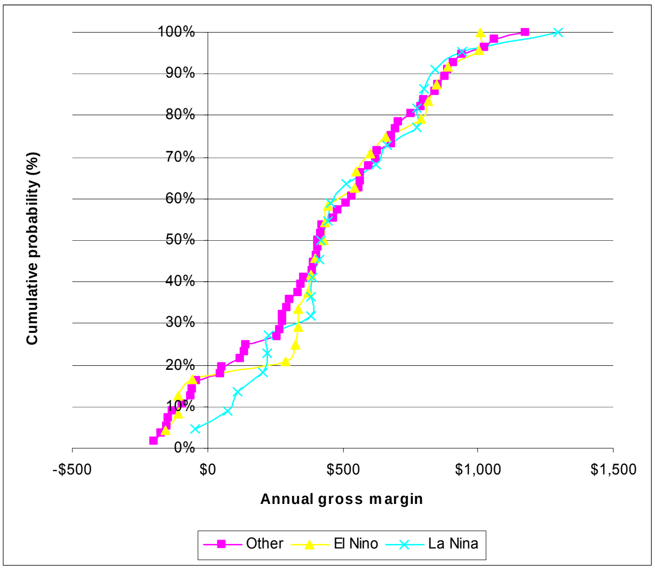


Figure 87 Cumulative gross margin distribution for opportunity cropping sorghum and wheat at Dalby on a 190mm PAWC soil. Phases of ENSO (Potgieter et al 2003)

The relatively small differences in potential gross margins between the phases of ENSO suggest that this responsive cropping system has the potential to minimise the impact of ENSO events on dryland cropping systems at Dalby. *What you lose on the swings you may tend to pick up on the roundabouts.*

SOI phase

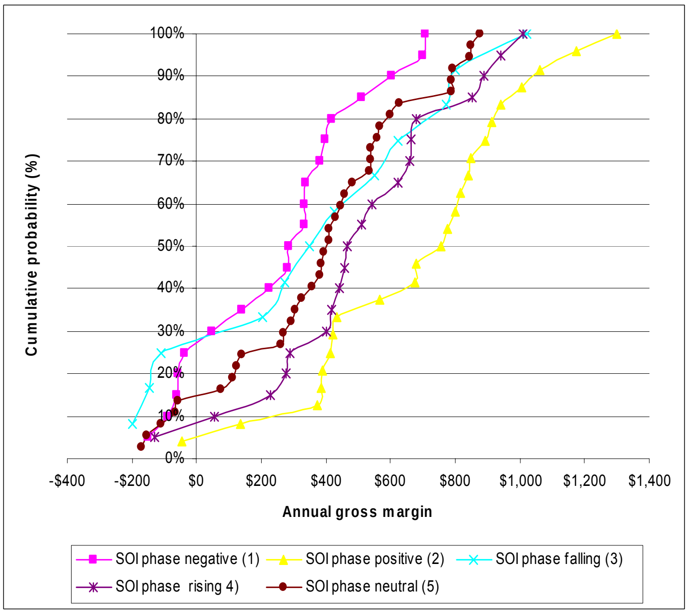


Figure 88 Opportunity cropping sorghum and wheat annual gross margins on a 190mm PAWC soil at Warra classified by SOI phase in the year prior to the annual gross margin.

Annual gross margins for opportunity cropping sorghum and wheat have been grouped in figure 88 on the basis of the phase of the SOI in August of the year prior to the calculation of the annual gross margin.

As both wheat and sorghum or wheat or sorghum individually could make up the figure for the annual gross margin, the relationship between SOI phase and annual gross margin may be more complex than first impressions and some caution may be required before firm conclusions are drawn.

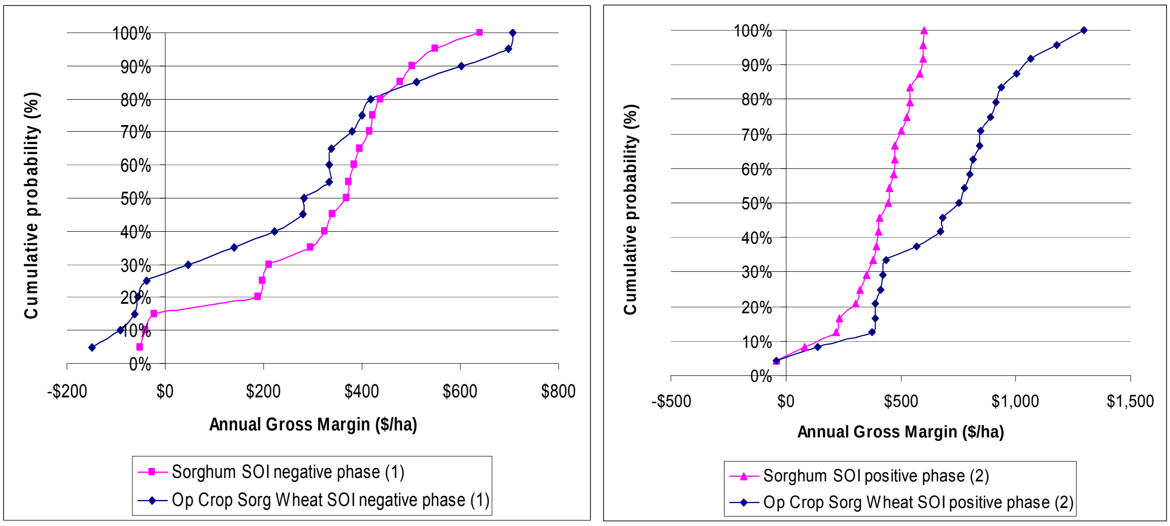
The most likely explanation for the fairly distinct separation of the distributions is that the five phase forecasting system using the SOI gives a good indication of the amount of water available for cropping over the next six to twelve months.

Additional water can be used by this responsive cropping system to produce extra total yield with possibly lower variable costs of production due to savings in fallow costs.

Opportunity cropping during periods of water deficit appears to encourage opportunities being grasped that result in restricted yields and increased variable costs per tonne of grain harvested. This could lead to a suppression of annual gross margins when compared to a less intensive cropping system.

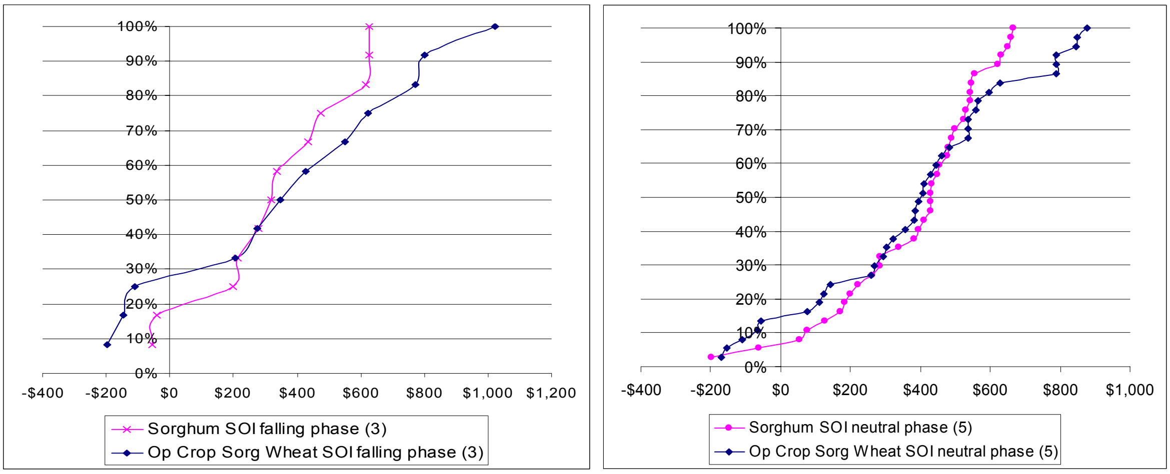
The increased spread of distributions shown in figure 88 could be due to:

- the phase forecasting system having some skill for this cropping system or,
- it could be due to the way in which annual gross margins have been calculated for this cropping system and related to the forecasting system.



(a) (b)

Figure 89 Opportunity cropping sorghum and wheat annual gross margins classified by SOI phase. (a) SOI negative phase and (b) SOI positive phase (b)



(a) (b)

Figure 90 Opportunity cropping sorghum and wheat annual gross margins classified by SOI phase. (a) SOI falling phase and (b) SOI neutral phase (b)

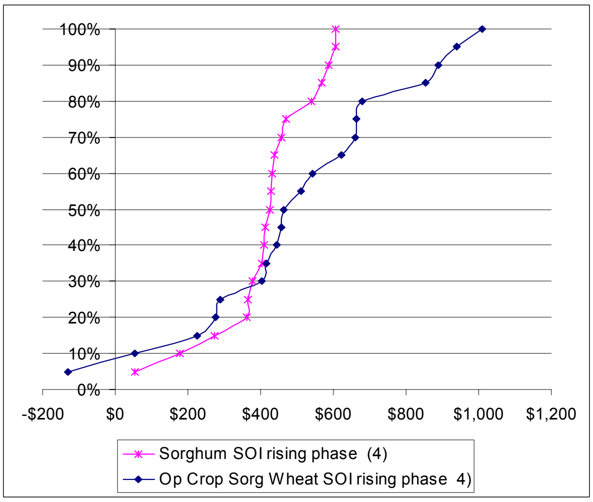


Figure 91 Opportunity cropping sorghum and wheat annual gross margins classified by SOI phase.

Investigation of the distribution of annual gross margin for monoculture sorghum and opportunity cropping sorghum and wheat indicates that monoculture sorghum would be the preferred cropping system if the SOI phase was negative prior to sorghum planting.

An opportunity to plant wheat immediately after the sorghum crop would be better ignored.

If the SOI was positive or rising, the chances of an opportunity crop of wheat paying off are quite good after the sorghum crop.

If the SOI was neutral or falling when sorghum was ready to be planted, then taking opportunity crops of sorghum and wheat as they arose would probably not lessen the performance of the farm business compared to planting sorghum alone.

As these relationships seem to fit with expectations we accept that the spread of distributions for the SOI phase forecasting system shown in figure 88 is probably not a consequence of the method of calculation.

4.7.6 Investment returns

It is expected that an existing monoculture sorghum grower with the complement of plant and equipment we have provided him with would not have to invest extra capital to implement the opportunity cropping sorghum and wheat cropping system.

The costs of extra tractor hours needed to plant extra crops and extra labour to handle extra plantings and harvests has been incorporated by increasing the annual operating hours requirements of the machines effected by the change and increasing the wages paid by the farm business. The increase in annual hours of operation for plant effectively shortens the period the plant is held by the farm.

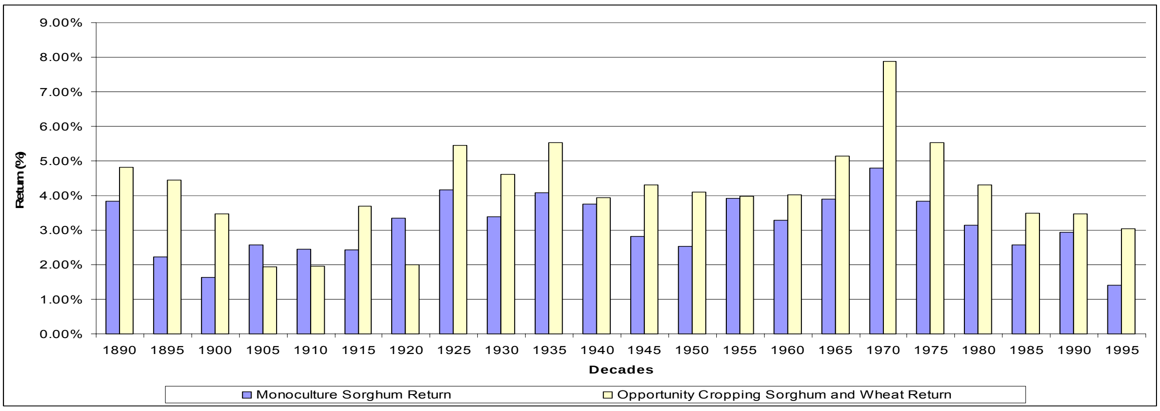


Figure 92 Modelled investment returns for monoculture sorghum and opportunity cropping sorghum and wheat at Dalby on a 190mm PAWC soil

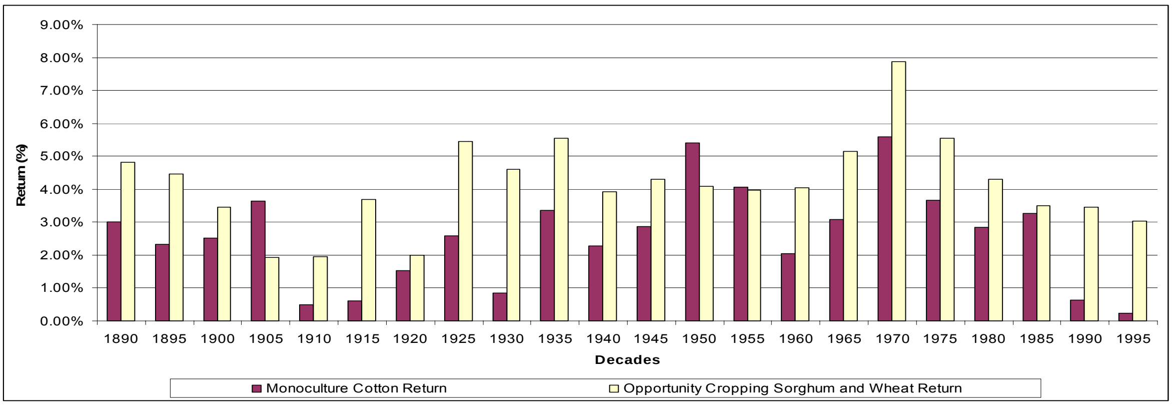


Figure 93 Modelled investment returns for monoculture cotton and opportunity cropping sorghum and wheat at Dalby on a 190mm PAWC soil

Figure 94 Net present value of investing in opportunity cropping sorghum and wheat compared to monoculture sorghum

Changing the cropping system from monoculture sorghum to opportunity cropping sorghum and wheat at Dalby is expected to provide a substantial benefit in the majority of occasions that the change is made.

4.7.7 Summary of opportunity cropping sorghum and wheat

Cropping systems that are designed to capitalise on soil water and planting windows without respect to fallow length have the capacity to outperform cropping systems that have a fixed fallow length or a low cropping intensity.

The improvement in economic performance for a responsive cropping system depends upon very precise timeliness and crop management by the farm manager. The improvement in sustainability indicators also depends upon successfully maintaining the same precision and crop management.

5 Discrete Years for Climate Indices

5.1 Discrete years for the 9y 13 y DCV index

The 9y13y DCV Index has been broken into periods when the index was above zero and periods when the index was below zero. The cut of and start dates were chosen as close as possible to the date at which the 9y13y DCV index changed its sign value. Table 5 shows these dates.

Table 3 Start and finish dates for phase values 9y 13y DCV index

Start	**Finish**	**Index sign**	**Years**
1-01-1890	31-12-1896	-	7
1-01-1897	31-12-1905	+	9
1-01-1906	31-12-1911	-	6
1-01-1912	31-12-1918	+	7
1-01-1919	31-12-1925	-	7
1-01-1926	31-12-1931	+	6
1-01-1932	31-12-1939	-	8
1-01-1940	31-12-1945	+	6
1-01-1946	31-12-1956	-	11
1-01-1957	31-12-1960	+	4
1-01-1961	31-12-1964	-	4
1-01-1965	31-12-1969	+	5
1-01-1965	31-12-1976	-	7
1-01-1977	31-12-1983	+	7
1-01-1984	31-12-1990	-	7
1-01-1991	31-12-1998	+	8
		Total	109

5.2 Discrete years for the IPO index

Table 4 Start and finish dates for phase values IPO DCV index

Start	Finish	Index sign	Years
1-01-1890	31-12-1895	-	6
1-01-1896	31-12-1907	+	12
1-01-1908	31-12-1919	-	12
1-01-1920	31-12-1944	+	25
1-01-1945	31-12-1977	-	33
1-01-1978	31-12-1998	+	21
		Total	109 years

Note –01/01/1945 to 31/12/1977 was truncated to 30 years in the analysis.

5.3 Discrete years for the ENSO classification

Table 5 ENSO classification (Potgieter *et al.* 2003)

El Nino years	**La Nina years**	**Other years**
1902	1908	1901
1905	1909	1903
1911	1910	1904
1914	1916	1906
1919	1917	1907
1925	1921	1912
1940	1922	1913
1941	1924	1915
1946	1928	1918
1951	1933	1920
1953	1938	1923
1957	1943	1926
1965	1945	1927
1969	1950	1929
1972	1955	1930
1977	1956	1931
1982	1971	1932
1987	1973	1934
1991	1974	1935
1992	1975	1936
1993	1988	1937
1994	1998	1939
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		2001

6 Modelling Framework for Farming Systems at Dalby

6.1 Structure of model runs

APSIM simulations were completed for each phase of the nominated cropping system (rotation) with model simulations starting prior to either the summer or winter cropping phase of the cropping system (rotation).

Simulations started on the 1st of April (for winter starts) and 1st September (for summer starts) of the starting year of individual simulations.

APSIM model runs were started at the beginning and middle of each decade (eg 1890 and 1895) of reliable climate records for the location being simulated.

Each run continued for 30 winters and 30 summers (1st April start) or 30 summers and 30 winters (1st September start) or finished as late as climate data allowed.

A simulation that started after a fallow period had initial soil water (PAW) set to 100mm. A simulation that started immediately after a crop had been harvested had initial soil (PAW) water set to 50mm.

Once soil water had been set at the beginning of each run it was not reset.

Once the cropping sequence was started, no crop was planted within 10 days of the harvest of a prior crop.

A suitable soil file with a PAWC of 190mm was used.

Initial soil nitrate was set at 35 kg N/ hectare at the start of each run and was **not** reset during the modelling sequence. This starting soil fertility is equivalent to that of a continuously cropped soil that has been under fertilised for some time.

Nitrate fertiliser was added at the planting of each cereal and cotton crop. Wheat and cotton were fertilised so that 100 kg of soil N is available at planting. Sorghum was fertilised at planting so that 80 kg of soil N was available.

6.2 Individual crop parameters used in APSIM

6.2.1 Wheat

Model	I Wheat
Planting window:	1st May to 15th July
Planting constraint:	rain over 4 days > 10 mm and PAWC > 50 mm
Cultivar:	Hartog (quick maturing variety)
Plants/m^2:	75
Sowing depth:	50
Fertilizer:	top up to 100 (kg N /ha)

6.2.2 Sorghum

Planting window:	15th September to 15th January
Planting constraint:	rain over 4 days > 25 mm and PAWC > 75 mm
Cultivar:	medium maturity
Plants/m^2:	7
Sowing depth:	30

Row spacing:	1000 (mm)
Fertilizer:	top up to 80 (kg N /ha)
Tillers:	1

6.2.3 Cotton

Planting window:	30th September to 30th November
Planting constraint:	rain over 4 days > 25 mm and PAWC > 75 mm
Cultivar:	siok
Plants/m^2:	8.5
Sowing depth:	50
Row spacing:	double (2000mm)
Fertilizer:	top up to 100 (kg N /ha)

6.2.4 Opportunity Cropping planting windows

When sorghum was planted in an opportunity-cropping window with cotton the sorghum window began on the 1st December and to finished on the 15th January. That is, sorghum was only planted once the cotton window closed and cotton had not been planted.

Sorghum planted into an opportunity cropping system of sorghum and wheat maintained the planting constraints listed above except that the next wheat or sorghum planting was delayed by the presence of an unharvested sorghum or wheat crop.

The planting windows of wheat and cotton were retained as per the specifications outlined above when planted into opportunity cropping systems.

In general, APSIM was set up so that each crop was planted if the rainfall and soil water restrictions were met within the planting window nominated. The rules for planting crops were designed to produce a similar cropping frequency to that expected by farm managers who follow a low tillage farming system.

Varieties of crops planted and row spacings applied were also based on expected industry practice.

6.3 Cropping systems modelled

1. Cotton monoculture

1st September Start

	Summer	**Winter**
Phase 1	Cotton	Fallow

2. Sorghum monoculture

1st September Start

	Summer	**Winter**
Phase 1	Sorghum	Fallow

3. Wheat monoculture

1st April Start

	Winter	**Summer**
Phase 1	Wheat	Fallow

4. Opportunity Cropping Cotton, Sorghum and Wheat

1st September Start

	Summer	**Winter**
Phase 1	Cotton/Sorghum	Wheat

5. Opportunity Cropping Sorghum and Wheat

1st September Start

	Summer	**Winter**
Phase 1	Sorghum	Wheat

6. Opportunity Cropping Cotton and Sorghum

1st September Start

	Summer	**Winter**
Phase 1	Cotton/Sorghum	Fallow

7. Short fallow Cotton short fallow Sorghum

1st September Start

	Summer	**Winter**	**Summer**	**Winter**
Phase 1	Cotton	Fallow	Sorghum	Fallow
Phase 2	Sorghum	Fallow	Cotton	Fallow

This cropping system will not plant a sorghum crop if the cotton opportunity is missed but will wait until the next summer to plant the next crop in the rotation. This will occasionally lead to long fallows.

6.4 Plant Register

This is for a property that is going to grow cotton but uses contractors to harvest all crops.

Table 8 Dalby plant register

Item	Market Value	Years to Replacement	Replacement Cost	Subsequent Replacement Interval (yrs)	Salvage Value
JD 8970	$140,000	8	$195,000	14	$48,750
JD 4440	$25,000	5	$50,000	22	$7,500
Shearer 45ft	$25,000	16	$45,000	50	$4,500
Flexicoil 820 60ft	$60,000	14	$120,000	20	$12,000
JD1720 maximerge	$45,000	12	$70,000	20	$10,500
Orthman Scuffler	$12,000	20	$20,000	33	$4,000
18m Spray rig	$25,000	5	$25,000	5	$3,750
Shielded Sprayer 12row	$8,000	6	$20,000	10	$2,000
Chaser Bins	$10,000	12	$20,000	15	$5,000
Module Builder	$5,000	10	$15,000	15	$2,500
Boll Buggies	$15,000	10	$25,000	10	$2,500
Grain Augers	$15,000	14	$25,000	20	$1,500
Grain Truck	$25,000	12	$30,000	15	$30,000
Albulk grouper	$10,000	16	$15,000	20	$3,500
Slasher	$7,500	4	$10,000	10	$0
Fuel trailer	$1,750	15	$2,100	25	$0
Welder trailer	$5,000	10	$10,000	20	$1,000
Motor Bikes	$6,000	4	$12,000	10	$0
4WD Ute	$25,000	3	$40,000	5	$20,000
Farm Truck	$5,000	10	$65,000	30	$2,500
Workshop	$40,000		$80,000		$1,000
Total	**$510,250**		**$894,100**		

To arrive at the original market value of plant and equipment we asked the question “what is the typical good quality, possibly second hand set of plant and equipment we need on this property?” Makes and models are only identified to help with the costing process and do not contain any implied or other recommendation as to fitness for purpose or availability at particular values.

The replacement cost figure is an estimate of the current value of the machine to be purchased when a particular item is to be replaced. The replacement machine may be new or second hand.

All values are calculated in current dollars. Inflation is therefore not included in expected replacement cost or salvage value. “Years to replacement” is the number of years before existing plant and equipment is to be replaced. “Subsequent replacement interval” is the number of years an item of plant is to be held after it has been replaced the first time.

6.5 Machine Operating Costs

Table 9 Dalby machinery operating costs

Fuel price ($/Litre net of rebates):	$0.50
Interest Rate (%)	7.50%
Inflation Rate (%)	2.50%
Insurance Cost $ per $1000 insured	$7.00

	JD 8970		JD 4440
Tractor Number for matching with implement	1	2	7
	High rate fuel use	Med rate fuel use	Fuel use rate 1
MACHINERY INPUTS: -			
Fuel Consumption (l/h)	65	50	15
Replacement Price ($)	$195,000	$195,000	$50,000
Repairs over life (% New Value)	45%	45%	75%
Hours/Life	10,000	10,000	10,000
Trade In (% New Value)	25.00%	25%	15.00%
Hours/Year	700	700	460
COST ESTIMATES ($/hour)			
Fuel, Oil Cost	35.75	27.50	8.25
Repairs, Tyres Cost	8.78	8.78	3.75
Depreciation	14.63	14.63	4.25
Interest	8.71	8.71	3.13
Shelter	1.39	1.39	0.54
Insurance	1.95	1.95	0.76
Labour	0.00	0.00	0.00
COST ESTIMATE ($/hour)			
FORM per hour	44.53	36.28	12.00
Total Cost per hour	71.20	62.95	20.68

	Shearer 45ft	Flexicoil 820 60ft	JD1720 maximerge	Orthman Scuffler	18 m spray rig	Shielded Sprayer 12row
	Tractor No 1	Tractor No 1	Tractor No 2	Tractor No 2	Tractor No 7	Tractor No 2
MACHINERY INPUTS: -						
Replacement Price ($)	$45,000	$120,000	$70,000	$20,000	$25,000	$20,000
Repairs (% New Value)	20.00%	30.00%	30.00%	20.00%	25.00%	50.00%
Hours/Life	5,000	3,000	3,000	5,000	1,000	2,000
Trade In (% New Value)	10.00%	10.00%	15.00%	20.00%	15.00%	10.00%
Hours/Year	100	150	150	150	200	200
Labour Cost $/h						
Effective work rate (ha/h)	11.00	15.00	10.00	12.00	16.00	12.00
COST ESTIMATES ($/hour)						
Repairs, Tyres Cost	1.80	12.00	7.00	0.80	6.25	5.00
Depreciation	8.10	36.00	19.83	3.20	21.25	9.00
Interest	12.38	22.00	13.42	4.00	3.59	2.75
Shelter	2.25	4.00	2.33	0.67	0.63	0.50
FORM per hour	1.80	12.00	7.00	0.80	6.25	5.00
Total cost per hour	24.53	74.00	42.58	8.67	31.72	17.25
COST ESTIMATES ($/ha)						
Work rate (ha/hour)	11.00	15.00	10.00	12.00	16.00	12.00
Fuel and Oil Cost / ha	$3.25	$2.38	$2.75	$2.29	$0.52	$2.29
Repairs and Maintenance / ha	$0.96	$1.39	$1.58	$0.80	$0.63	$1.15
Total FORM / ha	$4.21	$3.77	$4.33	$3.09	$1.14	$3.44

Note: there are no labour costs included in F.O.R.M. estimates for implement and tractor operation.

6.6 Farm Overhead Costs

Farm Overhead Expenses	
Accountant	$2000
Administration	$500
Bank Charges	$500
Electricity	$5000
Fuel and Oil (not including farming)	$5000
Insurance	$5000
Motor Vehicle Expenses	$5000
Rates and Rents	$4500
Repairs (other than farm machinery)	$5000
Casual labour	
Telephone	$5000
Wages	$50000
Total Overhead Expenses	$87,500

6.7 Cotton -typical growing costs and crop management at Dalby

The typical fallow costs for cotton are three weed sprays incurred in the fallow prior to planting and one trifluralin treatment.

Cotton is planted in a double skip configuration on 40″ rows. Plant emergence target is 8.5 plants/m. Planting window is normally from 30th September to 10th November but can be extended to 30th November once planting begins.

Flurometuron plus Diuron is applied to cotton as a band at planting. Two shielded sprays of 1.2L Roundup CT/ha are used for weed control in-crop. Nitrogen is applied within APSIM to top available soil N at planting up to 100 kg N/ha. The cost of this fertiliser is calculated on the variable rate applied to each crop. Starter fertiliser is also applied at planting at a fixed rate of 50kg/ha.

Insecticide costs including spray costs and cotton consultant average around $350 /ha /season.

Harvest costs are based on the use of contract services (calculated on a per bale basis) and together with processing costs are multiplied by the bales harvested in any year to calculate total harvest costs on a per bale basis. Low yield crops that are not economic to harvest do not incur harvest costs.

It is expected that two tillage operations with a chisel plough and the use of a contract cotton eliminator will be needed after cotton to pupae bust and/or remove cotton plants

Fallow Costs						
	Litres, grams					**PER HA**
Hardi Explorer	1.00		x	$1.14	each	$1.14
Roundup CT	1.20		x	$5.64	each	$6.77
Surpass 300	1.00		x	$4.65	each	$4.65
Hardi Explorer	1.00		x	$1.14	each	$1.14
Roundup CT	1.20		x	$5.64	each	$6.77
Hardi Explorer	1.00		x	$1.14	each	$1.14
Roundup CT	1.20		x	$5.64	each	$6.77
Flexicoil 820 60ft	1.00		x	$3.77	each	$3.77
Trifluralin 480	2.80		x	$7.80	each	$21.84
					Total	**$53.98**
Planting Costs						
JD1720 maximerge	1.00			$4.33	each	$4.33
Cotton seed	10.00			$5.60	/ kg	$56.00
					Total	**$60.33**
Fertilizer Costs						
JD1720 maximerge	1.00		x	$4.33	each	$4.33
Starter Z	50.00	kg	x	$0.55	c/kg	$27.25
					Total	**$31.58**
Planting to Harvest Costs			Treatments			
Shielded Sprayer 12row	1.00	x	1.00	$3.44	each	$3.44
Cotogard	4.50	x	0.15	$12.00	each	$8.10
Diuron	3.00	x	0.15	$8.50	each	$3.83
Shielded Sprayer 12row	1.00	x	2.00	$3.44	each	$6.88
Roundup CT	1.20	x	2.00	$5.64	each	$13.54
Regent	0.06	x	0.50	$304.00	each	$9.12
Endosulfan EC	2.10	x	0.50	$11.00	each	$11.55
Hardi Explorer	1.00	x	2.00	$1.14	each	$2.28
Cotton Eliminator	1.00	x	1.00	$22.00	each	$22.00
Shearer 45ft	1.00	x	1.00	$4.21	each	$4.21
Costs incurred if crop planted and not harvested						**$84.94**
Hardi Explorer	1.00	x	4.00	$1.14	each	$4.56
Tracer	0.15	x	1.00	$91.75	each	$13.76
Steward	0.85	x	1.00	$80.00	each	$68.00

Amitraz EC	2.00	x	1.00	$14.27	each	$28.54
Dipel	1.50	x	1.00	$12.00	each	$18.00
Aerial spraying-cotton EC	1.00	x	2.00	$12.50	each	$25.00
Dropp	0.10	x	1.00	$147.00	each	$14.70
Ethephon (Prep equivalent)	2.00	x	1.00	$18.00	each	$36.00
Cotton Consultant	1.00	x	1.00	$55.00	each	$55.00
Cotton Crop Insurance	1.00	x	1.00	$53.00	each	$53.00
Cotton chipping	1.00	x	1.00	$20.00	each	$20.00
Costs incurred for "average" crop						**$421.51**
Shearer 45ft	1.00	x	1.00	$4.21	each	$4.21
Aerial spraying-cotton EC	1.00	x	1.00	$12.50	each	$12.50
Dominex Duo	3.00	x	1.00	$22.00	each	$66.00
Talstar EC	0.80	x	1.00	$61.00	each	$48.80
Cotton casual labour	1.00	x	1.00	$80.00	each	$80.00
Costs incurred for "above average" crop					**Total**	**$633**
	TOTAL PER HECTARE COSTS					**$779**
Per Bale Cotton Costs						
Cotton Harvesting Double skip	1.00	x	1.00	$41.67	per bale	$41.67
Module Builder	$9.00	$/bale				$9.00
Tarps	$2.00	$/bale	x			$2.00
Module Lift/ Transport	$11.00	$/bale				$11.00
Ginning Costs	$60.00	$/bale				$60.00
Research Levy	$4.25	$/bale				$4.25
	Total per bale costs					**$127.92**

6.8 Sorghum - typical growing costs and crop management

Fallow weed control costs prior to sorghum planting are expected to be similar to cotton except that pre-emergent Trifluralin is not used.

Sorghum is planted with a disc opener on 40″ rows into a core-planting window that runs from mid Sept to the end of October, although it can be planted until the end of January in dry years.

Urea is applied separately within APSIM to achieve a soil N level of 80kg /ha at planting. 50kg Starter fertiliser /ha is also applied at planting.

Plant emergence of 7 plants /m^2 is targeted with separate applications of Atrazine and Roundup CT at 1L/ha post-plant pre-emergent undertaken to control weeds in crop.

Virus spray at 375ml /ha is used to control heliothis every second year. Sorghum is sprayed out crop with 1.6 L/ha Roundup pre harvest.

Fallow Costs						
	Litres, grams					**PER HA**
Hardi Explorer	1.00		X	$1.14	each	$1.14
Roundup CT	1.20		X	$5.64	each	$6.77
Surpass 300	1.00		X	$4.65	each	$4.65
Hardi Explorer	1.00		X	$1.14	each	$1.14
Roundup CT	1.20		X	$5.64	each	$6.77
Surpass 300	0.80		X	$4.65	each	$3.72
Hardi Explorer	1.00		X	$1.14	each	$1.14
Roundup CT	1.20		X	$5.64	each	$6.77
					Total	**$32.10**
Planting Costs						
JD1720 maximerge	1.00			$4.33	each	$4.33
Sorghum seed	3.00			$5.80	/ kg	$17.40
					Total	**$21.73**
Fertilizer Costs						
JD1720 maximerge	1.00		X	$4.33	each	$4.33
Starter Z	50.00	kg	X	$0.55	c/kg	$27.25
					Total	**$31.58**
Planting to Harvest Costs			treatments			
Hardi Explorer	1.00	x	1	$1.14	each	$1.14
Gesaprim	3.60	x	1	$5.84	each	$21.02
Hardi Explorer	1.00	x	1	$1.14	each	$1.14
NPV Gemstar / Vivus	0.38	x	1	$61.50	each	$23.06
Hardi Explorer	1.00	x	1	$1.14	each	$1.14
Roundup CT	1.00	x	1	$5.64	each	$5.64
Hardi Explorer	1.00	x	1	$1.14	each	$1.14
Roundup CT	1.60	x	1	$5.64	each	$9.02
Crop not harvested						**$63.31**
Average cost crop						**$63.31**
Full cost crop					**Total**	**$63**
	TOTAL PRE-HARVEST COSTS					**$149**
Harvesting:						
	5.50	ha/hr		$250	/hour	$45.45
plus fuel	40.00	litres/hr	X	$0.50	/Litre	$3.64
	TOTAL HARVEST COSTS					**$49.09**

6.9 Wheat – typical growing costs and crop management

Wheat fallow costs are based on a zero till farming.

Urea is applied to wheat at planting to top up soil N to 100kg N/ha. This cost is calculated separately and added to the farm cash flow as it can vary with each wheat crop planted. 50kg/ha Starter fertiliser is applied to each crop planted.

Wheat is planted at a rate of 40 kg/ha in 9″ rows with an airseeder to target 75 plants per m^2. The planting window is early May to mid July. Ally is applied at 5g/ha for weed control.

Wheat

Fallow Costs

		Litres, grams					**PER HA**
	Hardi Explorer	1.00		x	$1.14	each	$1.14
	Roundup CT	1.00		x	$5.64	each	$5.64
	Surpass 300	1.60		x	$4.65	each	$7.44
	Hardi Explorer	1.00		x	$1.14	each	$1.14
	Roundup CT	1.20		x	$5.64	each	$6.77
	Surpass 300	1.00		x	$4.65	each	$4.65
	Hardi Explorer	1.00		x	$1.14	each	$1.14
	Roundup CT	0.80		x	$5.64	each	$4.51
						Total	**$32.43**
Planting Costs							
	JD1720 maximerge	1.00			$4.33	each	$4.33
	Wheat	40.00			$0.64	/ kg	$25.60
						Total	**$29.93**
Fertilizer Costs							
	JD1720 maximerge	1.00		x	$4.33	each	$4.33
	Starter Z	50.00	kg	x	$0.55	c/kg	$27.25
						Total	**$31.58**
Planting to Harvest Costs				treatments			
	Hardi Explorer	1.00	x	1	$1.14	each	$1.14
	Ally	5.00	x	1	$0.33	each	$1.65
						Total	**$2.79**
		TOTAL PRE-HARVEST COSTS					**$96.73**
Harvesting:							
	Contract header	5.50	ha/hr		$250	/hour	$45.45
	plus fuel	33.37	hr/hr	x	$0.60	/Litre	$3.64
		TOTAL HARVEST COSTS					**$49.09**
TOTAL VARIABLE COSTS ($/ha)							**$146**

6.10 Cost File

Name	kg bag/drum		$ per kg or per litre	
Aerial spraying - broadacre			$12.50	per ha
Aerial spraying-cotton EC			$12.50	per ha
Aerial spraying-cotton ULV			$9.50	per ha
Broadacre Harvesting			$250.00	per hr
Chickpea scouting			$10.00	per ha
Cotton casual labour			$80.00	per ha
Cotton chipping			$20.00	per ha
Cotton Consultant	per ha		$55.00	per ha
Cotton Crop Insurance			$53.00	per ha
Cotton Harvesting Double skip	$170 per hour at 1.36 ha per hour		$125.00	per ha
Heavy Offsets - contract			$0.00	per ha
Light Chisel Plough - contract			$0.00	per ha
Light Offsets - contract			$0.00	per ha
Peanut Scouting			$45.00	per ha
Cotton Eliminator			$22.00	per ha
Cotton Harvest Solid NSW			$280.00	
Dropp	thidiazuron + diuron	120 g/L + 60 g/L	$147.00	$/kg
Salt Defoliant			$1.55	
Big N	82N		$0.6060	c/kg
CK 700	32.3N;5.1P;18.9S		$0.4110	c/kg
CK1	14.6P;14.5K;1S;10.6Ca		$0.4510	c/kg
CK600 (s)	17.9N;5.1P;18.9S		$0.4210	c/kg
DAP	18N;20P		$0.5000	c/kg
Granam	20.2N;24S		$0.3950	c/kg
Granulock ST-Z	10.5N;19.5P;2.2S		$0.5450	c/kg
Gypsum	14.5S;18.5Ca		$0.0620	c/kg
Lime	Ca		$0.0680	c/kg
MAP			$0.5800	c/kg
Muriate of Potash	50K		$0.4700	c/kg
Nitram	34N		$0.5710	c/kg
Nitram & Sulphur			$0.1303	c/kg
Phosul			$0.5700	c/kg
Potassium Nitrate	13N;38.3K		$1.0100	c/kg
Solubor	20.5B		$4.2800	c/kg
Starter Z			$0.5450	c/kg
Starterphos	10N;21.9P;1.5S		$0.4450	c/kg
Sulphate of Potash	41K;18S		$0.7180	c/kg
Supazinc	7.5Zn		$6.0000	/ litre
Superphosphate	8.8P;11S;20Ca		$0.3110	c/kg
Tech Feed			$0.5800	c/kg
Urea	46N		$0.4000	c/kg
Zinc Sulphate Heptahydrate			$0.9200	c/kg
Zinc Sulphate monohydrate	35Zn;17.2S		$1.7200	c/kg
Alto 100SL	cyproconazole	100 g/L	$106.00	$/litre
Dithane	mancozeb	750 g/kg	$7.42	$/kg
Elect 750 (chlorothalonil)	chlorothalonil	750 g/L	$19.70	$/l
Folicur 430 SC	tebuconazole	430 g/L	$113.40	$/l
Fortress 500	procymidone	500 g/L	$67.00	$/litre
Rover			$14.75	
Rovral Aquaflo	iprodione	250 g/L	$64.00	$/l
Wettable Sulphur			$2.36	$/kg
Ethephon (Prep equivalent)	ethephon	480 g/L	$18.00	
Reward (pix equivalent)	Mepiquat	38 g/l	$27.26	
Achieve			$86.94	
Ally	metsulfuron	600 g/kg	$0.33	
Amicide 500	2,4-D	500 g/L	$5.00	
Avadex Xtra	tri-allate	500 g/L	$14.29	
Basagran	bentazone	480 g/L	$30.00	
Blazer 2L	acifluorfen	224 g/L	$36.50	

Broadstrike	flumetsulam	800 g/kg	$0.61	
Bromicide MA	bromicide + MCPA	200 g/L + 200 g/L	$13.95	
Buticide	2,4-DB	500 g/L	$11.69	
Cotogard	flurometuron + prometryn	250 g/L + 250 g/L	$12.00	
Cotoran	flurometuron	500 g/L	$12.30	
Diuron	diuron	500 g/L	$8.50	per gram
Dual Gold	metolachlor	960 g/L	$33.34	
Eclipse	metosulam	714 g/kg	$1.19	
Eptam	EPTC		$23.90	
Flame	imazipac	240 g/L	$137.50	
Fusilade	fluazifop-p	212 g/L	$71.80	
Garlon 600	triclopyr	600 g/L	$67.00	
Gesagard 500SC	prometryn	500 g/L	$22.40	
Gesaprim	atrazine	500 g/L	$5.84	
Glean	chlorsulfuron	750 g/kg	$0.18	
Glyphosate 450 CT	glyphosate IPA salt	450 g/L	$4.75	
Gramoxone 250	paraquat	250 g/L	$10.00	
Harmony M	thifensulfuron-methyl + metsulfuron-methyl	682 g/kg + 68 g/kg	$0.36	
Jaguar	bromoxynil + diflufenican	250 g/L + 25 g/L	$31.20	
Kamba 200	dicamba		$19.00	
Kamba M	MCPA + dicamba	340 g/L + 80 g/L	$10.29	
MCPA LVE	MCPA ester	500 g/L	$8.29	
Primextra Gold	metolachlor + atrazine	290 g/L + 370 g/L	$14.04	
Promo-mix	fluometuron + prometryn	250 g/L + 250 g/L	$11.75	
Reglone	diquat	200 g/L	$17.50	
Roundup CT	glyphosate IPA salt	450 g/L	$5.64	
Roundup MAX	glyphosate MEA salt	510 g/L	$7.44	
Select	clethodim	240 g/L	$84.50	
Simazine 900DF	simazine	900 g/kg	$9.93	
Simazine Flowable	simazine	500 g/L	$5.65	
Spinnaker 700 WDG	imazethapyr	700 g/kg	$320.00	
Sprayseed	paraquat + diquat	135 g/L + 115 g/L	$9.95	
Starane	fluroxypyr	200 g/L	$21.29	
Stomp 330EC	pendimethalin	330 g/L	$8.35	
Striker	diuron	500 g/L	$43.60	
Surpass 300	2,4-D IPA salt		$4.65	
Tigrex	MCPA + diflufenican	250 g/L + 25 g/L	$21.95	
Topik	clodinafop + cloquintocet	240 g/L + 60 g/L	$360.00	
Tordon 242	MCPA + picloram	420 g/L + 26 g/L	$15.29	
Tordon 75D	2,4-D + picloram	300 g/L + 75 g/L	$35.54	
Trifluralin 480	trifluralin	480 g/L	$7.80	
Verdict 520	haloxyfop	520 g/L	$235.00	
Wildcat			$78.60	
S-metolachlor			$32.14	

Absorba-cide	amorphous silica	900 g/kg	$10.60
Actellic 900 SF	pirimiphos-methyl	900 g/L	$76.00
Amino-feed			$3.60
Amitraz EC	amitraz	200g/L	$14.27
Cosmos	fipronil	200 g/L	$635.00
Curacron Pro	profenofos	500 g/L	$27.00
Decis Options	deltamethrin	27.5 g/L	$22.00
Dimethoate	dimethoate	400 g/L	$7.95
Dipel	Bt		$12.00
Dipel	Strain HD-1		$66.00
Dominex 100 EC	alpha cypermethrin	100 g/L	$19.50
Dominex Duo	alpha cypermethrin	100 g/L	$22.00
Elect 760			$24.00
Emamectin			$102.92
Endosulfan EC	endosulfan	375 g/L	$11.00
Ethion + Zeta-cypermethrin			$18.41
Fastac Duo	alpha cypermethrin	100 g/L	$6.00
Fenitrothion 1000	fenitrothion	1000 g/L	$28.00

Lannate L	methomyl	225 g/L	$12.45
Larvin 375	thiodicarb	375 g/L	$26.50
Larvin LV			$17.97
Lorsban 500 EC	chlorpyrifos	500 g/L	$12.25
Lorsban 750WG	chlorpyrifos	750 g/kg	$65.00
NPV Gemstar/Vivus	NPV		$61.50
PBO	piperonyl butoxide	800 g/L	$31.00
Phostoxin tablets	aluminium phosphide	560 g/kg	$0.14
Predator 300	chlorpyrifos	300 g/L	$94.00
Regent	fipronil	200 g/L	$304.00
Sabre EC	profenofos	250 g/L	$14.00
Semevin	thiodicarb	500 g/L	$67.00
Steward	indoxacarb	200 g/L	$80.00
Talstar EC	bifenthrin	100 g/L	$61.00
Thidiazuron			
Tracer	spinosad	480g/L	$91.75
Barley			$0.50
Chickpea			$1.50
Cotton			$5.60
Forage Sorghum			$4.40
Lucerne			$7.80
Maize			$6.80
Millet			$0.80
Mungbean			$1.45
Navy Bean			$1.40
Peanuts			$2.30
P-Pickle T			$0.04
Sorghum			$5.80
Soybeans			$1.10
Sunflowers			$11.00
Wheat			$0.64
Agridex	paraffinic petroleum oil	730 g/L	$5.60
BS1000	alcohol alkoxylate	1000 g/L	$6.44
Hasten crop oil	fatty acid esters	704 g/L	$5.29
LI-700	propionic acid	350 g/L	$9.90
Liase	ammonuim sulfate	417 g/L	$1.64
Non ionic surfactant			$7.06
Ulvapron	paraffinic petroleum oil	855 g/L	$1.54
Uptake Oil	paraffinic petroleum oil	582 g/L	$6.14
Innoculant			$4.50
Mouse Bait			$12.60

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APPENDIX 4

GRDC Project DAQ469/CRDC Project DAQ104C

Using Seasonal Forecasts for More Effective Grain-Cotton Production Systems

Climate variability, climate forecasts and grain-cotton production systems at Emerald

November 2005

Table of contents

1. Summary of results

The climate of Emerald is non-stationary with recent trends in rainfall, temperature and ENSO indicating that either low-frequency climate variability or anthropologically induced climate change (or both) may currently be having an impact.

Most dryland farming activities were largely established and rapidly expanded during the wettest thirty-year period since 1766.

In terms of the aspects of cropping systems management that we considered, the results of this work are:

- There have been three favourable climate periods for investing in dryland cotton at Emerald since 1890 (i.e. the ones providing the best return on investment when all non climate factors are held constant). Unfortunately there appear to be 30 to 40 year gaps between their occurrence and they normally last less than a decade.
- At all other times dryland cotton at Emerald on a 150mm PAWC soil is a relatively risky cropping system to invest in.
- Short-term forecasts based on the SOI phase being positive in September or the cotton planting year being classified as a La Nina seem to identify years that cotton may be relatively less risky to produce. In these years cotton still remains relatively less reliable than sorghum but shows an increased chance of improving on sorghum gross margins. A SOI positive phase in September together with a sound cotton price should encourage an increased dryland cotton planting at the expense of other cereal crops.
- None of the other potential or existing forecasting systems tested here seem to have the capacity to change the perception by many dryland farmers at Emerald that cropping systems including dryland cotton are relatively more risky than alternate cropping systems.

2. Introduction

The central highlands farming district of Central Queensland is located towards the northern margin of successful broadacre dryland farming activities in Queensland, encounters a very variable climate and was largely developed for dryland farming activities in the second half to last quarter of the 20th Century. The central highlands district accounts for about 10% to 15 % of the dryland farming area of the Queensland.

Variations in the prevailing climate have a dramatic impact on the success of dryland farming activities on the Central Highlands. Howden *et al.* (2001) also found that any impact of possible climate change is likely to manifest itself first in such marginal environments.

The purpose of this report is to firstly identify known sources of climate variability that may impact on central highlands farming systems and then to estimate the potential benefits of responding to forecasts for the various sources of climate variability.

The climate records of the Emerald Post office and airport (Emerald composite records 1890 to 2003, Rainman version 4.3) will be used in the analysis of climate variability.

3. Climate variability

3.1 Potential sources of climate variability at Emerald

Rainfall variability in Australia (and central Queensland) is only partially explained by the El Nino – Southern Oscillation phenomenon (ENSO). Some of the other climate phenomena that combine with an inherently unpredictable chaotic component of climate to produce "climate variability" are identified in Table 1.

Table 1 Known climate phenomena and their return intervals (frequency) that contribute to rainfall variability in Australia (From Meinke and Stone 2004)

Name and/or Type of Climate Phenomena	*Reference (eg. only)*	*Frequency (approx. in years)*
Madden-Julian Oscillation, Intra-seasonal (MJO or ISO)	Madden and Julian (1972)	0.1 – 0.2
SOI phases based on El Niño – Southern Oscillation (ENSO), Seasonal to inter-annual	Stone *et al.* (1996)	0.5 – 7
Quasi- biennial Oscillation (QBO)	Lindesay (1998)	1 – 2
Antarctic Circumpolar Wave (AWC), inter-annual	White (2000b)	3 – 5
Latitude of Sub-tropical ridge, Inter-annual to decadal	Pittock (1975)	10 – 11
Interdecadal Pacific Oscillation (IPO)	Zhang *et al.* (1997) Power *et al.* (1999)	13+
or Decadal Pacific Oscillation (DPO)	Tourre and Kushnir (1999) Mantua *et al.* (1997) Allan (2000)	13 – 18
Multi-decadal Rainfall Variability	Allan (2000)	18 – 39
Interhemispheric Thermal Contrast (secular climate signal)	Folland *et al.* (1998)	50 – 80
Climate change	Timmerman *et al.* (1999) Kumar *et al.* (1999)	???

3.2 Climate phenomena to be tested at Emerald

3.2.1 SOI phase forecast system

Variation in seasonal rainfall over much of northern and eastern Australia has been related to the El Nino and Southern Oscillation (ENSO) phenomena (McBribe and Nicholls (1983)). The monthly Southern Oscillation (SOI) is a key indicator of ENSO and can correlate significantly with rainfall in subsequent months.

The SOI phase forecast system is a probabilistic rainfall forecast system based on defined phases of the Southern Oscillation. (Stone & Auliciems (1992), Stone *et al.* (1996))

3.2.2 ENSO classification

An ENSO classification provided by Potgieter (Potgieter *et al.* 2003) has been used to test relationships between the ENSO phenomena and cropping system results at Emerald.

El Nino and La Nina events in the period 1901-2002 were derived by Potgieter *et al.* (2003) using a classification system based on the combination of Extended Reconstructed Sea Surface Temperatures ERSST 18 and Troup SOI10 data sets. (See Appendix 1 for the classification of individual years)

Using the SST time series, a year was classified as El Nino if the 5-month running mean was greater than or equal to 0.5 for 6 or more months between April and December 19. Using the SOI time series, a year was classified as El Nino if the 3-month running mean was less than or equal to -5.5 for 6 or more months between April and December 20. The La Nina classification was the opposite in sign of both the El Nino classifications for SST's and SOI's.

The threshold value for the classification of El Nino years based solely on SST or SOI yielded near 25% occurrence for each. Combining both classification systems resulted in 24 El Nino years and 22 La Nina years in the 102 years used in this analysis. See Smith *et al.* (2003), Trenberth KE (1997) and Ropelewski (1987) for the derivation of the base climate indices.

3.2.3 9y 13y DCV Index

Meinke *et al.* (2003) described correlations between global, low frequency sea surface temperature (SST) anomalies and seasonal rainfall in the tropics and subtropics, the North Atlantic region, India, northern Africa and Australia.

For their study they used factor scores from time series based on Empirical Orthogonal Function (EOF) analyses of (a) near-global SST and Mean Sea Level Pressure (MSLP) data (4 time series band pass filtered for significant frequencies) and (b) Pacific SST data alone (1 series).

The four frequencies for the combined SST and MSLP analysis were (i) 2.5 to 8.0 years representing the ENSO timescale; (ii) 9 to 13 years or decadal timescale; (iii) 13 to 18 years or inter-decadal timescale and (iv) 18 to 39 years or multi-decadal timescales (Allan 2000).

Meinke *et al.* (2003) report in addition to the traditional ENSO signal only "phenomena operating on decadal (9 to 13 years) and interdecadal (13 to 18 years) time scales produce significant modulations of annual terrestrial rainfall. The greatest and most coherent low frequency effect is evident at the decadal (9 to 13 years) timescale".

The frequency of the 9 to 13 years or decadal timescale index is graphed in Figure 1. The index will be referred to as the 9y 13y DCV index in this report.

Meinke *et al.* (2003) found that the decadal frequency domain (9y 13y DCV index) had most affect in central eastern Australia during the January to March period. When index values are negative, rainfall in this period may be enhanced. When index values are positive, rainfall values in this period could be suppressed.

Other research has shown that indices of decadal climate variability corresponded with variations in soil water drainage. (Keating *et al.* 2003)

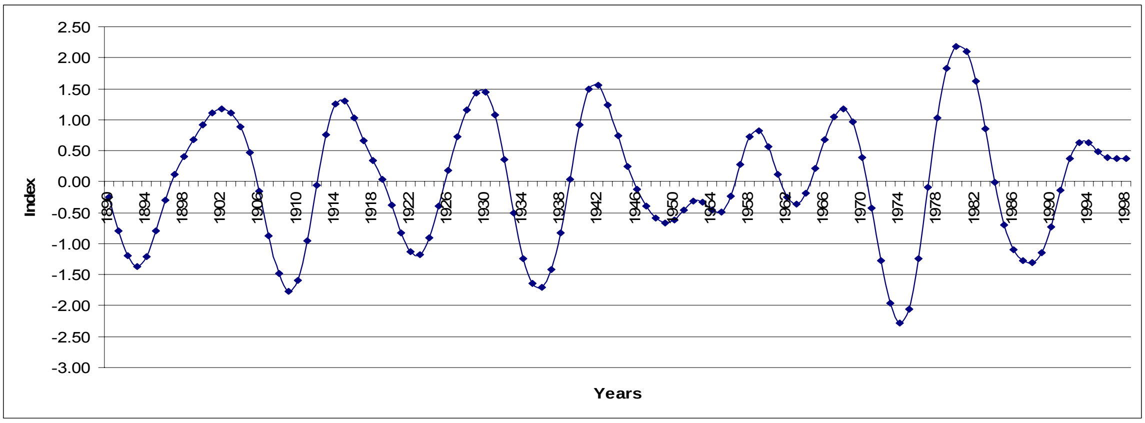


Figure 1 Graph of Decadal Climate Variability 9y 13y index values

Climate scientists have also proposed that climate phenomena occurring at decadal to multi-decadal timescales can modify ENSO leading to the enhancement of ENSO impacts. (Kleeman and Power (2000), Meehl *et al.* (2001)) Enhancement in this case means that dry periods are expected to be dryer and wet periods are expected to be wetter when the correct alignments of the longer-term climate phenomena and ENSO occur.

3.2.4 Interdecadal Pacific Oscillation

Power *et al.* (1999) found that many of the Pacific Low Frequency SST based indices are similar and can be combined into what is collectively known as the Inter-decadal Pacific Oscillation (IPO).

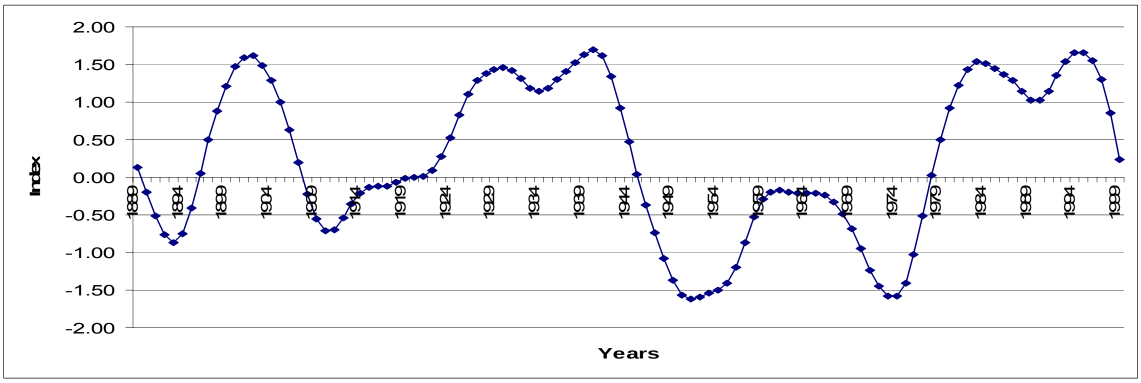


Figure 2 Inter-decadal Pacific Oscillation phase values

Meinke *et al.* (2003) found that there was no statistical relationship between annual rainfall and the phase value of the IPO. They found a significant relationship between the phase value of the IPO index and January to March quarter rainfall. Similar to the 9y 13y DCV index, when IPO values are negative rainfall in this period may be enhanced and when IPO values are positive rainfall values in this period could be suppressed.

3.3 Climate variability at Emerald

3.3.1 Monthly rainfall recorded at Emerald airport composite

Table 2 Monthly rainfall recorded at Emerald airport composite (Australian Rainman version 4.3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	100	97	68	36	34	33	27	22	24	40	59	88	629
Median	87	74	51	21	24	18	15	11	10	31	49	79	604
Standard deviation	85	83	68	41	42	43	35	27	32	39	46	67	211
Highest on record	556	471	340	191	258	299	200	131	135	213	246	317	1,406
Lowest on record	0	0	0	0	0	0	0	0	0	0	0	2	205
Mean rain days	8	7	6	4	4	3	3	3	3	4	6	7	58
No. of years	121	121	121	121	121	120	120	120	120	120	120	120	120

Rainfall at Emerald is highly variable with 60% expected to fall in the months from December to March. High evaporation and in some situations, low infiltration rates of rainfall can lead to low fallow efficiencies for cropping systems.

Median monthly rainfall at Emerald is more variable than Dalby and Breeza. Reliability during the autumn and winter months is also lower than Dalby and Breeza. Median monthly rainfalls for Emerald, Dalby and Breeza are shown in figure 3.

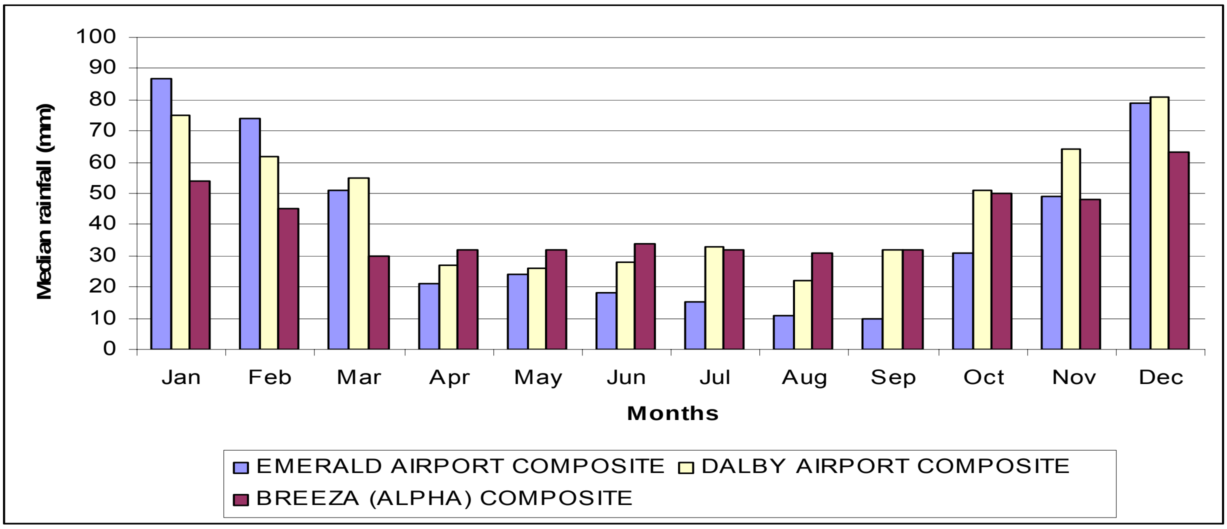


Figure 3 Median monthly rainfalls for Emerald, Breeza and Warra. (Australian Rainman version 4.3)

3.3.2 Droughts calculated on Emerald airport composite rainfall

Rainman (Clewett et al (2003)) defines drought (or severe rainfall deficits) as a 12-month period that receives less rain than in the driest 10% of calendar years. A severe drought is classified on the basis of the driest 5% of years for each 12-month period. A moderate drought is classified as the second driest 5% of years. A drought ends when rainfall records fall into the wettest 10% of years. Droughts may start in any month. Total number of droughts in the 120 years from 1883 to May 2003 equals 23 (Table 3).

Table 3 Drought periods for Emerald (Australian Rainman version 4.3)

Drought	Period	Duration (months)	Total rainfall (mm)	% of time in severe drought
1	Jan 1883 to May 1886	41	1,233	23
2	Jan 1888 to Apr 1889	16	611	40
3	Jul 1891 to Aug 1892	14	393	0
4	Apr 1901 to Nov 1902	20	369	78
5	Mar 1911 to May 1912	15	377	75
6	Jul 1914 to Feb 1916	20	573	33
7	Feb 1918 to Aug 1920	31	879	80
8	Mar 1922 to Feb 1923	12	349	0
9	Jul 1925 to Feb 1927	20	636	67
10	Jun 1930 to Jun 1933	37	1,075	19
11	Feb 1939 to Jan 1940	12	357	0
12	Feb 1946 to Jan 1947	12	320	0
13	Oct 1947 to Jan 1949	16	529	60
14	Feb 1951 to Feb 1952	13	312	100
15	Sep 1963 to Aug 1964	12	353	0
16	Nov 1964 to Jul 1966	21	776	0
17	Aug 1968 to Sep 1969	14	389	0
18	Jan 1982 to Dec 1982	12	344	0
19	Mar 1992 to Aug 1993	18	425	71
20	Apr 1994 to Sep 1995	18	403	0
21	Apr 1997 to Mar 1998	12	335	0
22	Jan 1999 to Jan 2000	13	476	0
23	Sep 2000 to May 2003	33	947	59

3.3.3 Rainfall variability

Monthly rainfall data for Emerald from January 1883 to the end of December 2003 were used in this analysis.

Annual rainfall can vary between ⅓ of the median annual rainfall up to 2⅓ times the median annual rainfall value of 604mm. (Figure 4)

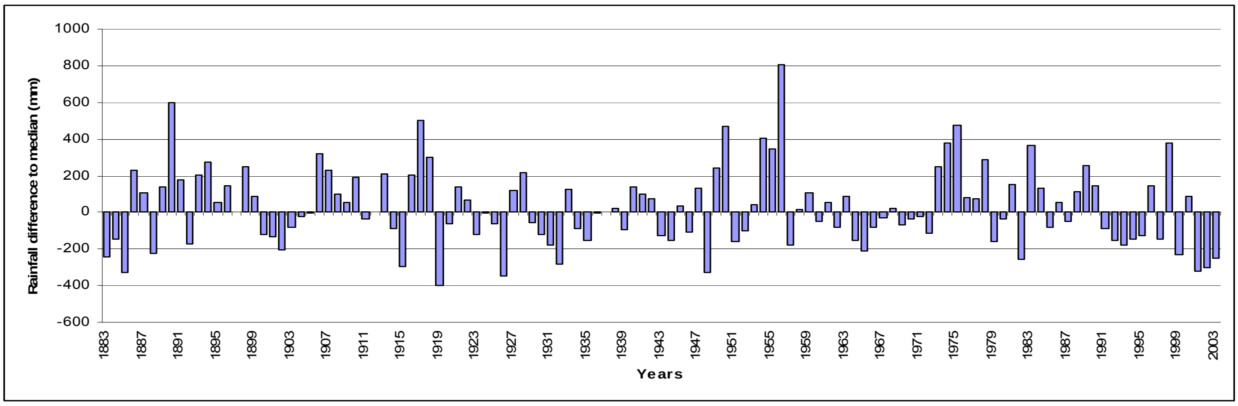


Figure 4 annual differences to median annual rainfall at Emerald

3.3.4 ENSO frequency

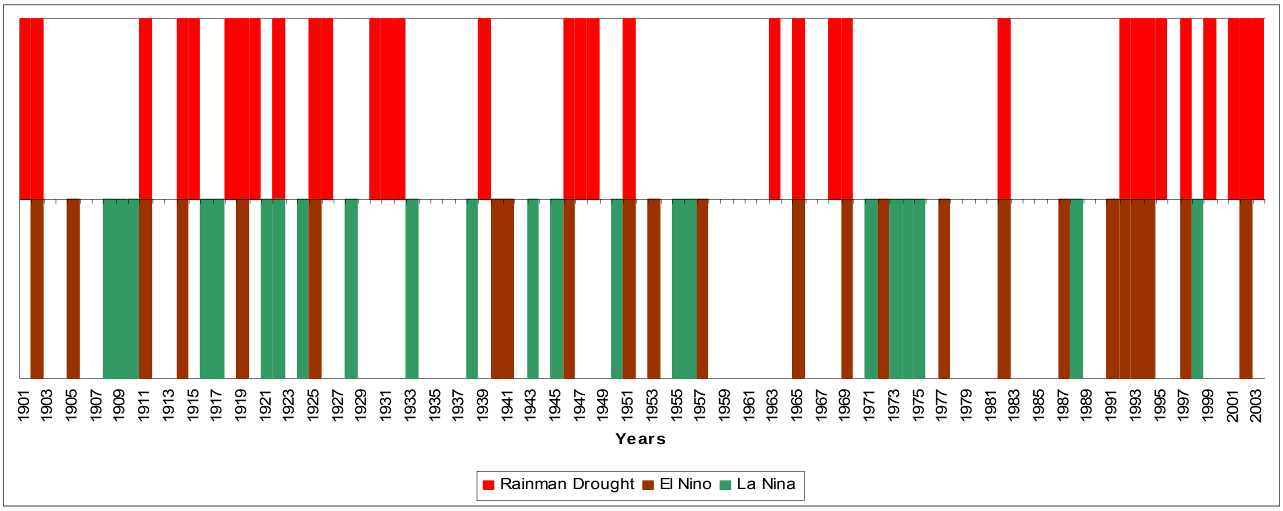


Figure 5 Frequency of El Nino and La Nina events since 1902 (Potgieter *et al*. 2003) plus drought (Rainman 3.4)

The classification system provided by Potgieter (2003) indicates that there have been 22 La Nina events from 1902 to the end of 2003 at an average frequency of one every 4.5 years (Figure 5). For the 27-year period since 1976 there have only been two. The frequency of La Nina events from 1902 to 1975 was one every three to four years.

The years classified as drought years by Rainman version 4.3 (Clewett *et al.* 2003) and the years classified as El Nino by Potgieter *et al.* (2003) do not always coincide (Figure 5). Approximately sixteen out of thirty-three years classified as drought do not coincide with years classified as El Nino. One year classified as a La Nina coincides with a drought year.

3.3.5 Climate trends at Emerald

Rainfall trends

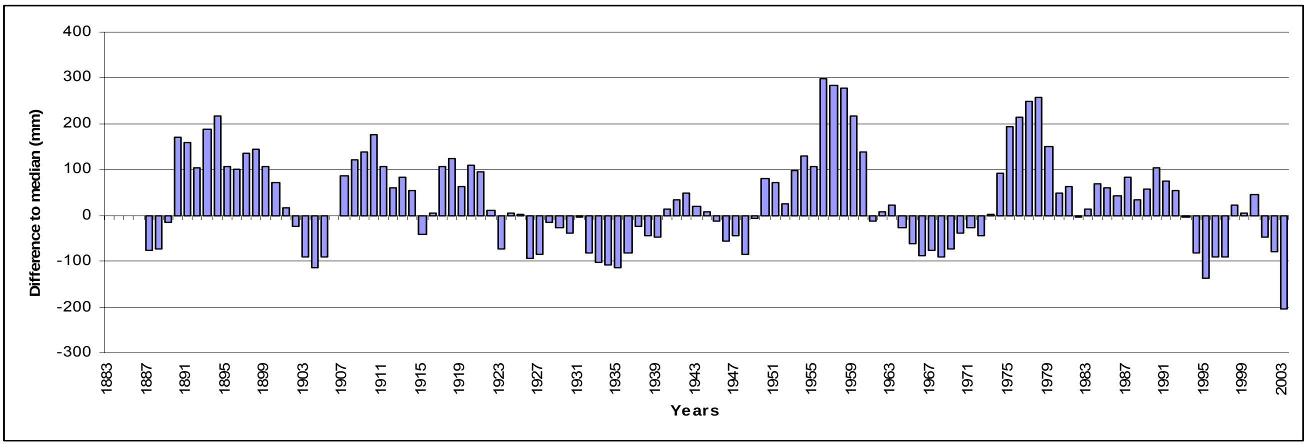


Figure 6 Annual rainfall differences to median at Emerald – 5-year trends

The difference between median annual rainfall at Emerald and the average rainfall for the previous five years shows a series of above average and below average trends (Figure 6). For example, the annual rainfall for the five years to the end of December 2003 was, on average, 200 mm per annum less than the median annual rainfall for the 120-year rainfall record. This five-year deficit is almost double any previous five-year deficit.

Emerald rainfall data shows high annual and decadal variability. The difference between the median annual rainfall at Emerald and the average rainfall for the previous ten years (Figure 7) shows similar trends to the five-year difference (Figure 6). Both Figure 6 and Figure 7 indicate that Emerald suffered an extended period (of about 30 years) of generally below average rainfall from the early 1920's to the late 1940's.

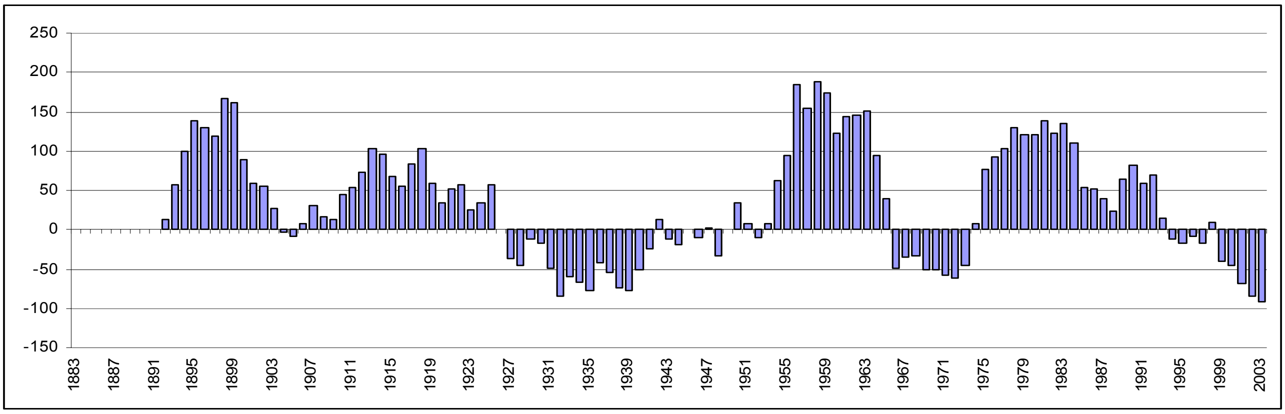


Figure 7 Annual rainfall differences to median at Emerald – 10-year trends

Temperature trends

Meinke *et al.* (2003) showed that there has been a sustained increase in continent-wide temperatures since 1950 with the rises greatest over the northeastern interior of Australia.

Howden *et al.* (2003) analysed temperature trends at Emerald. The analysis indicated that mean annual maximum temperatures have increased by 0.4 degrees from 29.3^{o}C in 1900 to 29.7^{o}C in 2000. Over the same period, mean annual minimum temperatures have increased by 2.1 degrees from 14.0^{o}C to 16.1^{o}C (Figure 8).

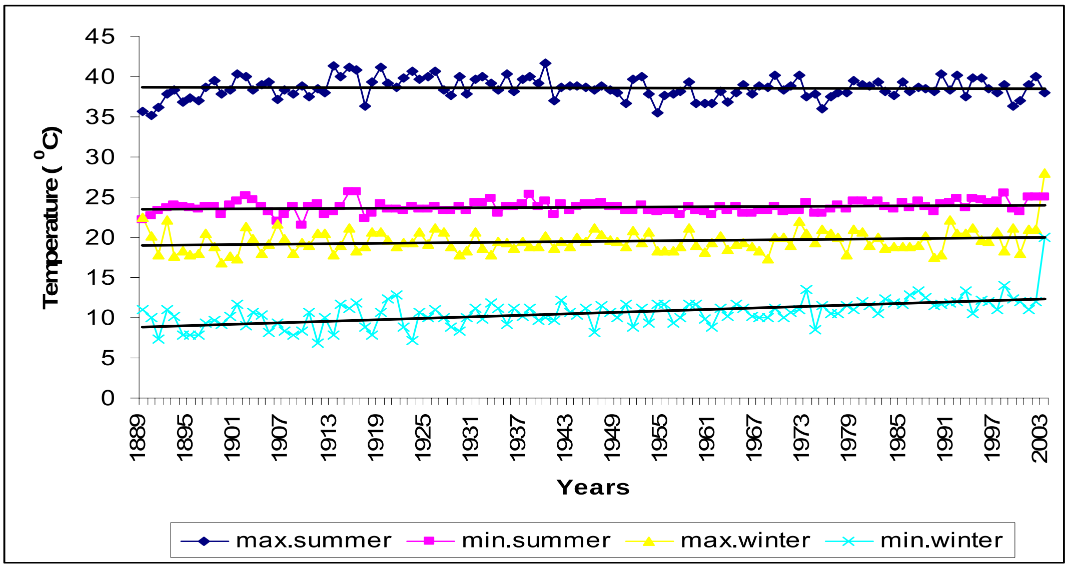


Figure 8 Mean annual maximum (□) and minimum (x) temperatures and annual extreme maximum (Δ) and minimum (□) temperatures recorded at Emerald between 1894 and 2002.

The frost risk period for Emerald has been reduced from approximately 80 days at the end of the 19th century to about 20 days today (Figure 9).

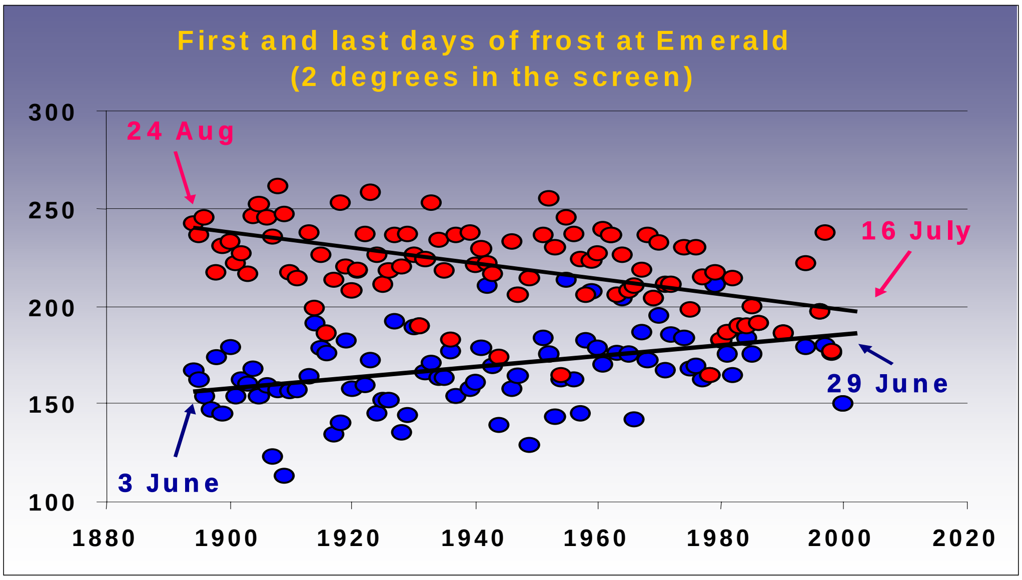


Figure 9 Incidence of frost and last days of frost at Emerald. (Source: Howden *et al.* (2003)

Howden *et al.* (2003) showed that the warming trend observed for Emerald during the last century was nearly entirely due to increases in winter and spring minimum temperatures.

Their work provides firm evidence that in addition to the observed, year-to-year climate variability, there are also trends in climate factors (e.g. increases in minimum temperatures, changes in the degree of rainfall variability etc.) that result in a non-stationary climate (Suppiah and Hennessy, 1998; Collins *et al.*, 2000). These trends are the combined results of low-frequency climate variability as well as anthropologically induced climate change (Meinke *et al.*, 2003).

ENSO trends

The frequency of El Nino and La Nina per thirty-year period has varied markedly since 1902. (Figure 10) Over this time period the El Nino phenomena has become much more frequent and the La Nina phenomena has become much more infrequent.

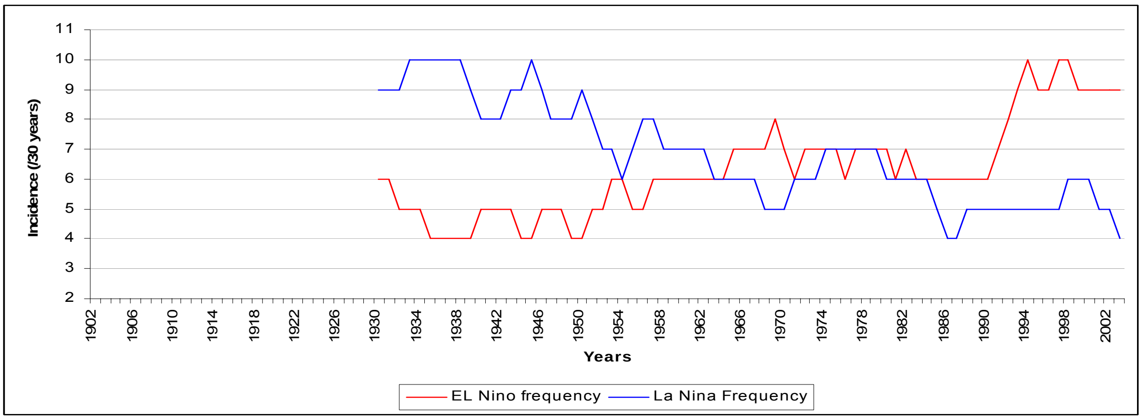


Figure 10 30 year frequency of El Nino and La Nina based on classification of Potgieter *et al.* (2003)

The frequency of El Nino and La Nina events can also change rapidly within any particular decade. (Figures 10 and 11)

Long term proxy climate records

A number of research teams have been working on building proxy climate records from documentary evidence, tree rings, ice cores and coral cores. Coral records from Palmyra in the central pacific and the Great Barrier Reef provide some insight into the variability and impact of ENSO and other climate phenomena at Emerald over the past 500 to 1000 years.

Cobb (2002) shows how coral has accurately recorded the intensity of ENSO and the frequency of La Nina and El Nino events over the past 1000 years (Figure 11).

Cobb (2002) classified El Nino and La Nina events on the basis of the NIÑO3.4 SST index. The NIÑO3.4 index represents an average of SST's from 5°N to 5°S, and from 120°W to 170°W, and its variability explains a large fraction of global inter-annual climate variability (Trenberth and Hoar, 1996). The frequency of ENSO events classified using the NIÑO3.4 SST index is lower than the frequency of events gained by using the classification of Potgieter *et al.* (2003).

Cobb (2002) found climate variability in the coral records at the ENSO (2-7 yr), decadal, multi-decadal and century scale. Cobb (2002 page 140) also found "the Palmyra corals suggest that the tropical Pacific climate system has moved through a variety of "regimes" in the last ten centuries, sometimes transitioning from one "regime" to another in less than five years. Examples of such regimes include, but are likely not limited to, the following: ENSO-dominated regimes analogous to the modern-day situation, decadal-dominated regimes wherein decadal-scale variability contributes more variance than ENSO, and seasonal-dominated regimes wherein ENSO and decadal variability are essentially "turned off".

Cobb (2002) also states at page 141 that "the steep trend towards warmer, wetter mean climate conditions in the tropical Pacific that began in 1976 cannot easily be explained by natural variability". Such conditions in the central pacific generally lead to El Nino like conditions in the central Highlands.

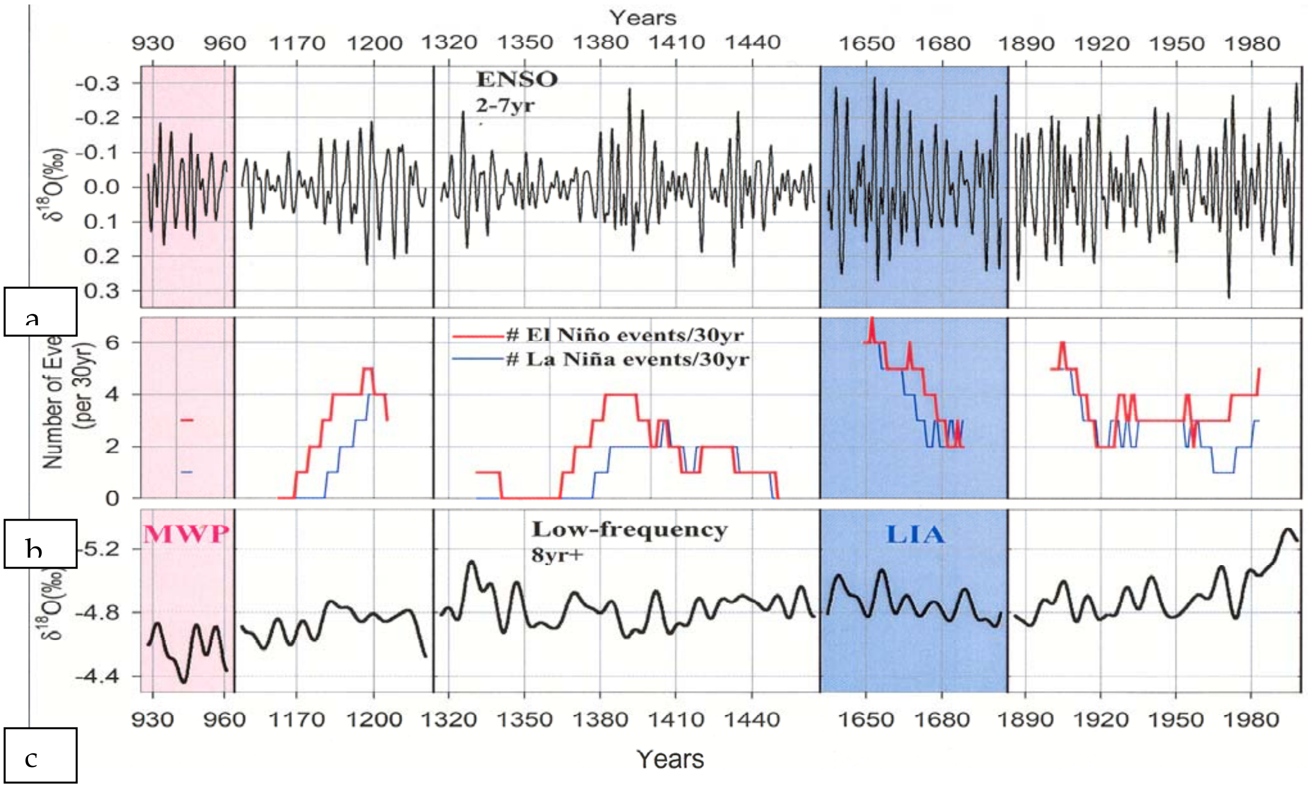


Figure 11 a) 2-7 year bandpass filtered versions of the Palmyra coral δ 18 O records, b) the number of El Niño (red) and La Niña (blue) events in a 30-year sliding window. El Niño (La Niña) events are defined by annual mean δ 18 O anomalies (computed from the 2-7 year bandpass filter series) that exceed - 0.11‰ (+0.11‰), c) 8-yr lowpass filtered versions of the Palmyra coral δ 18 O records. (Cobb 2002)

Cobb (2002) found that "changes in the background tropical climate state, whether by decadal- or century-scale variability, seem to have little effect on ENSO amplitudes or frequencies". Cobb (2002) supports the argument that "the mechanisms responsible for low-frequency tropical climate variability are independent of those that govern the expression of ENSO.

In commenting on the source of ENSO variability Cobb (2002) finds "the coral data are consistent with the theory that low-order chaos is at least partly responsible for observed ENSO variability" and "abrupt transitions between relatively quiescent and active ENSO regimes may be a fundamental feature of the tropical climate system".

Finally "the Palmyra reconstruction reveals that inter-annual to decadal-scale tropical climate variability of the last millennium was far more variable than that of the 20th century " and "there is no evidence that this warming (that began in 1976) has affected the behaviour of ENSO – in fact, ENSO statistics are uncorrelated with mean climate conditions in the last millennium".

Lough *et al.* (2002) found the occurrence and intensity of luminescence lines in massive corals from the Great Barrier Reef to be a robust proxy for freshwater flow – particularly the Burdekin River in this case (Figure 12).

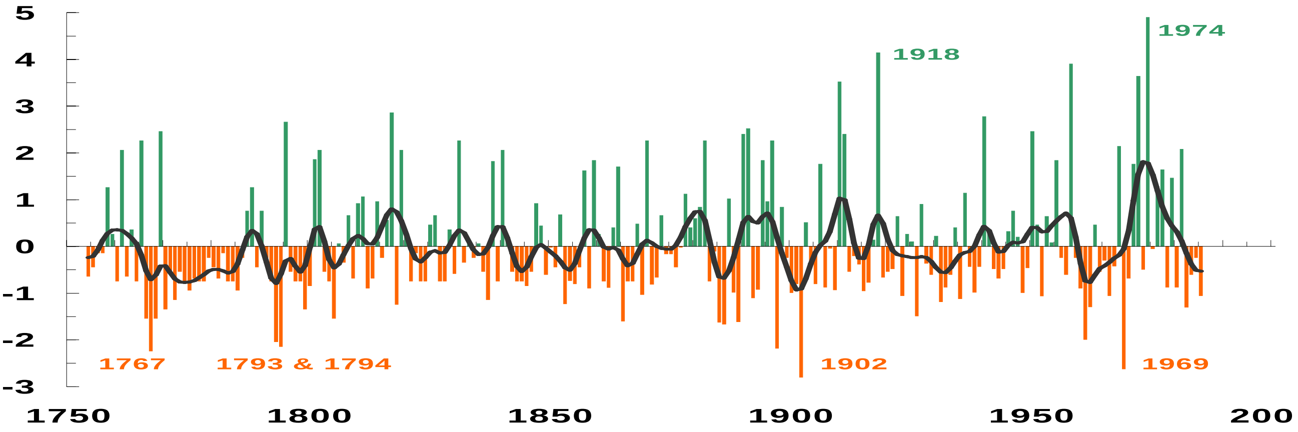


Figure 12 Central Great Barrier Reef luminescence 1754 to 1985 (Hendy *et al*. 2003 The Holocene 13: 187-199)

It is interesting to note that the end of the period shown as the LIA (Little Ice Age 1500's to 1800 Figure 11) corresponds with low levels of luminescence and a period of extreme dryness (1767 to 1794) in the Burdekin catchment (Figure 12).

Cobb (2002) reported that the LIA and the MWP (Medieval Warm Period) were probably both results of climate variability at the century (not ENSO or decadal) scale resulting from basic changes in the activities of global circulations such as the Hadley circulation. During the LIA the tropical pacific was generally warmer (or more El Nino like) which may explain the periods of extended dryness in central Queensland.

Hendy *et al.* (2003) nominated the wettest and driest years during the period 1767 to 1985 based on coral luminescence. (Table 4)

Table 4 Luminescence annual extremes 1754-1985 (Hendy *et al.* 2003)

Wettest	Driest
1974	1902
1918	1969
1958	1767
1972	1897
1910	1794
1817	1793
1940	1961
1795	1886
1891	1885
1769	1889

Four of the ten wettest years experienced by the central Queensland region during the past 250 years have occurred during the farming history of the central Highlands. Eight of the ten driest years occurred prior to farming activities commencing.

Hendy *et al.* (2003) also nominated the wettest and driest decades during the period 1767 to 1985 based on coral luminescence. (Table 5)

Table 5 Luminescence decadal extremes 1754-1985 (Hendy *et al.* 2003)

Wettest	Driest
1972-1981	1766-1775
1950-1959	1791-1800
1910-1919	1960-1969

More fresh water reached the Great Barrier Reef during the 1970's and early 1980's than during any other recorded period (Figure 12). Some of this increase may have been due to accelerated land clearing activities that accompanied the development of improved pastures for beef cattle in the catchment during the late 1960's and early 1970's and peaked in the 1980's.

Even so, the data provided by Hendy *et al.* (2003) together with the rainfall records for Emerald suggest that the 1950's and the 1970's may have been the most consistently wet decades experienced by the central Queensland region for 250 years but that these two wettest decades were bisected by one of the driest decades for the same 250 year period.

Summary of Emerald climate

The climate of Emerald has been shown to be non-stationary with recent trends in rainfall, temperature and ENSO indicating that either low-frequency climate variability or anthropologically induced climate change (or both) may currently be having an impact.

Most dryland farming activities were largely established and rapidly expanded during the wettest thirty-year period since 1750 (1950 to 1979 - Hendy *et al.* (2003)).

4. Cropping systems and climate forecasting

4.1 Climate science and forecasting

The inability of climate science to accurately predict the timing and impact of climate variability partly contributes to the conservative, risk averse management of Australian farming systems. It has been proposed that more accurate forecasts would help to buffer against the severe downsides of climate variability but also help managers capitalise on the upsides of climate variability. (Carberry *et al.* 2001)

Current forecasting methods are either categorical or probabilistic. Categorical forecasts predict climate outcomes on the basis that they will fall into certain categories that have deterministic outcomes. For example, next season will be "a drought" or next season will be "wet". As the physical processes that drive climate have many influences, some of which are chaotic and non-deterministic in nature, categorical forecasts should be seen as either "wrong or dishonest" and "should never be endorsed". (Meinke et al 2003)

Probabilistic forecasts are based on a statistical analysis of available climate data where records are partitioned into year or season types based on concurrently prevailing ocean and atmospheric conditions. Current conditions are statistically compared to the previous year or season types to provide a probability of the biological system behaving in a similar way as it did in the past under similar conditions. Such terms as "analogue years" are used to describe groups of years or seasons that had similar characteristics to the current state of ocean and/or atmosphere.

The approach taken in probabilistic forecasting is –"*if that group of years had that range of outcomes then this year (that has the same set of prevailing conditions) will most probably have this range of similar outcomes".* The climate factor being forecast has a mean or median value but also a dispersion of outcomes about the mean or median. For the forecast to have skill, both the mean or median and the dispersion of outcomes of the forecast must be statistically different to a reference distribution. (Potgieter *et al.* 2002b)

Statistical approaches to producing probabilistic forecasts have considerable limitations, not the least of which is the ability of the climate to change as well as just be chaotic and non-deterministic in nature.

Climate change may not negate probabilistic forecasts based on known phenomena and their relationships because the climate phenomena may not change - only its frequency and severity might change. (Kumar *et al.* 1999, Timmermann *et al.* 1999, Salinger, 2000)

Therefore for a probabilistic forecast to be valuable it must not only be:

- Based on a known climate phenomena

It must also be:

- Skilful (statistically proven)
- Timely
- Applicable (relevant)

Meinke and Stone (2004) make the following points about forecast value and skill. "A climate forecast can be extremely skilful, but have no value whatsoever. Conversely, even rather moderate forecast skill can translate into high value and impact if applied appropriately" and "Climate information only has value when there is a clearly defined benefit for the user, once the content of the information is applied".

Hammer *et al.* (1996) define a valuable forecast as providing information that leads "to a changed decision, which must ultimately result in an improved outcome".

4.2 Climate variability and cropping system success

Rainfall amount is not the only determinant of plant growth. Starting soil water, temperature, planting dates, rainfall intensity and rainfall timeliness will strongly influence crop yield.

Simulation models can integrate all these effects in a physiologically meaningful way to indicate the impact of climate variability on cropping system success.

The benefits of simulating cropping systems to consider impact of climate variability can be listed as:

- Climate and management effects on cropping systems can be integrated in a meaningful way
- It is a cost effective alternative to field experimentation
- A large number of combinations can be assessed
- Inter-relationships between sustainability, resilience and productivity of cropping systems can be assessed
- A predictive capacity can be developed for agricultural system outcomes, that is, relationships can be quantified in probabilistic terms.

4.2.1 APSIM model

APSIM is a daily time step model that mathematically reproduces the physical processes taking place in a cropping system. This calculation of daily outcomes within the model allows the collection of cropping system outputs on a time basis and/or event basis.

APSIM can be run for any number of days up to the total length of suitable climate records.

Cropping systems modelled in APSIM can:

- respond accurately to rainfall incidence and effectiveness;
- reflect soil water balance over time;
- calculate dates for events and time spans between events

to generate expected crop yields and cropping frequency for the climate period modelled.

When this information is combined with farm economic data, the financial impacts of alternate management systems can be related to specific sequences of climatic events or states of the farming system.

For example, the annual gross margin for each cropping system can incorporate variable fallow costs that respond to the amount of rainfall and the number of days of the fallow period between crops.

Fallow costs relating to specific crops can also be included along with variable fertiliser costs that responded to the efficiency of soil N use by the cropping system.

The costs of crops that are planted and then fail or have yield significantly reduced by seasonal conditions can also be accounted for.

In this way the costs associated with the cropping system can be made to respond to the type of crops grown, the intensity of the cropping system and the climatic conditions encountered by the cropping system.

There are some limitations to this modelling approach.

- APSIM has to be configured specifically for each location.
- APSIM plants crops on a single day with an even plant establishment plus optimal plant population and spacing.
- APSIM crops are grown without significant weed or insect competition and do not suffer harvest losses or frost damage.
- APSIM crops and rotations respond only to the crop sequence characterised during model initiation. They do not respond over time to changing price relationships or the timeliness of alternate farming systems.

The limitations of APSIM need to be remembered when the results of simulations are being interpreted.

4.2.2 Climate variability and farm decision making

Farm decisions can be broken into tactical and strategic.

Tactical decisions are more frequent decisions that have a short-term impact and can respond to climate forecasts.

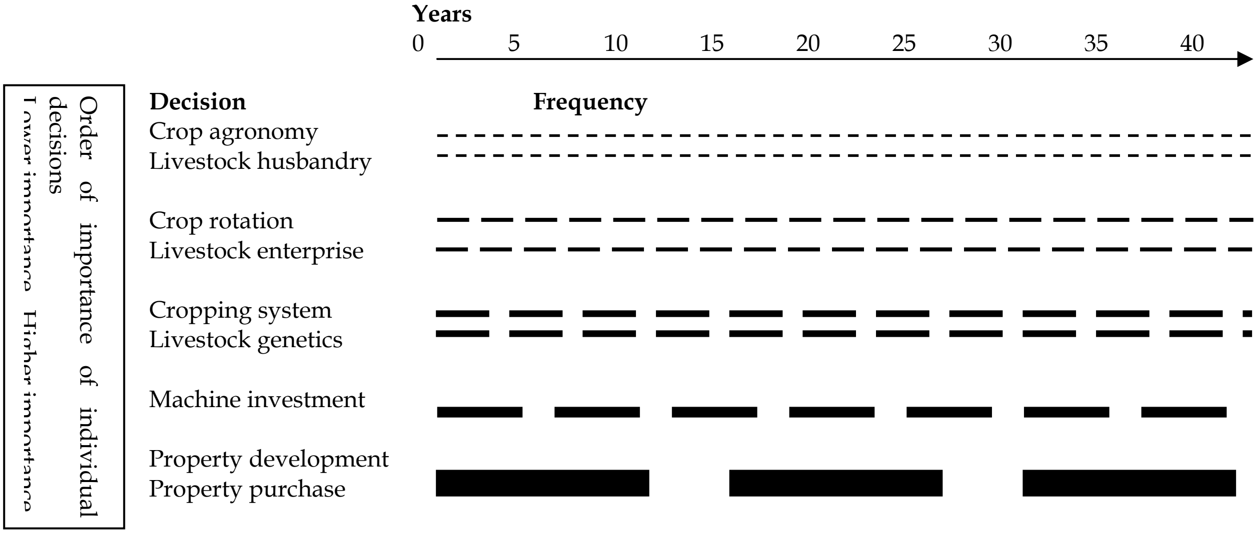
Strategic decisions are less frequent decisions that have an impact over the longer term and have to cope with or be resilient to climate variability.

An example of a tactical decision is the choice between crop varieties or the level of inputs to apply to a cropping system. This decision type can occur a number of times within any season and can be varied in response to a seasonal forecast. Individual decisions with a high temporal frequency do not have great individual value as choosing a less than optimal input does not normally lead to a critical loss.

An example of a strategic decision is the decision to purchase a property. This type of decision will not be affected much by a seasonal forecast but could be greatly impacted by a forecast for the next series of seasons or decade. These infrequent decisions have great individual value as they set the framework for the potential profitability of the investment and can prove very expensive and difficult to rectify if the wrong choice is made.

The impact of making the wrong investment decision will not be overcome by subsequently getting the more frequent tactical or operational decisions right. Once the correct investment decision is made, the farm business can be made much more profitable if the operational decisions are soundly based.

Table 6 Frequency and relative importance of farm decisions.



The value of seasonal forecasts to operational decisions has been more widely studied because of the frequency of the decision, not necessarily the value of the decision. Remember that only about 2% of farm businesses will make a significant strategic decision next year whereas 100% of farm businesses will make many operational or tactical decisions.

Seasonal forecasts are much more *applicable* even if the decisions they support are individually not as important as the decisions supported by inter-seasonal to decadal forecasts.

Farm decisions can be viewed from the perspective of the tactical or operational level (the farm manager level). Farm decisions can also be viewed from the strategic level (the level of the farm investor). The value of forecasts at different time scales can be assessed using these perspectives.

Note that both farm manager and farm investor can be the one person

The farm manager and the farm investor will place different values on forecasts at different timescales. (Table 7)

Table 7 Expected value of forecasts at differing timescales (* Index of DCV is Index of Decadal Climate Variability)

Time Scale	**Forecast**	**Expected value to the farm manager**	**Expected value to the farm investor**
Intra-seasonal	MJO	Low	Very low
Seasonal	SOI phase	High	Low
Inter-seasonal	ENSO	Moderate	Moderate
Decadal	IPO, Index of DCV*	Low	High
Multi-decadal	Climate change	Very low	Low

It can be seen that a forecast for a climate phenomena has the highest value when its temporal frequency matches that of the farm decision. Therefore, seasonal forecasts have the highest potential value to the farm manager and forecasts at the decadal timescale are expected to have the greatest potential value to the farm investor.

5. Climate forecasts and Emerald cropping systems

5.1 Monoculture sorghum

Spackman *et al.* (2001) report that grain sorghum is the most important crop in Central Queensland (CQ) both in terms of the area planted and the tonnage of grain produced. Factors that contribute to its widespread use in CQ cropping systems include its suitability to the summer dominant rainfall of the region, its reliable grain yield and consistent, but modest, profitability.

Sorghum will be used as a benchmark for alternative cropping systems in this analysis.

5.1.1 Sorghum yields

Conditions under which sorghum could be planted by the model were set to mimic the current expectations of central highlands farmers. The planting window opened in the second week of December and closed in the second week of February. For a planting to occur stored soil water had to be at least 75mm and 15mm of rain had to occur over the previous ten days. The soil surface also had to be sufficiently dry for the planting operation to take place.

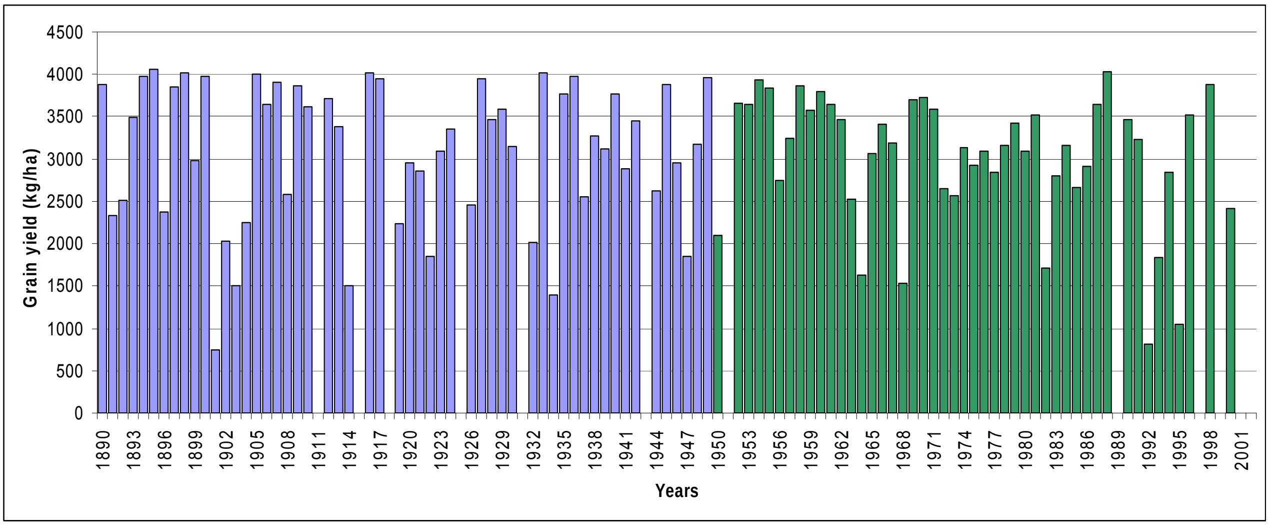


Figure 13 Modelled yields and cropping frequency for monoculture sorghum at Emerald for planting years 1890 to 2003 on a 150mm PAWC soil

Figure 13 has been modified so that the yields for the years since major farming activities commenced at Emerald have been shown in green. During the first ¾ of this more recent period, sorghum has been a very reliable cropping system at Emerald on a 150mm PAWC soil that is fallowed over winter.

Individual sorghum yields for the harvest years from 1950 to 1990 seem to agree with the comments made Hendy *et al.* (2003) concerning climate variability during this period (see table 5 previously) That is, the 1950's and 1970's both show low variability in yields while the 1960's show relatively higher variability.

The modelled sorghum yields for the period of time after the GBR coral data finishes show a much more variable result suggesting that this period was consistently drier than the 1960's and therefore could have been one of the driest periods in the past 250 years.

In 50% of years grain yield exceeded 3 t/ha. (Figure 14) Few yields above 4 t/ha have been generated in this analysis due to the planting conditions chosen and the variety planted. A variety that matured later in the season may have generated some higher yields but would also have shown lower cropping reliability.

The distribution of crop yields also indicates that sorghum would not have been planted in 10% of the years from 1890 to 2003 due to either a lack of a planting rain and/or insufficient water being stored in the soil profile during the planting window.

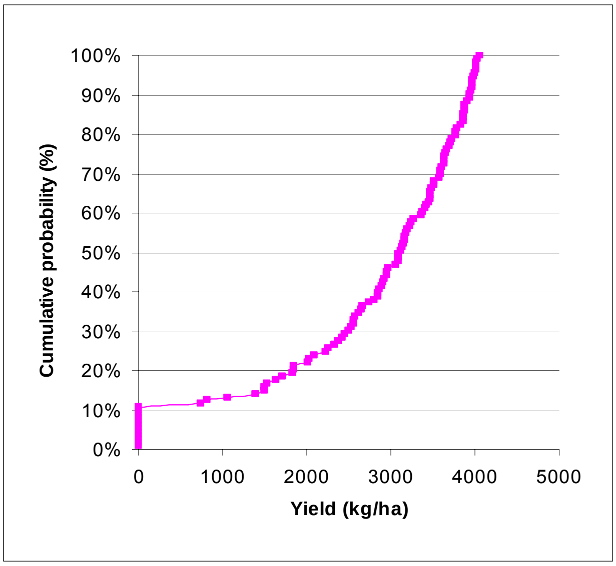


Figure 14 Distribution for monoculture sorghum yields at Emerald for all years 1890 to 2002

The individual distributions of yield for the last four decades show the last decade (plant years 1993 – 2002) as having 20% lower median yield than the previous three decades. (Figure 15)

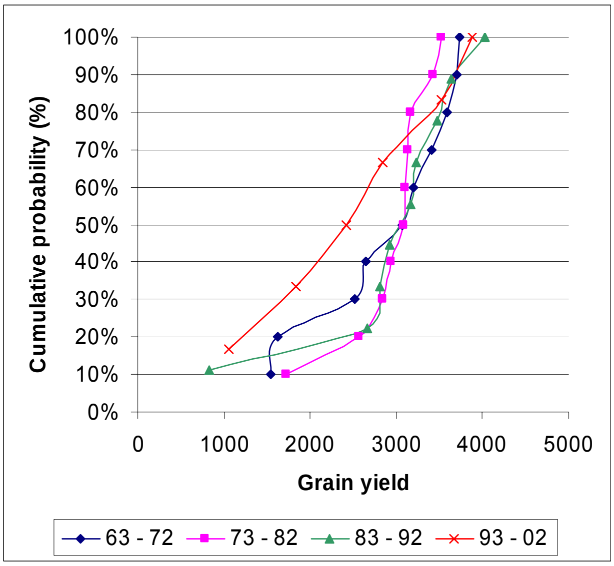


Figure 15 Potential monoculture sorghum yields for the last four decades at Emerald

The most recent decade at Emerald has therefore had both fewer planting opportunities and a significantly lower yield potential (for crops that were planted) compared to the three immediately preceding decades.

As most farm managers began their broadacre farming activities sometime during the 60's, 70's or 80's the most recent decade stands out as a significant shift from their expectations.

5.1.2 Sorghum reliability

The most reliable cropping season at Emerald is the summer season and sorghum is the crop typically planted into the summer cropping window.

Missed planting opportunities occurred when the "traditional" planting rules for sorghum were not met.

As stated previously, these rules allowed sorghum to be planted between the 16th December to 15th February if 15mm rain had fallen over the previous 10 days and the plant available water (PAW) was greater than 75 mm. The top 15cm of the soil also had to be dry enough for planting operations to proceed.

The rules are based on the observed practices and statements of central highlands farm mangers and our modelled outputs mostly achieve a similar planting frequency to theirs. The exception is the "desperation factor" planting where the planting window is about to close or has closed and the farm manager needs cash flow. Our model runs do not currently respond to such stimuli although such plantings have occurred in the past six years.

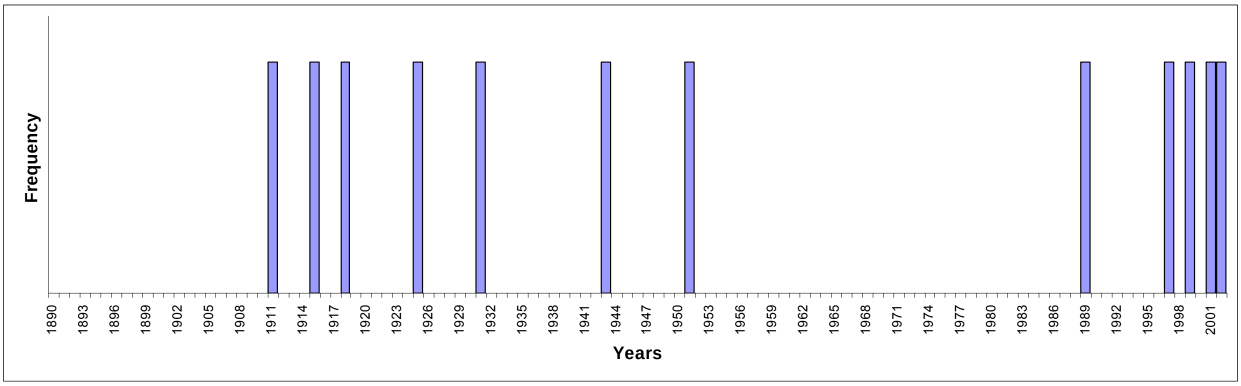


Figure 63 Sorghum non-planting events at Emerald on a 150mm PAWC soil for plant years 1890 to 2002.

Broadacre farming mostly commenced in the late 1940's around Emerald with many current farm businesses beginning their farm investments during the late 1970's or 1980's. Most of these farm managers and investors, even the oldest, would only have seen two or three seasons up until 1990 where sorghum was not able to be planted. This is a farming history of about 50 years (Figure 16).

Four out of the past six modelled traditional planting windows for sorghum (1997 to 2002) have closed without an "acceptable" planting opportunity for sorghum being received.

This change in the reliability of the traditional sorghum planting window could be due to the change in climate experienced at Emerald over the past two to three decades.

Farm managers have the opportunity to plant outside the traditional planting window modelled here. The current recommendation is that sorghum should not be planted later than mid February due to the threat of ergot infection making the grain unmarketable.

Sorghum can be planted much earlier than December but many farmer managers believe the risks of doing so outweigh the benefits.

To test the impact of planting sorghum earlier in the season two additional planting window scenarios were modelled for sorghum.

The first scenario considered an early planting window from the 1st October to the 15th of December. The second scenario considered the impact of planting sorghum at any time during the combined early and late (traditional) planting windows. In the combined planting window sorghum could be planted at any time from the 1st of October up until the 15th of February.

Note: the discrete five-year periods of figure 17 do not overlap and the totals shown represent the modelled yield potential for the five plantings from the beginning year of each sequence.

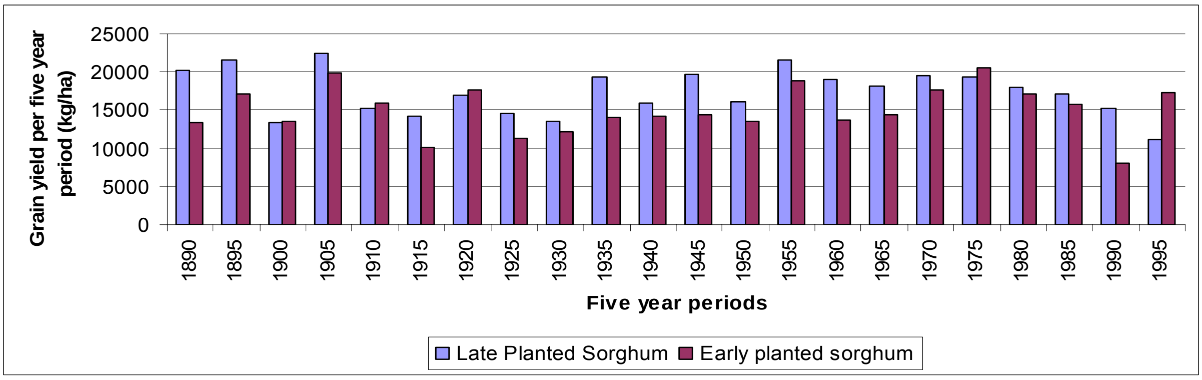


Figure 647 Modelled total yield per five year period for monoculture sorghum at Emerald on a 150mm PAWC soil – traditional and early planting windows.

The traditional planting window would generally have been the way to go although the differences are not great. (Figure 17) More recently the right planting window has been not so easy to pick. From 1990 to 1994 the late planting scenario almost doubled the yield potential for the early planting scenario and then from 1995 to 1999 the early planting scenario outperformed the late planting scenario by about 50% (Figure 17).

Analysis of the second planting scenario modelled indicates that taking any planting opportunities that occur in the early planting window as well as including later opportunities when early crops are not planted does not significantly change outcomes. (Figure 18)

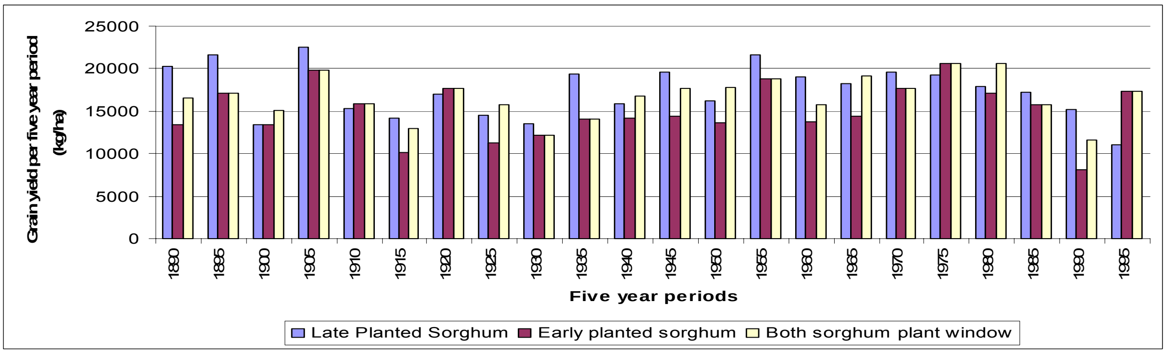


Figure 18 Modelled total yield per five year period for monoculture sorghum at Emerald on a 150mm PAWC soil – three planting scenarios.

The combined planting window scenario has its performance compromised by always taking early opportunities as they occur and not being able to identify when to wait for better opportunities later in the season. This suggests that the ability to forecast when early or late sorghum planting opportunities should be taken might now have some value. The value was unlikely to be significant in the past due to the generally small difference in potential outcomes between planting scenarios.

The increase in difference between the planting scenarios towards the end of the 20th Century tends to support the points made by climate change advocates that rainfall will become more irregular and intermittent with follow up rainfall less likely.

Such a rainfall pattern would lead to significantly less planting opportunities in any central highlands summer season and existing farmers may have to consider the potential outcomes for their business of waiting for the "traditional" window before they plant. More variable rainfall with less planting opportunities could significantly increase the value of a forecast for the seasonal break as well as seasonal rain.

The total gross margin for the early plant scenario from 1995 to 1999 was about double the total gross margin for the late plant scenario for the same period. On the typical 2000 ha farming property at Emerald this knowledge could have added between $100,000 and $700,000 to property income over this five-year period depending upon the amount of sorghum planted and its planting date.

5.1.3 Sorghum gross margin

Modelled yields produced by the traditional planting window can be used to generate gross margins for the years 1890 to 2002. Costs and returns have been held constant at current prices for the entire climate record.

An average selling price of $130 per ton on farm was chosen for sorghum and at this price a gross margin greater than $200 per ha could have been expected in 50% of years (Figure 18). Sorghum prices have varied between $90 and $300 per ton on farm in the past decade. This range of values for price should also be remembered when cropping systems are being compared.

Negative gross margins were produced in about 15% of years by monoculture sorghum on a 150mm PAWC soil at Emerald (Figure 19).

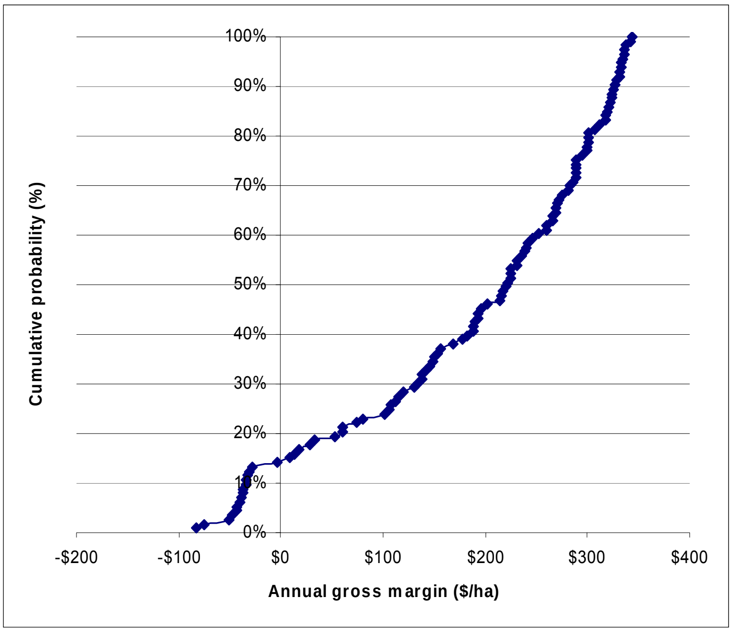


Figure 19 Distribution for modelled monoculture sorghum annual gross margins at Emerald on a 150mm PAWC soil.

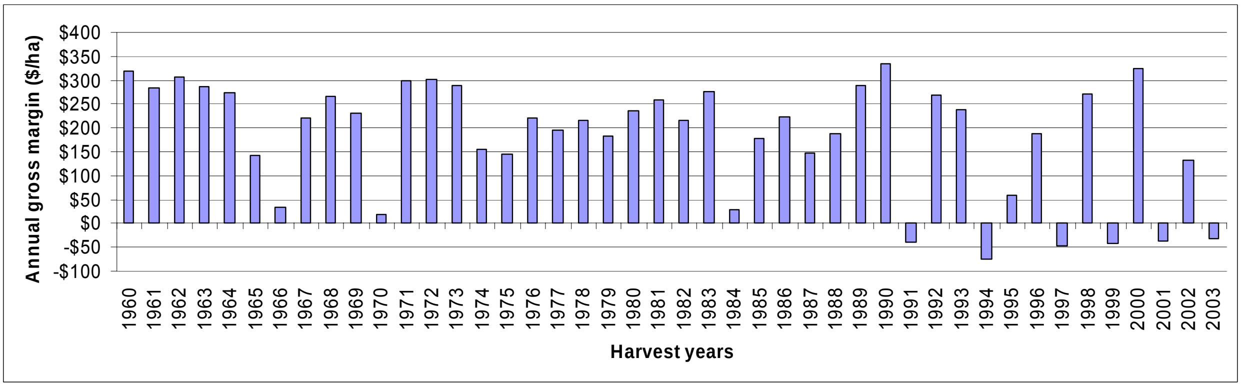


Figure 20 Harvest year gross margins for modelled monoculture sorghum yields at Emerald on a 150mm PAWC soil (1960 to 2003 harvest years).

During the last decade, modelled annual gross margins for dryland sorghum production at Emerald have only exceeded the median twice and were negative on five out of ten occasions. (Figure 20). This is in stark contrast to the reliability of the crop from 1960 to 1993.

The total annual gross margin for any decade can vary by up to 40% around the median value for the total period modelled. (Figure 21) Note that the total gross margin for each decade overlaps by five years and therefore tends to smooth out some of the decadal fluctuations in returns. The total for the decade beginning in 1995 only contains eight harvest periods and if good cropping conditions are received in late 2003 and 2004 then the total for this decade could be significantly improved.

All of the variability shown in figure 21 is driven by the prevailing climate. At current costs and returns, the poor climatic result for dryland sorghum growing encountered in the decade from 1990 to 2000 would not have been encountered in any previous decade since 1890.

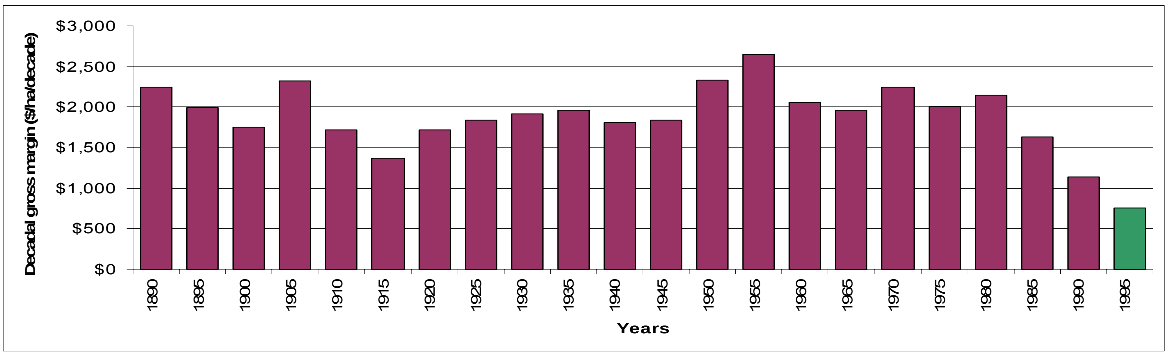


Figure 21 Total gross margins by decade for monoculture sorghum at Emerald.

If the unfinished current decade (1995 to 2004 plant years) produces two average crops to finish the decade (i.e. one for the current plant year of 2003 and one for the next plant year of 2004), it will also produce a total gross margin below any prior climate decade up to 1990 to 1999.

Modelled potential decadal gross margins have more than halved between the decade beginning in 1955 and the decade beginning in 1990. This reduction is due to the change in the prevailing climate at Emerald.

In the real world, rapidly declining soil fertility and changing costs have aggravated the impact of the changing climate. However, skilled managers have been able to slightly offset the deterioration in their terms of trade by increasing productivity.

5.1.4 Sorghum sustainability indicators

The crop sustainability indicators compiled for this report rely upon the apportionment made within APSIM for runoff, drainage and evaporation. Although the crop water balance calculations within APSIM are considered to be reliable, the sustainability indicators presented here will be subject to further research and should be viewed in that light.

The sustainability indicators output from APSIM can be compiled to provide a comparison between decades for an individual cropping system and a comparison between modelled cropping systems over a number of decades.

The absolute values for runoff, drainage and soil loss provided by the model should not be compared to actual figures estimated in the field.

In this analysis the relationships between the decadal values for each indicator are used to indicate the *relative* differences that may have occurred between climate sequences and cropping systems, not the absolute differences that did occur. The pattern and timing of modelled soil loss at Emerald fits reasonably well with farmer and researcher experience but the model may be slightly over-estimating the absolute amount of soil loss expected under the modelled farming system.

High levels of runoff can occur when rainfall cannot infiltrate into the soil. Monoculture sorghum appears reasonably susceptible to runoff on this soil profile in this environment (Figure 22).

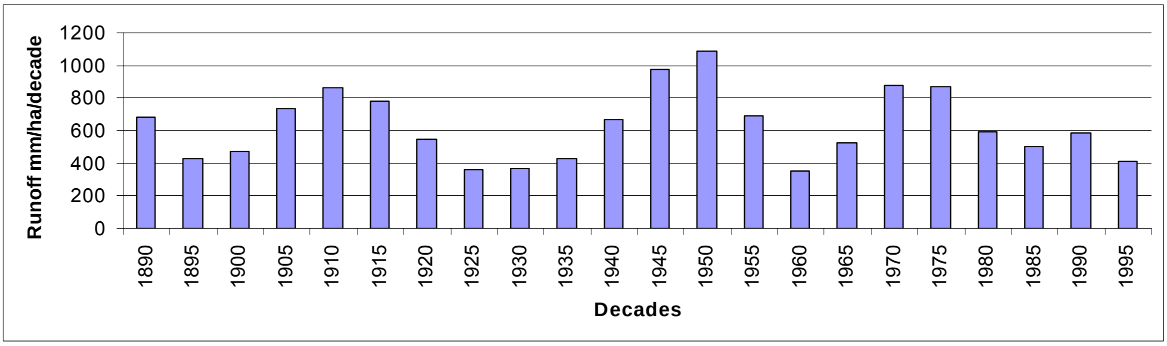


Figure 22 Total modelled runoff per decade at Emerald from monoculture sorghum grown on a 150mm PAWC soil

Periods of high drainage appear to correlate with periods of high runoff suggesting that monoculture sorghum in this environment is not capable of using an increased water supply provided by favourable rainfall seasons (Figure 23).

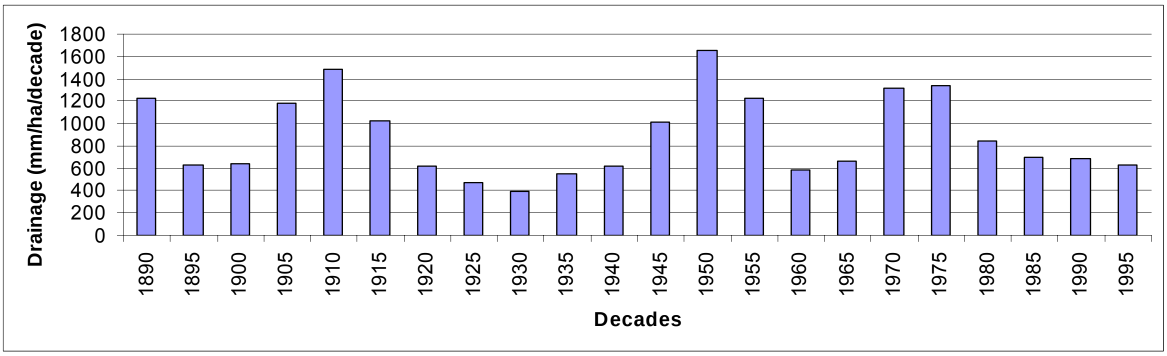


Figure 23 Total modelled drainage per decade at Emerald from monoculture sorghum grown on a 150mm PAWC soil

The median soil loss modelled by APSIM for this farming system at Emerald is about 60 tonnes/ha/decade or 6 t/ha per annum (Figure 24). The inability of monoculture sorghum to respond to and use an increased decadal water supply could lead to periods of considerable soil loss.

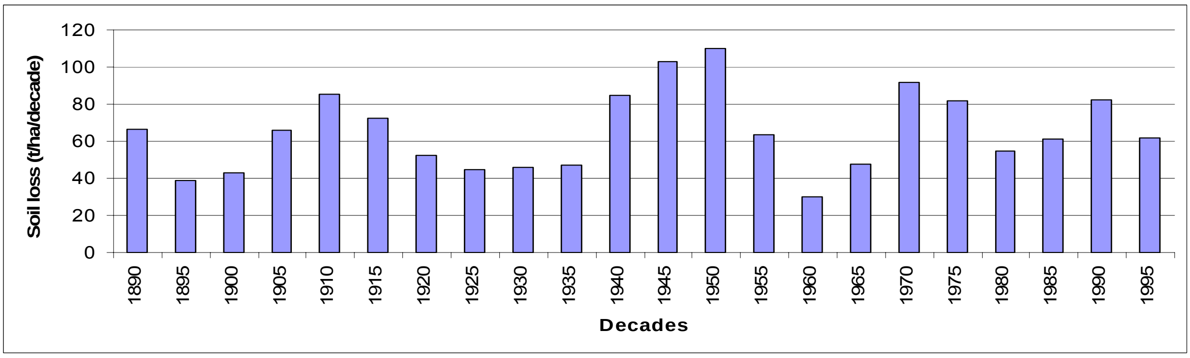


Figure 24 Modelled decadal soil loss for monoculture sorghum at Emerald on a 150mm PAWC soil.

Soil loss is a function of many things including the farming system, soil cover, soil type, soil slope, rainfall intensity and stored soil water. More than 40% of the modelled soil loss between 1976 and 2003 was due to less than ten individual rainfall events (Figure 25).

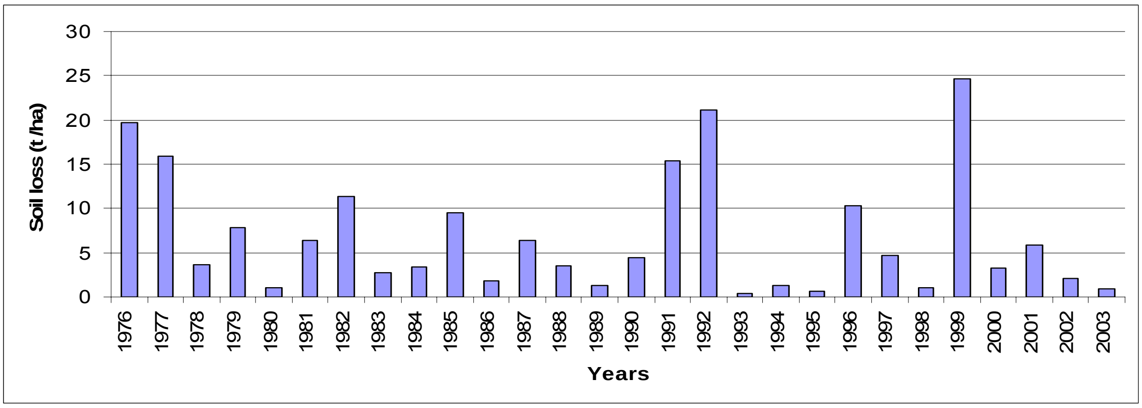


Figure 25 Modelled annual soil loss for monoculture sorghum at Emerald on a 150mm PAWC soil

Soil loss both in the paddock and in the model remains an episodic event that may not be well controlled by a low intensity farming system that does not use the rainfall available during wetter periods well.

5.1.5 Monoculture sorghum response to climate phenomena at Emerald

SOI phase

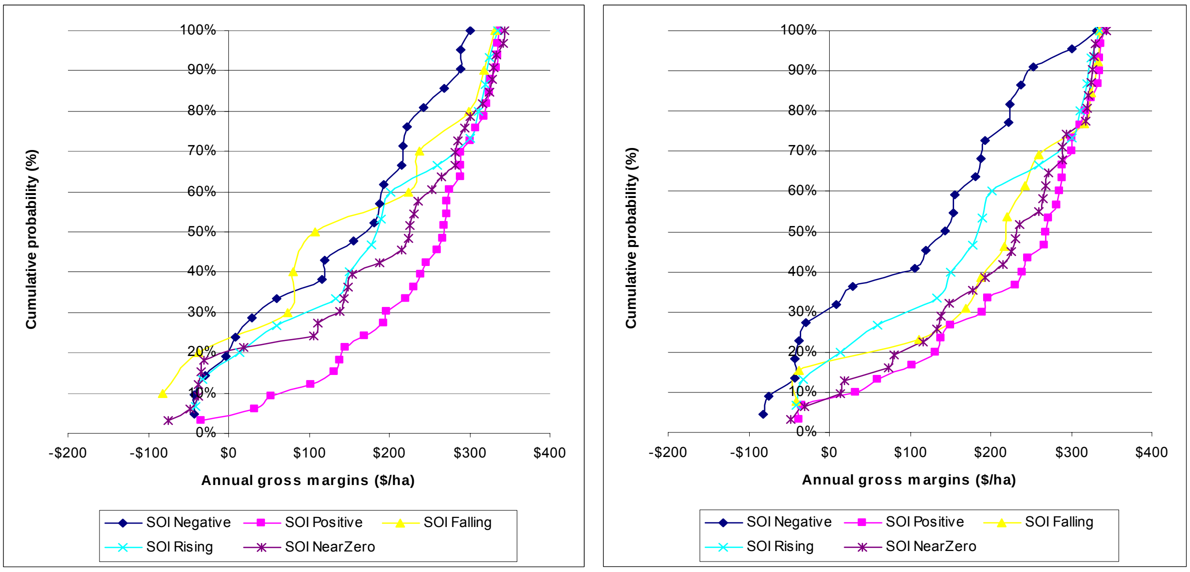
The SOI phase is the most likely forecast tool that a farmer intending to plant sorghum at Emerald will have available to support a decision. The SOI phase system used to analyse the response of cropping systems in this report is that of Stone et al (1996).

The impact of the phase of the SOI on sorghum gross margins at Emerald has been considered by compiling distributions of annual gross margins on the basis of the phase in September and November. The phase value at the end of September is two months before our traditional planting window opens and the November value is immediately prior to our traditional window opens.

Dryland sorghum planted at Emerald in those years with a SOI positive phase in September shows a reduced risk of suffering a negative gross margin and a much more reliable cropping outcome in about 60% of years. (Figure 26a) In contrast, sorting the gross margins on the basis of the SOI phase in November blurs the clear advantage of the SOI positive phase but highlights the riskiness of the SOI negative phase. (Figure 26b)

The probabilities of rainfall given by Rainman (Rainman version 4.3) for the November SOI for rainfall in the December to February period show a similar pattern to the gross margin distributions of figure 26b.

Figure 26a shows the distributions for the SOI phase at the end of September and figure 26b shows the distributions for the phase at the end of November.



(a) (b)

Figure 26 (a) Dryland sorghum distributions of annual gross margin at Emerald on a 150mm PAWC soil separated on the basis of the SOI phase in September of the year of planting and (b) of the SOI phase in November of the year of planting.

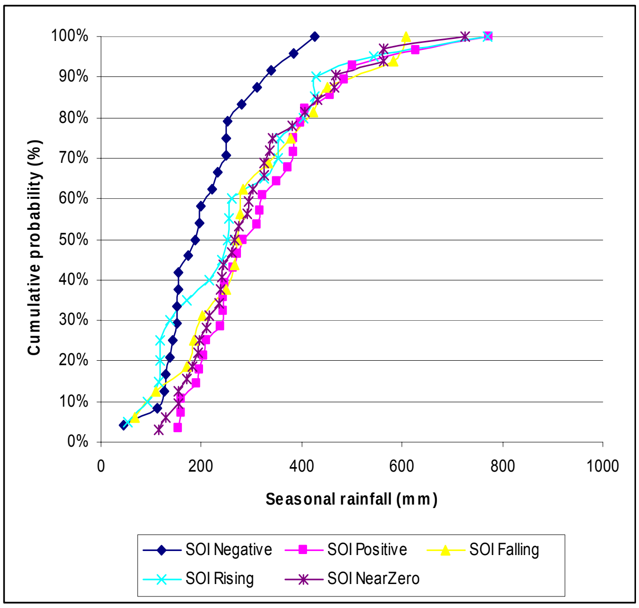


Figure 27 December to February seasonal rainfall at Emerald separated on the basis of the phase of the SOI in November (Source Rainman 4.3).

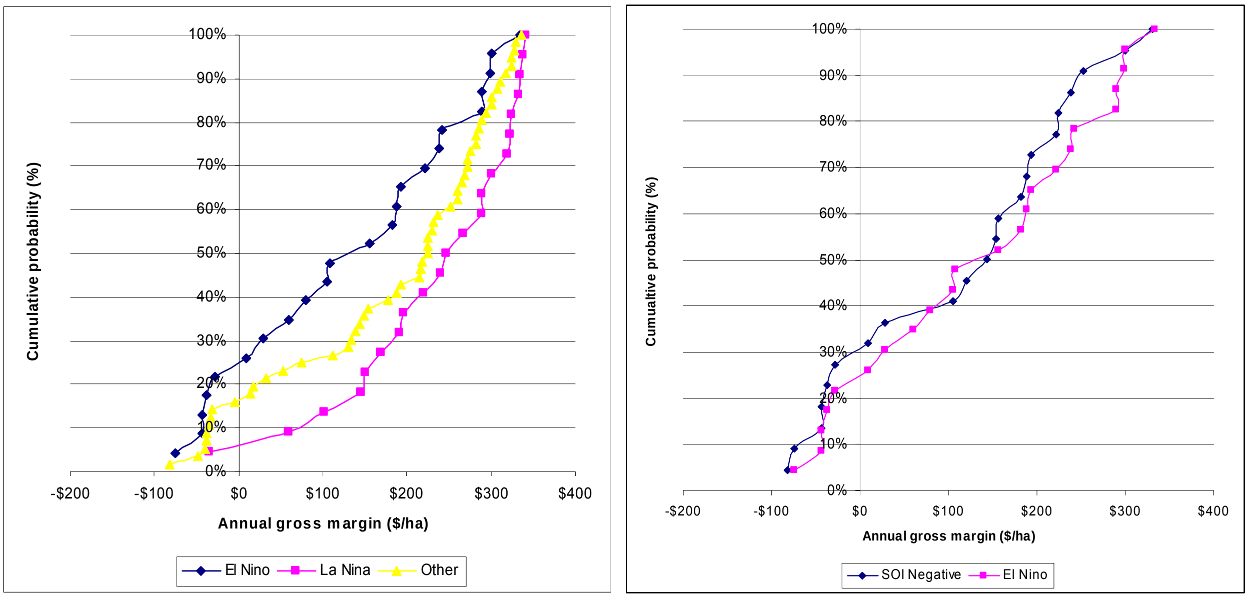
Our modelled cropping systems rely mainly upon rainfall for their success and therefore the relationship between annual gross margins and rainfall forecasts shown here is not unexpected. The impact of the phase forecast on the riskiness of sorghum production shown by figure 26b is something that the rainfall probabilities can only imply.

The value of this knowledge in swapping between alternate cropping systems (mainly dryland cotton) will be considered later.

ENSO classification

Annual gross margins for dryland sorghum production at Emerald were separated on the basis of the ENSO classification of the year of planting (Figure 28).

Sorghum is generally planted in December of one year and harvested in the first half of the following year. As the ENSO classification is also calculated in December of the planting year for the previous calendar year, the classification of the year at planting may not be known but there would probably be a fairly strong indication of what it may be.



(a) (b)

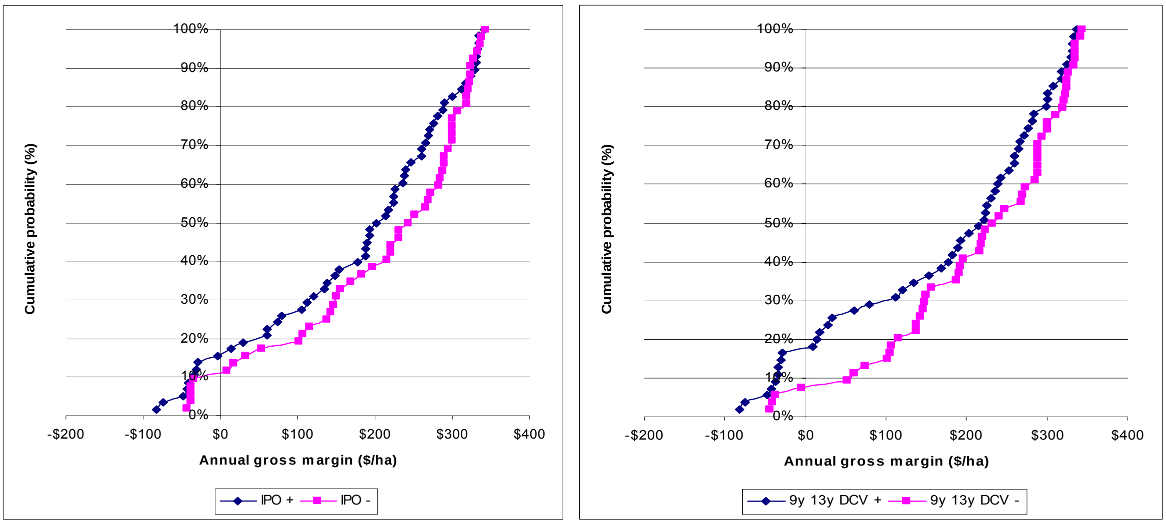
Figure 65 Annual gross margins for monoculture sorghum production at Emerald separated on the basis of ENSO classification of the year of planting (a) and annual gross margins for El Nino years and SOI negative in November years (b).

Years classified as El Nino years at the time sorghum is normally planted in CQ seem to have a significantly different range of possible outcome to those years classified as Other and La Nina. (Figure 28a) The distribution of outcomes for El Nino years is also not that different to those years where the SOI phase is also negative in November (Figure 28b). Fifteen of the twenty-two years that had an SOI negative phase in November were also eventually classified as El Nino years.

9y 13 y DCV Index and IPO

To test whether dryland sorghum production at Emerald responded to the different phases of the 9y 13y DCV index and IPO index, annual gross margins were separated on the basis of the value of the index in December of the year of planting. The December value was chosen for convenience. As the index values vary at decadal or multi-decadal timescales, the value in any month could have been chosen and not expected to change the outcome.

The IPO index shows a median gross margin of about $200 per ha in positive years (+) years and a median gross margin of $250 per ha in negative (-) years (Figure 29a). The IPO index also indicates that the chance of suffering a negative gross margin increases from about 10% of years when the index has a negative (-) value to 17% of years when the index has a positive (+) value. These impacts appear to confirm the finding by Meinke *et al.* (2003) that the IPO can impact on January to March rainfall, the main growing season for sorghum in this environment.



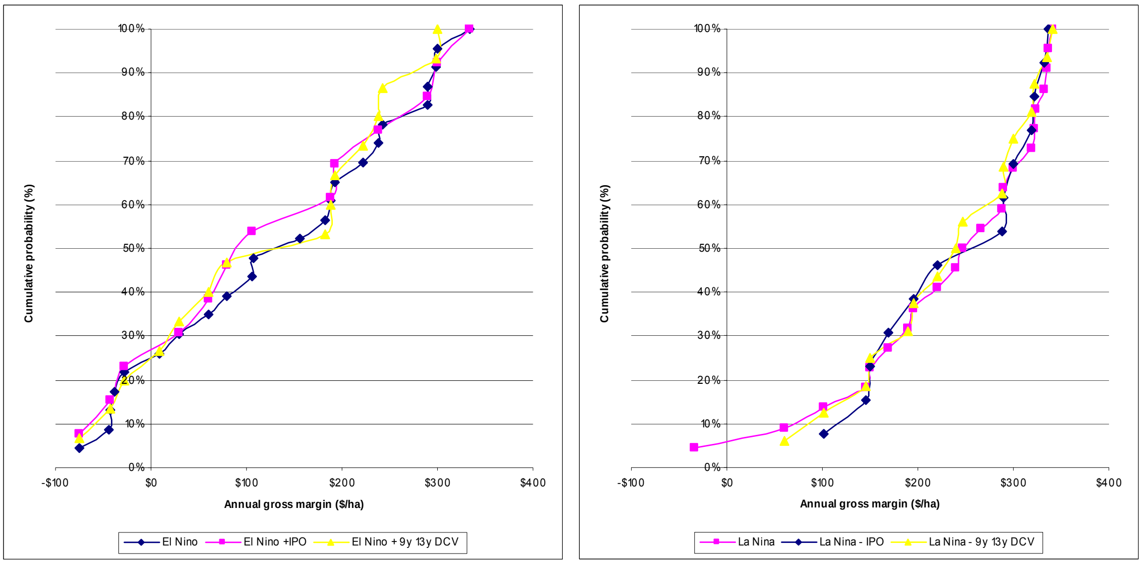
(e) (b)

Figure 29. Distribution of annual dryland sorghum gross margins for the (a) IPO and (b) the 9y 13y decadal index.

The phase value of the 9y 13y DCV index also differentiates annual sorghum gross margin at Emerald.

Interactions between ENSO and DCV indices at Emerald

Meinke *et al.* (2003) found a relationship between the phase values of the decadal indices and the ENSO phenomena. They found that El Nino years may have had their impact enhanced during the positive phases of the decadal indices. La Nina years may have also been enhanced during the negative phases of the decadal indices.



(a) (b)

Figure 30 Distributions for monoculture sorghum annual gross margin at Emerald on a 150mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

The distribution of annual gross margin of sorghum was not significantly affected by El Nino or La Nina events if the phase value of either the 9y 13y DCV index or IPO is negative or positive respectively (Figure 30 a, b).

5.1.6 Summary of monoculture sorghum

Dryland sorghum growers on the central highlands initially developed a farming system for sorghum that made it reliable and fairly low risk. This farming system was developed over a thirty-year period that may have contained two of the most reliable rainfall decades for the past 250 years.

Spackman *et al.* (2000) detail some of the adaptive responses made to maintain the reliability of dryland sorghum during the highly variable but generally drier climate of 1990 to 1999. These more adapted farming systems have been reflected in this modelling exercise.

The current sorghum monoculture farming system has been shown as fairly responsive to forecast periods of enhanced rainfall but it may also be susceptible to soil loss and increased subsoil drainage during these periods.

Monoculture sorghum exhibits both annual and decadal variation in yields and returns. Some of this variation in yield or returns seems to be explained by a response to the climate phenomena analysed here.

The yield performance and reliability of dryland sorghum over the most recent decade at Emerald stands as significantly different to any previous farming experience held by local farmers. This most recent climate period may eventually reveal relationships between climate phenomena and sorghum productivity that were previously hidden by the predominance of above average rainfall records in our recent climate records.

5.2 Monoculture cotton

Dryland cotton is a summer crop that can be planted as a substitute for dryland sorghum in the central highlands.

The traditional planting window for cotton is the same as the early planting window for sorghum (1st October to 15th December) but experienced dryland cotton growers say they generally wait for about 100mm of stored soil water prior to planting cotton compared to the 75mm required for planting sorghum. This strategy is seen as offsetting some of the production risks of cotton.

Spackman (2001) found that "the dryland cotton industry in central Queensland is comparatively smaller than in summer cropping areas of southern Queensland and northern New South Wales. There is only a small number of dedicated growers in the region, along with an equally small number of growers who grow the crop on an opportunity basis or when circumstances are appropriate, such as when prices are high."

5.2.1 Modelled cotton yields

Annual variability in modelled dryland cotton yields at Emerald is quite high. The reliability of the crop is also less that that of sorghum with a significant number of gaps evident since 1890. (Figure 31)

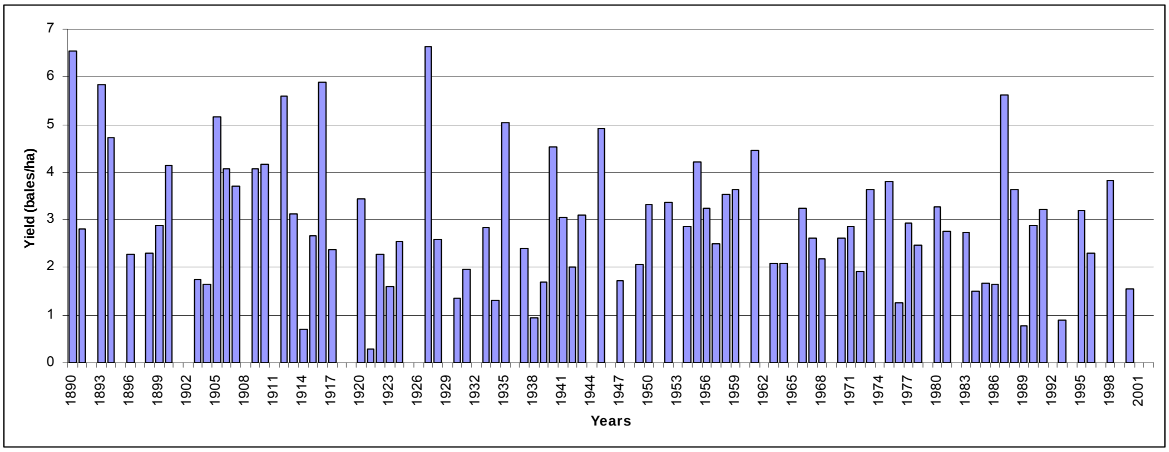


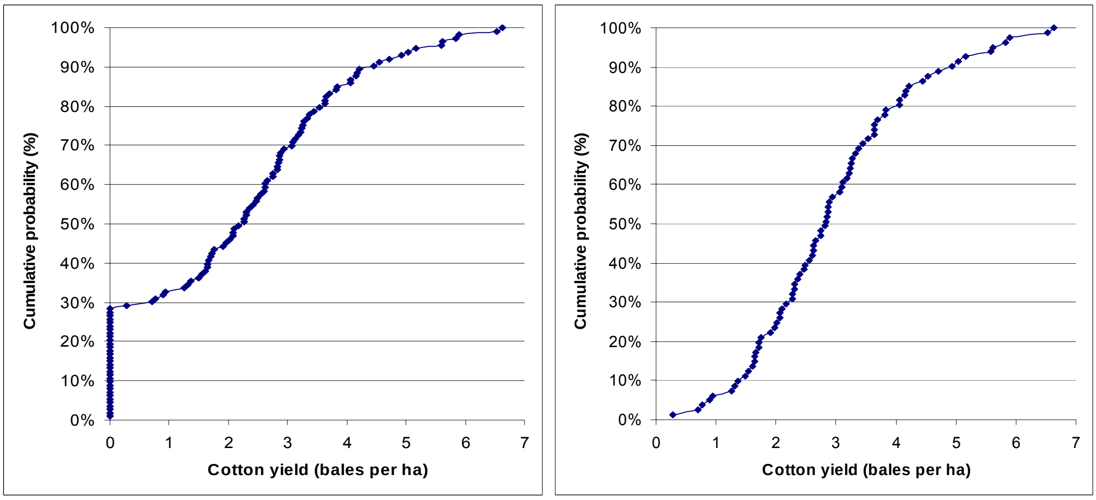
Figure 31 Modelled yields for dryland cotton at Emerald for the plant years from 1890 to 2002 grown on a 150mm PAWC soil

Over the modelled climate history, monoculture cotton systems at Emerald would have failed to plant in about 30% of years due to a lack of planting rain or stored soil water or both.

When cotton crops were successfully established, APSIM produced a median yield of about 2.5 to 2.8 bales per ha. (Figure 32) A farm manager would need to employ suitable weed, insect and harvest management to achieve these yields. The top 10% of years produced yields between 4.5 to 6.5 bales per ha.

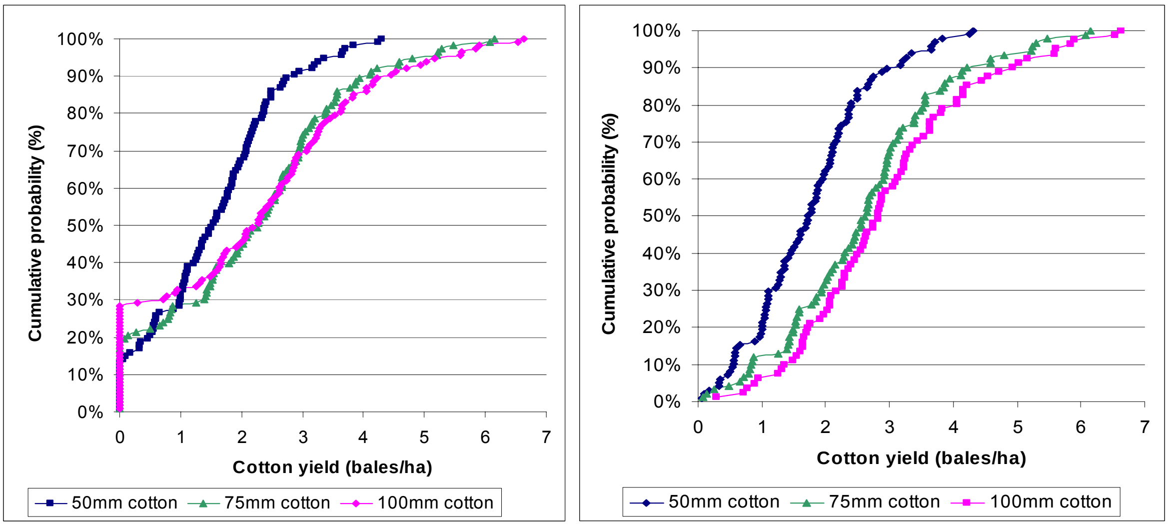
Dryland cotton has a fairly restricted planting window on the central highlands due to agronomic requirements of the crop other than rainfall. To test the impact on dryland cotton yields of varying the level of starting soil water at planting, two additional planting scenarios were tested.

Additional scenarios were tested in which the crop was planted in the same window but only required 75mm or 50mm respectively of stored soil water prior to planting.



(a) (b)

Figure 32 Distribution for monoculture cotton yields at Emerald (a) all years 1890 to 2002 and (b) years planted 1890 to 2002.



(a) (b)

Figure 33 Distribution for monoculture cotton yields at Emerald with three separate starting soil water requirements (a) all years 1890 to 2002 and (b) years planted 1890 to 2002

Reducing the soil water requirement for planting to 75mm from 100mm increased the planting frequency to 80% of years but only lowered yield potential slightly (Figure 33). If soil water at planting was reduced to 50mm the impact was to increase the percentage of years planted to 87% but to reduce the median yield by about 1 bale/ha. (Figure 33)

As the cropping frequency shown by the 75mm starting soil water distribution fits the planting frequency shown by experienced cotton growers and as few if any growers would accurately measure soil water at planting, this scenario will be used in the remainder of the analysis.

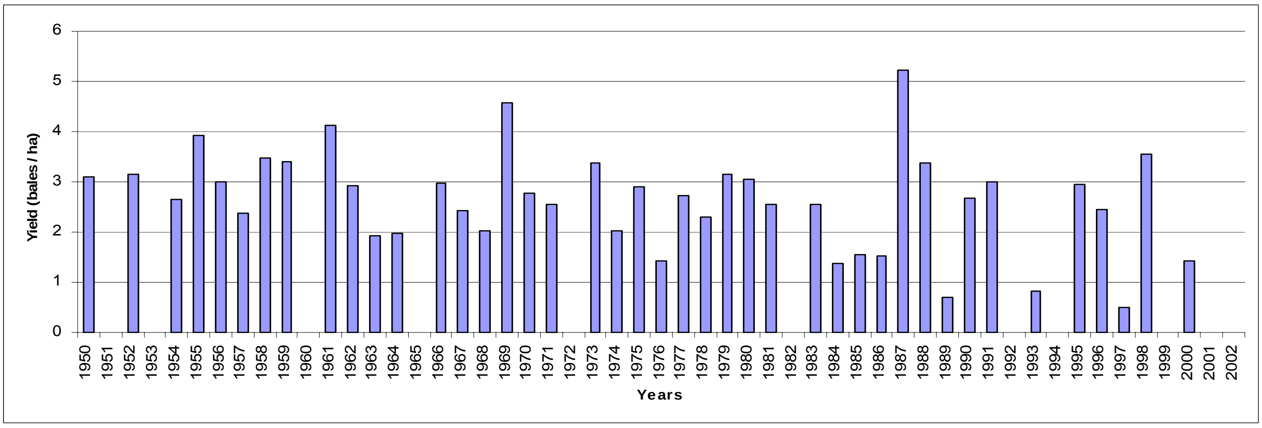


Figure 34 Cotton yields as modelled for Emerald 150mm PAWC soil by APSIM (1950 to 2002 plant years, 1951 to 2003 harvest years)

Modelled cotton yields show a slightly different pattern over recent years to modelled sorghum yields. The earlier planting window used in this scenario together with the different growth habit of cotton may give rise to most of the differences. (Figure 34)

5.2.2 Cotton gross margins

Cotton gross margins are calculated with an average selling price of $475 per bale ex gin with current growing costs applied across all years. (See appendix 1 for growing costs)

The variable selling prices and different growing costs of the past would have obviously produced different (real) results for cotton growers who actually grew the crops during the years modelled. It must be remembered that the purpose of the modelling exercise is to reflect the impact of past climate variability on potential returns, not to reflect the past returns of existing dryland cotton producers.

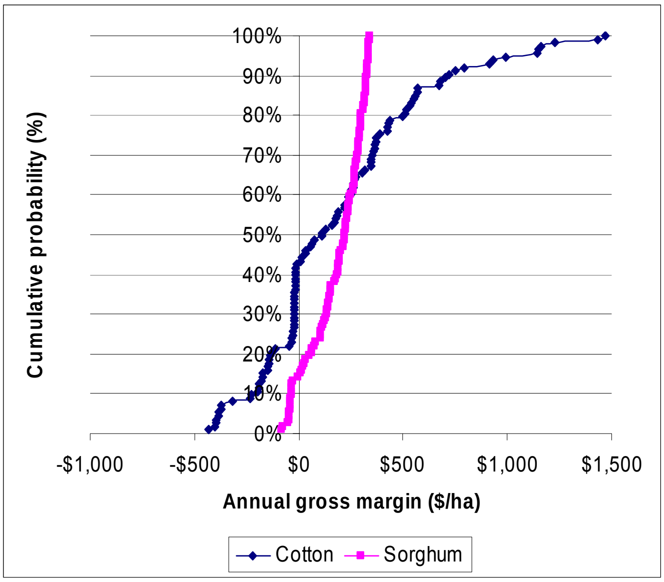


Figure 35 Distribution for monoculture cotton gross margin at Emerald on a 150mm PAWC soil.

Negative annual gross margins for cotton are produced by missed cropping opportunities as well as by crops that are planted, incur high growing costs then suffer a low yield or fail.

In about 40% of years more funds would have been spent on growing dryland cotton at Emerald than were earned. The top 20% of years produce gross margins of greater than $500 per hectare and up to $1500 per hectare at the prices and costs selected.

Cotton gross margins are also very sensitive to the cotton price. A slight improvement in the average bale price of cotton (about $25 per bale) would have lifted the performance of the crop significantly above that of sorghum in about 50% of years. At higher prices the significant downside risk of a failed cotton crop still exists.

The total gross margin for each decade is the sum of the annual gross margins for the same period. When a crop is missed or has a low yield, the annual gross margin can be a negative value and reduce the total gross margin for the decade.

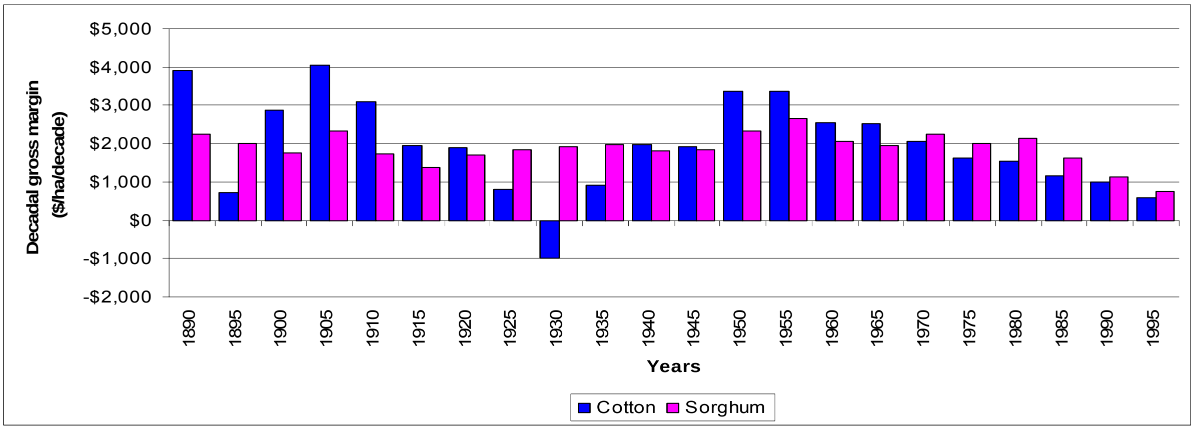


Figure 36 Total gross margins by decade for monoculture cotton at Emerald.

All of the decadal variability shown in figure 36 is driven by the prevailing climate. At current costs and returns, the poor climatic result for dryland cotton growing encountered in the decade from 1990 to 2000 would have been encountered in four of the previous decades since 1890.

It is interesting to note a very favourable climate period for cotton production at the beginning of the 20th century that does not show the same advantage for sorghum. This suggests that cotton and sorghum are responding to slightly different climate signals at different times over our climate history even though they are both grown over the summer period of the year.

Cotton shows a greater variability in potential returns due to climate variability than did sorghum over the climate record modelled. Sorghum shows a greater reliability in returns but also shows a lack of ability to capitalise on more favourable climate sequences, even up until current decades.

Note that the total gross margin for each decade overlaps by five years and therefore tends to smooth out some of the decadal fluctuations in returns. The total for the decade beginning in 1995 only contains eight harvest periods and if good cropping conditions are received in late 2003 and 2004 then the total for this decade could be significantly improved.

5.2.3 Sustainability Indicators

The potential for runoff, drainage and soil loss are similar for cotton and sorghum (Figures 37,38 and 39).

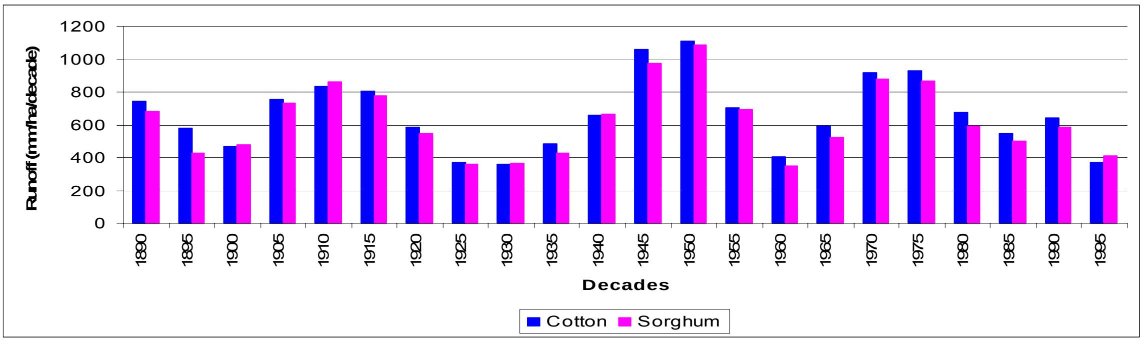


Figure 37 Total modelled runoff per decade at Emerald from monoculture cotton and sorghum grown on a 150mm PAWC soil

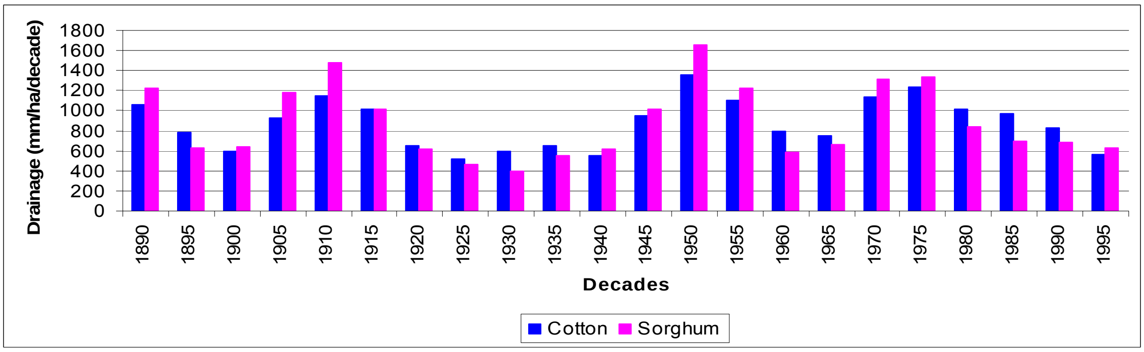


Figure 38 Total modelled drainage per decade at Emerald from monoculture cotton and sorghum grown on a 150mm PAWC soil

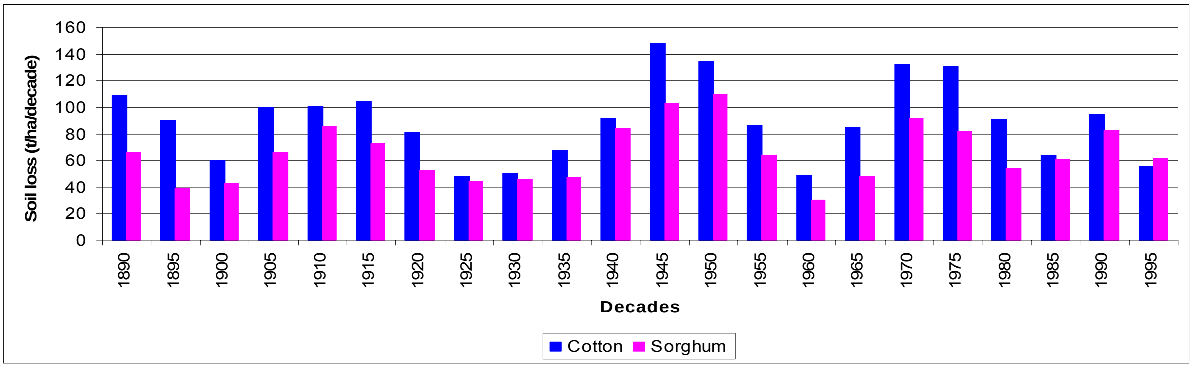


Figure 39 Total modelled soil loss per decade at Emerald from monoculture cotton and sorghum grown on a 150mm PAWC soil

5.2.4 Monoculture cotton response to climate phenomena at Emerald

SOI phase

Annual gross margins for dryland cotton production at Emerald have been separated based on the phase of the SOI in September of the planting year (Figure 40).

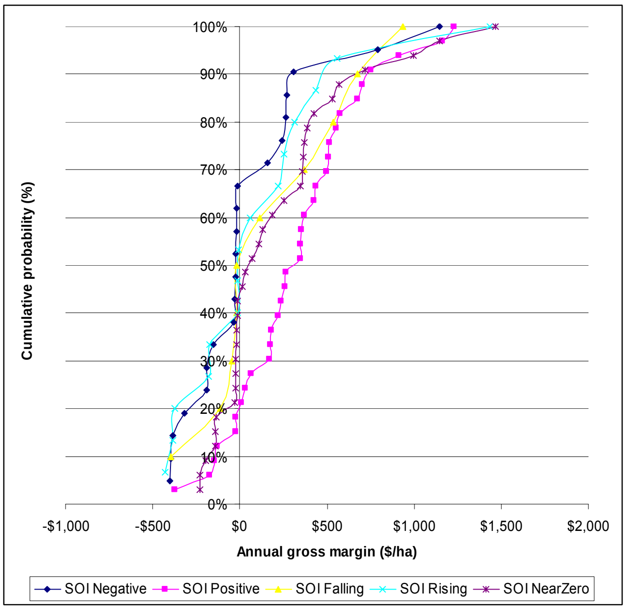


Figure 40 Dryland cotton gross margin distributions at Emerald on a 150mm PAWC soil separated on the basis of the SOI phase in September of the year of planting.

The returns from cotton may be more reliable/less risky if planted after the SOI phase was positive in September. Sorghum showed a similar response.

ENSO classification

Annual gross margins for dryland cotton production at Emerald were separated on the basis of the ENSO classification in the year of planting (Figure 41)

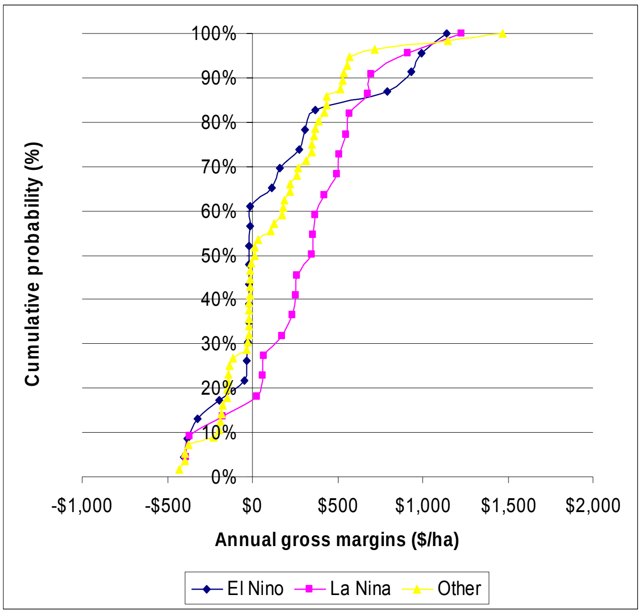


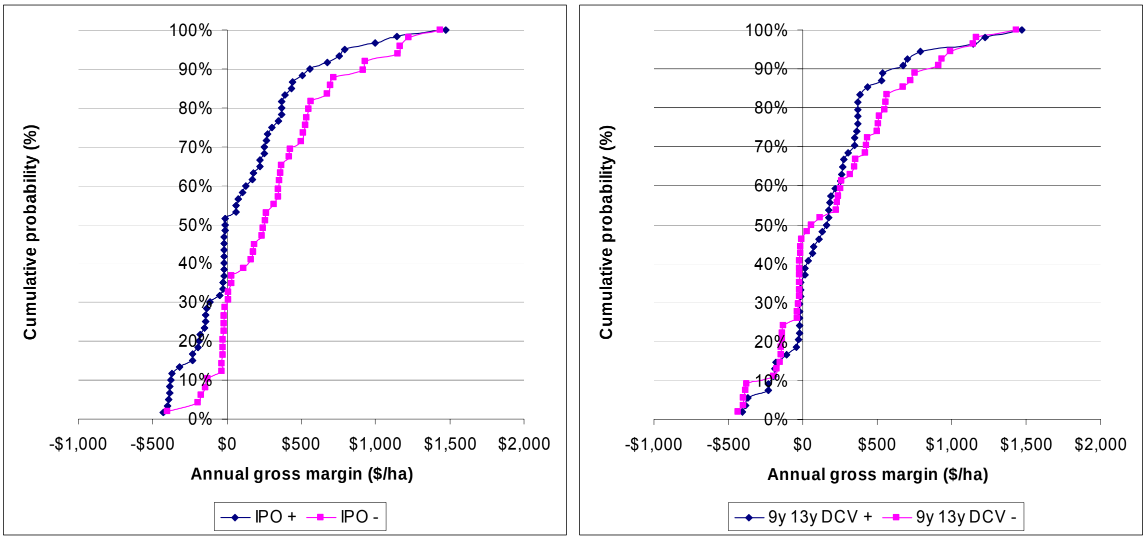
Figure 41 Annual gross margins for monoculture cotton production at Emerald separated on the basis of ENSO classification of the year of planting (a) and year of harvest (b).

Cotton appears to be relatively less risky if planted in La Nina years. (Figure 41) Those plantings that coincide with El Nino years seem to suffer consistently negative gross margins. The slightly negative nature of the gross margins could be due to either a poor yield or a failure to plant. The comparison of El Nino planting years and SOI negative in September planting years (Figure 40 and 41) also show the same similarities as exhibited by sorghum planted in those years.

9y 13 y DCV Index and IPO

To test whether dryland cotton production at Emerald responded to the different phases of the 9y 13y DCV index and IPO, annual gross margins were separated on the basis of the value of the index in December of the year of planting.

Cotton gross margins showed a statistically significant response to the phase of the IPO. The IPO index shows a median gross margin of about $0 per ha in positive years (+) years and a median gross margin of $260 per ha in negative (-) years. The IPO index also indicates that the chance of suffering a negative gross margin increases from about 35% of years when the index has a negative (-) value to 50% of years when the index has a positive (+) value.



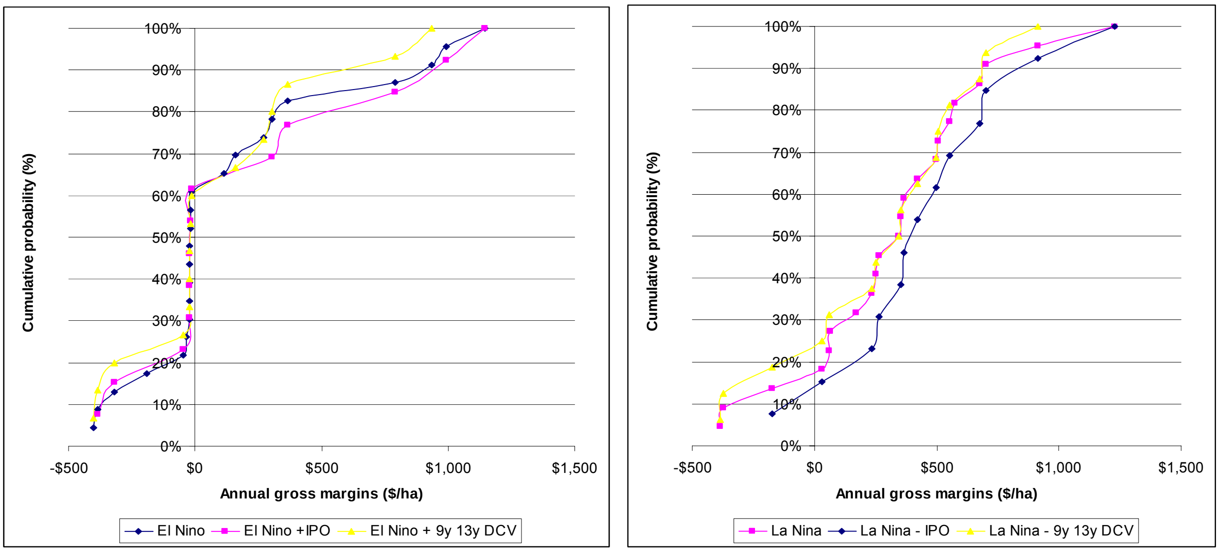
(a) (b)

Figure 42 Distribution of annual dryland cotton gross margins for the (a) IPO and (b) the 9y 13y decadal index

The phase value of the 9y 13y DCV index does not differentiate annual cotton gross margins at Emerald.

Interactions between ENSO and DCV indices at Emerald

There is no statistically significant interaction between the various ENSO classifications and the tested phases of the DCV indices even though the La Nina -IPO interaction seems to increase the reliability of cotton above that of La Nina years alone.

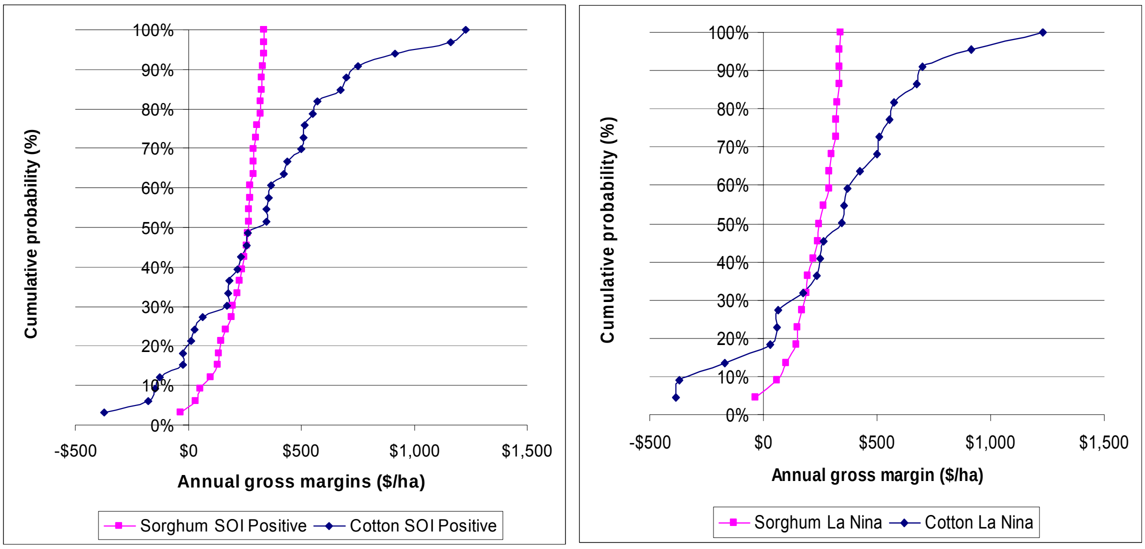


(a) (b)

Figure 43 Distributions for monoculture cotton annual gross margin at Emerald on a 150mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

Interaction between sorghum and cotton forecasts

For a dryland sorghum producer at Emerald to replace some dryland sorghum with dryland cotton on the basis of a climate forecast, the production risks associated with dryland cotton would have to be significantly reduced by the forecast and the chances of a payoff not reduced.



(a) (b)

Figure 44 Annual gross margins for cotton and sorghum in SOI positive planting years (a) and La Nina planting years (b)

Figure 40 showed dryland cotton would be relatively more reliable in planting years when the SOI phase was positive in September. Figure 41 showed that dryland cotton would be relatively more reliable in planting years that coincided with La Nina years.

Figure 44 compares the outcome for cotton and sorghum in SOI positive years and the outcome for cotton and sorghum in La Nina years.

The reduction in the overall riskiness of cotton in the years that the SOI is positive in September may encourage many farm managers to consider replacing some sorghum with cotton.

Planting cotton and not sorghum into a summer cropping window is expected impact on the following cropping opportunities differently to planting sorghum. The cropping systems impact of substituting cotton for sorghum when the SOI phase was positive in the month prior to cotton planting was tested using APSIM.

Since 1890 there have been 47 times when the SOI phase was positive in either the month of September, October or November. APSIM substituted cotton for sorghum 26 times out of the available 47 climate signals. Cotton was substituted if the planting rules for cotton were met and the SOI phase was positive in the month prior to the cotton planting opportunity arising.

Whenever a cotton crop was not planted, sorghum was planted.

The economic impact of the decision within any decade is measured as the difference between the cotton and sorghum gross margin in the year after the crop is planted plus the impact on subsequent sorghum or cotton crops of having a cotton crop and not a sorghum crop planted in the previous cropping window.

Table 8 Number of cotton crops planted per five-year period and per overlapping decade

Five year frequency		No Cotton crops
1890	1894	2
1895	1899	0
1900	1904	0
1905	1909	3
1910	1914	1
1915	1919	2
1920	1924	0
1925	1929	1
1930	1934	1
1935	1939	1
1940	1944	0
1945	1949	2
1950	1954	2
1955	1959	2
1960	1964	1
1965	1969	0
1970	1974	2
1975	1979	1
1980	1984	1
1985	1989	2
1990	1994	0
1995	1999	2
	Total	26

Decadal Frequency		No Cotton Crops
1890	1899	2
1895	1904	0
1900	1909	3
1905	1914	4
1910	1919	3
1915	1924	2
1920	1929	1
1925	1934	2
1930	1939	2
1935	1944	1
1940	1949	2
1945	1954	4
1950	1959	4
1955	1964	3
1960	1969	1
1965	1974	2
1970	1979	3
1975	1984	2
1980	1989	3
1985	1994	2
1990	1999	2
	Median	2

In any decade analysed, the frequency of cotton crops had a range from 0 to 4 with a median of 2. (Table 8)

The impact of adding cotton to a sorghum cropping system at Emerald when the SOI phase is positive prior to planting and cotton planting requirements are met generally improves decadal returns. (Figure 45) The decades beginning 1925 and 1930 both added two cotton crops and reduced the returns for the decade when compared to just growing sorghum alone. Just adding one cotton crop in the decade beginning 1935 cost about $380 per hectare. If the farm manager at Emerald had substituted 1000ha of sorghum with cotton on the basis of the forecast, the business would have been $380,000 worse off over the decade.

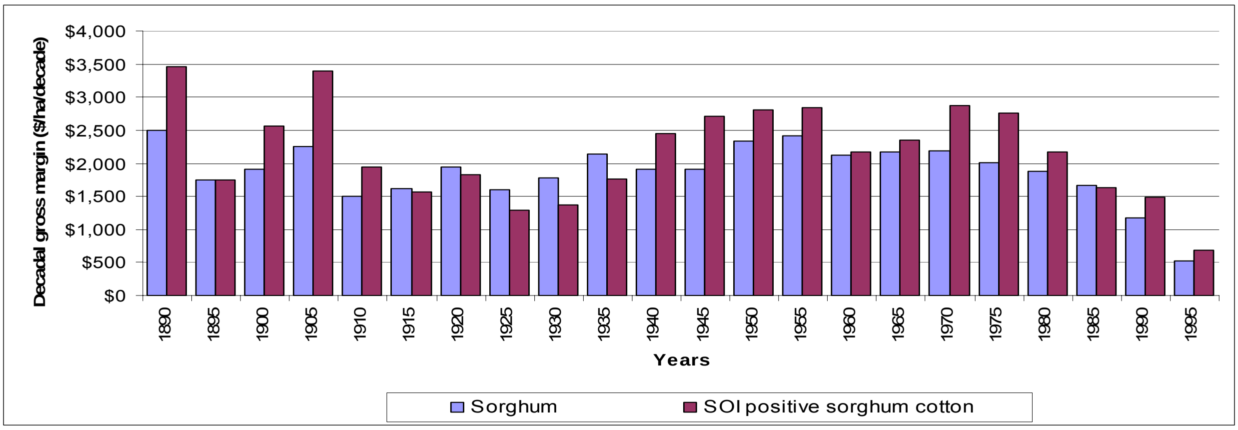


Figure 45 Total gross margins per decade for monoculture sorghum and sorghum with cotton at Emerald based on a positive SOI in the month prior to planting

Substituting cotton for sorghum on the basis of the SOI positive phase in the month prior to cotton planting would not have lost money over any decade since 1940.

The riskiness of the decision on a crop by crop basis can be considered by comparing the distribution of gross margins for sorghum with the distribution of gross margins for sorghum and cotton. (Figure 46a) and the distribution of difference in gross margin between cotton and sorghum (or the net benefit) for those years when cotton was planted (Figure 46b)

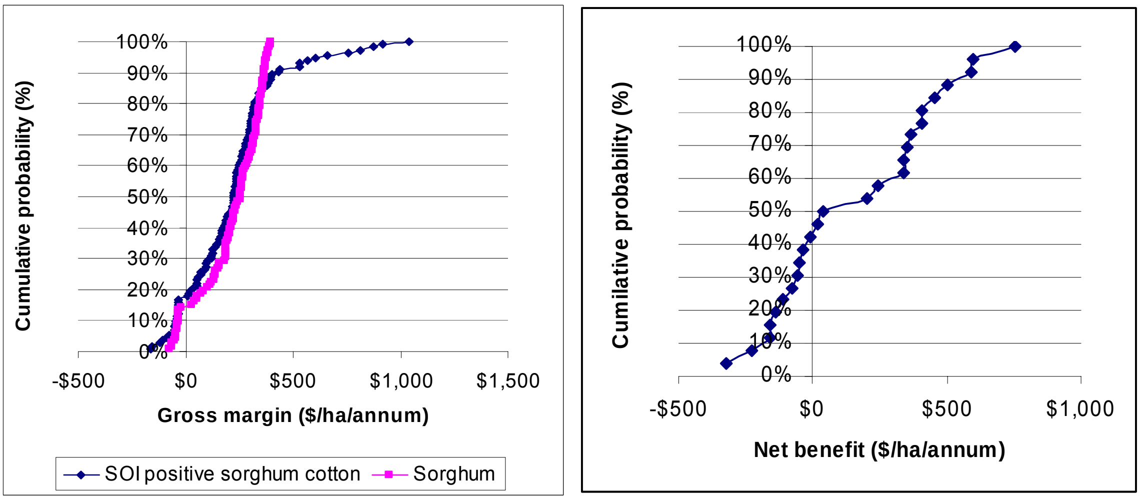


Figure 46 Monoculture sorghum and SOI responsive sorghum and cotton at Emerald

Including cotton on the basis of a SOI positive phase prior to cotton planting increases the risk of a negative gross margin in about 5% of years overall. The strategy has the potential to improve returns in about 10% of years or about once every decade. On a crop by crop basis, the decision to plant cotton would only improve returns in about 50% of years.

This forecast system seems to significantly reduce, but not eliminate, the risk of dryland cotton growing at Emerald.

5.3 Monoculture wheat

Monoculture wheat is an alternative cropping system to both monoculture sorghum and monoculture cotton at Emerald.

The planting window for wheat opened on the 15th of April and closed on the 30th of June. Wheat was planted if 15mm of rain fell over ten days (or less) in the sowing window and the soil plant available water was greater than 75mm. The soil surface layer also had to be suitably dry for planting operations to be undertaken.

5.3.1 Wheat Yields

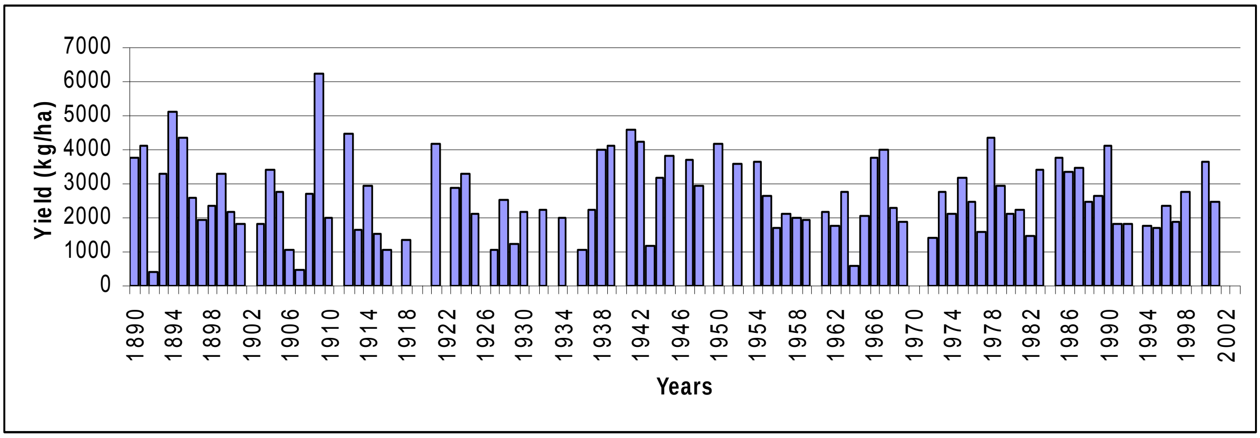
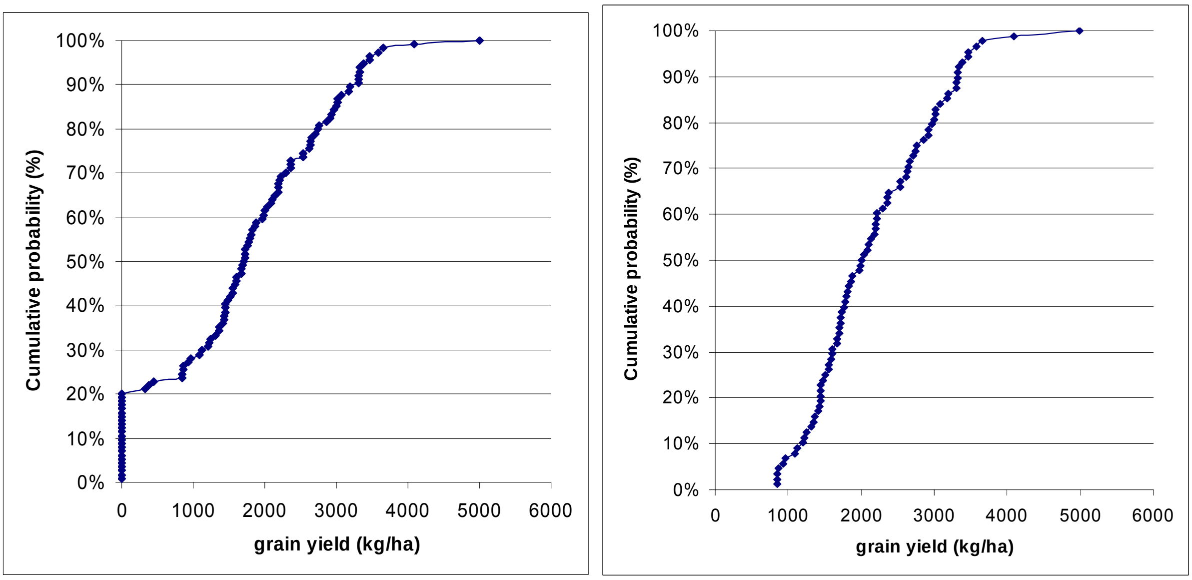


Figure 47 Wheat yields at Emerald on a 150mm PAWC soil (plant years 1890 to 2003)

Wheat has been relatively more reliable during the last half of the 20th Century than the first half of the 20th Century. It was also relatively reliable during the last few years of the 19th Century modelled.



(a) (b)

Figure 48 Yield for monoculture wheat grown on a 150mm PAWC soil at Emerald (a) all years yields and (b) years planted yields

The fertiliser strategy chosen for this analysis seemed to produce a typical range of wheat yields (Figure 47, 48) and proteins (Figure 49).

5.3.2 Wheat proteins

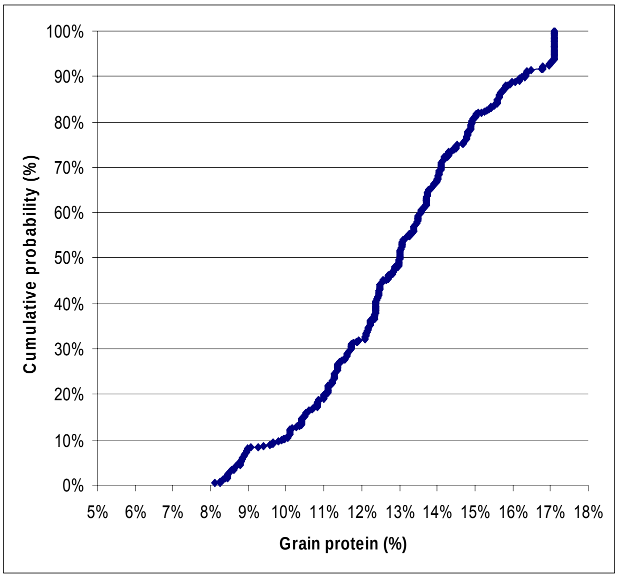


Figure 49 Grain protein for monoculture wheat grown on a 150mm PAWC soil at Emerald

5.3.3 Wheat reliability

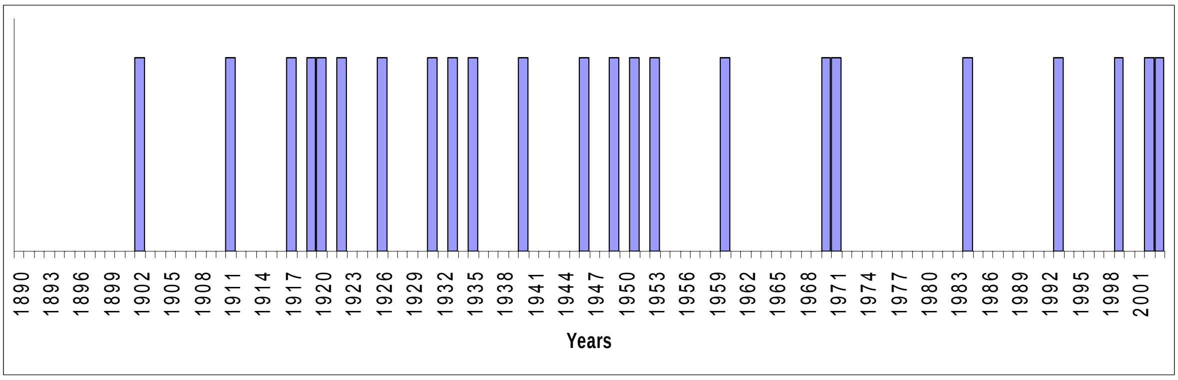


Figure 50 Wheat missed planting events at Emerald on a 150mm PAWC soil (plant years 1890 to 2003)

Modelled wheat was not planted at Emerald once every five years on average over the total climate record. Since the start of major dryland farming activities (about 1950) the frequency of missed opportunities has been slightly lower at once every seven to eight years. About one out of three planting windows closed without a wheat planting opportunity being received in the period from 1900 to 1950.

5.3.4 Wheat prices

Wheat prices and premiums for protein are highly variable. The crop is also subject to price downgrades for screenings caused by undersized grain and harvest damage.

A price scale has been selected to allow wheat, sorghum and cotton to be reasonably comparable on price. (That is, we have selected expected values - not current values.) Hopefully the selection of prices will allow comparison of the crops across seasons for the purposes of valuing the impact of climate forecasts and the suitability of using seasonal forecasts to swap between summer and winter cropping systems.

Table 9 Estimated on farm wheat price at Emerald

Wheat Price		
Protein %	**$ /ton on farm**	
7.00%	$145.00	
7.50%	$145.00	
8.00%	$145.00	
8.50%	$145.00	
9.00%	$145.00	
9.50%	$145.00	Feed
10.00%	$160.00	ASW 10
10.50%	$162.50	
11.00%	$165.00	
11.50%	$167.50	
12.00%	$170.00	AH (12%)
12.50%	$172.50	
13.00%	$180.00	PH (13%)
13.50%	$182.50	
14.00%	$185.00	PH (14%)
14.50%	$187.50	
15.00%	$190.00	

5.3.5 Wheat gross margins

APSIM estimates of wheat yield and protein were combined with the price data shown in table 9 to calculate annual gross income from wheat growing. The variable costs of each crop we calculated on the basis of the costs shown in Appendix 1 to determine the per crop and annual gross margin for wheat growing.

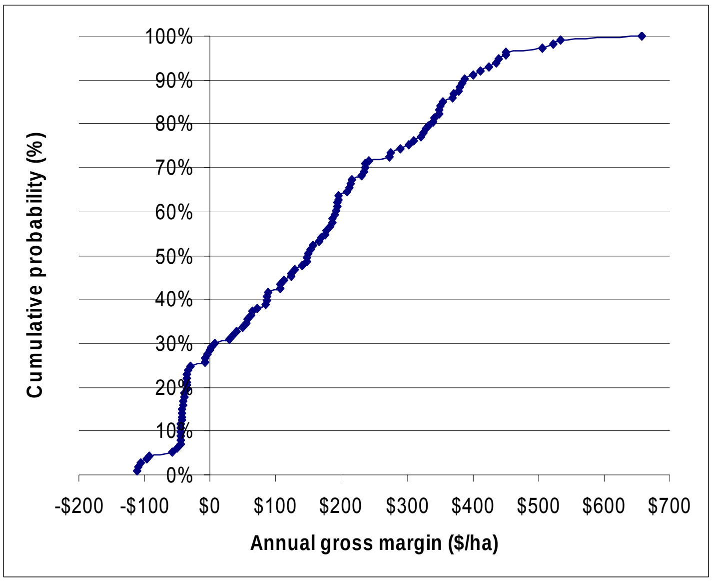


Figure 51 Distribution of annual dryland wheat gross margins at Emerald on a 150mm PAWC soil, all years.

Modelled dryland wheat at Emerald on a 150mm PAWC soil would have produced negative gross margins in about 30% of the years from 1890 to 2003 at the level of prices chosen and yields modelled. (Figure 51) In 20% of years the potential gross margin would have been greater than $350 per hectare.

5.3.6 Sustainability Indicators

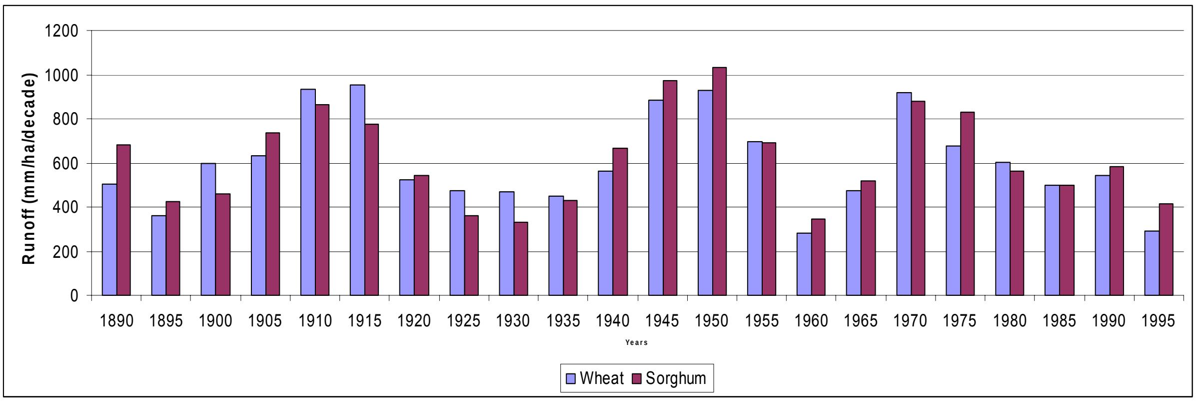


Figure 52 Total modelled runoff per decade at Emerald from monoculture sorghum and monoculture wheat grown on a 150mm PAWC soil.

APSIM outputs indicate that monoculture wheat and monoculture sorghum would have had similar levels of runoff in this environment. All simulations begin with 1.5 t/ha of crop residue. Residue levels are then calculated by APSIM on a daily basis and reported as the simulation progresses.

The inability of either cropping system to effectively use the extra water provided during the more favourable rainfall periods is evident.

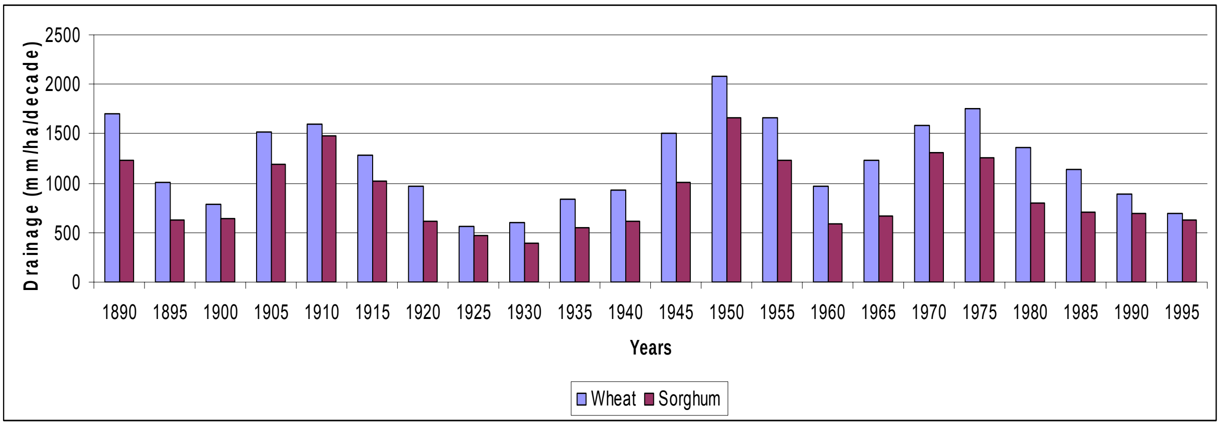


Figure 53 Total modelled drainage per decade at Emerald from monoculture sorghum and monoculture wheat grown on a 150mm PAWC soil.

Wheat consistently shows more drainage than sorghum suggesting that its stubble does catch some of the summer dominant rainfall that sorghum may use for growth. Unfortunately APSIM predicts that wheat does not effectively use all its stored water and some is potentially lost through drainage.

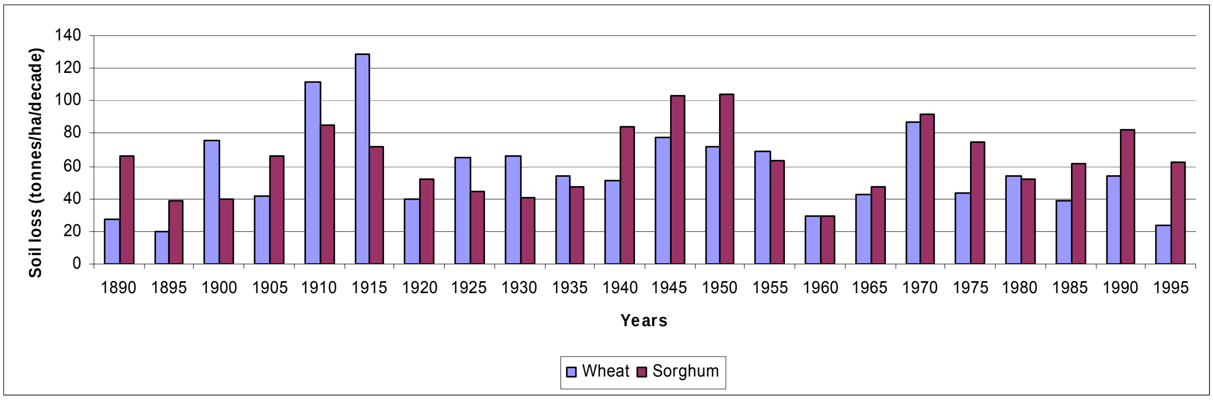


Figure 54 Total modelled soil loss per decade at Emerald from monoculture sorghum and monoculture wheat grown on a 150mm PAWC soil.

In total or on average there is little difference between monoculture wheat and sorghum in any of the indicators over the period from 1890 to 2003. Within individual decades some differences arise from variations in the seasonal distribution of rainfall.

5.3.7 Monoculture wheat response to climate phenomena at Emerald

The modelled total gross margins for both wheat and sorghum for the decades from 1890 to 1995 show considerable variability due to climate (Figure 55). Decades overlap by five years.

Note that the decade beginning in 1995 is short, the result of one cropping season for wheat (winter 2004) and two cropping seasons for sorghum (summer 2003-4 and 2004-5).

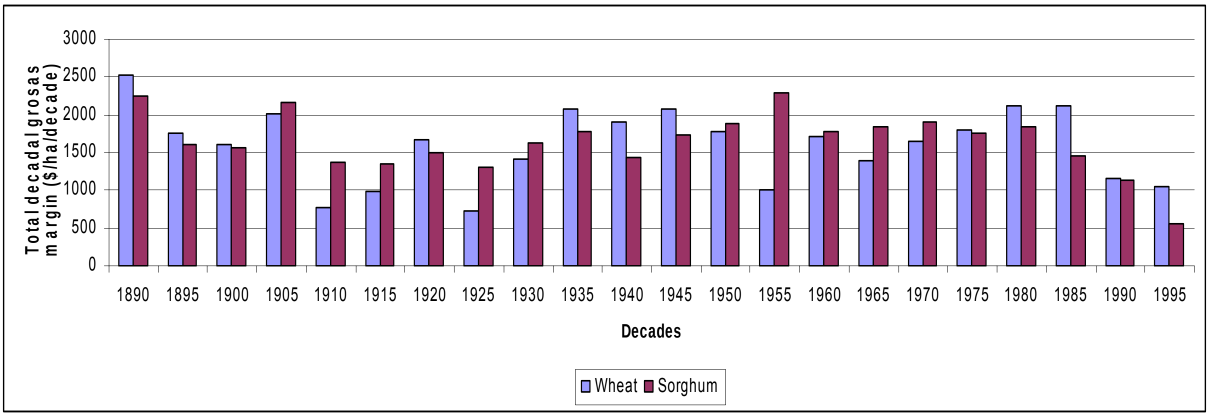


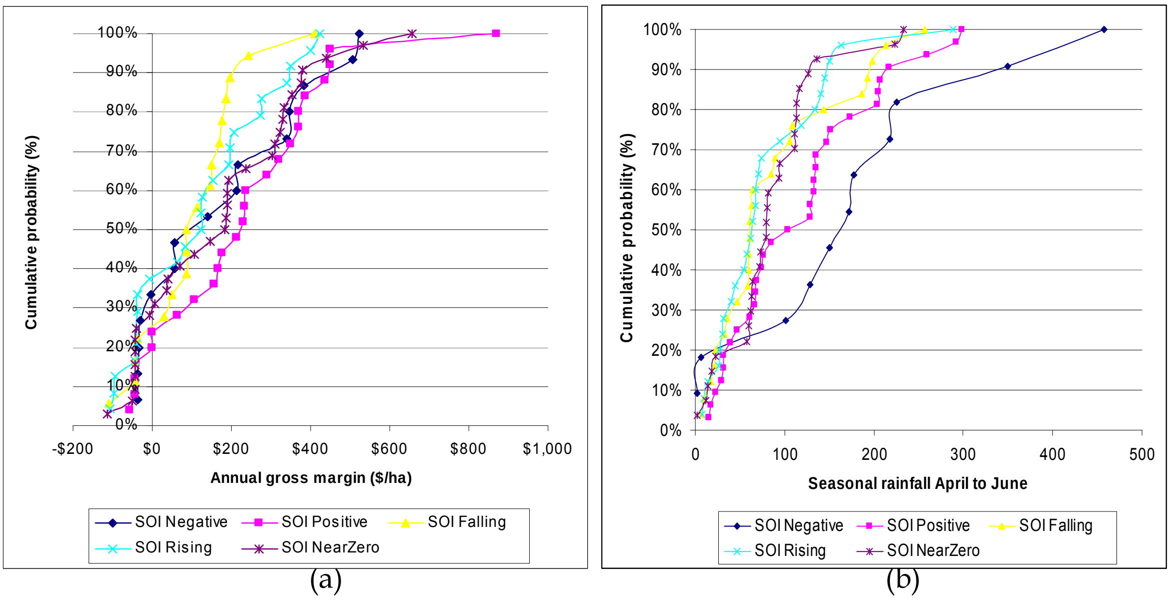
Figure 55 Decadal gross margins for monoculture sorghum and wheat at Emerald on a 150mm PAWC soil.

All five decadal gross margins after 1975 show wheat performing as well as sorghum if not better in this environment. Wheat only outperforms sorghum in six occasions out of the seventeen decades modelled prior to 1975.

SOI phase

Dryland wheat gross margins do show some differentiation when separated on the basis of the SOI phase in March. (Figure 56a) The March phase has been chosen because important wheat management decisions must be made by this time in CQ although it is generally considered that forecast skill using the SOI phases gets better after this date and increases up to the end of May.

Rainman version 4.3 was used to look at seasonal rainfall (April May June) based on the SOI phase value at the end of March. Rainman reports the SOI negative phase to be highly significant (although in an unexpected direction) and the SOI neutral phase to be significant. (Figure 56b)



(a) (b)

Figure 66 (a) Monoculture wheat yield distributions at Emerald on a 150mm PAWC soil separated on the basis of the SOI phase in March of the year of planting and (b) April to June rainfall distributions at Emerald separated on the basis of the phase of the SOI in March.

The median rainfall at Emerald in the three months after the SOI phase is positive in March is only about □ of the medial rainfall after the SOI phase is negative in March (Figure 56b).

The median gross margin produced when the SOI phase is negative in March will be about half that produced when the SOI phase is positive (Figure 56a). This is almost an opposite relationship to the rainfall distribution shown in Figure 56b.

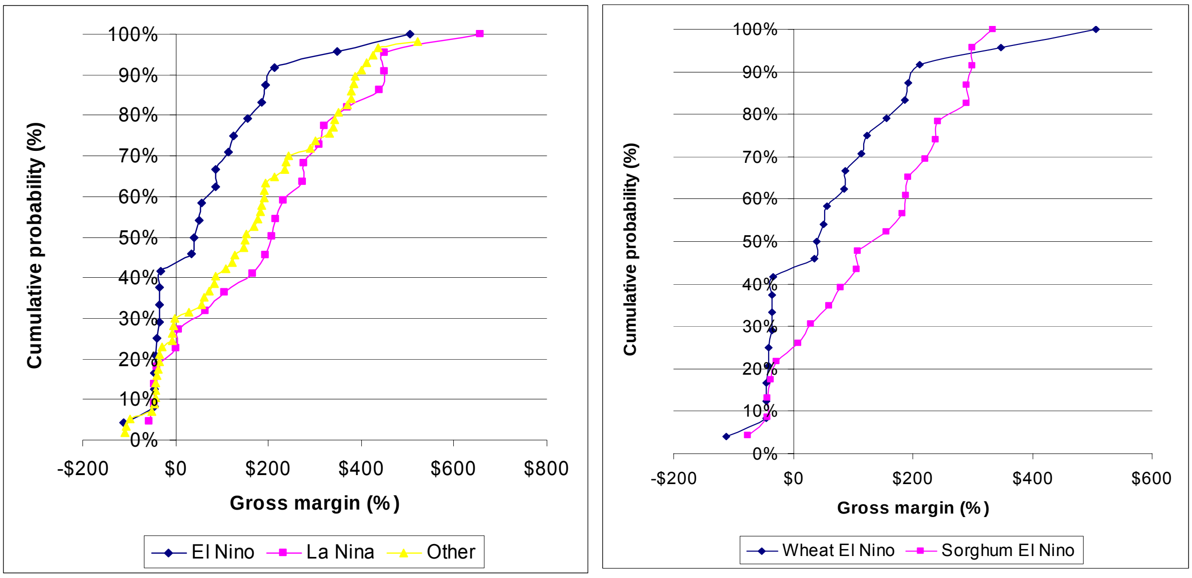
Most of the differences between the rainfall and gross margin distributions are thought to be due to the combination of a fairly wide planting window for wheat at Emerald and uncertain planting rains. In many years wheat was not planted until either May or June.

A comparison of figures 56a and 56b is probably not valid for this reason.

ENSO classification

Annual gross margins for dryland wheat production at Emerald were separated on the basis of the ENSO classification in the year of planting (Figure 57).

A calendar year receives its ENSO classification after about mid December and the classification then applies for the entire year. Even though we have separated the wheat gross margins on the basis of the ENSO classification at planting, the classification would not be known until about eight months after planting. The value of knowing the classification earlier through building a forecast model is what is considered here.



(a) (b)

Figure 57 (a) Annual gross margins for monoculture wheat production at Emerald separated on the basis of ENSO classification of the year of planting. (b) Annual gross margins at Emerald for Wheat and Sorghum planted in El Nino years

The capacity to predict the occurrence of an El Nino year may be of value to wheat farmers at Emerald.

The availability of an accurate forecast for an ENSO event prior to or during the early part of the winter planting window (up to the 1st two weeks of April) would allow time for farmers to reallocate land from winter crop production to summer crop production. Waiting for a summer crop would delay the receipt of income by 6 months but could significantly improve the income that was received. (Figure 57b)

In years forecast to be La Nina's the choice between planting wheat now or holding on for sorghum would not be so clear and the cropping choice is more likely to be made on the basis of price expectations than the forecast season. (Figure 58)

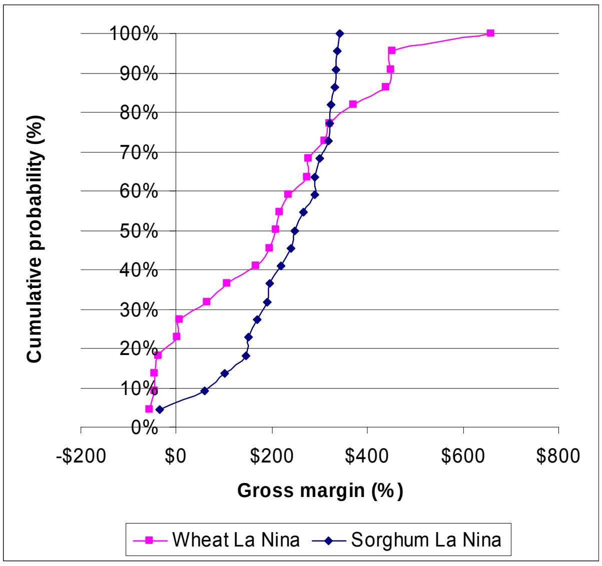
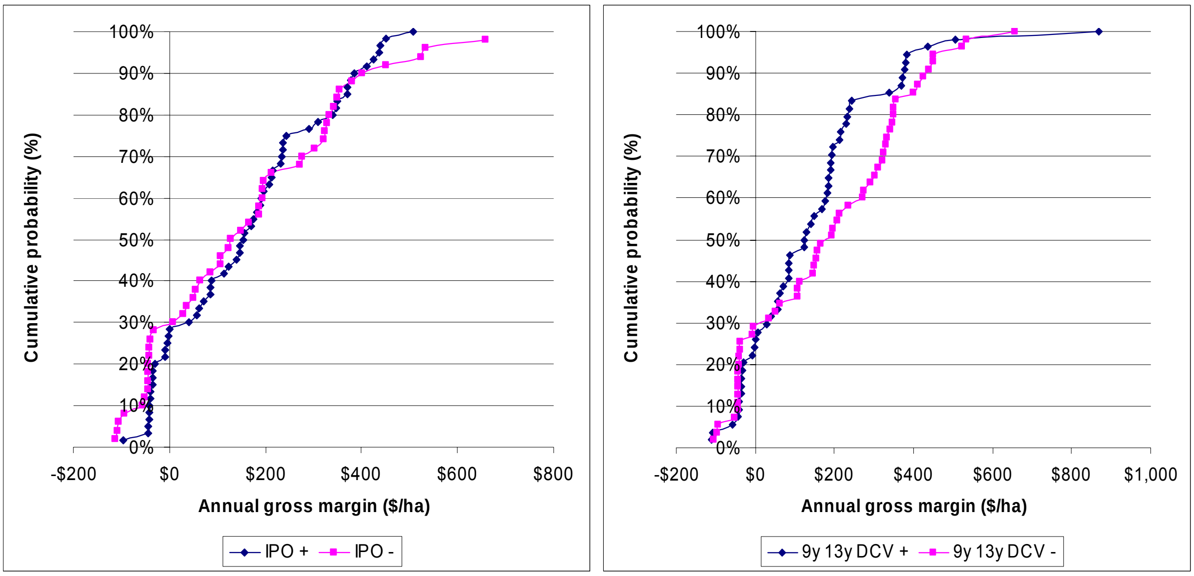


Figure 58 Modelled annual gross margins for wheat and sorghum planted in La Nina years.

9y 13 y DCV Index and IPO

To test whether dryland wheat production at Emerald responded to the different phases of the 9y 13y DCV index and IPO index, annual gross margins were separated on the basis of the value of the index in January of the year of harvest (Figure 59). Neither the phase of the IPO or the phase of the 9y 13y DCV index showed any statistically significant difference.

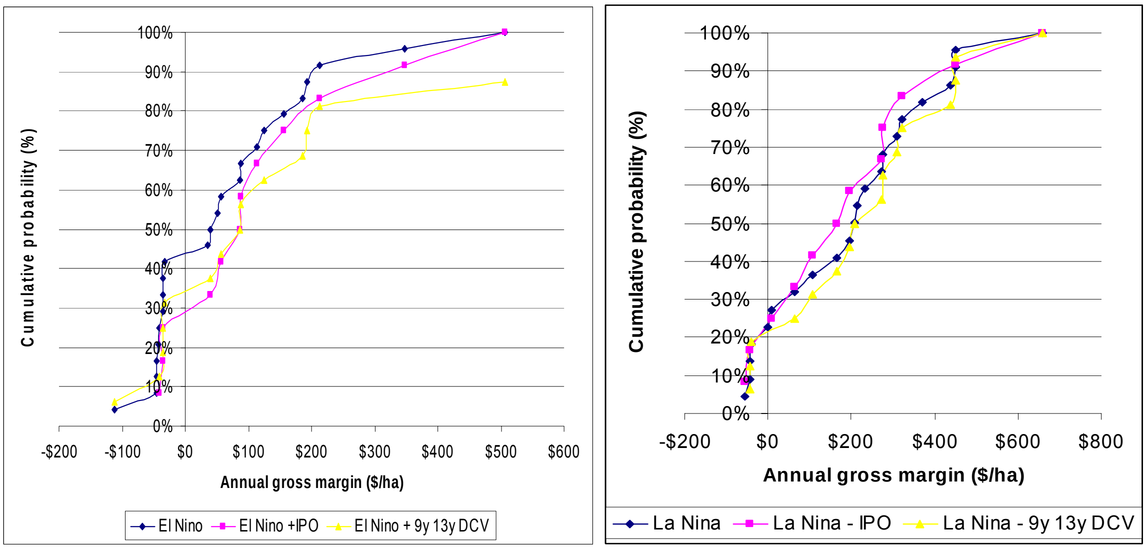


(a) (b)

Figure 59 Distribution of annual dryland sorghum gross margins for the (a) IPO and (b) the 9y 13y decadal index

Interactions between ENSO and DCV indices at Emerald

When an El Nino event coincided with the positive phase of the IPO or the positive phase of the 9y 13y DCV index annual gross margin was increased (Figure 60a). No significant impact on the modelled gross margin was evident when the negative phase of the IPO and 9y 13y DCV index coincided with a La Nina year (Figure 60b).



(a) (b)

Figure 60 Distributions for monoculture wheat annual gross margin at Emerald on a 150mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

5.3.8 Summary of wheat

Wheat monoculture responds to the ENSO classification and possibly the SOI phase forecast system.

At current prices sorghum outperforms wheat in a majority of decades but recent decades show that wheat can perform as well as sorghum if soil fertility and protein premiums are adequate.

The lack of real difference in sustainability indicators between sorghum and wheat cropping systems suggests that a more intense cropping system that takes advantage of favourable rainfall periods may be the only way to show improvement in any of these indicators.

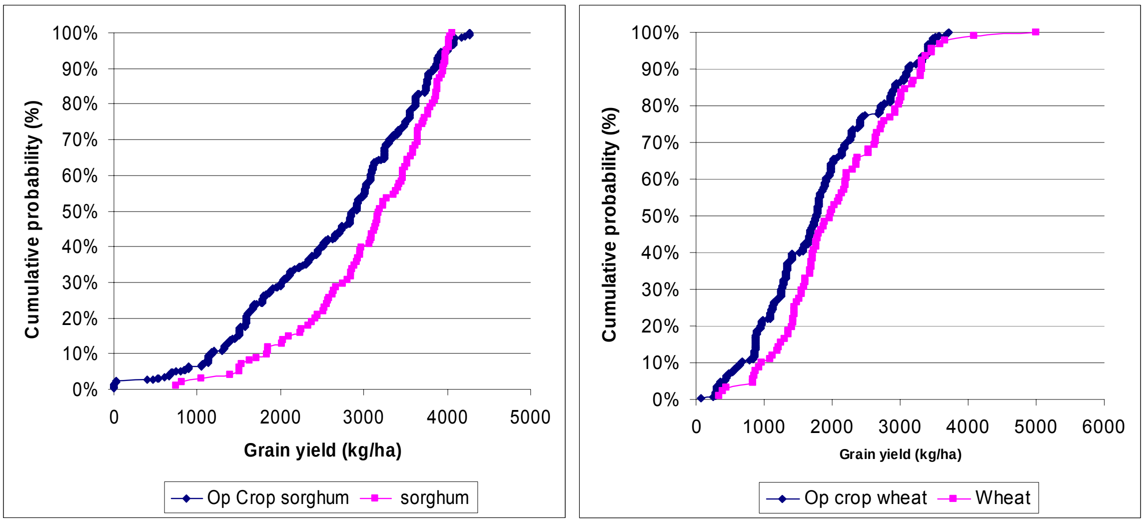
5.4 Opportunity cropping sorghum and wheat

Opportunity cropping sorghum and wheat is a cropping system designed to maximise cereal planting opportunities over any period of time.

This cropping system has been modelled on the basis that planting opportunities for either wheat or sorghum were to be taken when the planting window was open and rainfall plus stored soil water conditions were met.

The planting window and planting criteria for wheat were maintained as for the analysis of monoculture wheat. The planting criteria for sorghum were maintained but the planting window used was the combination of the early window (1st October to 15th December) and the more traditional window of (16th December to 15th February). This means that if conditions were suitable, sorghum was be planted at any time from the 1st of October to 15th of February.

5.4.1 Crop yields



(a) (b)

Figure 61 Distribution of sorghum yield (a) and wheat yield (b) on a 150mm PAWC soil at Emerald. Cropping systems modelled are monoculture wheat, monoculture sorghum and opportunity cropping sorghum and wheat.

Modelled sorghum yields for sorghum grown within opportunity cropping sorghum and wheat show a significant reduction in about 90% of years compared to modelled monoculture sorghum yields. (Figure 61a)

The modelled median yield for wheat grown within opportunity cropping sorghum and wheat is slightly reduced when compared to the median yield for monoculture wheat. (Figure 61b)

The median wheat protein percentage for wheat grown in the opportunity cropping system is reduced by about 1% when compared to the protein percent expected for monoculture wheat. (Figure 62) This reduction is probably due to the higher cropping frequency of opportunity cropping tending to reduce the available soil nitrate for protein production in wheat (at the level of N fertiliser used).

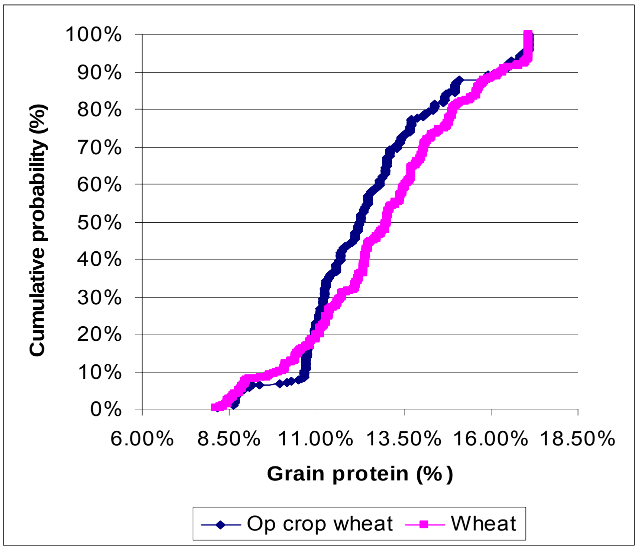


Figure 62 Distribution for grain protein in wheat at Emerald on a 150mm PAWC soil.

5.4.2 Cropping frequency

Sixteen double cropping sequences were achieved over the period 1975 to 2003. (Figure 63) This is more than was achieved in most previous sequences (data not shown). Changing the planting window for sorghum back to the traditional window may alter the relative frequency of sorghum and wheat crops but is not expected to alter the outcomes of the analysis.

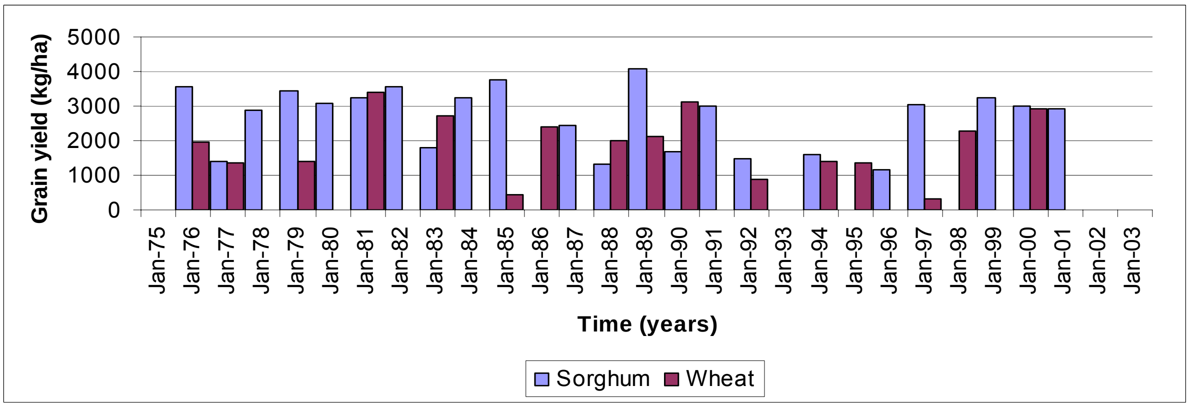


Figure 63 Cropping pattern and modelled yields for opportunity cropping sorghum and wheat at Emerald on a 150mm PAWC soil. (1975 to 2003 plant years)

The impact on crop yield of cropping frequency can be seen in figure 63.

5.4.3 Gross margins

Modelled opportunity cropping sorghum and wheat produced negative gross margins in about 10% to 15% of years. (Figure 64) 40% of years showed higher potential gross margins than those that could be produced by monoculture sorghum. In the remainder of years, the two cropping systems showed little difference.

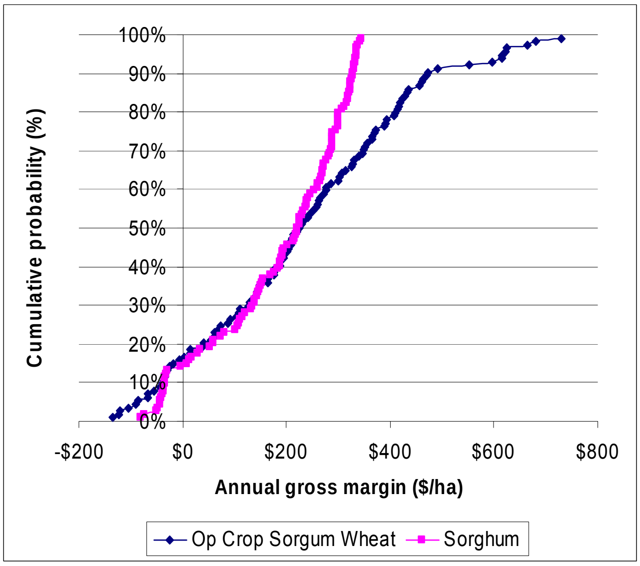


Figure 64 Cumulative distributions for monoculture sorghum and opportunity cropping sorghum and wheat on a 150mm PAWC soil at Emerald

The modelled individual annual gross margins for the opportunity cropping system show greater variability than the modelled individual gross margins for the monoculture sorghum system (Figure 65).

On some occasions the attempt to plant extra crops within the opportunity cropping system tended to increase costs and reduce returns. The extended El Nino event of the early 1990's favoured monoculture sorghum. At most other times, a farm business would have been no worse off and occasionally better off if extra planting opportunities had been taken when they presented themselves.

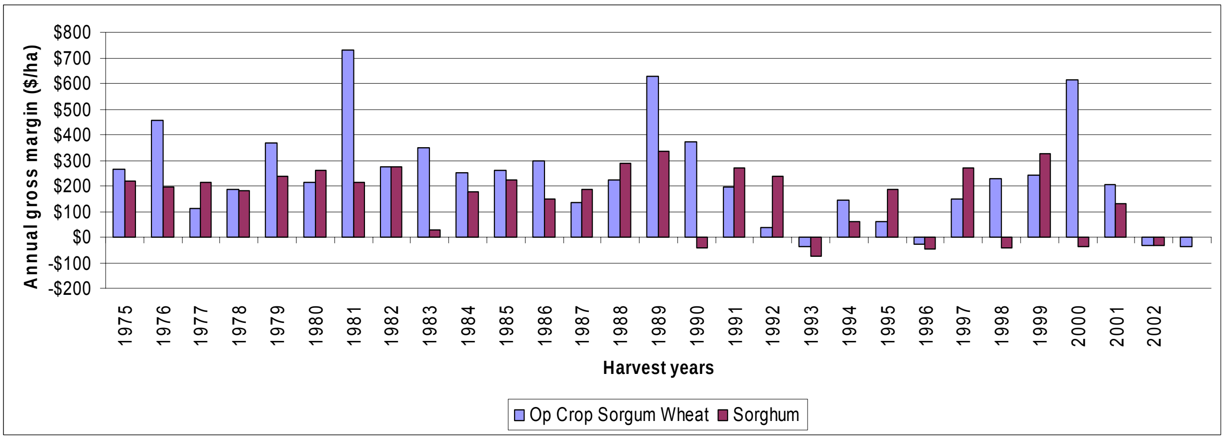


Figure 65 Modelled annual gross margins for monoculture sorghum and opportunity cropping sorghum and wheat at Emerald on a 150mm PAWC soil.

The best performing decades for sorghum are improved by adding opportunity crops of wheat (Figure 66). Note that 1905 actually produced a lower total gross margin if opportunity crops of wheat are added to the cropping mix.

The worst performing decade for opportunity cropping (1925) was improved by maintaining a monoculture sorghum approach to cropping.

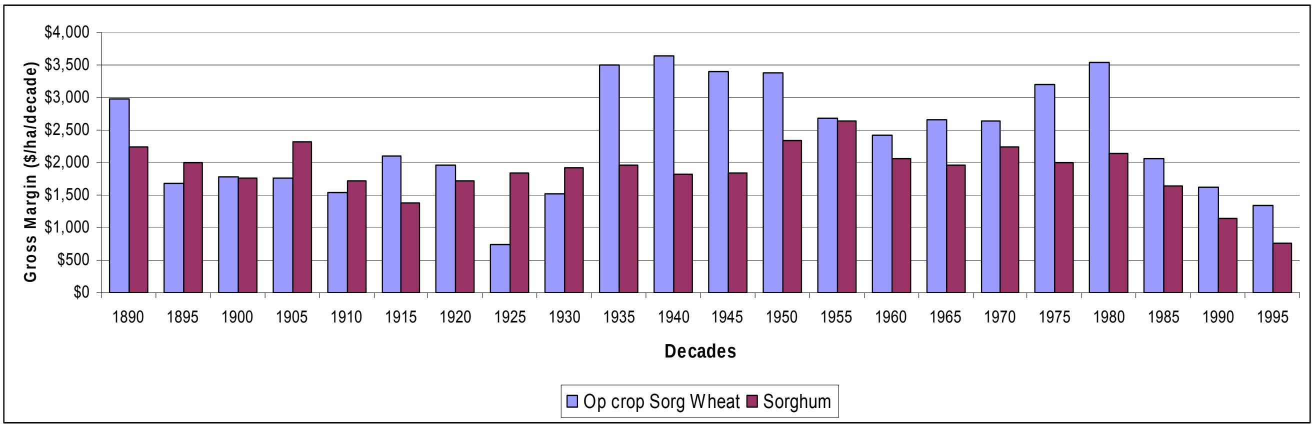


Figure 66 Modelled decadal gross margins for monoculture sorghum and opportunity cropping sorghum and wheat at Emerald on a 150mm PAWC soil

Opportunity cropping performs significantly better than monoculture sorghum on about seven occasions and significantly worse than monoculture sorghum on about four occasions. The remaining thirteen decades show little difference between the cropping systems.

5.4.4 Sustainability indicators

Opportunity cropped sorghum and wheat results in runoff at comparable or lower levels than other cereal cropping systems. It reduces potential drainage in most climate sequences and reduces potential soil loss. This would be expected because the additional crops produced under this system use excess water rather than loose it through runoff and deep drainage)

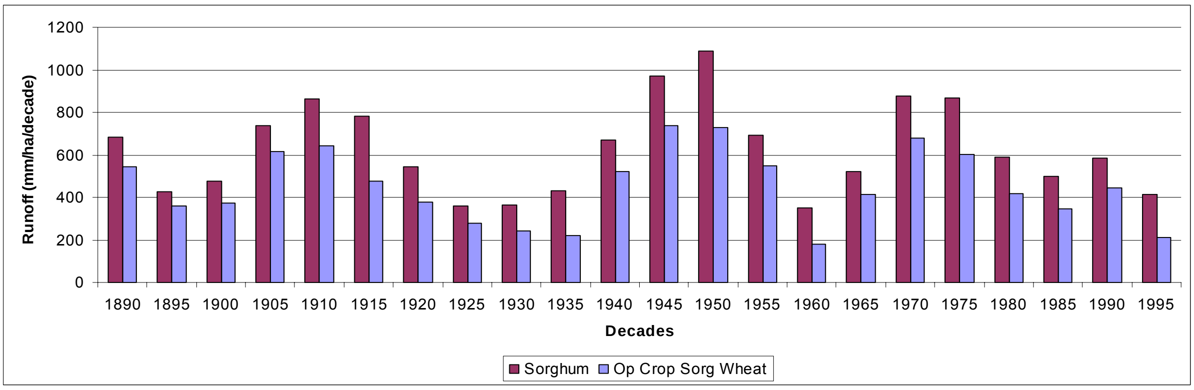


Figure 67 Modelled runoff for opportunity cropped sorghum and wheat compared to the modelled runoff for monoculture sorghum on a 150mm PAWC soil at Emerald

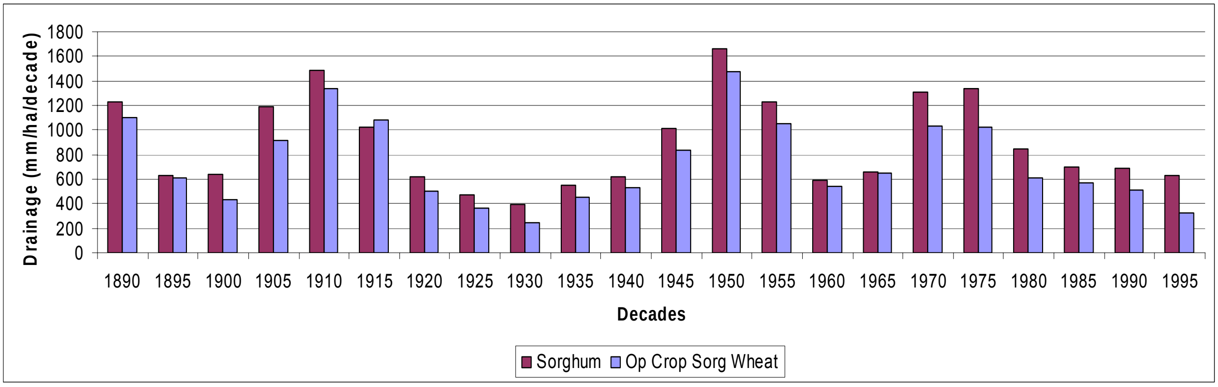


Figure 68 Modelled drainage for opportunity cropped sorghum and wheat compared to modelled drainage for monoculture sorghum on a 150mm PAWC soil at Emerald

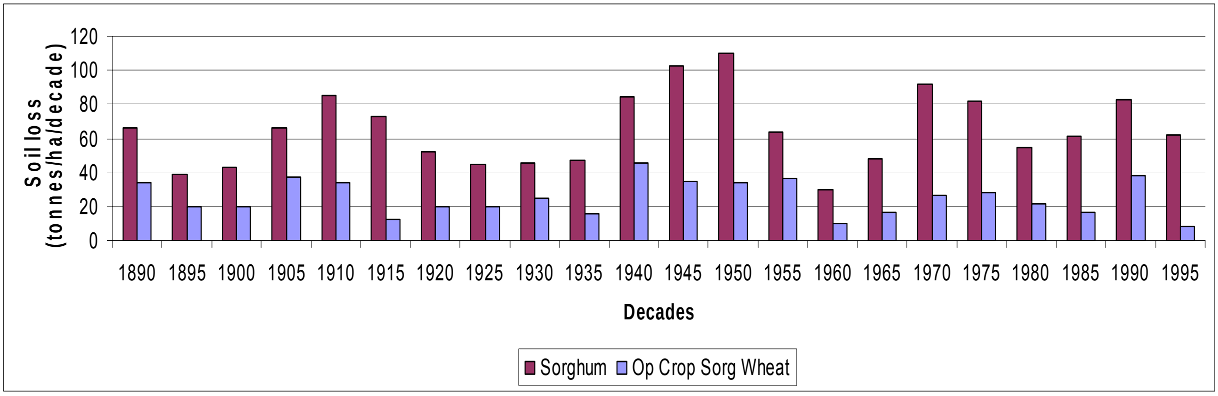


Figure 69 Modelled soil loss for opportunity cropped sorghum and wheat compared to modelled soil loss for monoculture sorghum on a 150mm PAWC soil at Emerald

5.4.5 Investment returns

A farmer currently growing sorghum with a low tillage or zero till farming system would not have to invest extra capital to implement the opportunity cropping sorghum and wheat cropping system.

The extra tractor hours needed to carry out the opportunity cropping system will range between about 500 hours per decade up to about 2500 hours per decade (Figure 70).

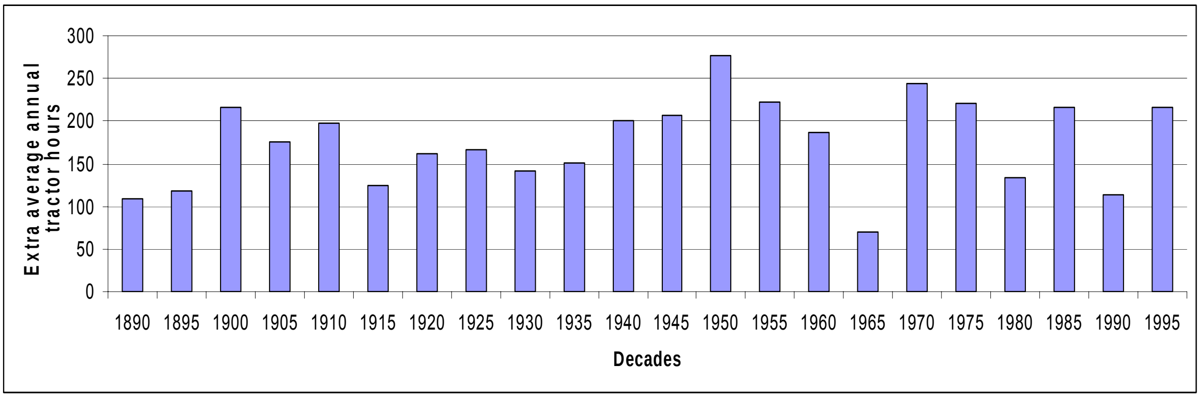


Figure 70 Modelled extra tractor hours per annum for opportunity cropping sorghum and wheat (above those for monoculture sorghum) at Emerald on a 150mm PAWC soil.

Most of the costs associated with these extra tractor hours are already accounted for in the gross margin calculation. For example, extra fuel and repairs are also included on a proportional basis.

The costs that may arise from replacing plant and equipment at shorter intervals due to increased use rates and the additional labour costs associated with the additional cropping activities have both been captured by compiling investment budgets for each scenario.

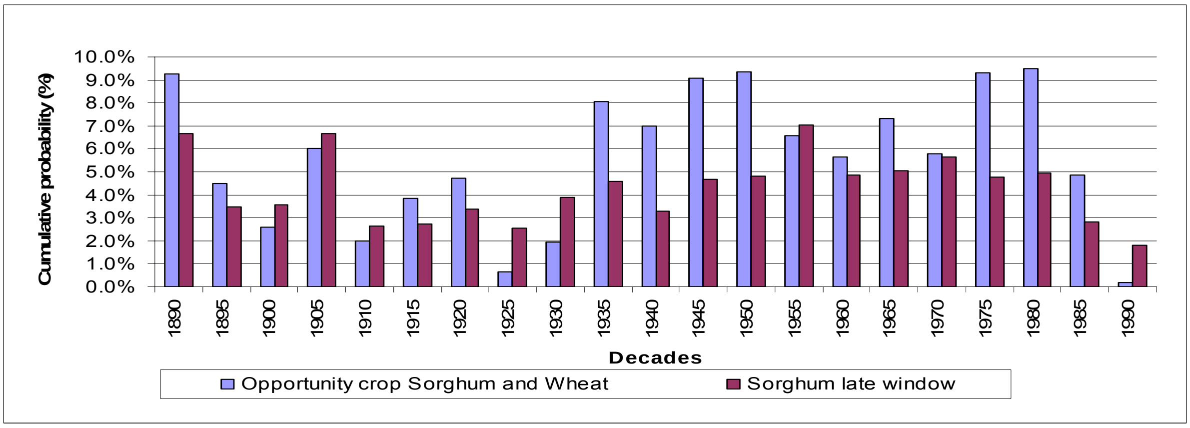


Figure 71 Modelled investment returns for monoculture sorghum and opportunity cropping sorghum and wheat at Emerald on a 150mm PAWC soil.

Although the investment budget is a more complete analysis tool that the decadal gross margin used previously, the relationship between the two cropping systems shown for total decadal gross margins is largely repeated within the investment returns. (Figure 71)

The incorporation of the extra costs not counted in the gross margin calculation proportionally reduces the returns generated by the opportunity cropping system. The potential investment returns for monoculture sorghum have also been relatively suppressed by the starting date selected for the modelling process. The opportunity cropping returns are still generally better than the returns available from the monoculture sorghum system although the decades that produce a poor return for opportunity cropping seem to show an improved performance by sorghum.

5.4.6 Opportunity cropping sorghum and wheat response to climate phenomena at Emerald

ENSO classification

Annual gross margins for modeled opportunity cropping at Emerald were separated on the basis of the ENSO classification the year of planting (Figure 72).

ENSO events do have an impact on the outcomes of the opportunity cropping system but the amount of impact is significantly less than that shown for monoculture cropping systems.

This lack of impact is mostly due to the ENSO classification being for the year of planting of the sorghum crop. Quite often the ENSO event may lose impact prior to the opportunity wheat crop that may follow the sorghum crop. It is thought that the losses on the sorghum crop may be picked up on the wheat crop leading to the lowered impact of ENSO events on the overall profitability of the cropping system.

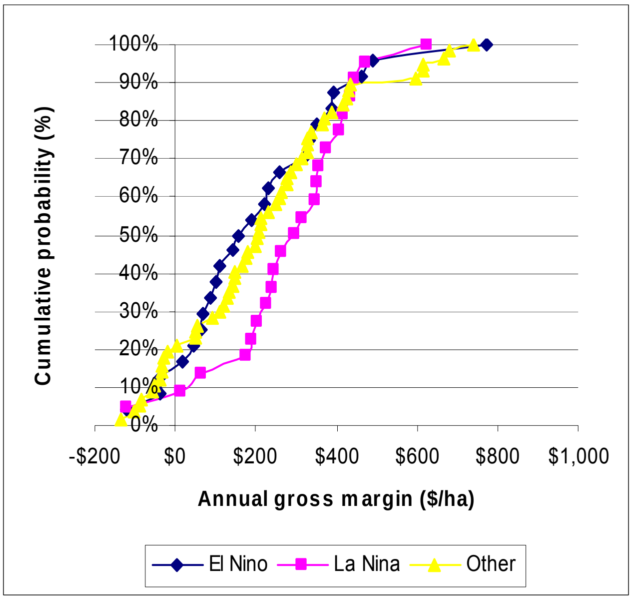
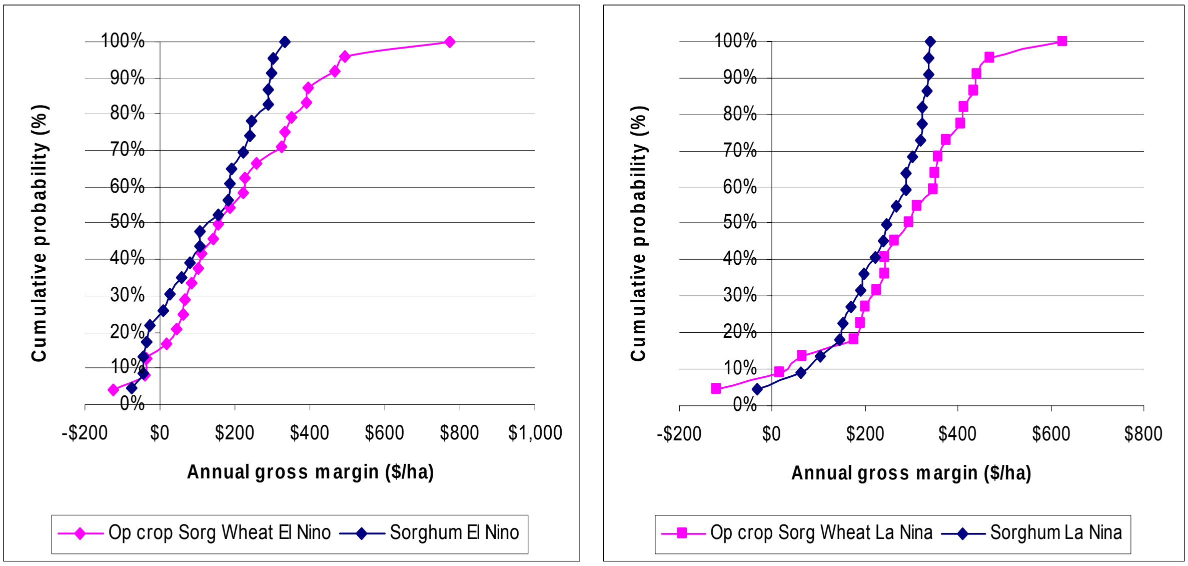


Figure 72 Annual gross margins for opportunity cropping sorghum and wheat at Emerald separated on the basis of ENSO classification of the year of planting.

Although gross margin returns are significantly different in El Nino and La Nina years, farm managers would be unable to use this knowledge to change the intensity of their cropping systems.

Maintaining an opportunity cropping system in El Nino years shows no significant reduction in gross margin or increase in risk compared to only planting a sorghum crop in those years (Figure 73a). Conversely, monoculture sorghum is outperformed by opportunity cropping in years classified as La Nina and opportunity cropping shows no greater degree of riskiness. (Figure 73b)



(a) (b)

Figure 73 Annual gross margins for opportunity cropping of sorghum and wheat and monoculture sorghum production at Emerald separated on the basis of ENSO classification of the year of planting (a) El Nino years and (b) La Nina years.

The opportunity cropping systems modelled in this exercise only plant crops when soil water and rainfall are adequate for a planting opportunity to be taken. More aggressive opportunity cropping systems that plant inside and outside the traditional planting windows on the basis of a seasonal forecast may show a larger forecast response but would also be expected to be more risky and less acceptable to farm managers.

SOI phase

Annual gross margins for opportunity cropping sorghum and wheat gross margins at Emerald were separated based on the phase of the SOI in September of the summer cropping season (Figure 74).

The SOI positive phase in September of the year of planting has a significant impact on the outcomes for opportunity cropping sorghum and wheat at Emerald.

To test the value of the SOI phase forecasting system in allowing decisions about cropping intensity to be made, the annual gross margins for opportunity cropping and monoculture sorghum were separated on the basis of the phase of the SOI in September of the planting year (Figure 75 a, b, c, d, and e).

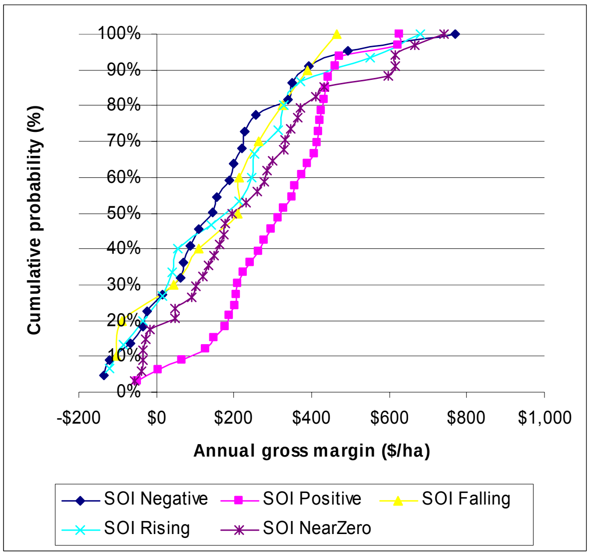
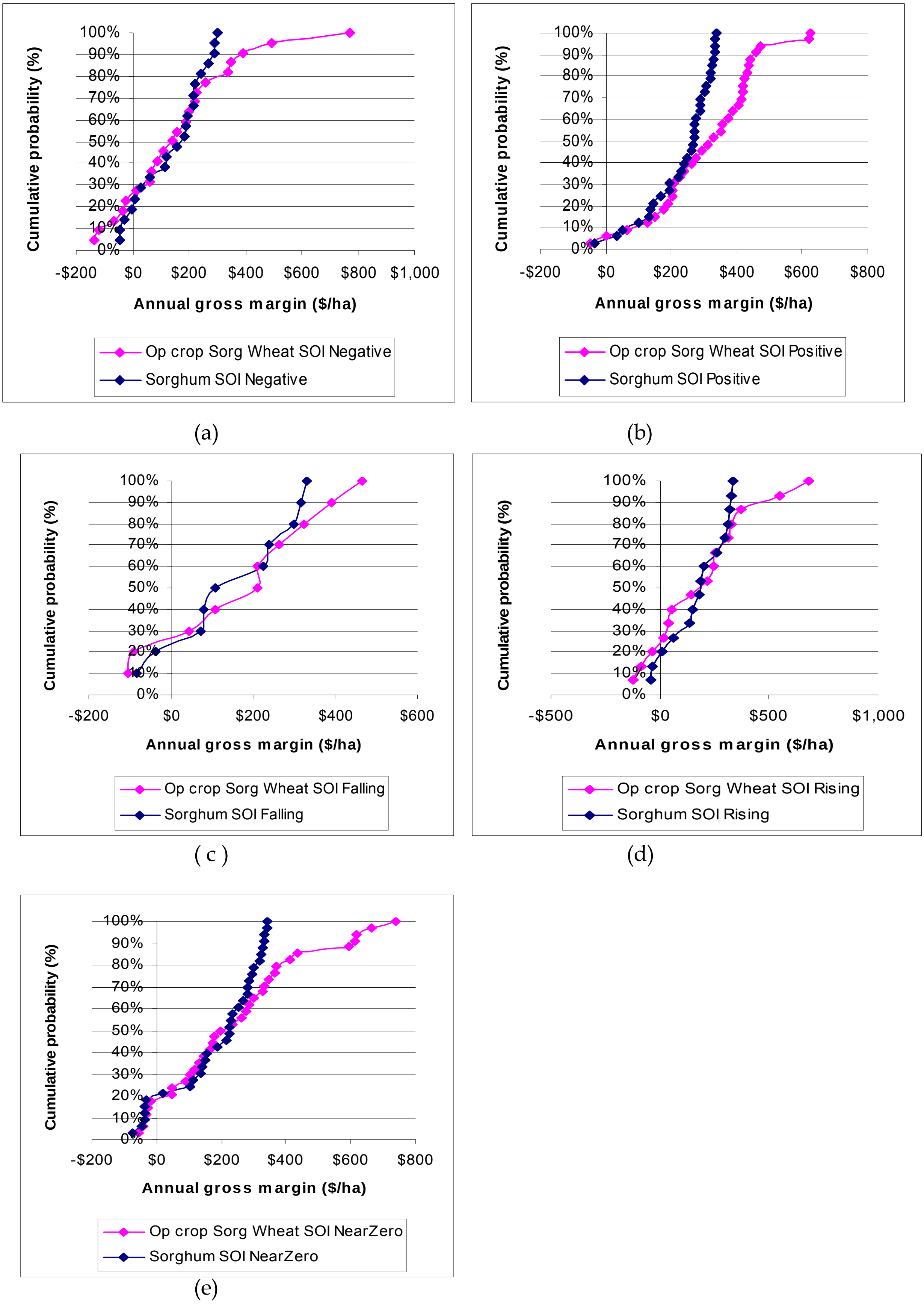


Figure 74 (a) Opportunity cropping gross margin distributions at Emerald on a 150mm PAWC soil separated on the basis of the SOI phase in September of the year of planting.



(a) (b)

(c) (d)

(e)

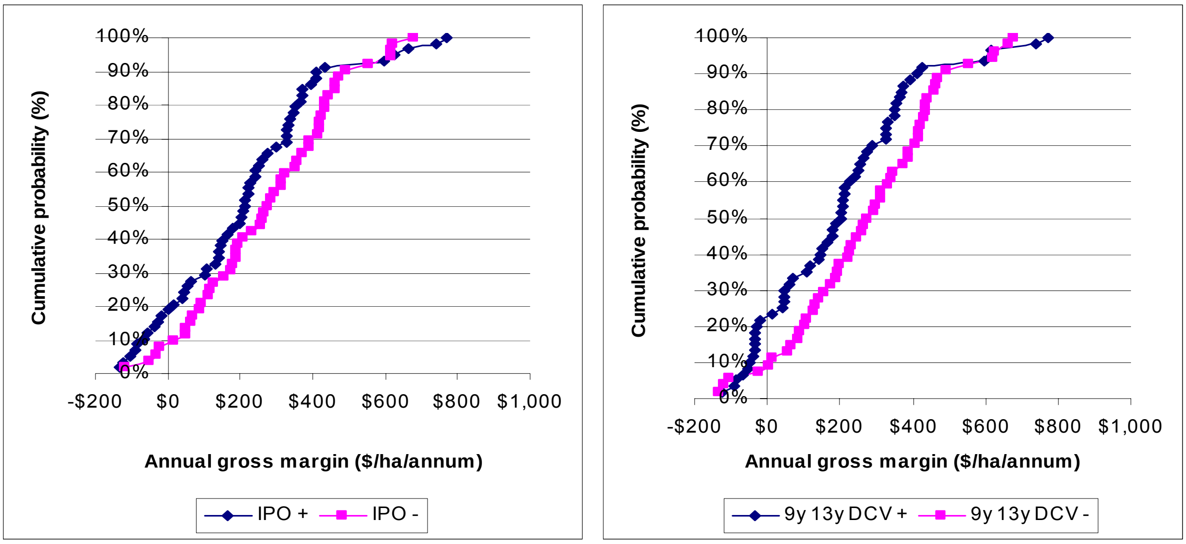
Figure 75 Distribution of annual gross margin by SOI phase in September for Opportunity cropping sorghum and wheat and monoculture sorghum at Emerald on a 150mm PAWC soil.

Figure 73 shows that opportunity cropping sorghum and wheat performs as well as or better than monoculture sorghum when annual gross margins for each cropping system are separated on the basis of the SOI in September.

There is also no SOI phase at this time of the year where monoculture sorghum would be preferred to opportunity cropping sorghum and wheat. On this basis there is no value in knowing the SOI phase prior to the summer cropping season for a farm manager who wants to select between opportunity cropping and monoculture sorghum, as outcomes cannot be significantly improved by changing the cropping intentions within the opportunity cropping system.

9y 13 y DCV Index and IPO

To test whether opportunity cropping of sorghum and wheat at Emerald responded to the different phases of the 9y 13y DCV index and IPO, annual gross margins were separated on the basis of the value of the index in December of the year of planting (Figure 76).



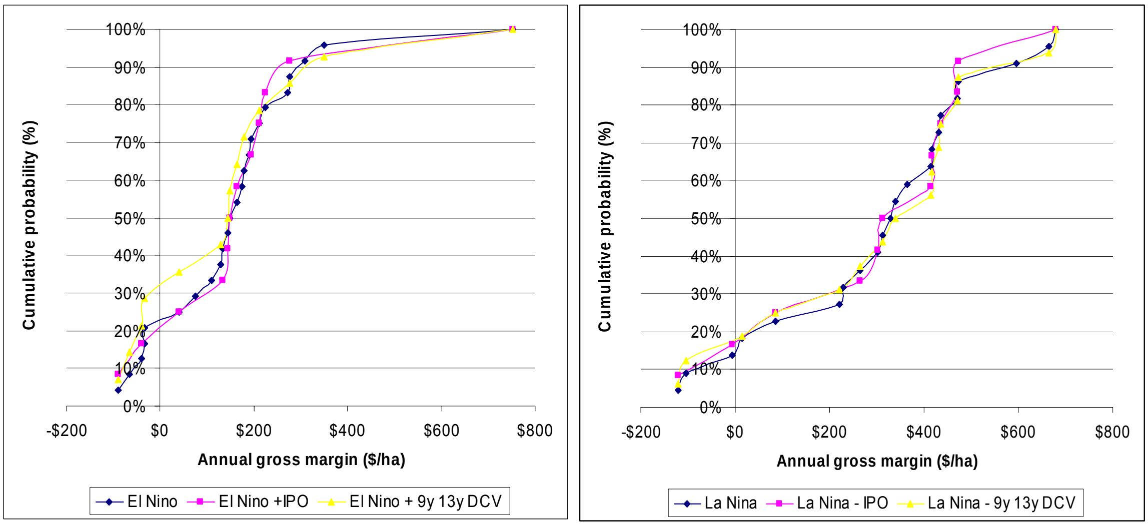
(b) (b)

Figure 67 Distribution of annual opportunity cropping sorghum and wheat gross margins for (a) the IPO and (b) the 9y 13y decadal index

Both decadal indices show a significant separation of the annual gross margins for opportunity cropping sorghum and wheat. This cropping system has the capacity to respond to increased rainfall whereas the monoculture systems showed no response due to their inherent inability to profitably utilise the better seasons. Knowledge of the phase of either decadal index would not add value to decisions about cropping intensity, as the underlying relationships between the cropping systems do not significantly change.

Interactions between ENSO and DCV indices at Emerald

There is no altered impact of El Nino or La Nina events on opportunity cropping activities at Emerald if the phase value of either the 9y 13y DCV index or IPO is negative or positive respectively (Figure 77 a and b).



(a) (b)

Figure 77 Distributions for opportunity cropping sorghum and wheat annual gross margin at Emerald on a 150mm PAWC soil in (a) El Nino years separated by the positive phase of the 9y 13y DCV index and IPO and (b) in La Nina years separated by the negative phase of the 9y 13y DCV index and IPO

5.4.7 Summary of opportunity cropping sorghum and wheat

Opportunity cropping systems on the central highlands show a strong financial response to climate phenomena that enhance rainfall.

The level of performance of opportunity cropping system for sorghum and wheat as modelled here will not be improved by altering cropping intensity on the basis of any of the forecast mechanisms tested. The moderating influence of the traditional parameters used to decide planting opportunities appears to “self adjust” the cropping system to climate signals, thereby reducing the riskiness and maintaining the reliability of the cropping system in drier seasons.

The improvement in economic performance from a responsive cropping system depends upon very precise timeliness and crop management by the farm manager. The improvement in sustainability indicators also depends upon successfully maintaining the same precision and crop management.

6 Discrete Years for Climate Indices

6.1 Discrete years for the 9y 13 y DCV index

The 9y13y DCV Index has been broken into periods when the index was above zero and periods when the index was below zero. The cut of and start dates were chosen as close as possible to the date at which the 9y13y DCV index changed its sign value. Table 5 shows these dates.

Table 10 Start and finish dates for phase values 9y 13y DCV index

Start	**Finish**	**Index sign**	**Years**
1-01-1890	31-12-1896	-	7
1-01-1897	31-12-1905	+	9
1-01-1906	31-12-1911	-	6
1-01-1912	31-12-1918	+	7
1-01-1919	31-12-1925	-	7
1-01-1926	31-12-1931	+	6
1-01-1932	31-12-1939	-	8
1-01-1940	31-12-1945	+	6
1-01-1946	31-12-1956	-	11
1-01-1957	31-12-1960	+	4
1-01-1961	31-12-1964	-	4
1-01-1965	31-12-1969	+	5
1-01-1965	31-12-1976	-	7
1-01-1977	31-12-1983	+	7
1-01-1984	31-12-1990	-	7
1-01-1991	31-12-1998	+	8
		Total	109

5.2 Discrete years for the IPO index

Table 11 Start and finish dates for phase values IPO DCV index

Start	Finish	Index sign	Years
1-01-1890	31-12-1895	-	6
1-01-1896	31-12-1907	+	12
1-01-1908	31-12-1919	-	12
1-01-1920	31-12-1944	+	25
1-01-1945	31-12-1977	-	33
1-01-1978	31-12-1998	+	21
		Total	109 years

Note –01/01/1945 to 31/12/1977 was truncated to 30 years in the analysis.

5.3 Discrete years for the ENSO classification

Table 12 ENSO classification (Potgieter *et al.* 2003)

El Nino years	La Nina years	Other years
1902	1908	1901
1905	1909	1903
1911	1910	1904
1914	1916	1906
1919	1917	1907
1925	1921	1912
1940	1922	1913
1941	1924	1915
1946	1928	1918
1951	1933	1920
1953	1938	1923
1957	1943	1926
1965	1945	1927
1969	1950	1929
1972	1955	1930
1977	1956	1931
1982	1971	1932
1987	1973	1934
1991	1974	1935
1992	1975	1936
1993	1988	1937
1994	1998	1939
1997		1942
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		1999
		2000
		2001

6 Modelling Framework for Farming Systems at Emerald

6.1 Property Investment at Emerald

The chosen characteristics for the model property at Emerald are as follows:

- 2000 ha total size of property
- 1800 ha cultivation
- $800 / ha value for land and fixed improvements = $1,600,000
- Opening plant and equipment value for a property that can grow cotton is $557,750
- The capital cost of setting up to grow dryland cotton is $35,000.

In this analysis, properties that do not have a capacity to grow dryland cotton (those that only grow grain crops) do not own an 8 row precision planter, a module builder or the boll buggies. This reduces the value of farm plant to $522,750. (See appendix 1 for details)

- Soil – deep, self-mulching grey vertosol, 150mm PAWC
- Rainfall – summer dominant, 600mm median rainfall
- Farming system – zero till where possible
- Farm overhead expenses $92,000 per annum. Farm overhead expenses represent the fixed costs of operating the farm business.
- Cotton growing is expected to incur additional labour costs compared to cereal cropping systems and these costs have been estimated on a per hectare basis and included in the cotton variable costs of production.
- Opportunity cropping systems that require a higher cropping frequency and use additional tractor hours per annum have the investment life or plant and equipment adjusted accordingly.
- The owner manager of the property is paid a return of $60,000 per annum for management skills and labour.
- No debt is held by the business at the beginning of each simulation.

The example property is considered to be a high quality property that is equipped with modern farming equipment highly suited to the low tillage farming system at hand. The manager is also considered to have the skills and experience to manage the cropping systems modelled with a similar degree of timeliness and success to that captured in the model.

The property and its management are considered to be very capable of producing dryland cotton in this environment - something that properties with lesser management, equipment, financial resources or shallower soils may not be able to do with the same level of success.

The property is also considered to have the most likely overall configuration for responding successfully to a climate forecast.

6.2 Cotton -typical growing costs and crop management

The typical fallow costs for cotton are two weed sprays incurred in the fallow prior to planting and one trifluralin treatment. Insecticide costs including spray costs and cotton consultant average around $350 /ha /season. Harvest costs are based on the use of contract services (calculated on a per bale basis) and together with processing costs are multiplied by the bales harvested in any year to calculate total harvest costs on a per bale basis. Low yield crops that are not economic to harvest do not incur harvest costs. It is expected that two tillage operations with a chisel plough will be needed after cotton to pupae bust and/or remove cotton plants

	Litres, grams				PER HA
Fallow Costs					
24 m trailing sprayer	1.00		x	$2.14each	$2.14
Roundup CT	1.20		x	$5.64each	$6.77
Surpass 300	1.00		x	$4.65each	$4.65
24 m trailing sprayer	1.00		x	$2.14each	$2.14
Roundup CT	1.20		x	$5.64each	$6.77
24 m trailing sprayer	1.00		x	$2.14each	$2.14
				Total	**$31.38**
Planting Costs					
8 row Precision Planter	1.00			$9.13each	$9.13
Cotton seed	10.00			$5.60 / kg	$56.00
				Total	**$65.13**
Fertilizer Costs					
8 row Precision Planter	1.00		x	$9.13each	$9.13
Starter Z	25.00	kg	x	$0.55 $ / ton	$13.63
				Total	**$22.76**
Planting to Harvest Costs			New Treatments'		
24 m trailing sprayer	1.00	x	1.00	$2.14each	$2.14
Cotogard	4.00	x	0.20	$12.00each	$9.60
12 row Shielded Sprayer	1.00	x	0.90	$2.71each	$2.44
Roundup CT	1.00	x	0.90	$5.64each	$5.08
Endosulfan EC	2.10	x	1.00	$11.00each	$23.10
24 m trailing sprayer	1.00	x	2.00	$2.14each	$4.28
Shearer 35 ft	2.00	x	1.00	$11.33each	$22.65
Crop not harvested					**$69.29**
24 m trailing sprayer	1.00	x	4.00	$2.14each	$8.56
Tracer	0.15	x	0.50	$91.75each	$6.88
Steward	0.85	x	0.50	$80.00each	$34.00
Amitraz EC	2.00	x	1.00	$14.27each	$28.54
Dipel	1.50	x	0.50	$12.00each	$9.00
Aerial spraying-cotton EC	1.00	x	2.00	$12.50each	$25.00
Dropp	0.10	x	1.00	$147.00each	$14.70
Ethephon (Prep equivalent)	2.00	x	1.00	$18.00each	$36.00
Cotton Consultant	1.00	x	1.00	$35.00each	$35.00
Cotton Crop Insurance	1.00	x	1.00	$30.00each	$30.00
Cotton chipping	1.00	x	1.00	$20.00each	$20.00
Average cost crop					**$316.97**
Shearer 35 ft	1.00	x	1.00	$11.33each	$11.33
Aerial spraying-cotton EC	1.00	x	1.00	$12.50each	$12.50
Dominex Duo	3.00	x	1.00	$22.00each	$66.00
Talstar EC	0.80	x	0.50	$61.00each	$24.40
Cotton casual labour	1.00	x	1.00	$80.00each	$80.00
Full cost crop				**Total**	**$511**
	TOTAL PRE-HARVEST COSTS				**$630**
Per Bale Cotton Costs					
Cotton Harvesting Double skip	1.00	x	1.00	$41.67each	$41.67
Module Builder	9.00/bale				$9.00
Tarps	2.00/bale		x		$2.00

Module Lift/ Transport	11.00/bale	$11.00
Ginning Costs	60.00/bale	$60.00
Research Levy	4.25/bale	$4.25
	TOTAL HARVEST COSTS	**$127.92**

6.3 Sorghum - typical growing costs and crop management

Fallow weed control costs prior to sorghum planting are expected to be similar to cotton except that pre-emergent Trifluralin is not used.

Urea is applied separately within APSIM.

Fallow Costs						
	Litres, grams					**PER HA**
24 m trailing sprayer	1.00		x		$2.14each	$2.14
Roundup CT	1.20		x		$5.64each	$6.77
Surpass 300	1.00		x		$4.65each	$4.65
24 m trailing sprayer	1.00		x		$2.14each	$2.14
Roundup CT	1.20		x		$5.64each	$6.77
Surpass 300	0.80		x		$4.65each	$3.72
24 m trailing sprayer	1.00		x		$2.14each	$2.14
Roundup CT	1.20		x		$5.64each	$6.77
					Total	**$35.10**
Planting Costs						
12 m Zero till planter	1.00				$5.68each	$5.68
Sorghum seed	3.00				$5.80 / kg	$17.40
					Total	**$23.08**
Fertilizer Costs						
12 m Zero till planter	1.00		x		$5.68each	$5.68
Starter Z	25.00	kg	x		$0.55 $ / ton	$13.63
					Total	**$19.31**
Planting to Harvest Costs				New Treatments'		
No treatment	1.00	x		1	$0.00each	$0.00
24 m trailing sprayer	1.00	x		1	$2.14each	$2.14
Gesaprim	3.50	x		1	$5.84each	$20.44
Crop not harvested						**$22.58**
24 m trailing sprayer	1.00	x		0.5	$2.14each	$1.07
NPV Gemstar/Vivus	0.38	x		0.5	$61.50each	$11.69
24 m trailing sprayer	1.00	x		1	$2.14each	$2.14
Roundup CT	1.50	x		1	$5.64each	$8.46
Average cost crop						**$45.94**
Full cost crop					**Total**	**$46**
	TOTAL PRE-HARVEST COSTS					**$123**
Harvesting:						
Contract header	6.00ha/hr				$200 /hour	$33.33
plus fuel	litres/hr		x		$0.50 /Litre	$0.00
	TOTAL HARVEST COSTS					**$33.33**
Total Variable Costs						**$157**

6.4 Wheat – typical growing costs and crop management

Wheat fallow costs are based on a zero till farming.

Fallow Costs						
	Litres, grams					**PER HA**
24 m trailing sprayer	1.00		x		$2.14each	$2.14
Roundup CT	1.00		x		$5.64each	$5.64
Surpass 300	1.60		x		$4.65each	$7.44
24 m trailing sprayer	1.00		x		$2.14each	$2.14
Roundup CT	1.20		x		$5.64each	$6.77
Surpass 300	1.00		x		$4.65each	$4.65
24 m trailing sprayer	1.00		x		$2.14each	$2.14
Roundup CT	0.80		x		$5.64each	$4.51
					Total	**$35.43**
Planting Costs						
12m Air seeder	1.00				$4.70each	$4.70
Wheat seed	40.00				$0.64 / kg	$25.60
					Total	**$30.30**
Fertilizer Costs						
12m Air seeder	1.00		x		$4.70each	$4.70
Starter Z	25.00	kg	x		$0.55 $ / ton	$13.63
					Total	**$18.33**
Planting to Harvest Costs			New Treatments'			
24 m trailing sprayer	1.00	x		1	$2.14each	$2.14
Ally	5.00	x		1	$0.33each	$1.65
Crop not harvested						**$3.79**
Average cost crop						**$3.79**
Full cost crop					**Total**	**$4**
	TOTAL PRE-HARVEST COSTS					**$87.85**
Harvesting:						
Contract header	5.50ha/hr				$250 /hour	$45.45
plus fuel	40.00litres/hr		x		$0.50 /Litre	$3.64
	TOTAL HARVEST COSTS					**$49.09**
Total variable costs						**$137**

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APPENDIX 5

Summary of crop rotation performance, climate forecasts and sustainability indicators for case study locations

Monoculture Wheat

Details	Breeza	Dalby	Emerald
Yields	Median: 2.9 t/ha Range: 0.8 to 5 t/ha	Median: 3.6 t/ha Range: 0 to 6 t/ha	Median: 2.1 t/ha Range: 0.9 to 5.1 t/ha
Cropping Frequency	Planting conditions met 95% of years.	Planting conditions met in virtually all years.	Planting conditions met in 80% of years – the frequency of planting misses was greatest in the period prior to 1950, the start of major dryland farming activity.
Gross Margins	Median: $250/ha Range: -$80/ha to $625/ha Negative gross margins: 5% of years	Median: $300/ha Range: -$50/ha to $600/ha Negative gross margins: 5% of years Negative gross margins: less then 5% of years	Median: $160/ha Range: -$110/ha to $650 Negative gross margins: 30% of years. Since 1975 wheat returns have been equal to that of sorghum – prior to this period sorghum returns have generally exceeded those of wheat.
SOI Phase	SOI phase in April of year of planting does not discriminate between wheat cropping seasons – no statistical difference between gross margin distributions (the risk of a negative gross margin is less then 10% for all phases).	There is some separation in gross margins between the SOI phases at planting – the negative SOI phase generally has a lower gross margin then the positive SOI phase. It is also interesting to note that the neutral phase has the greatest gross margins.	Gross margin shows some differentiation when separated on the basis of the SOI phase in March. The median gross margin produced when the SOI phase is negative in March is about half that produced when the SOI phase is positive. However, even in

			years with a positive SOI in March there is a zero to negative gross margin in 25% of years.
ENSO Classification	La Nina years: 2% chance of negative gross margins El Nino years: 25% chance of negative gross margins Presently, ENSO forecasts are not available at time of planting wheat.	La Nina years: 5% chance of a negative gross margin El Nino years: Above 10% chance of a negative gross margin. Returns from La Nina years exceed those from El Nino years.	La Nina years: 30% chance of a negative gross margin El Nino years: 45% chance of a negative gross margin In La Nina years the choice between wheat and sorghum is most likely to be made on the basis of price expectations.
9y 13y DCV	Negative Phase: Rainfall enhanced but most will be lost to deep drainage. Chance of negative gross margin is 3% Positive Phase: Chance of a negative gross margin is 10%	Negative Phase: Wheat returns improve significantly – no negative gross margins occurred. Positive Phase: Chance of a negative gross margin is 10%.	There was no statistical significant difference in the performance of wheat between the phases of the 9y 13y DCV index
IPO	Negative Phase: Rainfall enhanced but most will be lost to deep drainage. Gross margins: No difference between IPO phases.	There was no statistical significant difference in the performance of wheat between the IPO phases.	There was no statistical significant difference in the performance of wheat between the IPO phases
ENSO and DCV Indices Interactions	El Nino years: Those with a positive 9y 13y DCV had the gross margin further reduced by $100/ha compared with all El Nino years. La Nina years: No effect on gross margins for La Nina years with a negative (-) 9y 13y DCV	NA	El Nino years: Those with a positive 9y13y DCV index annual gross margin was improved La Nina years: No significant impact of a negative phase 9y13y DCV on crop returns.
Sustainability	Wheat cropping system unable to	There is a lower potential for runoff and	There is a greater risk of drainage

	use all the extra available from a wetter then average climate sequence – water lost to drainage	soil loss compared with sorghum and cotton. However, drainage is greater then for these other crops – in some decades it is more then double for monoculture wheat systems.	from monoculture wheat compared to monoculture sorghum. Runoff for both systems is similar – neither system is capable of effectively using the extra water provided during more favourable rainfall periods.
Summary	A cropping system with summer fallows and winter wheat is unable to respond very well to climate periods with enhanced rainfall – this results in drainage and runoff losses of water	Wheat monoculture is low risk, and performs best during SOI neutral years.	Wheat monoculture responds to the ENSO classification and possibly the SOI phase forecast system. Sustainability indicators suggest that a more intense cropping system is needed to take advantage of favourable rainfall periods to reduce deep drainage and runoff losses.

Monoculture Sorghum

Details	Breeza	Dalby	Emerald
Yields	Median: 3.8 t/ha Range: 1 t/ha to 6.2 t/ha	Median: 4.5 t/ha Range: 0 t/ha to 6.1 t/ha	Median: 3.1 t/ha Range: 0.75 to 4 t/ha
Cropping Frequency	Planting conditions met in over 80% of years.	Planting conditions for sorghum met all years.	Planting conditions met in 90% of years.
Gross margins	Median: $300/ha Range: -$150 to $650/ha Negative gross margins produced in 20% of years	Median: $400/ha Range: -$200 to $650/ha Negative gross margins produced in 10% of years.	Median: $220/ha Range: -$80 to $340/ha Negative gross margins produced in 15% of years.
SOI Phase	The chance of a negative gross margin is 40% when the October SOI is falling or negative. Years with a positive SOI in September are reliable and profitable years to grow sorghum – the chance of a negative gross margin is 10%.	The significant effect of a negative SOI phase in August on subsequent rainfall probabilities in September, October and November is not reflected in sorghum gross margins. This is because there is usually sufficient rain to successfully produce sorghum in most cropping years here.	Dryland sorghum planted in those years with a SOI positive phase in September shows a reduced risk of negative gross margins and a mush more reliable cropping outcome in about 60% of years. SOI negative and SOI falling phases increases the risk of crop failure (to around 20% of years) and a lower return from the crop.
ENSO Classification	Planting in El Nino years has a similar effect to falling or negative SOI phases – the risk of a negative gross margin is 40%. La Nina years has a similar effect to SOI positive years – the chance of a negative gross margin is only 10%.	There is little difference in the returns from sorghum grown during a El Nino or La Nina year. However, the gross margins for sorghum planted into the end of an El Nino year is significantly affected – in this situation the risk of a negative gross margin is 25% compared to 5% for all years.	Years classified at El Nino years at the time sorghum is normally planted in CQ (December-January) generally produce lower gross margins then those years classified as Other or La Nina years.
9y 13y DCV	There is a slight increase in the chance of a negative gross margin when the	There is no significant difference between negative (-) and positive (+) indices years	The phase of the 9y13y DCV differentiates annual sorghum

	index is positive (+) and an improved median gross margin the index is negative (-).	on sorghum gross margins.	gross margins at Emerald – positive (+) indices years have lower annual gross margins compared with negative (-) indices years.
IPO	The riskiness of sorghum production is the same for both phases. The median gross margin improves by 25% in negative (-) IPO years.	There is no significant difference between negative (-) and positive (+) indices years on sorghum gross margins.	The IPO index shows that the chance of suffering a negative gross margin increases from 10% in negative (-) indices years to 17% in positive (+) indices years. The median gross margin for negative IPO years is $250/ha compared to $200/ha for positive IPO years.
ENSO and DCV Indices Interactions	There was no significant interaction with either index during either El Nino or La Nina events on gross margins.	Effect not significant	There is no significant interaction with either the DCV or IPO indices with either El Nino or La Nina events on the annual gross margin of sorghum.
Sustainability	The sorghum system significantly reduced water lost from the system compared to the monoculture wheat system.	Generally there are lower levels of runoff and soil loss compared to monoculture cotton, and similar drainage levels.	Monoculture sorghum is reasonably susceptible to runoff at Emerald. It is also prone to deep drainage and the risk of significant soil loss (the median soil loss is about 6 t/ha per annum) for this system. The soil loss is an episodic event that may not be well controlled by a low intensity farming system that does not use the rainfall available during wetter periods.

Summary	Negative gross margin risk elevated by dry conditions (El Nino, -ve SOI, falling SOI) and reduced in wetter conditions (La Nina, SOI +ve)	Best opportunities for high gross margins occur during SOI neutral conditions.	The sorghum monoculture system is fairly responsive to forecast periods of enhanced rainfall but it may also be susceptible to soil loss and increased subsoil drainage. The most recent climate period may eventually reveal relationships between climate phenomena and sorghum productivity that were previously hidden by the predominance of above average rainfall in our recent climate record.

Monoculture Cotton Results

Details	Breeza	Dalby	Emerald
Yields	The median yield for cotton when it was successfully established was 2.25 bales/ha (with yields ranging from 0.1 to 5.8 bales/ha)	The median yield of cotton is 3.25 bales/ha (with a range of 0 to 5.4 bales/ha).	When planted yields ranged from 0.2 to 6.7 bales/ha (with a median yield of 2.8 bales/ha)
Cropping Frequency	The planting rules used ensured that cotton was planted in 90% of years.	Cotton fails to be planted in 15% of years.	Using a 75mm stored soil water criteria for planting resulted in cotton failing to be planted in 20% of years due to a lack of planting rain or stored soil water or both.
Gross Margins	Negative gross margins for cotton occurred in 30% of years, with a median of $200/ha (with the top 20% of years producing gross margins greater then $700/ha).	Negative gross margins occurred in 35% years, with a median of $300/ha (with a range of -$350 to $1150/ha).	In 40% of years 0 or negative gross margins would have resulted – cotton showed greater variability in potential returns due to climate variability then sorghum for the climate record modelled.
SOI Phase	The SOI positive phase prior to planting doubles the median gross margin and halves the chance of a negative (-) gross margin compared with all other phases – this was statistically significant	There is little effect of the July-August SOI phase on the performance of raingrown cotton in 70% of years. In 30% of years there is an increased risk of a negative gross margin in years with a SOI negative phase at this time.	The returns from cotton may be more reliable/less risky if planted after the SOI phase was positive in September – sorghum showed a similar response.
ENSO Classification	Median gross margin improved by 300% in La Nina years compared to El Nino and other years – not sufficient to influence the planting decision by a regular cotton grower	Planting raingrown cotton in a La Nina year reduces the risk of a negative gross margin from 40% to 20% compared with a El Nino year. However, the gross margins of crops planted in a El Nino year outperform those in La Nina years 40% of the time.	Cotton is relatively less risky if planted in La Nina years. If planted in El Nino years there is a tendency for consistent negative gross margins to result (with 0 or negative gross margins in 60% of El Nino years compared to 20% for

			La Nina years)
9y 13y DCV	The median gross margin improves by about 100% in years with a negative (-) 9y 13y DCV	There is no statistical significant impact of the index on cotton gross margins – the risk of a negative gross margin remains over 30%.	The phase value of the 9y 13y DCV index does not differentiate annual cotton gross margins at Emerald.
IPO	Gross margins show a response to the phase of the IPO – in positive (+) IPO years the median gross margin is about $70/ha compared to $330/ha for negative (-) IPO years. The chance of a negative gross margin increases from 25% in negative (-) IPO years to 35% in positive (+) IPO years.	There is no statistical significant impact of the index on cotton gross margins – the risk of a negative gross margin remains over 30%.	Cotton gross margins showed a statistically significant response to the phase of the IPO. In positive IPO years the median gross margin was $0 per ha (with 50% of years with a negative gross margin), with median gross margins in negative IPO years of $260/ha (with 35% of years with a negative gross margin).
ENSO and DCV Indices Interactions	The impact of an El Nino year is not modified by coinciding with a positive (+) DCV or positive (+) IPO index	NA	There is no significant interaction between the ENSO classifications and the tested phases of the DCV indices even though the La Nina – IPO interaction seems to increase the reliability of cotton above that of La Nina years alone.
Sustainability	Drainage significantly less then that of monoculture wheat	Generally there are greater levels of runoff and soil loss compared to monoculture sorghum, and similar drainage levels.	The potential for runoff, drainage and soil loss are similar for cotton and sorghum.
Summary	The SOI phase forecast system does not provide useful information for the decision to alternate between wheat and cotton. The performance of	While planting La Nina years reduces risk, the opportunities for profit during El Nino years is greater.	The use of the SOI phase forecast system seems to significantly reduce, but not eliminate, the risk of dryland cotton growing at

	cotton in La Nina years is no different to its performance in all years – it can be both very profitable and incur significant losses – wheat has high reliability and very little risk.		Emerald. Planting cotton on the basis of a SOI positive phase: – Increases the risk of a negative gross margin in 5% of years – Improves returns in 10% of years

Opportunity Cropping Sorghum and Wheat

Details	Breeza	Dalby	Emerald
Yields	The median yield for wheat within the opportunity sorghum and wheat system is reduced by 1 t/ha when compared to the median yield for monoculture wheat. The yields for sorghum within the opportunity sorghum and wheat system shows a potential improvement in most years compared to monoculture sorghum.	The wheat yield in this system is halved when compared to the monoculture wheat yield. The sorghum grown in this system has a lower yield in 50% of years compared to monoculture sorghum yields.	Modelled sorghum yields for sorghum grown within this opportunity cropping system show a significant yield reduction in 90% of years compared to monoculture sorghum. There is also a slight reduction in the median yield for opportunity cropped wheat compared to monocultured wheat.
Cropping Frequency	Planting conditions met 75% years.	On average about 75% more crops could expect to be sown over a 30-year cropping period under this cropping system when compared to monoculture wheat or sorghum.	For the period 1975 to 2003 sixteen double cropping sequences were achieved – more then was achieved in previous sequences.
Gross margins	Opportunity cropping wheat and sorghum produced negative annual gross margins in about 10% to 15% of years. Since 1940 the opportunity cropping system has outperformed monoculture wheat.	Opportunity cropping sorghum and wheat is not as reliable as either monoculture wheat or monoculture sorghum and will produce negative gross margins in about 10% to 15% of years. It has the potential to outperform or equal the performance of either cereal monoculture in about 80% of years.	Negative gross margins for this system occurred in 15% of years. In 40% of years this system produced higher potential gross margins than those produced by monoculture sorghum – in the remaining years there was little difference between the systems.
Investment returns	Compared to monoculture what protein is reduced, and sorghum is riskier, so overall opportunity cropping sorghum/wheat is riskier	The change from monoculture to opportunity cropping sorghum and wheat as Dalby is expected to provide a substantial benefit in investment returns in the majority of years (an improvement	The opportunity cropping system generally produces better returns than those available from monoculture sorghum.

		ranging from 0.5 to 3.0%)	
SOI Phase	No phase of the SOI in April has a significant impact on the outcomes for opportunity cropping for wheat and sorghum.	There is a string relationship between SOI phase and performance of this system. The greatest gross margins occur with a positive SOI and the least with the negative SOI phase. The risk of a negative gross margin is around 5% for the SOI positive phase compared to 25% for SOI negative phase.	The SOI positive phase in September of the year of planting has a significant impact on the outcomes for opportunity cropping sorghum and wheat at Emerald. There is no SOI phase at this time of year when monoculture sorghum would be preferred to the opportunity cropping system.
ENSO Classification	An El Nino in the year of planting significantly reduces the annual gross margin for this system – the risk of a negative gross margin increases from less the 10% (for La Nina and other years) to 35%. Maintaining a wheat monoculture in El Nino years may reduce the chance of loss in the opportunity cropping systems by about 25%.	There are only small differences in gross margins between the ENSO phases – this system masks the impact of ENSO in most years due to the higher cropping frequency associated with this system.	ENSO events impact on the outcomes of the opportunity cropping system to a lesser extent then for the monoculture cropping systems. The system produces lower returns in El Nino years compared to La Nina years but in all cases better then those from the alterative monoculture cropping systems.
9y 13y DCV	A negative index results in only a slight improvement in gross margins for this system.	There is only a slight response in gross margins to the 9y 13y DCV index.	There is a significant separation of the annual gross margin for this system in response to the 9y 13y DCV index with returns enhanced by a negative (-) index.
IPO	A negative index results in only a slight improvement in gross margins for this system.	There is no response in gross margins to the IPO index.	There is a significant separation of the annual gross margin for this system in response to the IPO index with returns enhanced by a

			negative (-) index.
ENSO and DCV Indices Interactions	There was no significant interaction with either index during El Nino or La Nina events on opportunity cropping gross margins	NA	There was no significant interaction with either index during El Nino or La Nina events on opportunity cropping gross margins
Sustainability	The potential for drainage is significantly reduced compared to the monoculture wheat. However, there is still increased drainage during higher rainfall periods.	Runoff and soil loss is significantly less then for monoculture sorghum and cotton systems, and very similar to the monoculture wheat system. Drainage is generally less then all other systems – monoculture wheat, sorghum and cotton.	Opportunity cropped sorghum and wheat results in runoff at comparable or lower levels than other cereal cropping systems. It reduces potential drainage and potential soil loss in most climate sequences.
Summary	Opportunity cropping systems show an economic advantage over the wheat cropping system in 50% of years. None of the climate forecasts clearly identifies when the inclusion of extra summer crops would consistently improve returns and reduce risk.	Incorporation of the SOI phase forecast system into the management of the opportunity cropping sorghum and wheat cropping system may improve returns in those years when the SOI phase is negative prior to sorghum being planted.	The level of performance of the opportunity cropping system for sorghum and wheat is not improved by altering cropping intensity on the basis of any of the forecast mechanisms tested. This system “self adjusts” to climate signals reducing its riskiness and maintaining its reliability in drier seasons.

Opportunity Cropping Cotton and Sorghum

Details	Breeza	Dalby	Emerald
Yields	Sorghum yields improve, but wheat protein levels fall.	Cotton yields are unaffected by changing from monoculture cotton to this opportunity system. Sorghum yields are lower in 50% of years when compared to those in a monoculture sorghum system.	Yields are maintained.
Cropping Frequency	Conditions for sorghum are met less frequently than for cotton.	The frequency of cotton crops is unchanged when comparing this system with monoculture cotton. However, the frequency of sorghum crops is reduced compared with monoculture sorghum.	Cotton is selected just over 50 % years, with sorghum the remainder.
Gross margins	Negative gross margins 10-15 % years.	The opportunity cropping system will potentially have fewer years that produce a negative gross margin than monoculture cotton due to its higher cropping frequency but will only perform better then monoculture sorghum in about 50% of years.	Risk reduced by ability to select sorghum, therefore gross margins can be higher.
SOI Phase	No significant impact.	When SOI –ve sorghum monocultures outperform the opportunity cropping, otherwise opportunity cropping generates better gross margins.	Dryland cotton is relatively more reliable in planting years when the SOI phase is positive in September. The addition of cotton to a sorghum cropping system when the SOI phase is positive prior to planting (and cotton planting requirements are met) generally improves decadal returns. However, it increases the

			risk of a negative gross margin by 5% of years. The use of this forecast system significantly reduces but not eliminates the risk of dryland cotton growing here.
ENSO Classification	El Ninos reduce the gross margin.	Higher cropping frequency is though to mask any ENSO impact.	Planting cotton in La Nina years improves the annual gross margin over sorghum in 70% of years.
9y 13y DCV		Opportunity cropping cotton and sorghum cropping system shows no response to the 9y 13y DCV index.	NA
IPO		Opportunity cropping cotton and sorghum cropping system shows no response to the IPO index.	NA
ENSO and DCV Indices Interactions			NA
Sustainability		The runoff and soil loss is generally less then for monoculture cotton, but exceeds that for monoculture wheat and sorghum. Drainage is much less then for monoculture wheat, but similar or less than that for monoculture cotton and sorghum.	
Summary	Monoculture wheat is a more reliable option.	Opportunity cropping is more sustainable.	Cotton monocultures provide more reliable gross margins, but opportunity cropping reduces risk.

Fixed Rotation Cotton and Sorghum

Details	Breeza	Dalby	Emerald
Yields		The change in cotton and sorghum yields in growing these crops in a fixed rotation when compared with monocultures of each crop is slight.	Dryland cotton present a high failure risk.
Cropping Frequency	Sorghum is cotton risk too high.		
Gross margins	Cotton is twice as likely to fail, but can provide higher gross margins	The fixed rotation reduces the riskiness associated with monoculture cotton production (the incidence of a negative gross margin falls from 35% to 10%) but also reduces the reliability associated with sorghum production (the fixed rotation sorghum gross margin is less then or equal to the monoculture sorghum gross margins in all years).	Potentially high gross margins, but risks are high.
Investment returns	Outperformed by winter wheat monocultures	The fixed rotation outperforms monoculture sorghum in only 30% of decades and monoculture cotton in 75% of years.	Opportunity cropping is less risky than fixed rotations.
SOI Phase	Forecast release after plating dates	Cotton is impacted by SOI	Cotton and sorghum impacted by SOI
ENSO Classification	Sorghum performs better under all ENSO regimes.	Cotton is impacted by ENSO classification	Cotton and sorghumis impacted by ENSO classification
9y 13y DCV	NA	There is a small response in gross margins to the 9y 13y DCV index. The response is too small to be significant.	NA
IPO	NA	There is a small response in gross margins to the IPO index. The response	NA

		is too small to be significant.	
ENSO and DCV Indices Interactions	NA		NA
Sustainability		The runoff and soil loss is generally less then for monoculture cotton, but exceeds that for monoculture wheat and sorghum. Drainage is much less then for monoculture wheat, but similar or less than that for monoculture cotton and sorghum.	
Summary	Risk is offset by potentially higher gross margins during 50% of years.	Opportunity cropping provides less risk, and similar or better gross margin probabilities.	This high risk of failure for cotton precludes the application of this option.

Opportunity cropping cotton, sorghum and wheat

Details	Breeza	Dalby	Emerald
Yields	NA	The potential median wheat yield is reduced by 1.5 t/ha when grown and the cotton yield by about 0.7 bales/ha when grown in this system. The median yield for sorghum is lower in 50% of years when planted in this system compared to monoculture sorghum.	NA
Cropping Frequency	NA	Over any 30 year period there are 15-17 cotton crops, 8-10 sorghum crops and 15-20 wheat crops.	NA
Gross margins	NA	This cropping system outperforms all others in the top 20% of years but is more risky than all others in the bottom 10% of years. Monoculture sorghum outperforms it in 50% of years.	NA
SOI Phase	NA		NA
ENSO Classification	NA	There is little difference between the phases for this forecast	NA
9y 13y DCV	NA	There is some differentiation between phases of the 9y 13y DCV index – crops grown during the positive (+) 9y13y DCV have a greater risk of a negative gross margin (30%) then those grown during a negative (-) 9y13y DCV (around 10%).	NA
IPO	NA	There is little difference in gross margins between the positive and negative IPO indices.	NA

ENSO and DCV Indices Interactions	NA	NA	NA
Sustainability	NA	This aggressive system is very soil water dependant.	NA
Summary		This option provides some opportunities for high gross margins, with attendant high risk.	

Appendix 6

PUBLICATIONS

Journal papers and book chapters

1. Donald, A., Meinke, H., Power, B., Wheeler, M., Maia, A.H.N., Stone, R.C., Ribbe, J. and White, N., 2006. Near-global impact of the Madden Julian Oscillation on rainfall. Geophysical Research Letters, in press.
2. Meinke, H. and Stone, R.C., 2005. Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations. Climatic Change, 70: 221-253.
3. Meinke, H., deVoil, P., Hammer, G.L., Power, S., Allan, R., Stone, R.C., Folland, C. and Potgieter, A., 2005. Rainfall variability at decadal and longer time scales: signal or noise? Journal of Climate, 18: 89-96.
4. Meinke, H., Wright, W. Hayman, P. and Stephens, D., 2003. Managing cropping systems in variable climates. In: Pratley, J. (editor). Principles of field crop production. Fourth Edition. Oxford University Press, Melbourne, Australia, p. 26-77.

Conference papers

5. Meinke, H. and Stone, R.C., 2005. A systems approach to increase preparedness for climate change based on scenario planning. Greenhouse2005, Melbourne, Australia, 14-17 November 2005.
6. Donald, A., Meinke, H., Power, B., Wheeler, M. Ribbe, J., 2004. Forecasting with the Madden-Julian Oscillation and the applications for risk management. Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia, published on CDROM and www.cropscience.org.au.
7. Meinke, H., Donald, L., deVoil, P., Power, B., Baethgen, W., Howden, M., Allan, R. and Bates, B., 2004. How predictable is the climate and how can we use it in managing cropping risks? Invited Symposium Paper, Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia, published on CD and www.cropscience.org.au.
8. Meinke, H., Hammer, G.L. and Stone, R.C., Hayman, P. and Rodriguez, D., 2004. Climate variability, change and seasonal forecasting in Australia - global lessons from two decades of local effort. Invited Symposium Paper, Impact of Climate Variability on Agricultural and Natural Resource Management, Annual Meetings Abstracts, American Society of Agronomy, 31 Oct – 4Nov 2004, Seattle, WA, USA, published on CD, paper 3738.pdf.
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11. Donald, A., Ribbe, J., Stone, R, Meinke, H., Harris, G., Power, B. and Wheeler, M., 2003. The influence of the Madden Julian Oscillation on Queensland's rainfall. Proceedings of the 15th Australasian Forum on Climatology (ANZ), New Zealand, March 2003, in press.

12. Howden, S.M. and Meinke, H., 2003. Climate change: challenges and opportunities for Australian agriculture. Proceedings, Climate Impacts on Australia's Natural Resources: Current and Future Challenges, 25-27 November 2003, Surfers Paradise, Queensland, Australia, pp 53-55.

13. Howden, S.M., Meinke, H., Power, B. and McKeon, G.M, 2003. Risk management of wheat in a non-stationary climate: frost in Central Queensland. Post, D.A. (ed.) Integrative modelling of biophysical, social and economic systems for resource management solutions. Proceedings of the International Congress on Modelling and Simulation, July 2003, Townsville, Australia, pp 17-22.

14. Howden, S.M., Reyenga, P.J. and Meinke, H., 2003. Managing wheat grain quality under global change. Post, D.A. (ed.) Integrative modelling of biophysical, social and economic systems for resource management solutions. Proceedings of the International Congress on Modelling and Simulation, July 2003, Townsville, Australia, pp ??

15. Howden, S.M., Meinke, H., Reyenga, P.J. and deVoil, P., 2003. The effects of climate change on mixed wheat-sorghum cropping systems in eastern Australia. Post, D.A. (ed.) Integrative modelling of biophysical, social and economic systems for resource management solutions. Proceedings of the International Congress on Modelling and Simulation, July 2003, Townsville, Australia, pp ??

16. Meinke, H., 2003. Options for cropping systems management at a range of timescales. In: Stone, R and Partridge, I (eds), Science for drought, Proceedings National Drought Forum, Department of Primary Industries, Brisbane, April 2003, pp. 82-87.

17. Meinke, H., Abawi, Y., Stone, R.C., Hammer, G.L., Potgieter, A.B., Nelson, R.A., Howden, S.M, Baethgen, W. and Selvaraju, R., 2003. Climate risk management and agriculture in Australia and beyond: Linking research to practical outcomes. In: The International Conference on Total Disaster Risk Management Report, Asian Disaster Reduction Center (ADRC) and The United Nations Office for the Coordination of Humanitarian Affairs (OCHA), Kobe, Japan, 2-4 December 2003, pp 83-87.

18. Meinke, H., Howden, S.M., Baethgen, W., Hammer, G.L., Selvaraju, R. and Stone, R.C., 2003. Can climate knowledge lead to better rural policies and risk management practices? Proceedings, NOAA Office of Global Programs Workshop. Insights and Tools for Adaptation: Learning from Climate Variability, November 2003, http://www.climateadaptation.net/papers.html.

19. Meinke, H., Howden, S.M, Wright, W. and Gifford, R.G., 2003. Adaptive responses of cropping systems management to climate change. In: Birch, C.J and Wilson, S.R. (eds), Versatile maize – golden opportunities, Proceedings Fifth Australian Maize Conference, Toowoomba, 18-20 February 2003, Maize Association of Australia, Darlington Point, NSW, pp. 58-66.

20. Meinke, H., Howden, S.M. and Selvaraju, R., 2003. Australia's experience in the development and application of climate information to reduce vulnerability to extreme events. Invited Paper, Pacific Science Congress, Bangkok, Thailand, 17-21 March 2003.

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24. Power, S., Wang, W., Colman, R., Wu, Z. and Meinke, H., 2002. Interdecadal modulation of ENSO's impact on Australia. Western Pacific Geophysics Meeting, Wellington, NZ, July 2002.