Climate Change in Cotton Catchment Communities A Scoping Study

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Cotton Catchment Communities CRC

Introduction

Our climate is always changing. It is influenced by both natural phenomena and human induced environmental changes on differing time scales.

Natural phenomena includes the annual seasonal cycle, El Nino/Southern Oscillation, Pacific Decadal Oscillation, North Atlantic Oscillation, volcanic eruptions, fluctuations in solar irradiance, changes in orbital cycles and variations in ocean, land and polar ice.

Human induced or anthropogenic drivers of climate change include changes in land use, urbanisation, and anthropogenic sources of atmospheric greenhouse gases, aerosols and other pollutants.

There is now sound evidence to show the increasing impact of human activity on our climate. In the Intergovernmental Panel on Climate Change (IPCC) Summary for Policymakers 2007 report the authors state that "warming of the climate system is unequivocal" and that there is a "very high confidence that the globally averaged net effect of human activities since 1750 has been one of warming".

A significant contributor to this warming has been the increase in the levels of atmospheric greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) much of which can be attributed to human activity.

Overall Australia is a small contributor to global greenhouse gas emissions. However compared with other developed nations, Australia differs in that its agricultural sector is its second highest emitter of greenhouse gases.

This raises the challenge of how agriculture can not only adapt to climate change but also reduce its overall greenhouse gas output while remaining a sustainable and profitable section of the Australian economy. For the Australian cotton industry the further development and extension of best practice techniques common to the industry (such as used with irrigation, fertiliser use and soil management) provides the key to meeting this challenge.

To enable industry participants to minimise their emissions and environmental footprint while maintaining and improving sustainability and profitability, further research is required based on good science and delivered through a sound extension system. Given the growing awareness of greenhouse gas emissions within the wider community, coupled with the urban community's current perceptions of agriculture, it is in the cotton industry's best interests to be proactive and well informed.

Cotton

Cotton is a natural fibre produced by the cotton plant, a leafy, green shrub and a member of the Hibiscus family. Although cotton is a perennial shrub that grows naturally to 3.5 metres, commercially it is grown as an annual. Australia's cotton growing season usually starts in September and October with planting and finishing in March to April with picking.

Below: Cotton crop ready for picking Narrabri, NSW.

Everyday, clothing made from cotton fibre and products made from cotton seed oil are used. Cotton is the most widely produced natural fibre in the world and represents about 46 per cent of the global textile market. By contrast, wool accounts for 3 per cent, synthetics 51 per cent and other fibres like silk, hemp and mohair make up a very small proportion.

Cotton seed is a by-product of the more valuable cotton fibre, and makes up about 15 per cent of the total financial returns to farmers. For every 227 kilogram bale of cotton lint, about 300 kilograms of cotton seed is produced. Cotton seed is a valued raw material for food oils for human consumption and high protein feed for livestock. Cottonseed oil is one of the world's most popular vegetable oils.

The Australian Cotton Industry

Although cotton was introduced to Australia with the First Fleet, it was not established even as a minor commercial crop until the 1850's. In the 1860's cotton became an important dryland crop in Queensland used to clear the way for dairying and pasture renovation and was considered a low input, low return crop.

The completion of Keepit Dam on the Namoi River and the subsequent introduction of irrigation into northern New South Wales during the 1960's and 1970's was the major trigger for the development of the Australian cotton industry.

Figure 1: Australian cotton growing regions (Cotton Catchment Communities CRC)

Currently seventy per cent of Australia's cotton is grown in New South Wales (the Macquarie Valley, the Namoi Valley, the Gwydir Valley, Bourke, Hillston, Hay and Menindee districts) with the remainder grown in Queensland (the Macintyre Valley, Darling Downs, St George, Theodore, Biloela and Emerald regions). Depending on water availability about 400,000 hectares of irrigated cotton is grown in Australia. The area of dry land or rain grown cotton varies considerably from year to year depending on commodity prices, soil moisture levels and rain. The area of dry land crop can vary from 5000 to 120,000 hectares.

In an effort to expand the cotton growing regions and address some of the challenges raised by our variable climate, cotton growing has been trialled in northern Australia.

Most Australian cotton farms are owned and operated by family farmers, are typically between 500 to 2000 hectares, are highly mechanised, capital intensive, technologically sophisticated and require high levels of management expertise. About 80 per cent of cotton farms are irrigated and as part of the enterprise mix generally grow other crops such as wheat and sorghum and/or graze sheep and cattle.
On a global scale Australia is a relatively small producer growing about 3 per cent of the world's cotton although has a reputation for producing high quality cotton. Similar to other agricultural commodities grown in Australia, the Australian cotton industry is a large exporter. As of 2007 the largest cotton producers are the China, India, USA, Pakistan, Brazil, Uzbekistan and Turkey. Major importers of Australian cotton are Indonesia, Japan, China, Thailand and South Korea.

Industry productivity

Since 1960, lint yields have steadily increased at about 22 kilograms of lint per hectare per year. Australian average yields are now the highest of any major cotton producing country in the world and yields have continued to edge upwards from 1200 kg/ha in the 1970s, through 1400 kg/ha in the 1980s to 1600 kg/ha in the 1990s and are now above 1800 kg/ha. Research and development, combined with its practical implementation by Australian cotton growers has under-pinned these significant increases in production. According to International Cotton Advisory Committee forecasts, the average global yield during 2006/07 was expected to be 716 kg/ha which is well below Australian productivity levels.

The gross value of cotton produced in Australia has increased rapidly since 1985, with the exception of the drought years 1986, 1992 to 1994, and 2003/2004. The gross value of production peaked at $1.9 billion in 2000/2001 and was $1.2 billion in 2004/2005 and $1.1 billion in 2005/06 making the industry important not only for the economy in cotton growing communities but also for Australian community as a whole.

The greenhouse effect

The greenhouse effect is a natural phenomenon. Naturally occurring greenhouse gases such as water vapour, carbon dioxide, methane and nitrous oxide trap some of the heat radiated by the earth's surfaces after being warmed by incoming solar radiation.

Somewhat similar to the effect of a greenhouse this has the effect of keeping surface temperatures higher than otherwise would be the case warming the atmosphere by about 33ºC (from minus 18ºC to plus 15ºC). It is this greenhouse effect that makes earth habitable for humans.

However, there is increasing evidence such as shown in the IPCC 2007 reports available at www.ipcc.ch/ that human activity is enhancing the greenhouse effect.

The burning of fossil fuels such as coal and oil for energy production and transport and through changing patterns of land use (such as land clearing and urbanisation) has lead to an increase in carbon dioxide levels in the atmosphere. Methane levels have also increased as a result of emissions from deforestation, landfills, livestock and agriculture and fossil fuel burning. These and other greenhouse gases added by human activities enhance the Earth's natural greenhouse effect and result in additional global warming (Bureau of Meteorology 2003, IPCC 2007).

Global greenhouse gas emissions have grown since pre-industrial times with an increase of 70% between 1970 and 2004 (IPCC 2007). Atmospheric carbon dioxide levels are rising particularly rapidly. In 2005, the globally averaged concentration of carbon dioxide in the atmosphere was about 379 parts per million (ppm), one-third higher than it was before the industrial revolution began in the late 18th century.

Scientists can measure the historical amount of greenhouse gas in the atmosphere by drilling into the Antarctic ice and measuring gases in the bubbles of air trapped in the layers of ice at the time the ice was formed. The ice itself provides information about past temperatures, through the ratio of naturally occurring oxygen isotopes. Ice cores drilled at Vostok and Dome Concordia in Antarctica, have provided information on climate going back 420 000 and 640 000 years respectively.

These measurements confirm that current atmospheric concentrations of carbon dioxide are unprecedented in the past 640 000 years (Barnola et al 2003).

In the past temperatures and carbon dioxide levels while following similar cycles have remained within lower and upper boundaries. Carbon dioxide levels have ranged from 180 to 280 ppm coinciding with ice ages (former) and the warmer interglacial periods (latter).

The significance of the relationship between air temperature anomalies and atmospheric greenhouse gas concentrations is in the corresponding trends. The trend in atmospheric greenhouse gas concentrations matches with the trends in air temperature (i.e. a rise in atmospheric greenhouse gas concentrations matches with a rise in air temperature). Temperature differences of about 8 to 10^{o}C are correlated with CO_2 changes of about 80 ppm.

The key issue this raises is that with present day levels of atmospheric greenhouse gas at record highs (for at least the last 650 000 years) what will happen with our climate into the future.

Cottons greenhouse gas footprint

Greenhouse gases emitted through cotton growing include:

- carbon dioxide (CO_2) from soils through the decomposition of soil organic matter especially after cultivation
- carbon dioxide (CO_2) from fuel and fertilizer use during cultivation, planting, harvesting, pumping and the use of some chemicals and urea based fertilisers
- nitrous oxide (N_20) from fertilizer & organic N sources
- methane (CH_4) from water logging

Below: Gas chambers as part of the farm trial measuring the greenhouse gasses from a cotton crop east of Dalby, QLD.

Nitrous oxide released to the atmosphere from the process of denitrification is the most significant greenhouse gas contributor from cotton production. It is of greater significance in irrigated soils particularly when high rates of nitrogen based fertilizers are used.

Nitrous oxide emissions have been measured on Australian irrigated cotton farms by Dr Peter Grace (QUT) and Dr Ian Rochester (CSIRO) at ACRI and are on average well below the IPCC default benchmark. This means that Australian cotton growers have a lower greenhouse gas footprint than producers from other cotton growing regions in the world.

However, there is the potential that as soil nitrogen levels increase beyond what is required by the crop (either through applied nitrogen and/or organic sources) there could be a rapid increase in nitrous oxide emissions. This is because unused nitrogen is lost to the atmosphere as nitrous oxide and has been particularly evident as nitrogen fertiliser rates exceed 200 kg/ha.

Therefore, reducing the potential loss of nitrogen to the atmosphere will have both environmental (reduction of greenhouse gas output) and economic (improvement in fertiliser use efficiency) benefits. Management strategies may include:

- Increasing soil carbon levels by reducing cultivation
- Reducing the opportunity for water logging
- Using legume cropping and green manures to reduce the application rates of N fertilisers
- Reducing the time between applying pre-plant fertilisers and planting and increasing the amount of N applied later in the season relative to pre-plant applications
- Matching fertiliser applications to plant demand

Cotton greenhouse calculator

Cotton growers interested in calculating their farms greenhouse footprint can use the Cotton Greenhouse Gas Calculator available at www.isr.qut.edu.au/tools/index.jsp

This will calculate an estimate of a farming enterprises greenhouse footprint by comparing the relative contributions from fuel, soils and nitrogen for that operation. On farm energy use is an area of likely further research and development with the goal of enabling individual growers to improve energy use efficiency where it is cost effective to do so.

Regional observations of climate change - temperatures

Australia has one of the most variable climates in the world. Adding to the challenges this poses is the large body of evidence of the increasing impact of human activity on our climate. Australia's mean maximum temperature has risen 0.06°C per decade and mean minimum temperature has increased 0.12°C per decade between 1910 and 2004 (Nicholls and Collins 2006). These trends vary regionally, but average temperatures have risen across almost all of Australia.

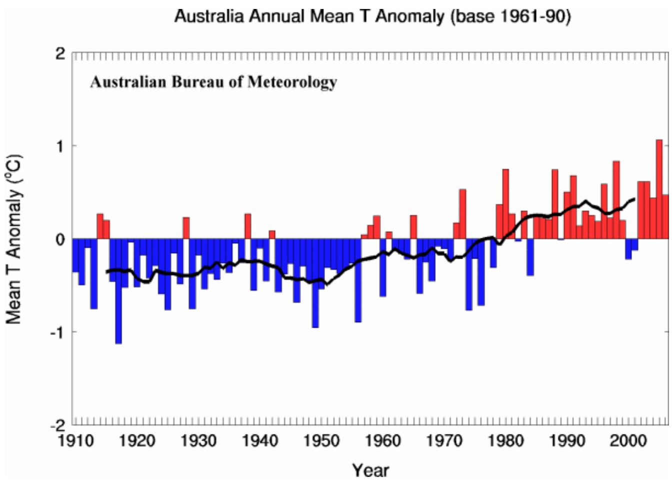


Figure 2: Australian annual mean temperature anomalies from 1901 to 2006

The difference between day and night temperatures (diurnal range) has also decreased in most areas since 1910, with the trend particularly evident in Queensland and parts of New South Wales. This is consistent with what is expected from an enhanced greenhouse warming.

The frequency of extreme hot events has also increased since the 1950s and the frequency of extreme cold events has declined. The Australian average for the 1957-2004 period shows an increase in the frequency of days of 35°C or more by 1 day per decade and an increase in the number of nights of 20°C or more by 1.8 days per decade.

At the same time there has been a decrease in the number of days of 15°C or below by 1.4 days per decade and of nights 5°C or below by 1.5 nights per decade (Nicholls 2005).

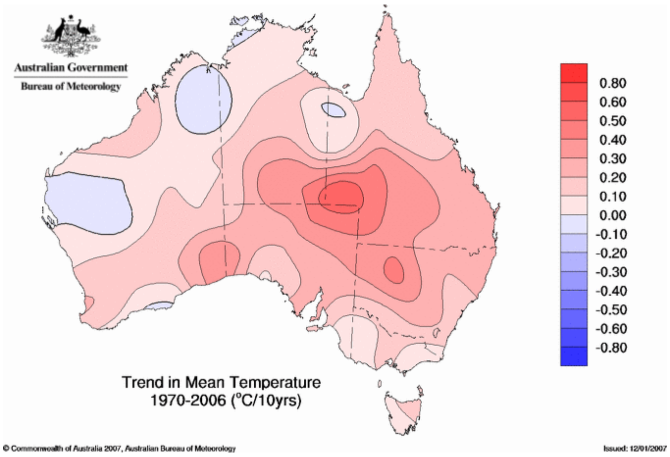


Figure 3: Trend in mean temperature from 1970 to 2006 (°C per decade)

Temperature trends throughout cotton growing regions are consistent with general Australian trends. Average annual minimum temperatures have increased by 0.9°C and average annual maximum temperatures by 0.6°C since 1950.

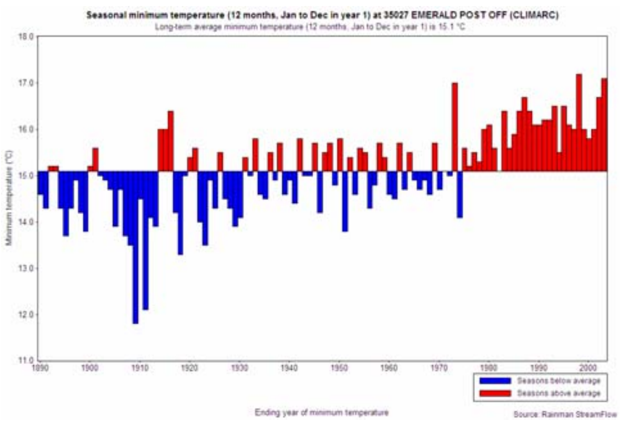


Figure 4: Annual minimum temperatures at Emerald from 1890 to 2006

Maximum summer temperatures also rose by up to 0.3°C per decade in many areas over the same period. The number of hot days is also increasing in many centres, while the incidence of cold nights is declining. Small increases in average temperature might not seem important on their own, but they reflect significant increases in extreme temperatures.

Simply, this means a higher incidence and increased severity of heatwaves and a decline in the number of very cold nights. These changes have the potential to provide both opportunities and threats to the cotton industry.

Regional observations of climate change – rainfall

Historically, rainfall across eastern Australia was relatively high in the late 1800's declining through to the mid 1940's. This period was followed by a general increase during the 1950's through to the 1970's and 1980's. Since then much of eastern Australia (particularly Queensland) and south-west Western Australia has seen a drying trend.

This trend has become particularly pronounced since 1970. At the same time, rainfall has increased throughout north-west Western Australia.

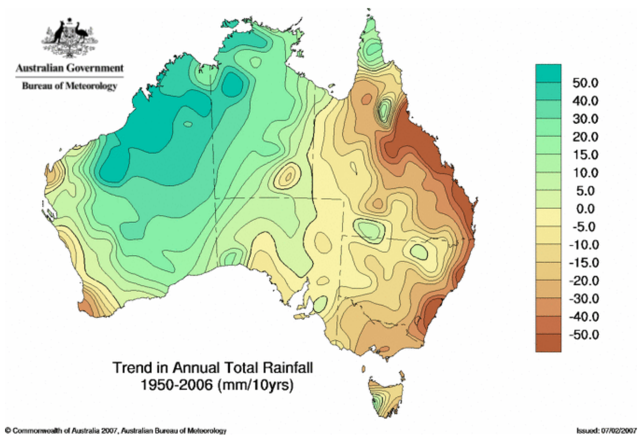


Figure 5: Trend in annual total rainfall from 1950 to 2006 measured in mm per decade

While this trend may be in part associated with natural or inter-decadal rainfall variability, research has also linked these changes to pollution, stratospheric ozone depletion and increasing atmospheric greenhouse gas concentrations.

The increasing rainfall in northwest Western Australian and the decline in rainfall in eastern Queensland has been associated with changes in the numbers of tropical cyclones crossing both the Queensland and western Australian coastline.

Initial studies on the causes of the increasing rainfall trend in the north west of Australia have also found that enhanced greenhouse gases and aerosols play a part (Liepert et al 2004).

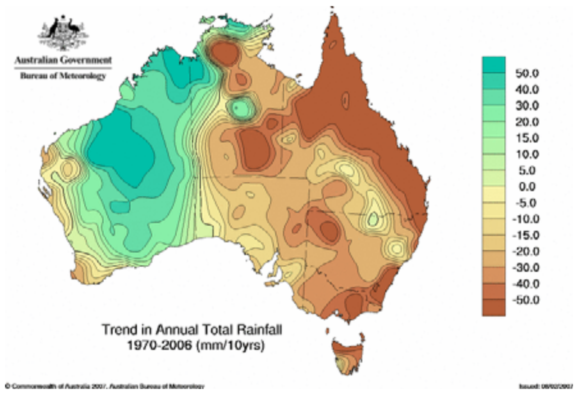


Figure 6: Trend in annual total rainfall from 1970 to 2006 measured in mm per decade. Note the increased drying trend across eastern Australia especially when compared to figure 5.

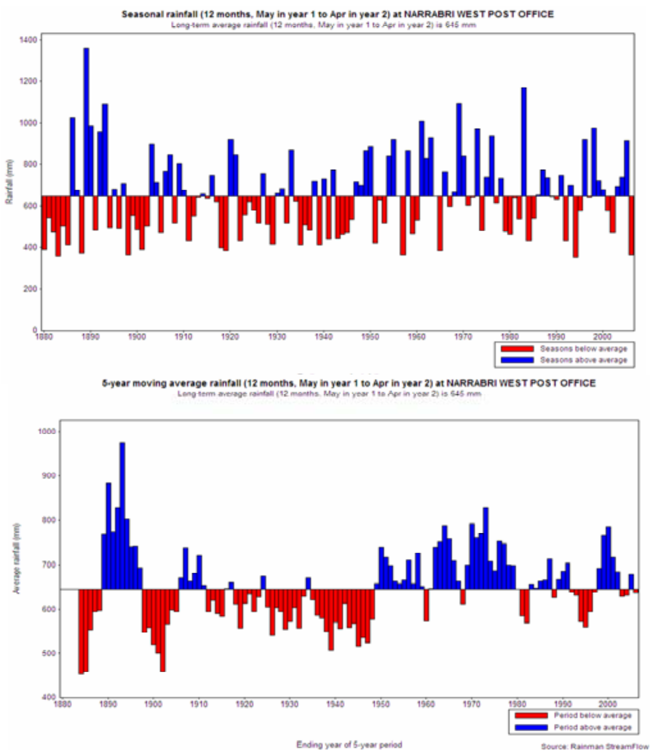
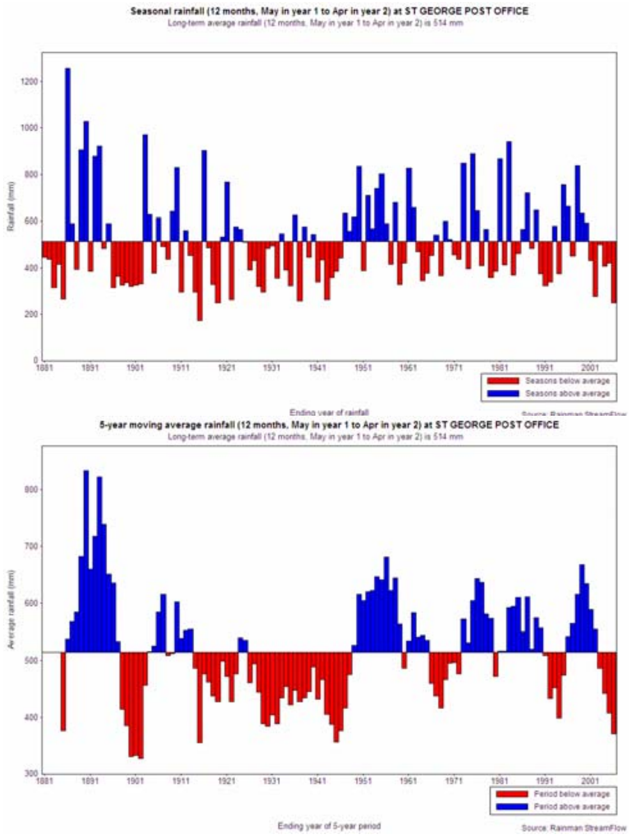


Figure 7: Annual rainfall recorded from 1880 to 2006 (top) and five year moving average rainfall at St George (bottom). Note the prolonged periods of above and below average rainfall.

Figure 8: Annual rainfall recorded from 1880 to 2006 (top) and five year moving average rainfall at Narrabri (bottom). Note the variability of rainfall recorded which is typical of Australian cotton growing regions.



This combination of increasing temperatures and decreasing rainfall especially throughout central and southern Queensland is likely to pose challenges especially with reduced soil water balances.

Projections of climate change

While the investigation of past rainfall, temperature and other climate trends provides useful information, this type of trend analysis should not be used as a forecast for the future. That is the role of Global Climate Models (GCM).

Climate change projections are developed from a range of computer based global climate models and scenarios of future greenhouse gas concentrations. There is a level of uncertainty with the projections especially out to 2070 as it is difficult to predict global greenhouse gas emission rates that far into the future.

There is also more confidence in temperature projections than rainfall projections due to the direct relationship between atmospheric greenhouse gas concentrations and global temperatures.

The models are constantly under review and are tested for how well they represent past climates and present climatic conditions, including extreme events, year-to-year variability and observed trends. Only models that can simulate the climate adequately are used to develop projections of future climate.

Projections of climate change - temperature

Key findings of the CSIRO climate change regional temperature projections for Australia include:

- Most of Australia to warm 0.4 to 2.0°C by 2030
- Most of Australia to warm 1 to 6°C by 2070
- Warming is expected to be higher inland
- A higher rate of warming in spring and summer than autumn and winter
- An increase in the average number of extreme hot days and decrease in the average number of extreme cold days and frosts

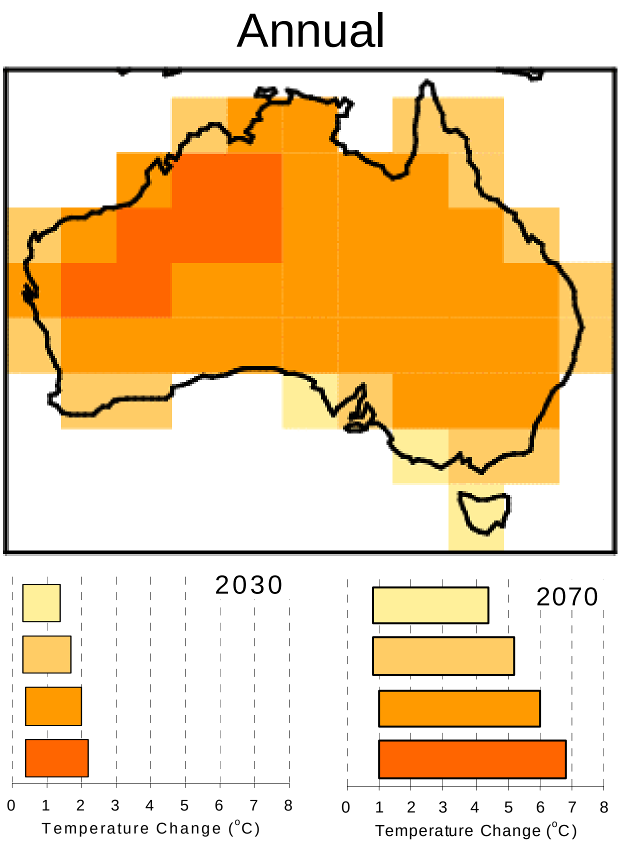


Figure 9: Projected temperature change to 2030 and 2070 (CSIRO)

Projections of climate change - rainfall

Key findings of the CSIRO climate change regional temperature projections for Australia include:

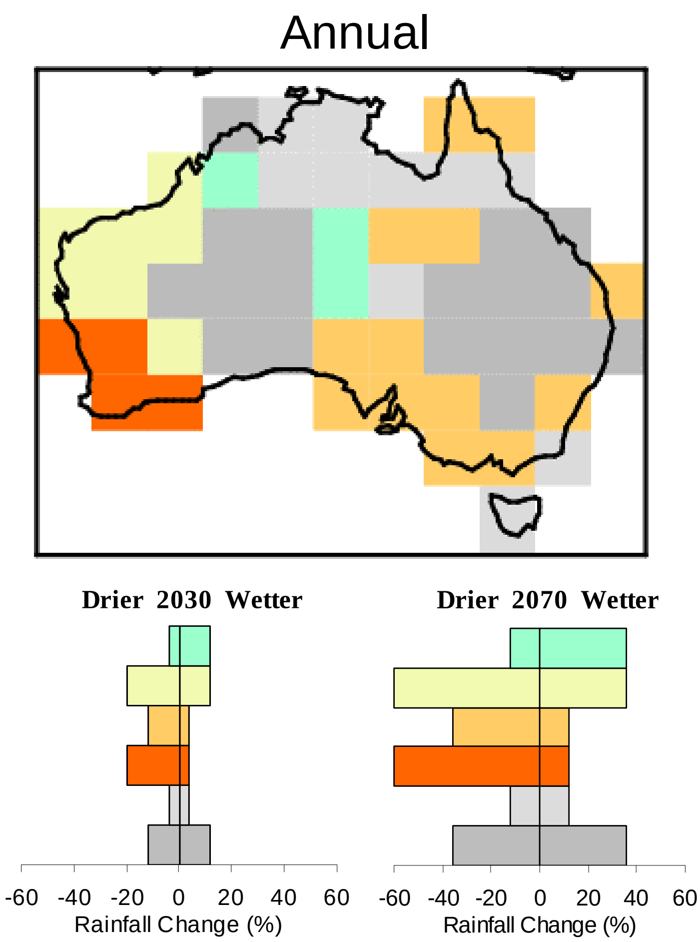


Figure 10: Projected rainfall changes to 2030 and 2070 (CSIRO)

- A tendency towards a lower annual average rainfall in the south west (-20 to +5% by 2030, 60 to +10% by 2070), south east and parts of Queensland (-10 to +5% by 2030, -35 to +10% by 2070)
- No distinct signal for annual average rainfall across the rest of Australia (-10 to +10% by 2030, -35 to +35% by 2070)
- A tendency towards less rainfall across most of Australia (especially southern Australia) during winter and spring: -20 to +5% by 2030, -60 to +10% by 2070
- Projected rainfall changes during summer and autumn for most locations are -10% to +10% by 2030 and -35% to +35% by 2070 or tend towards an increase. This excludes the south east, south west and Tasmania where there is a tendency towards less rainfall during summer and autumn: -10 to +5% by 2030, -60 to +10% 2070
- Northern Australia tends to have more pronounced wet and dry seasons
- Increases in extreme daily rainfall

Projections of climate change - potential evaporation and moisture balance

Key findings of the CSIRO climate change regional temperature projections for Australia include:

- A tendency towards an increase in potential evaporation of 0 to 8% per degree of warming throughout most of Australia with the larger tendency where there is a corresponding decrease in rainfall
- A tendency towards a decrease in the annual water balance throughout most of Australia of 40 to 120 mm per degree of warming
- This represents a decrease of 15 to 160 mm by 2030 and 40 to 500 mm by 2070 with the largest impact in spring

Even if rainfall remains consistent with long term averages, the rise in overall temperatures and potential decreases in water balance indicates greater moisture stress throughout Australia. Therefore water use efficiency, access to water and soil water management will remain dominate issues into the future.

Impacts of climate change on cotton growth and development

Climate change has the potential to impact on many facets of cotton growth and development. There will be a need to investigate:

- the inter-relationships of impacts of changes in rainfall, in carbon dioxide concentration, reduced water availability, increased atmospheric evaporative demand (lower humidity), and increases in temperature
- the relative degree of these impacts that may occur with growing cotton in different regions.

Increasing CO_2 levels has the potential to increase photosynthesis and water use efficiency leading to higher crop yields. However, the benefits may be offset by declines in rainfall, increases in temperature and/or increases in atmospheric evaporative demand.

Temperature increases at the start and end of seasons may have a positive effect on yield by extending the window for cotton growth. However, an increase in the frequency of days and nights with very high temperatures may negatively impact on both growth and development.

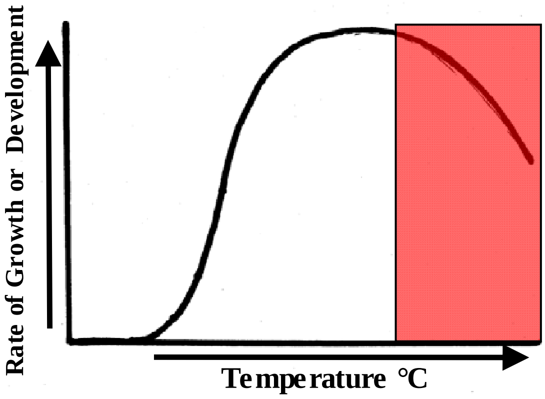


Figure 11: Negative consequences of high temperatures on plant growth and development include reduced photosynthesis, high night respiration, low pollination (parrot beak), shedding squares and flowers, boll freeze, short fibre and high micronaire (CSIRO)

Further studies of cotton plant physiology in Australian conditions with climate change scenarios are needed. This will need to include the combination of lower water availability with higher temperatures, increased evaporative demand and higher concentrations of atmospheric greenhouse gases.

	Current climate		2020		2050	
	Bange and Milroy (days)	1966-1995 base (days)	Days of cold shock	Decrease in cold shock (days)	Days of cold shock	Decrease in cold shock (days)
Bourke	26	33	22-30	3-11	10-27	6-23
Gunnedah	33	37	5-33	4-32	13-31	6-26
Moree	25	38	29-36	2-9	17-34	4-21
St George	16	23	15-21	2-8	1-19	3-22

Figure 12: Positive consequences of an increase in temperatures will include a reduction in cold shock, improved crop establishment, more growth, bigger leaves, longer fibres (Chris Mitchell, CSIRO)

The OZCOT cotton crop simulation model coupled with climate change projections will be a powerful tool to investigate what adaptation strategies there are to offset the impacts of climate change. The further development of downscaled or localised climate change projections would help.

New joint CSIRO and Bureau of Meteorology regional projections are due to be released during October 2007, and will include probabilistic projections for rainfall and temperature. Statistically downscaled localised projections are also being prepared by the Bureau of Meteorology Research Centre as part of the IOCI and SEACI projects (including the Murray Darling Basin).

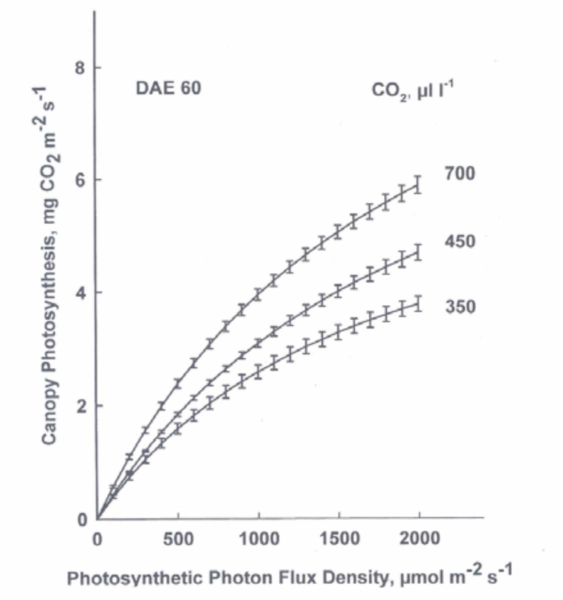


Figure 13: Impact of atmospheric CO2 concentrations on the canopy photosynthesis at different light levels (taken from Reddy et al., 1996). Positive consequences of an increase in CO_2 may include higher photosynthesis, better water use efficiency and potentially a 40% increase in yield.

More detailed information will allow industry to increase the use of climate change scenarios as part of longer term planning.

Industry Outlook

Management response to climate change in Australia has tended to be an extension of existing activities aimed at managing existing climate variability. There has been a general lack of research and evaluation in terms of the costs and benefits of differing adaptation strategies.

It can therefore be argued that currently the best option to manage climate change in any production system is to improve its resilience, sustainability and profitability.

It is irrelevant if changes in management systems are as a response to climate change or the need to remain economically viable – as long as suitable options are developed.

Many of the potential adaptation responses available to the Australian cotton industry have production efficiency benefits regardless of the rate and nature of future climate change. This is because the major responses will include:

- Improving Nitrogen use efficiency
- Improving Water Use Efficiency
- Improving management of climate variability (improving use of short medium and long-term weather and climate forecasts, improving climate risk management including understanding and managing the trends and extremes regionally and globally for production and implications for our markets such as impact of potential global drying trends on our competitors)
- Plant breeding and farming systems to take advantage of increased temperatures, handle increased water stress, respond to elevated atmospheric CO_2 etc
- Auditing energy use in cotton farming systems including developing benchmarks and tools to assess and improve efficiency and being ready to exploit opportunities such as bio-diesel
- Developing Best Management Practices for minimising the industry's greenhouse carbon footprint

Given that there will be the no one solution for all the challenges raised by climate change the best adaptation strategy for any industry will be to develop more resilient systems. Early implementation of adaptation strategies particularly in regard to enhancing resilience, have the potential to significantly reduce the negative impacts of climate change (Howden et al. 2004).

Cotton is currently being grown in hotter regions in the world. By focusing on its strengths the Australian cotton industry has little to lose and much to gain by reacting in a pro-active way.

Workshop participant feedback

As part of the Climate Change in Cotton Communities project funded by the Australian Greenhouse Office and the Cotton Catchment Communities CRC, climate change workshops were run at Narrabri, Dalby, St George, Goondiwindi and Emerald. Some common themes of interest were developed in the workshops. A sample of feedback from workshop participants covered by those themes included:

Crop Management/Agronomy

- Management is the key – always has been always will be

- Opportunities to take advantage of increased temperatures especially at the start and end of the growing season
- Better manage current system; row configurations, irrigation strategies, improve water storage and infrastructure
- Improve on-farm water use efficiency – aim to increase quantity and quality of yield over smaller area
- Use soil moisture tools and better scheduling of irrigation.
- Early maturing of crops using less water because of the shorter growing season. Opportunity to grow more crops in the rotation
- Plant breeding /transgenic development provides opportunities

Above: Cotton Grower Paul Hawkins measuring soil moisture with a capacitance probe

Cotton Farming Systems

- Profitability will have more impact than climate change
- Develop adaptable farming systems – already exists – manage for change as it occurs
- Designing a profitable and sustainable farm business – diversification and grow other crops.
- Educate about other suitable crops and drought tolerant varieties
- Diversify into other crops and livestock.
- Struggling with limited financial and time resources – solutions need to be realistic and profitable
- Develop a clear assessment of present impacts at the business level and what are the changes that can be made

Industry

- Water availability (access, government regulations) will be a challenge
- Industry expansion or relocation from traditional cotton growing regions raises a number of challenges - the expansion south may simply be a result of growers taking advantage of the recent window of warm weather and is into an area where there is already strong competition for water; while there may be more available water any further expansion into northern Australia will have pest and disease issues to overcome
- The industry is already dealing with climate change now
- Address community resilience - think globally and act locally - focus on the local scale
- Industries will respond at different rates
- Legitimate adaptation strategy is to exit industry
- Continue to build adaptive capacity and industry strengths
- Identify false hopes and promises like the shift to north Queensland – while it may provide increased access to water it raises different challenges with soil types and pest and weeds issues - so focus more on building industry resilience and less on industry relocation
- External pressures are overwhelming at times – need for more focussed political leadership - need mechanisms in place to influence policy
- Link communities to the catchments as well as industry

Research

- Need more research on the impacts on quality (length particularly) and yield
- Need more research on the likely impacts of increased CO_2
- Concern of the climate change research gravy train - needs a reality check
- Knowledge on possible pest trends (insects, weeds, diseases)
- Utilise information currently available and don't fund duplicate research.
- Need downscaled information - current broad (especially with rainfall) information little use at all - a -35 to +35% shift in value communicates absolutely nothing
- Accept temperature projections but what about decadal wetter and drier patterns - it's hard to believe that average rainfall is going to decrease in a straight line in Queensland and NSW

Case Study – a CSIRO plant scientist's perspective

Dr Greg Constable's specific research interests include cotton breeding, agronomy and crop management systems.

According to Greg, the use of crop management techniques and the development of cotton varieties to minimise any negative impacts of heat and moisture stress are an essential part of an integrated farming system.

While as a tropical plant cotton is well adapted to moderate levels of heat, the potential range of temperatures experienced by cotton plants grown in broad-acre cropping systems can induce temperature stress negatively impacting on growth and yield.

Daily maximum temperatures above 35^{o}C to 40^{o}C and/or minimum temperatures above 25^{o}C to 28^{o}C are known to reduce photosynthesis, increase respiration and reduce pollen viability. Extreme daily maximum temperatures also negatively impact on fibre length and fineness.

Greg explained that breeding programs are already aimed at developing cotton varieties well suited to the environmental and climatic conditions experienced throughout the cotton production regions of Australia. This investment in research and plant breeding has developed varieties with known high heat tolerance.

And as to the future, "New biotechnology tools as well as the measurement of yield performance under varying environmental conditions and other physiological measurements offer potentially faster and more targeted breeding to meet any challenges".

"The recent run of hot seasons in Australia has provided a suitable selection environment for the cotton breeding program with regard to likely conditions under a warming climate change scenario. Plant breeding experiments are located throughout the different production regions to evaluate the suitability of new breeding lines to each environment".

"CSIRO's cotton breeding program will continue to develop varieties suitable for the Australian cotton industry and which have been tested across a wide range of environmental and climatic conditions".

"It is of interest to note that cotton is grown successfully in regions currently hotter and drier than current climate change predictions for the cotton growing regions of Australia – such as in Pakistan and Arizona in the United States".

Above: Checking Cotton

Case Study – a researcher's perspective

Having completed a Bachelor of Science in Agriculture at The University of Sydney, Nicola Cottee is undertaking a PhD project titled 'Screening cotton cultivars for thermotolerance under field conditions'. The aims of this research are to firstly develop the best methodologies to estimate heat stress tolerance in cotton and to then develop techniques for screening a range of cotton cultivars for high temperature tolerance.

While cotton is generally grown in hot environments, consistent high temperatures (above 35^{o}C) throughout the growing season may limit the growth and development of the crop, and ultimately yield. Techniques that measure leaf function through photosynthesis, and cell damage after exposure to high temperature stress are currently being explored.

This project has provided Nicola with opportunities to collaborate with research scientists at The University of Sydney, CSIRO Plant Industry at Narrabri and Texas A&M University, and to undertake comparative field studies under contrasting hot environments in Australia and the United States of America. It is funded by CRDC.

Preliminary results have shown some success identifying techniques that may infer differences in cotton cultivars under high temperatures. This project will enable the selection of agronomically superior cotton cultivars for growth and production in the warmer cotton growing regions of New South Wales and Queensland. In addition, it may also assist with selection of cultivars for hotter environments as a consequence of climate change.

Above: Nicola taking photosynthesis measurements on a Li-6400 portable photosynthesis system.

Case Study – a landcare coordinator's perspective

John Scriven is the Landcare Coordinator for the Warroo Balonne Regional Landcare Association. John's area of responsibility covers the approximately 44 719 square kilometres of the Warroo and Balonne Shires. This includes the cotton growing regions of St George and Dirranbandi.

The aim of the Warroo Balonne Regional Landcare Association is to increase and foster community and landholder awareness and enthusiasm for the local environment and how it is managed.

John's role as a Landcare coordinator is to facilitate stakeholder groups through a sub-catchment planning process that focuses on natural resource management. These groups meet regularly with John and technical staff from government agencies to address environmental issues such as erosion, salinity, introduced species and weeds, riverine management and increasing biodiversity.

Individual Property Action Plans (IPAP) are developed with landholders who detail proposed on-ground works, budgets required and environmental outcomes.

John believes that one of the biggest challenges for the Warroo and Balonne Shires raised by climate change will be a decrease in rainfall reliability from season to season and an increase in the extremes of droughts and floods.

'This means that business and farm cash flows may become more variable. As Landcare rehabilitation work is usually joint funded by the landholder and government, this could mean that a lot of this work will only get done in the good years'

'This also means the days of sitting down between Christmas and New Year to draw up next years work calendar are finished, we will have to see what the seasons bring'.

And as to the impact on local farmers 'I think farmers and irrigators will have to be very flexible with farming practises and crop selection. This means being prepared to go with either winter or summer crops depending on the season'.

'As for graziers I think more will go in for backgrounding or dealing stock instead of breeding them. This means graziers will only have stock when they have feed. Or they may aim to get income from agistment stock when they have surplus feed available'.

Above: Mixed cropping, cotton and sorghum

Above: Monitoring equipment used to track the greenhouse gases from a cotton crop on the farm trial.

Case Study - a cotton grower's perspective

'Neilo' is a 4700 ha mixed farming enterprise located west of Toobeah, Queensland. It comprises approximately 1400 ha of land developed for surface irrigation on which cotton can be grown, 1100 ha of land developed for broad acre farming with the rest of the property used for grazing running on average 350 breeding cows and calves.

Dave Taylor from 'Neilo' believes that climate change will create a number of challenges and opportunities including:

- increases in extremes of rainfall and temperature
- increases in the speed of change between temperature patterns
- greater rainfall variability and changes in distribution throughout the year
- an increase in both beneficial and pest insect diversity as a reflection of these changes
- changes in weed diversity
- opportunities for changes in crop marketing strategies
- taking advantage of livestock purchasing or selling opportunities.

Dave explained that the focus at 'Neilo' on managing climate change and variability has taken the form of using modelling technology such as Rainman Streamflow, Howwet, Howoften, WhopperCroppa and Hydrologic to investigate the effect different rainfall and temperature patterns have on the production system and variations to planting opportunities, yield and harvest times.

The output from these tools is also incorporated into a budget analysis to investigate any potential impact on gross margins and changes to the level of acceptable risk and equity growth.

Dave believes that regardless of climate change, the basics of any farming or production system still need to be carried out correctly as getting the basics right has the biggest influence on production.

'For example we will have to be very careful in our reliance on residual type herbicides for weed management so as to not miss a cropping or cash-flow opportunity but in doing so we must be mindful on any developing resistance to contact herbicides'.

As to adapting to changes in the future 'I believe marketing is going to be one of the best tools to offset some production or yield loss and it may change our risk paradigms if there is an opportunity that looks too good to miss. I feel climate change and looking for potential opportunities further enhances my wish to develop a permanent bed system in irrigation country based around minimum tillage and moisture retention'.

'No doubt there will be challenges with climate change, but without these challenges and changes we may not realise any new opportunities nor identify our weaknesses!'

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Adaptation is all about creating opportunities

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