Department of Agriculture and Fisheries – Drought and Climate Adaptation Program

DCAP Project Final Report

Project ID	DCAP 4 Necessary climate change projections data for quantitative agricultural risk management.
Grantee Name	

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1. Executive Summary

The aim of this project was to provide high-resolution climate change projection daily data for Queensland in an 'application-ready' format to be used by common biophysical models for simulation modelling. The data have been made available through DSITI's existing Consistent Climate Scenarios (CCS) portal, to provide easy access to new high resolution climate change projections for direct input into biophysical impact assessment using hydrological, pasture and crop models.

High-resolution and validated climate change projection daily data for Queensland is now available for download through the CCS portal for three key variables - daily rainfall, minimum and maximum daily temperature. Non-climate scientists (e.g. hydrological, pasture and crop modellers) now have online access to latest climate change projections data with statistical scaling methods, as well as dynamically rather than statistically downscaled data, providing the ability to run models continuously from 1980 out to 2100. This experimental dataset will improve our capability to analyse climate change impacts and risks through the modelling of crops, pasture, forests and soils. In addition, general users have access to summarised data through climate change reports available through the FORAGE decision support system on the LongPaddock website. FORAGE Regional Climate Projections report based on the new AR5 climate change projections, have been used over the last 12 months to support climate change workshops held across Queensland (as part of related DCAP projects USQ 12.1 & DSITI 12.2). The CCS portal has been significantly enhanced by:

1. Building an online interface to IPCC Fifth Assessment Report (AR5) data sets and a new statistical method – Linear Mixed Effect State Space (LMESS) (Jin et al., 2015).
2. Upgrading the FORAGE Regional Climate Projections report to take advantage of the AR5 data access.
3. Calibrating the high resolution (10km) dynamically downscaled data from AR5 models.
4. CCS system has been enhanced to ingest new high resolution data and transform it into user friendly data sets.
5. CCS web site and user guide documentation updated to ensure the new downscaled data available and understood by users.

2. Project Background

The CCS portal was originally developed in 2012 by a joint DSITI- CSIRO project funded by the Commonwealth Department of Agriculture, Fisheries and Forestry (DAFF) through its Australia's Farming Future Climate Change Research Program. DSITI has recently produced high resolution with climate change projections on a 10 km grid, for the whole of Queensland up to 2100 using the CSIRO Cubic Conformal Atmospheric Model (CCAM) with funding from the Department of Environment and Heritage Protection (EHP). This new high-resolution dataset consists of the ten best performing IPCC models and will deliver calibrated (bias-corrected) daily data suitable for input to biophysical impact assessment using simulation models of hydrology, soil erosion, water quality, pastures, crops, biodiversity, pests and diseases.

By leveraging these CSIRO and EHP projects, we have provided easy and free access to a consistent set of the best available high resolution synthetic climate projections data across Queensland for use in biophysical models, which maintain 'weather-like' properties and also account for uncertainties and biases in climate change projections, as well as different methods of downscaling. The data are described as "application-ready" as they are delivered in a format and type to be used by common biophysical models (e.g. hydrology, crop and pasture models) for simulation modelling.

Without specific, detailed, consistent application-ready data, climate change scenarios are broad sweeping statements that do not adequately capture the trends, nuances and detailed daily changes in meteorology of future climates. Serious decision analytics for agricultural climate risk depend on being able to quantify future climate change impacts. Free and easy access provided to these datasets for Queensland will allow a better assessment of climate change impacts on water resources, catchment erosion and water quality, pasture and crop production, biodiversity, and agricultural pests and diseases.

3. Project Methodology

High resolution (10km) daily global climate model (GCM) output has been produced using the CCAM model (McGregor, 2005) to dynamically downscale coarse resolution grids from ten IPCC AR5 models for the RCP8.5 (high warming) scenario. The coarse resolution of GCMs means that when these are downscaled to higher spatial resolutions (e.g. 10km) the data exhibit systematic errors or biases. These errors may be due to:

- Limited spatial resolution (horizontal and vertical)
- Simplified physics and thermodynamic processes
- Numerical schemes
- Incomplete knowledge of climate system processes

Such errors should be corrected for, before using climate model data in impact studies. Therefore, to correct these errors or biases we need to 'calibrate' model simulations to ensure their statistical properties are similar to those of the corresponding observed values (the historical instrumental climate record 1981-2010). Data output from CCAM were bias corrected using measured data for the period 1981-2010 for three variables (maximum temperature minimum temperature and rainfall), using a parametric method (Piani et al., 2010). Bias correction was at 10km scale, annually based and similar to recent work in NSW (Argüeso et al., 2013).

The CCS processing system was adapted to access the new bias corrected data sets. The models with bias corrected downscaled data, available through CCS include; ACCESS1-0, ACCESS1-3, CCSM4, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-CM3, HadGEM2, MIROC5, MPI-ESM-LR, and NorESM1-M.

Extensive data and system checks were conducted to ensure the functionality of the CCS web site and the backend code processing on DSITI's high performance computing facility. Issues, such as fixing missing leap days in GCM output and controlling code versioning, were addressed.

The CCS web interface on the LongPaddock website has been modified to provide: (a) AR5 and LMESS method data; (b) High resolution dynamically downscaled data; and (c) access to data at both SILO gridded and patch point data

sets via an improved interface. In original project proposal, the CCS system was planned to be redeveloped on the cloud as part of the redevelopment of LongPaddock (DCAP DSITI project 10). However, due to a scope reduction in the LongPaddock project, we had to enhance the current CCS portal (on SharePoint), to include the new high resolution climate change projections. This solution has no impact to the users and is acceptable in the short-medium term.

4. Project Results

4.1 Achievements and Outcomes

The first achievement was to update the CCS portal to deliver data from AR5 models by using monthly change factors and Linear Mixed Effect State Space (LMESS) methodologies. Prior to the DCAP project, DSITI worked with CSIRO to provide an improved methodology LMESS (a quantile matching process) to improve the future representation of daily data from the historical record and at the same time DSITI implemented all processing for the AR5 models to supplement the existing AR4 data sets to supply data directly to a number of research projects. In summary:

- In October (2016) the CCS web interface on LongPaddock was enhanced to deliver AR5 data and the new improved methodology.
- The user guide was updated with Addendum 1, describing the new data sets and published on the LongPaddock website.
- Users have been downloading the new data sets (about 30 users requesting data each month so far in 2017)
- The system has been interfaced to the FORAGE Regional Climate Projections report replacing AR4 data sets with AR5 data sets.
- The updated FORAGE Regional Climate Projections report with new data from the CCS portal, was used to support:
    - A total of nine climate risk matrix workshops held in various locations across Queensland as part of related DCAP projects (USQ 12.1 & DSITI 12.2) and to support the Queensland Climate Change Adaptation Strategy (Q-CAS funded by EHP).
    - Two more climate risk matrix workshops are planned for July 2017.
    - Multiple FORAGE general awareness presentations have been delivered (2016/17) which have featured the Regional Climate Projections report and two training workshops for grazing extension staff.

Making new high resolution climate change projections accessible

A new data set for transient data daily from 1980-2100 have been produced to analyse the impacts of climate change with funding from EHP. Previous data sets produced in the CCS portal were for many views at one particular time in the future (e.g. 2030, 2050 and 2070) and drew daily variability from statistically adjusted historical records.

The new daily data are produced dynamically (from within the model) at high resolution 10km – as opposed to 96-192km in the original IPCC AR5 model runs. This makes the representation of future rainfall and rainfall rates much more realistic and in addition, improves the quality of data close to the coast line and in topographically complex areas. Variability, including extremes of temperature are directly produced by the down scaling process.

From each downscaled model a range of high resolution variables have been output to provide daily data portal for daily rainfall, minimum and maximum daily temperature, mean daily temperature, daily solar radiation, and daily wind speed at 10m height, daily pan evaporation and daily vapour pressure. In summary:

- Downscaled data have been produced for ten IPCC models, which gives a good basis for analysis of an ensemble, rather than relying on just one or two high resolution runs.
- To enable the application of the downscaled data, a bias correction methodology (also used by NSW) was applied to the data and three variables are now available in downscaled and bias corrected form.
- Users can “drill” the new bias corrected high resolution data layers and produce APSIM like data sets for any point on the SILO 5km grid, or for any station location.

- The CCS web interface was further modified to deliver the first version of bias corrected high resolution dynamically downscaled data.

4.2 Unintended Outcomes

The end of the project has created an unfunded liability to maintain an ongoing operational systems (e.g. maintenance associated with operating system, software upgrades, and corporate administrative requirements).

4.3 Partnership Formation

The following partnerships have been developed or strengthened during this project:

- This project was able to leverage Department of Environment and Heritage Protection (EHP) funded projects to provide high resolution climate change projections for Queensland and communicate the risk of climate change through a series the Climate Risk Matrix workshops across Queensland.
- The Terrestrial Ecosystem Research Network (TERN) has provided data and metadata links to the high resolutions climate change projections for Queensland raw data grids.
- Assistance to enhance the CCS code processing system by collaborating with one of the original developers of CCS, Mr James Ricketts, University of Victoria University, Melbourne.
- Access to the new high resolution climate change projections for Queensland through collaboration with A/Prof Jozef Syktus, Global Change Institute, University of Queensland.

4.4 Lessons Learned

This project has suffered some delays and scope changes due to dependencies on other projects, namely the DCAP redevelopment of LongPaddock (DCAP DSITI project 10) and the 'Deriving high resolution climate change projections' funded by EHP.

The scope of the redevelopment of LongPaddock had to be reduced half-way through this project, due to the complexity of the website. While the reduction in scope has been communicated and accepted by the project board, it has had flow-on effects to this project. The redevelopment of the CCS website onto the Amazon Web Services platform was not completed as planned, however as an alternative solution we modified the current CCS web interface. This is considered an acceptable solution for the medium-term and has not resulted in any reduction in functionality to the site or access to data therefore has no impact to users.

The statistical validation or bias correction of the climate change projections against the historical climate records (undertaken in the 'Deriving high resolution climate change projections' project) was a challenging process and it did cause some delays to the progress of the CCS project (e.g. a delay in achieving Milestone 3). However, the bias correction for the three main variables has now been completed and is available through the CCS system.

Subsequent variables e.g. daily solar radiation, daily pan evaporation and daily vapour pressure, will be updated as they are bias corrected through the ongoing EHP project 'Deriving high resolution climate change projections.'

4.5 Implications for the Future

- CCS enhancements will remain as part of the operational systems supported by DSITI and will continue to provide data sets to users free of charge providing a portal that supplies consistently prepared data in application-ready formats to help assess climate change impacts and risks. A second addendum to the user guide describing the methodology and data sets currently in the final stages of the DSITI publication process and will be published on the LongPaddock website in July 2017.

- Additional variables calibrated (bias corrected) as part of the ongoing EHP project 'Deriving high resolution climate change projections' will be added to CCS. Future work is also needed to review the bias correction methods, especially when applying bias correction on an annual basis (current method) using a parametric

method (current method) compared to monthly or seasonal using non parametric methods especially to better bias correct values of extreme rainfall coming from the models.

- The FORAGE Regional Climate Projections report will continue to provide simplified information for general users based on AR5 and change factors, however subject to future DCAP priorities, there is potential to integrate the new high resolution climate change data into the FORAGE report. For example, the prototype FORAGE Safe Carrying Capacity report could be enhanced to include an assessment of climate change impacts on carrying capacity and land processes such as runoff. This would assist producers to adapt to potential impacts of climate change on their businesses.

- The high resolution climate change projections can be used in assessments of the climate change impacts on the horticulture industry. There may be an opportunity to collaborate with DAF and the horticulture peak body Growcom through a potential future DCAP project developing climate change assessments and tools for horticulture crops and growing regions.

- There is also potential to apply these new high resolution projections to analyse climate change impacts of slowly evolving systems (e.g. forest growth and ecosystem changes in soil carbon and nitrogen), which would not have been possible with previous coarse resolution climate change data sets.

5. Conclusion

Experimental high-resolution climate change projection data for Queensland are now available through DSITI's existing CCS portal to provide fundamental climate change projections data for quantitative agricultural risk management. The advantage of this system is that it provides non-climate scientists (e.g. hydrological, pasture and crop modellers) with easy access to the latest climate change projections data with statistical scaling methods, for direct input into biophysical impact assessment using hydrological, pasture and crop models. This project has capitalised on previous DSITI foundational work (SILO -DSITI, the original development of the CCS system – DSITI/CSIRO/DAFF, development of high resolution climate change projections DSITI/EHP and the FORAGE decision support system DSITI/NRM/EHP). The backend processing system harnesses the capacity of DSITI's high performance computing facility and will provide users with the latest, application ready, and consistent climate change data for all of Queensland.

6. Financial Statement (Revenue received/Expenses paid/Revenue unspent

As agreed to be supplied after financial reporting for June has been completed.

7. Additional Information

- The URL for the CCS system is https://www.longpaddock.qld.gov.au/climateprojections/access.html (users must register before they can logon to the interface to download the data).

- The FORAGE Regional Climate Projections report is available from https://www.longpaddock.qld.gov.au/forage/climateprojections.php

8. References

Argüeso, D. Evans, J.P. & Fita, L. (2013) *Precipitation bias correction of very high resolution regional climate models.* Hydrol. Earth Syst. Sci., 17, 4379–4388

Jin, H., Kokic, P., Hopwood, G., Ricketts, J.H. and Crimp, S. (2015), A new quantile projection method for producing representative future daily climate based on mixed effect state-space model and observations 21st International Congress on Modelling and Simulation, Gold Coast, Australia, 29 Nov to 4 Dec 2015, pp1544-1550.

McGregor, J.L., (2005). *C-CAM: geometric aspects and dynamical formulation.* [Electronic publication]. CSIRO Atmospheric Research Technical Paper No. 70.

Piani, C., Haerter, J.O. and Coppola, E. (2010) *Statistical bias correction for daily precipitation in regional climate models over Europe*. Theor Appl Climatol 99:187–192. DOI 10.1007/s00704-009-0134-9

9. Appendices/Attachments

9.1 Milestone Reports

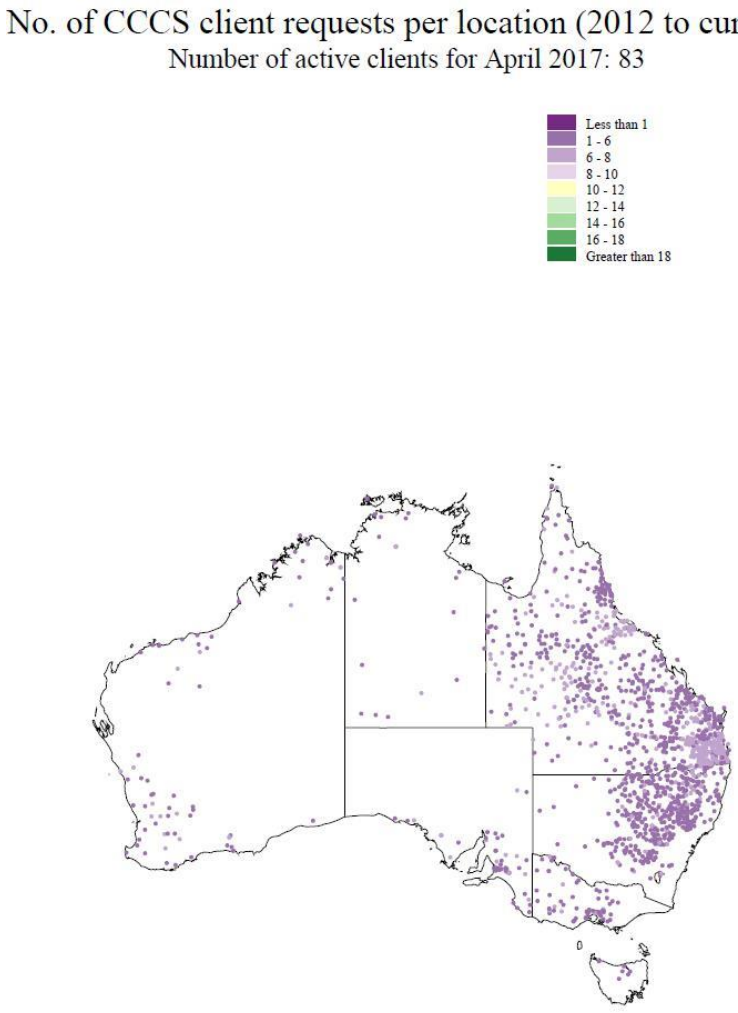
9.2 Case Studies

9.3 Project Reports

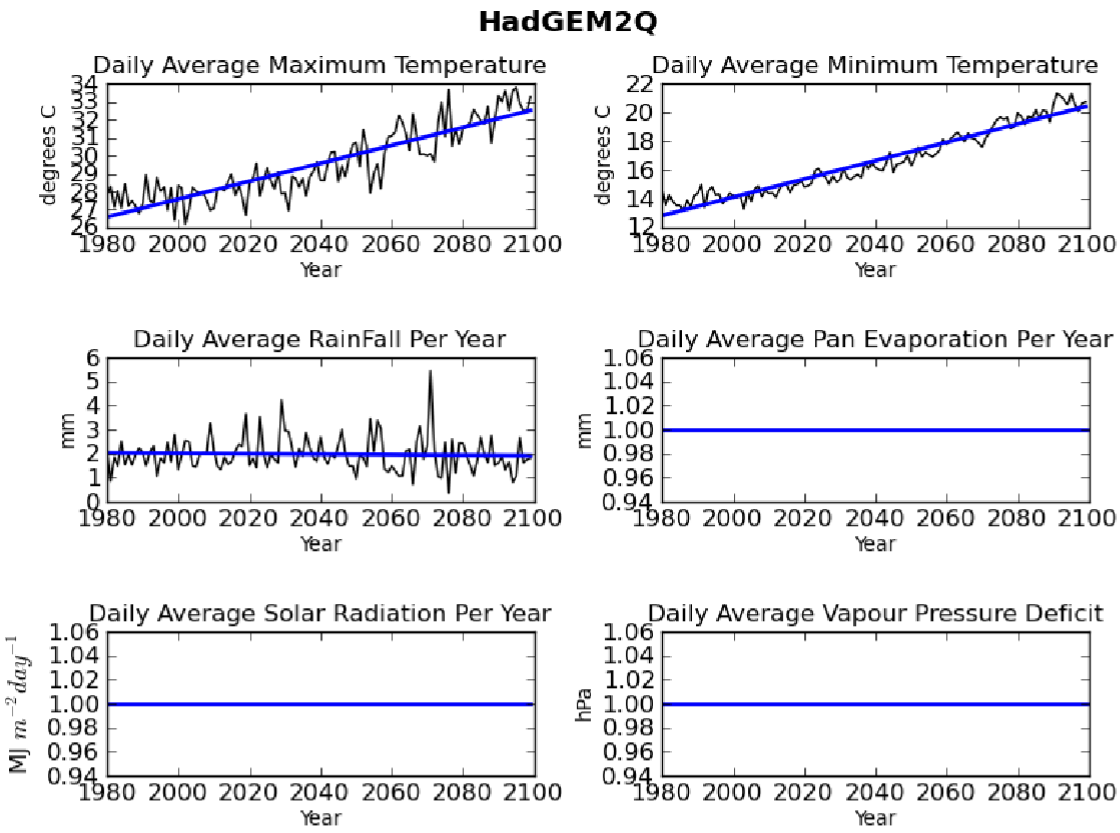
9.4 Scientific Papers

9.5 Products/Product Descriptions

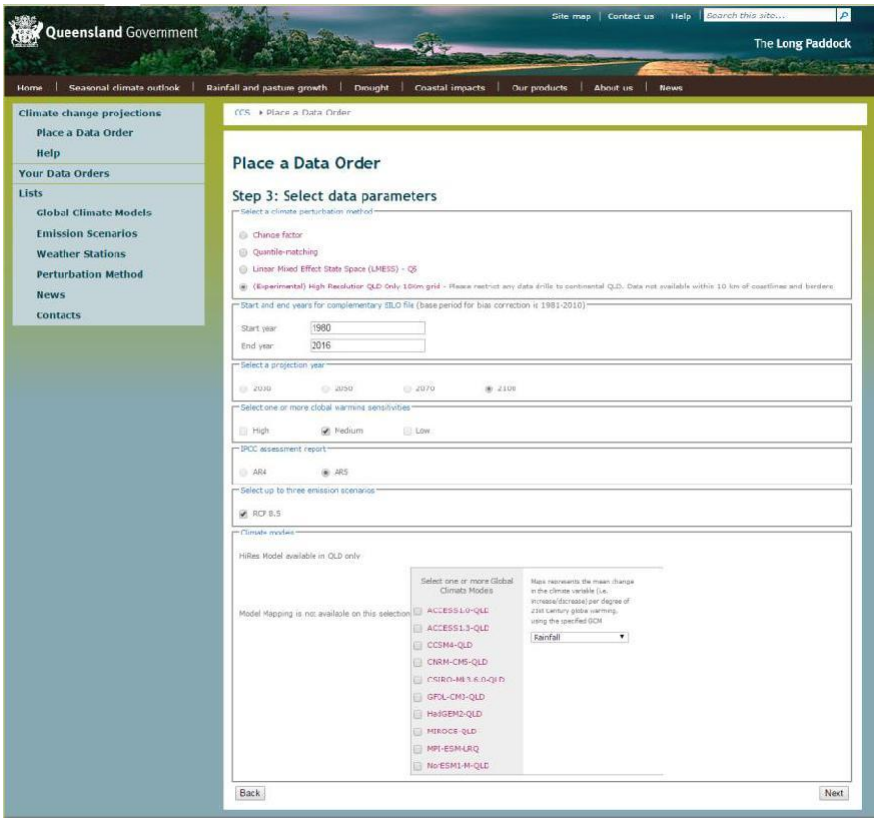
The CCS system has been extensively used especially for climate change studies in Queensland. See below a map of Australia showing the number of requests for data per location since 2012.



The graphs below show an example of the high resolution bias corrected data provided through the CCS system for Gayndah, Queensland (example diagnostic plot to be supplied to users with data files). Please note that currently bias corrected data is only available for maximum and minimum temperatures and rainfall. Pan evaporation, solar radiation and vapour pressure deficit will be added as the bias corrections is finished (as part of the ongoing EHP project 'Deriving high resolution climate change projections'.



A screen shot of the CCS web site data order page showing facility to obtain AR5 data sets and high resolution data from 10 GCM models



The regional climate projections FORAGE report constructed using AR5 data from the CCS data system.

FORAGE REPORT: REGIONAL CLIMATE PROJECTIONS

Queensland Government

http://www.longpaddock.qld.gov.au/forage June 26, 2017 Lot on Plan: 3MZ594 Label: noLabel

Introduction

This report is for the location indicated by the red crosshair symbol on the map below. The report presents information based on SILO historical climate data and Consistent Climate Scenarios (CCS) projections data (developed by the Department of Science, Information Technology and Innovation, DSITI). Annual and monthly climate projections data for 2030, 2050 and 2070 have been generated using 28 AR5 global climate models (GCMs), three model sensitivities to CO_2 rise (low, medium and high warming rates) and four Representative Concentration Pathways (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) which specify CO_2 levels from 435 to 449 ppm for 2030 and from 478 to 677 ppm for 2070. The baseline climate is the period between 1960 and 2015.

The monthly median values for the historical climate (1960 -2015) and climate projections for 2030, 2050 and 2070 are presented in the bar-dot graphs (below) which indicate the seasonal patterns of historical climate and projected climate under the different global warming rates and scenarios in 2030, 2050 and 2070.

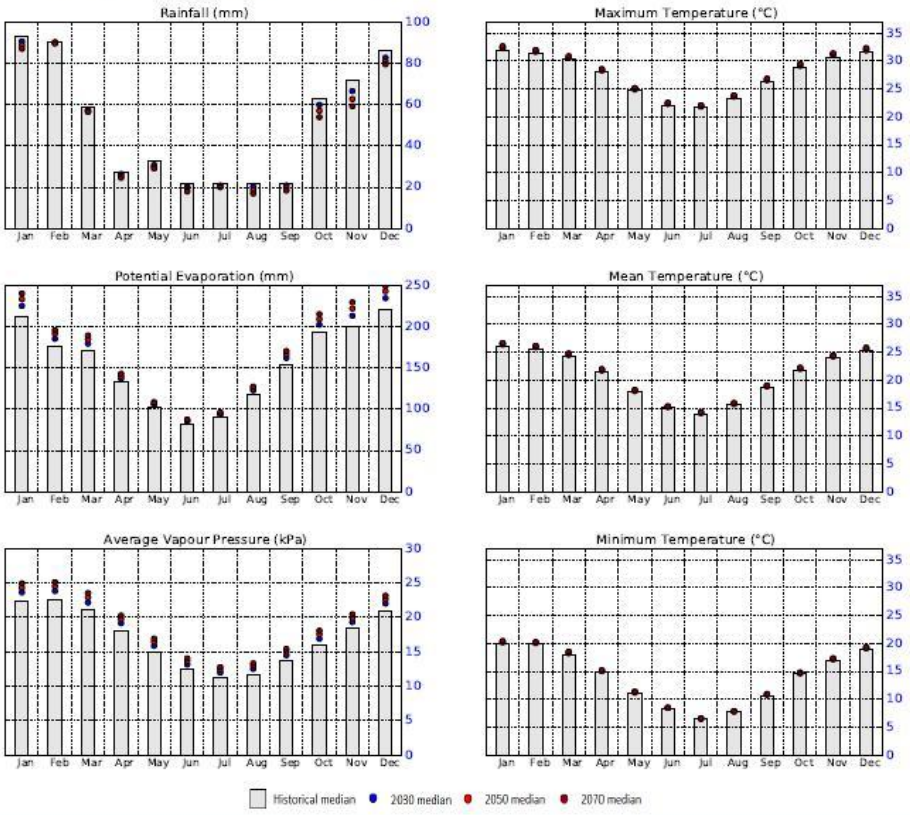
The results for annual projections as shown by the projected annual climate range plots (next page) indicate a range of possibilities of projected temperature, rainfall and other parameters under the different global warming rates and scenarios. For more information, see https://www.longpaddock.qld.gov.au/climateprojections/guide.html.

Historical and projected annual climate summary

Climate Variable (Median Annual)	Historical 1960-2010	Projection 2030	Projection 2050	Projection 2070
Rainfall (mm)	665.8	657.8	652.3	645.0
Evaporation (mm)	1854.0	1943.0	1996.1	2039.9
Mean Temperature (°C)	20.9	21.8	22.3	22.8
Maximum Temperature (°C)	27.6	28.5	29.1	29.6
Minimum Temperature (°C)	14.0	14.9	15.5	16.0
Average Vapour Pressure (kPa)	16.9	17.9	18.5	19.0

Location map

Historical and projected monthly median climate



9.6 Other Relevant Attachments