The process based Agricultural Production System SImulator (APSIM 7.5; Keating et al., 2003) was used to model the effect of climate change projections on cropping systems in the Central Slopes cluster region. The systems modelled include: monoculture wheat; monoculture sorghum; opportunity wheat and sorghum; and rainfed and furrow irrigated cotton. The objective of this work was to provide a broad indication of the relative effects of climate change in the major centres in the Central Slopes cluster and not to accurately reproduce broadacre cropping systems in these areas.

# Model

Inputs to APSIM include detailed soil parameters, daily climate data, crop cultivar specific parameters and agronomic management. Each of which is described in more detail below.

## Agronomic parameters/management

Within the simulations, crops are sown when the following specific rules are met. The date must be within each crops sowing window (listed in Table 1). For wheat, sorghum and non-irrigated cotton, rainfall over 7 days must be greater than 25 mm and stored soil water must be greater than 100mm. Irrigated cotton does not use sowing rules but is sown on a fixed date, 15-October, each year. Crop nutrients are unlimited to remove the effect of applied fertiliser amounts and crop agronomic parameters used in the model are listed in Table 2.

The two types of irrigated cotton simulations have either a maximum of one irrigation, just prior to sowing, or a maximum of two irrigations, on the 7th January in addition to the sowing irrigation. Irrigation was applied when the soil water profile was less than 80% full and the amount applied filled the soil water profile to capacity.

## Soil parameters

Representative soils were chosen for each region and are listed in Table 3, including Apsoil number ([www.apsim.info/Products/APSoil.aspx](http://www.apsim.info/Products/APSoil.aspx)). A number of sites include a secondary soil. APSIM’s soil erosion model uses the slope of the paddock as an input. Table 4 lists the average slope for the cropping area at each site.

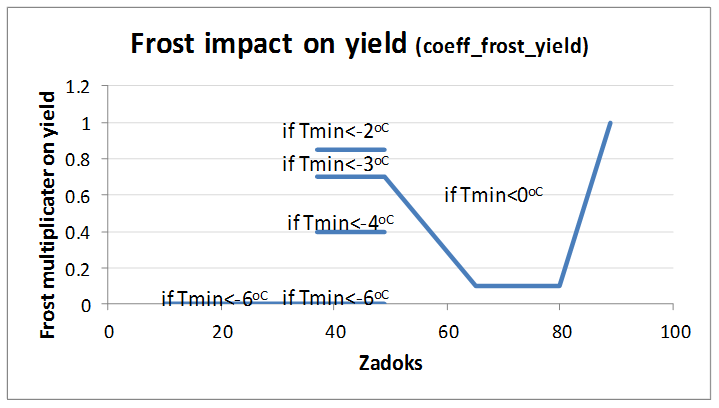
## Climate data

In-filled historical climate records (Jeffrey et al. 2001) of daily rainfall, maximum and minimum temperature and solar radiation were compared to modified climate records according to the future climate scenarios from CSIRO-MK35, ECHAM5, GFDL-21, HADGEM1 and MIROC-H global circulation models (GCM). See William et al. (2014) for a full description of the scenario chosen.

Each of the 5 climate records (4 climate change scenario and 1 historical climate) were run for each of the 6 cropping systems (i.e. wheat; sorghum; opportunity wheat and sorghum; rainfed cotton; irrigated cotton with maximum 1 irrigation at sowing; and irrigated cotton with maximum 2 irrigation at sowing and mid-crop) and each of the 19 sites and soil type combinations. This resulted in 864 simulations with each running for 50 years.

## Frost model

Currently APSIM-wheat has no effects due to frost. However, frost risk exists at screen temperatures less than or equal to 2°C (Hammer and Rosenthal; 1978). For this reason, an additional frost model (C. Chenu and T. Frederiks 2014, pers. comm.*,* 24 March) was included in the simulation models. This is implemented by including yield multiplier as a function of the severity and timing of the frost event as described in Figure 1.



**Figure 1.** Wheat yield multiplier due to frost as a function of timing and daily minimum temperature.

## CO2 fertilisation

The physiological effects of increased atmospheric CO2 on crop production were included in the model. Modifications were made to the wheat module through changes to radiation use efficiency (RUE), transpiration efficiency (TE) and to critical nitrogen concentration (CRC) based on experimental data (Reyenga et al., 1999a and Luo, 2003). Sorghum was assumed to have the same response to CO2 fertilisation as wheat and the cotton model fertilisation response follows that described in Bange (2007).

# Output

## Data

APSIM has the capability to produce many outputs of the farming system (see [www.apsim.info/Documentation.aspx](http://www.apsim.info/Documentation.aspx) for a complete list for each module). APSIM output files were collated into one of the following four comma delimited (csv) text files for each of the cropping systems: “APSIM wheat.csv”, “APSIM sorghum.csv”, “APSIM wheat and sorghum.csv” and “APSIM Cotton.csv”. Descriptions of column names for each output file are listed in Table 4. Each file can be easily loaded into a spreadsheet and filtered on inputs of interest. For example, to extract the data for the wheat simulations at Dalby using historical climate: load “APSIM wheat .csv” into a spreadsheet; filter column “site” on “Dalby”; and filter column “GCM” on “silo”. This will provide the required table of APSIM output.

## Plots

Simulation output was used to generate plots to compare the effect of predicted 2030 climates to historical climate on cropping systems. See the Appendix for a list and description of the plots generated. The box plots following the specification describe in Tukey (1977) where outliers are plotted for data that are greater than 1.5 times the interquartile range. Labels for sites Waverly Down and Pallamallawa were replaced with Roma and Moree respectively. These sites were used in place of Roma and Moree due to the higher quality climate records.

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# Tables

Table 1: Sowing windows for each crop.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | wheat | | Sorghum | | Cotton\* | |
| Site | Start | End | Start | End | Start | End |
| Chinchilla | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Dalby | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Pittsworth | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Warwick | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Goondiwindi | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Mitchell | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| St George | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Waverly Downs | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Walgett | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Nyngan | 1-May | 30-Jun | 1-Oct | 15-Jan | 1-Oct | 15-Nov |
| Narrabri | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Pallamallawa | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Warialda | 1-May | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |
| Attunga | 1-May | 30-Jun | 1-Oct | 15-Jan | 1-Oct | 15-Nov |
| Gunnedah | 1-May | 30-Jun | 1-Oct | 15-Jan | 1-Oct | 15-Nov |
| Glen Innes | 1-Jun | 15-Jul | 1-Nov | 15-Jan | 1-Oct | 15-Nov |
| Gilgandra | 1-Jun | 30-Jun | 1-Oct | 15-Jan | 1-Oct | 15-Nov |
| Dubbo | 1-Jun | 30-Jun | 15-Sep | 15-Jan | 1-Oct | 15-Nov |

\*Used for dryland cotton. Irrigated cotton has fixed sow date 15 October.

Table 2: Crop agronomic parameters.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Wheat | Sorghum | Cotton |
| Plant density (plant/m2) | 7 | 100 | 10 |
| Cultivar | Haartog | Early | S71BR |
| row spacing (mm) | 250 | 1000 | 1000 |

Table 3: Representative soils and APSoil numbers for each site.

|  |  |  |
| --- | --- | --- |
| **Site** | **Primary Soil** | **Secondary Soil** |
| Attunga | Red Chromosol (Harden No548) |  |
| Chinchilla | Grey Vertosol-Brigalow (Warra No019) | Brown Sodosol (Wallumbilla No064) |
| Dalby | Grey Vertosol-Cecilvale (Beverley No010) |  |
| Dubbo | Red Sodosol-Kurrajong\_Box Duplex  (Rocky Crossing No043) | Heavy Red Kandosol (Greenethorpe No619-YP) |
| Gilgandra | Red Kandasol (Boolba No 13) | Loam over a clay loam (Gilgandra No249) |
| Glen Innes | Black Vertosol (Biniguy No061) |  |
| Goondiwindi | Grey Vertosol (Goondiwindi No219) |  |
| Gunnedah | Black Vertosol (Breeza No119) |  |
| Mitchell | Brown Vertosol (Roma No063) |  |
| Moree | Black Vertosol (Moree No235) | Red Chromosol (North Star No236) |
| Narrabri | Grey Vertosol (Narrabri No124) |  |
| Nyngan | Grey Vertosol (Myall Vale No097) | Sandy clay loam over sandy clay (Nyngan No246) |
| Pallamallawa | Grey Vertosol (Terry Hie Hie No079) |  |
| Pittsworth | Black Vertosol-Irving (Greenmount No067) |  |
| St George | Red Kandasol (Boolba No 13) | Grey Vertosol (Dirranbandi No155) |
| Walgett | Grey Vertosol (Merrywinebone No126) |  |
| Warialda | Black Vertosol (Biniguy No061) | Red Chromosol (Croppa Creek No242) |
| Warwick | Brown Vertosol-Talgai-shallow phase (Hermitage No033) |  |
| Waverly Downs | Brown Vertosol (Roma No063) |  |

**Table 4:** Average paddock slopes for each site

|  |  |
| --- | --- |
| **Site** | **Slope** |
| Chinchilla | 2.17 |
| Dalby | 0.49 |
| Pittsworth | 1.21 |
| Warwick | 2.87 |
| Goondiwindi | 1 |
| Mitchell | 1.38 |
| St George | 0.9 |
| Walgett | 0.69 |
| Nyngan | 0.55 |
| Narrabri | 1.23 |
| Pallamallawa | 1.13 |
| Warialda | 1.3 |
| Attunga | 0.98 |
| Gunnedah | 1.25 |
| Glen Innes | 0.97 |
| Gilgandra | 1.32 |
| Dubbo | 0.66 |
| Moree | 0.58 |
| Waverly Downs | 1.83 |

Table 5: Column headers and descriptions for output files.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Column name | Simulation type | | | | Description |
| Wheat | Sorghum | Wheat and sorghum | Cotton |
| sim.no |  |  |  |  | Simulation number |
| year |  |  |  |  | Harvest year |
| biomass |  |  |  |  | Wheat biomass at harvest (kg/ha) |
| irrigations |  |  |  |  | Maximum number of irriagtions |
| yield |  |  |  |  | Wheat yield (kg/ha or ba/ha) |
| Incrop\_Cover |  |  |  |  | Average residue from sowing to harvest (kg/ha) |
| Incrop\_Rain |  |  |  |  | Total rain from sowing to harvest (mm) |
| Incrop\_Erosion |  |  |  |  | Total erosion from sowing to harvest (T/ha) |
| Incrop\_Drainage |  |  |  |  | Total drainage from sowing to harvest (mm) |
| Incrop\_Runoff |  |  |  |  | Total runoff from sowing to harvest (mm) |
| Incrop\_minT |  |  |  |  | Minimum daily temp. from sowing to harvest (°C) |
| Incrop\_maxT |  |  |  |  | Maximum daily temp. from sowing to harvest (°C) |
| sow\_esw |  |  |  |  | Soil water at swoing (mm) |
| Applied\_Irrigation |  |  |  |  | Total irrigation applied (mm) |
| AnnualRain |  |  |  |  | Total annual rainfall (mm) |
| AnnualErosion |  |  |  |  | Total annual erosion (T/ha) |
| AnnualDrainage |  |  |  |  | Total annual drainage (mm) |
| AnnualRunoff |  |  |  |  | Total annual rainfall (mm) |
| Avg\_AnnualCover |  |  |  |  | Average annual residue (kg/ha) |
| met |  |  |  |  | Met file name used in simulation |
| met.code |  |  |  |  | BOM met code. |
| slope |  |  |  |  | Paddock slope |
| site |  |  |  |  | Site name |
| erod |  |  |  |  | Soil erodability factor |
| sowdate1 |  |  |  |  | start sow window |
| sowdate2 |  |  |  |  | end sow window |
| Soil |  |  |  |  | APsoil name |
| GCM |  |  |  |  | Climate change scenario |