Scenarios of future climates at the sub-regional scale in Queensland's mixed farming zone

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Abstract
In order to develop adaptive strategies for future climate change, growers and researchers need to know likely reliable projected changes in climate parameters that may occur at the local scale. Projections of likely changes in rainfall and temperatures at national, state and regional scales can be perceived by farmers and advisors as lacking local relevance. Projections of future climate change scenarios also vary with the global climate model (GCM) used. There are 23 available GCM models, 8 emissions scenarios and 3 levels of warming sensitivity which are often used when assessing the impact of climate change on agricultural production. A variety of projected outcomes from these scenarios further contributes to uncertainty in the minds of producers and advisors. In this study we used a consistent set of synthetic climate projection data from 4 sets of composite GCM models and the two emission scenarios (A1B, low emission; A1FI, high emission), with high climate warming sensitivity to provide 4 climate scenarios for 2050. Rainfall and temperature parameters of relevance to crop and pasture production arising under these scenarios were compared against historical climate data (1900-2010) for 5 subregional centres in Queensland.

Key words: Future climate scenarios, composite models, regional, Queensland mixed farming zone

Introduction
Adaptation strategies to future climate change in Australia at national, state and regional scale has been highlighted (Howden et al. 2008; Crimp et al. 2010a; Stokes and Howden 2010). However, an understanding of changing climatic conditions at the subregional level is important for local relevance to growers and development of risk management strategies. The current climate in the subregional centres of Queensland's mixed farming zone has been changed and/or varied from time to time in the past as seen through the historical records of past climate (Singh et al. 2012). In particular, significant increases in minimum and maximum temperatures, reduction in solar radiation at subregional scale, along with impact on cereal productivity in Queensland have been reported (Singh 2010). Increased cereal productivity with increasing temperatures and frequent dry conditions in the last two decades (Singh 2010), indicated growers either have been adapting well to the current climate change/variability, or this could be due to the CO_2 fertilisation effect as reported through the modelling studies for subregional centres in Queensland (Zull et al. 2012). However, concerns have been raised for the projected future climate scenarios with further increases in temperatures and likely reductions in rainfall. These projected future scenarios while using GCM models are primarily developed for regional or national level, lacking local relevance to future climate change at the subregional level.

Projections of future climate change using GCM models at the subregional scale could be daunting. Currently there are 23 GCM model available, some more reliable with credible projection capability and some less reliable (Crimp et al. 2010b). In addition to these models, there are 6 non-mitigation IPCC scenarios and 2 stabilised CO_2 emission scenarios (CO_2-450 and CO_2-550) and 3 climate warming sensitivities (Low, 10th percentile; Median, 50th percentile; and High, 90th percentile) for 21st century. Therefore selection of one relevant future scenario at the subregional level from all sorts of combinations (552 possible scenarios) can be tedious and time consuming. The aim of this study was to determine reliable and appropriate models to develop and analyse future climate change scenarios at the subregional level in Queensland.

Methods
In this study we used a consistent set of synthetic climate projection data from 4 sets of composite GCM models forced by 2 emission scenarios and high climate warming sensitivity. These projection data are provided by Consistent Climate Scenario Project (CCSP), Department of Environment and Resource Management, Queensland Climate Change Centre of Excellence (QCCCE) for 5 subregional centres in Queensland (Dalby, Roma, Goondiwindi, Emerald, and St George). The aim of the CCSP is to develop a consistent set of synthetic climate projections data across Australia for use in biophysical models, such as

APSIM and GRASP. Generation of climate projection data by CCSP has involved the Coupled Model Intercomparison Research Program 3 (CMIP3) GCM Models and the CSIRO OzClim (http://www.csiro.au/ozclim) Model. The future climate projection data is basically generated by transforming the historical climate data (SILO daily climate files) while using monthly multiplier files and log warming files for a specific climate site. The projection data are synthetic and do not represent a forecast. Creation of composite GCM models involved partitioning and grouping of 17 CIMP3 GCM models (Fig. 1). Currently six models out of 23 are not recommended due to their unreliability and other issues.

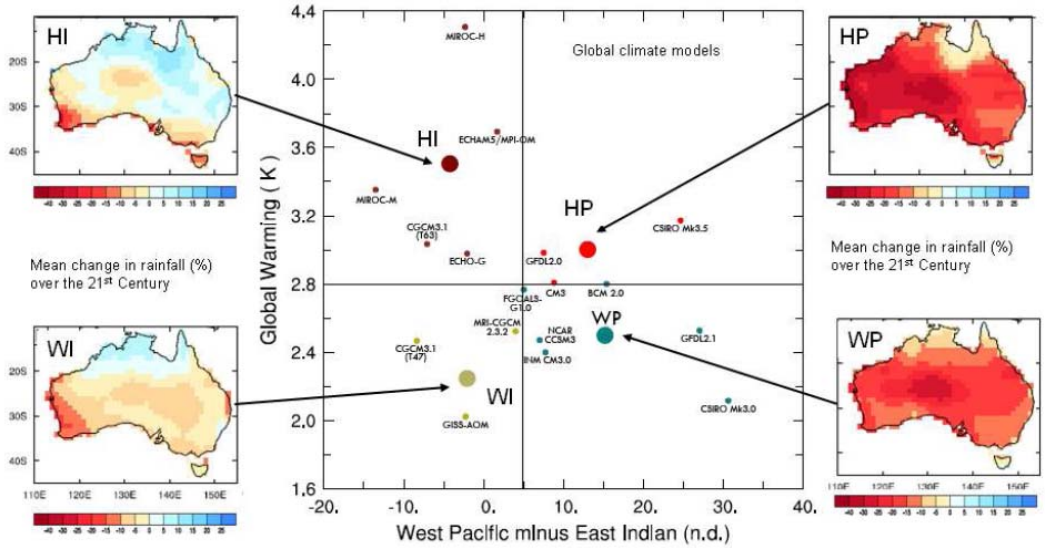

Figure 1. A partitioning of 17 CMIP3 GCM models for future climate using global warming sensitivity and ocean warming indices. Values of 17 GCM models are represented by small dots and labelled by their GCM model codes. The central horizontal and vertical lines separate the four Representative Future Climate (RFC) partitions. The larger dots indicates the CCS composite means for GCMs within each of the four RFC responses: (HI) large global warming and warmer Indian Ocean; (HP) large global warming and warmer Pacific Ocean; (WI) smaller global warming and warmer Indian Ocean; and (WP) smaller global warming and warmer Pacific Ocean. The maps (currently under development) depict projected 21st Century changes in rainfall for composite GCMs in each of the four RFC response areas.

The 6 non-mitigation emission scenarios are based on 4 types of future world (A1, A2, B1, and B2). Type A1 represents convergent world with rapid economic growth followed by rapid introductions of new and more efficient technologies. Within type A1, A1T represents use of non-fossil energy source (less likely), A1B represents use of a balance across all the energy sources available (more likely), and A1FI represents use of fossil-intensive sources (most extreme scenario among all). Type A2 represents a very heterogeneous world with an emphasis on family values and local traditions, slower in economic growth and technical change (less likely). B1 type represents convergent world with introduction of clean technologies (less likely). B2 represents world with regional focus and with emphasis on local solutions to environment and economic sustainability (less likely).

The selection of models and warming scenarios for this study is based on our requirement of understanding the magnitude of likely changes in temperature and rainfall in order to develop adaptation strategies for crop/pasture/livestock production to future climate change. We preferred using composite GCM model (average of few models) in order to negate any bias from individual model. Since the future increase in temperature is 'most likely' and there is an uncertainty in rainfall pattern (which may increase or decrease) therefore we chose composite models with large global warming but opposite in rainfall pattern, e.g. HI and HP composite models (Fig. 1). HI (with slightly increased rainfall) included cluster of 4 reliable and 1 less reliable, and HP (with significantly decreased rainfall) included cluster of 3 reliable and 1 less reliable GCM models. The global warming and ocean warming indices by less reliable models were within the range of reliable models for each composite model, HI and HP. We also chose to compare forcing of chosen models by extreme scenario (A1FI, with CO_2 level of 555ppm by 2050) and more realistic scenario, A1B (with CO_2 level of 522ppm by 2050), both with high climate warming sensitivity.

Results

Initially, we compared all 4 composite models (HI, HP, WI and WP) forced by most extreme emission scenario A1FI against the current levels of monthly (historical averages from 1900 to 2010) rainfall and maximum temperature for Dalby and Emerald (Fig. 2). The composite GCM model HP, as expected, projected the largest increase in monthly maximum temperature (between 3.5 °C and 4.0 °C) on one hand, and lower monthly rainfall for 2050 on the other hand. Opposite to these projections, HI resulted in slight increase in monthly rainfall, particularly during summer and autumn, and lower maximum temperature than HP for both Dalby and Emerald. The other two models WP and WI had projections in between the HP and HI (Fig. 2).

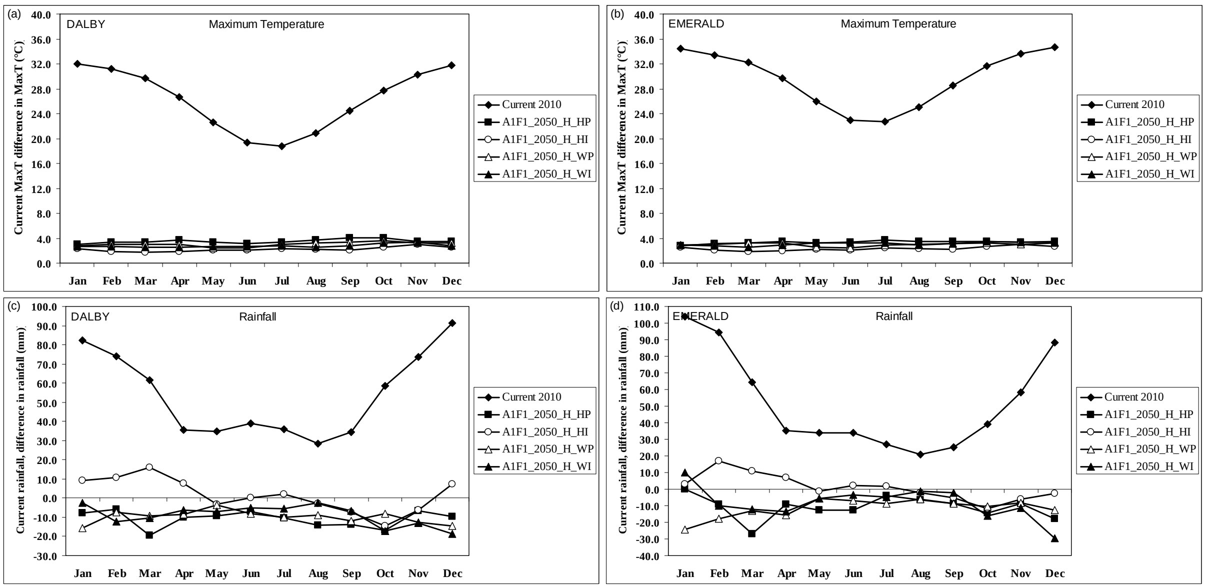

Figure 2. The current monthly maximum temperature and rainfall (average of historical SILO data from 1990 to 2010), and the difference between the current and the projected future (2050) climate data for maximum temperature (a, b) and rainfall (c, d) from 4 composite GCM models (HP, HI, WP and WI) forced by extreme emission scenario A1FI and high climate warming sensitivity (H) for Dalby (a, c) and Emerald (b, d). Among these projected climate scenarios A1FI_2050_H_HP represents most severe, whereas A1FI_2050_H_HI represents milder changes in maximum temperature and rainfall.

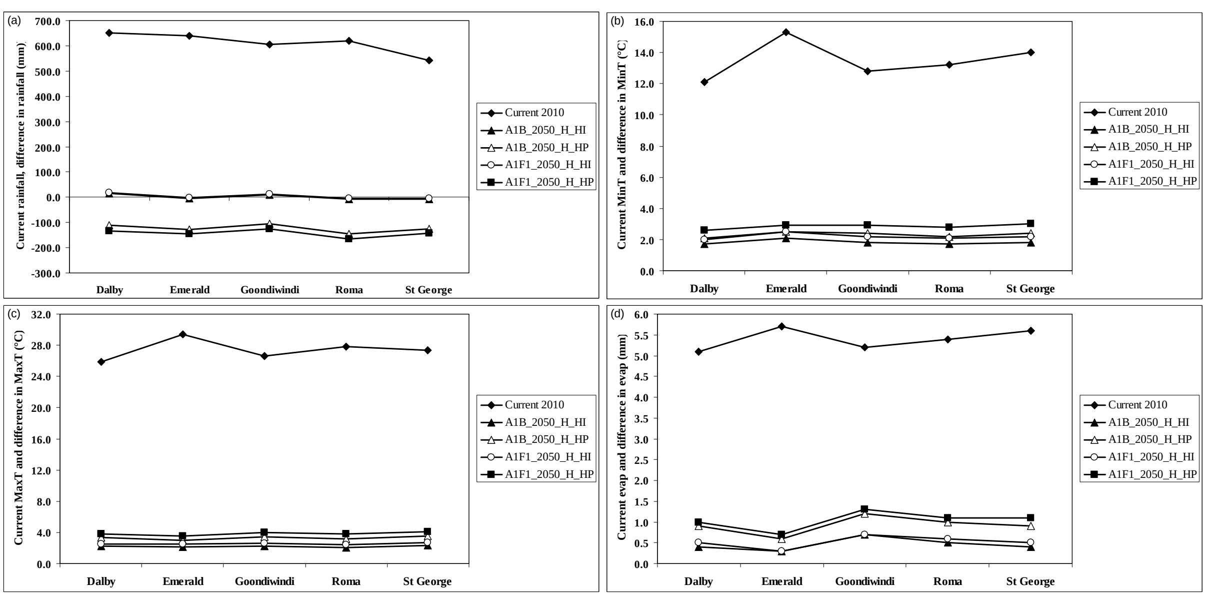

Figure 3. The current annual rainfall (a), mean minimum temperature (MinT) (b), mean maximum temperature (MaxT) (c) and mean annual evaporation (evap) (d), and differences between the current climatic parameters and the projected changes in 2050 from HI and HP composite models forced by A1B and A1FI emission scenarios for Dalby, Emerald, Goondiwindi, Roma and St George in Queensland.

Further analysis of HI and HP composite models forced by A1B and A1FI emission scenarios indicated almost no change in the annual rainfall from HI composite model whether forced by A1B or A1FI emission scenarios compared with the current annual rainfall for 5 subregional centres in 2050 (Fig. 3). On the other hand, HP model whether forced by A1B or A1FI resulted in around 130 mm less rainfall than the current annual rainfall across all the centres. This model (HP) also resulted in greater evaporation than HI (Fig. 3). Temperature differences between these two composite models were not as great as that for the rainfall and evaporation. However the HP composite model forced by A1FI had the greatest increase in temperatures, whereas HI composite model forced by A1B had the least increases in temperatures (Fig. 3). Projected data resulted in increase of max temp between 2° and 4°C, and between 2° and 3°C for min temperature (Fig. 3).

The number of days with max temperature more than 35°C, depicting heat stress days was also calculated from the projected data and compared with the current number of heat stress days (Table 1). Dalby recorded the maximum increase in the number of heat stress days compared with the current from various projected scenarios, between 2.3 and 3.6 fold increases. This increase for the other centres was between 1.6 and 2.8 fold (Table 1). Again projections from HP compared with HI composite model were greater whether forced by A1B or A1FI emission scenarios.

Table 1. The current and projected number of days with max temperature more than 35°C, depicting number of heat stress days, for the 5 subregional centres in Queensland's mixed farming zone.

Centres	Current and projected scenarios				
	Current	A1B-2050-HI	A1B-2050-HP	A1FI-2050-HI	A1FI-2050-HP
Dalby	19	43	56	47	69
Emerald	61	105	125	114	140
Roma	54	93	115	99	126
Goondiwindi	37	68	93	74	103
St George	55	90	113	97	124

Conclusion

Considering the range of projections, from 'no change' in rainfall to around 130 mm less rainfall in 2050, creates uncertainty and makes it difficult to transfer the impact of projection and/or develop adaptation strategies. However, the projected 'no change' in rainfall from HI composite model is similar to the current long-term trends in rainfall (Singh et al. 2012). But in contrast to the heat stress data projected from HI model, the current historical trends do not indicate any significant increase in the number of heat stress day for about 10 out of 15 subregional centres (Singh et al. 2012. Nevertheless, increases in both max and min temperatures as projected from most models seem to be beneficial for winter crops with wider planting window and lesser risks of frosts. On the other hand, projected increase in the number of heat stress days would have adverse impact on summer crops/pastures in Queensland. Adaptation strategies in particular development of heat tolerant varieties for summer crops/pastures and selection of better cattle/sheep breed need to be worked out for Queensland's mixed farming zone.

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