## Using temporal and spatial analogues to consider impacts and adaptation to climate change in the South Australian grain belt

**Peter Hayman**[1], Nigel Wilhelm[2], Bronya Alexander[1] , and Uday Nidumolu[1]

[1] SARDI Climate Applications, GPO Box 397, Adelaide SA 5001 www.sardi.gov.au Email Peter.Hayman@sa.gov.au

[2] SARDI Farming Systems

### Abstract

Climate change projections are difficult to use in farm management decision making. Temporal and spatial analogues can complement top down climate change projections. In this paper we investigate the extent that APSIM simulations support the simple notion of finding a run of seasons that was 10% drier or a region that has a 10% drier climate as a proxy for a 10% future drying. We found that within APSIM decreased rainfall could be offset by increased carbon dioxide not only for the mean yield but for the whole distribution from poor seasons to good seasons. Orroroo at the fringe of the grains belt is 17% drier than Booleroo. We found that running APSIM using Booleroo with 17% less rainfall leads to a very similar risk profile of simulated yields as Orroroo in the current climate. We then discuss the broad characteristics of farms in different zones in the SA grains belt. We discuss the strengths and weaknesses of temporal and spatial analogues in the SA grains crop. The end point is not prediction but rather risk management frameworks to consider adaptation options and vulnerabilities.

### Key words

Simulation, wheat, risk management

### Introduction

One of the goals of Australia's Farming Future program run by DAFF is to work with primary producers to understand the likely impacts of climate change for their enterprise and region. Southern Australia is one of the global regions that show a high degree of inter-model consistency on drying. Climate change projections indicate a relatively narrow range of warming for the SA grains belt in 2030 (0.8 to 1.5˚C). Although there is a strong tendency for drying in the models during the winter growing season, there is a wide range of rainfall outcomes with a mid range of about 5% drying but a 1 in 10 chance that the drying will be greater than 10% and some models showing a spring drying of up to 20% (www.climatechangeinAustralia.gov.au).

Three commonly raised problems in applying climate change projections are the uncertainty that stems from different emission scenarios and differing model outcomes; the coarse spatial scale of the global climate models (usually 200km grid) and the coarse temporal scale and distant time periods of 2030 and 2070. These are active areas of research; however the Intergovernmental Panel on Climate Change highlights irreducible uncertainty on both spatial and temporal scales. Even when grain farmers accept the uncertainty there remain difficulties in interpreting how different a 10% decline in rainfall might be to a 15% decline in terms of impacts, adaptation options vulnerabilities.

A complementary approach to the 'top down' projections is to use temporal analogues for future changes. A well known example is the 2003 heatwave in Europe which allowed health researchers, policy makers and the general community to consider the impacts, the causes of resilience and vulnerabilities and adaptation options. A run of very dry seasons on the upper Eyre Peninsula in South Australia was used to identify characteristics of farm enterprises that were sources of resilience (Doudle et al. 2009). Ecologists have long used spatial analogues for future changes. Agrogeological zones would be expected to move poleward with a warming and drying trend. Dating back to Goyder in the 1860s the South Australian grains belt has been understood as a transect from 'safe' high to medium rainfall land to low rainfall with extensive grazing and the desert to the north. The medium rainfall to low rainfall zone in South Australia covers a spectrum from intensive cropping with a high frequency of relatively high risk and high return crops such as canola and pulses to increasing proportion of cereal with lower inputs and then grazing enterprise with opportunity cropping. Figure 1 shows grain farms and the annual rainfall isohyets. The two main factors for rainfall in the region are distance from the western coast and topography, especially in the central region.

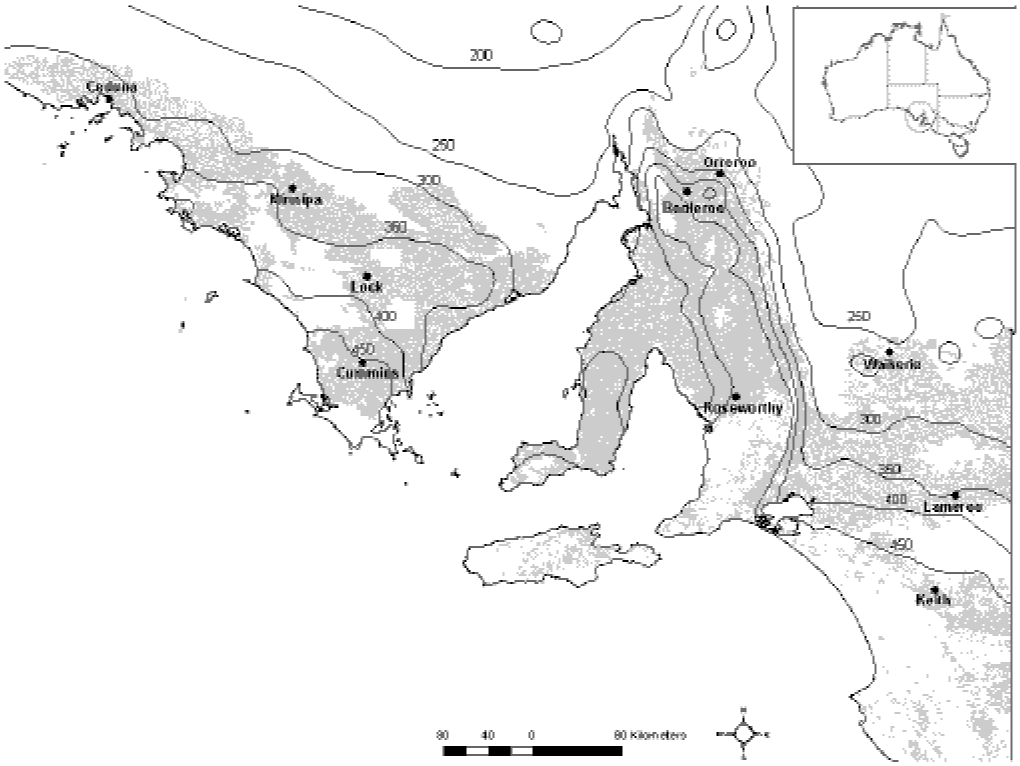


**Figure 1. Annual rainfall isohyets for SA grains belt. Grain farms shown with grey shading.**

**Methods**

For both temporal and spatial analogues the challenge is to provide meaningful climate data and analysis. APSIM simulations along transects can be used to combine climate with soils data and management options. In addition to mean wheat yields, APSIM simulations can present a probability distribution which contributes to discussions on risk. Climate data for the simulations came from the SILO database (http://www.nrw.qld.gov.au/silo/) and software within APSIM was used to simulate climate change. Higher carbon dioxide levels are simulated by modifying the transpiration and radiation use efficiency and the historical climate record is perturbed with a rainfall (% change) or temperature factor (degree change). This is consistent with the approach used by Crimp et al. (2007). APSIM version 7.1 was used with the same soil in all simulations (available moisture holding capacity of 80mm). A medium maturity wheat cultivar was sown on May 20 each year with soil water reset on May 18. Days to flower were about 140 days and nutrition was non-limiting except in very wet years.

To support discussion between farmers, researchers and policy makers on spatial analogues it is useful to have a framework for summarising some of the key differences. The South Australian grains belt is divided into three broad north-south transects; the Eyre Peninsula, the Northern and Yorke region and the eastern section of the state from the lower South East to the Murray Mallee bound in the north by the Murray river. All these regions run from high rainfall in the south to low rainfall in the north and can be discussed in latitudinal bands of low, medium and high rainfall. The data for this framework came from discussion with farmers and key advisers and should be considered preliminary data. The growing cost data came from the PIRSA gross margin handbook.

**Results and Discussion**

*APSIM simulations*

While it is relatively simple to find a spatial or temporal analogue that is 10% drier, there is no analogue in time or space that has higher carbon dioxide levels. Given uncertainty in the level of drying and uncertainty in future levels of carbon dioxide and how these will change transpiration and radiation use efficiency, a convenient simplification would be to consider the trade-off between drying on one hand and carbon dioxide on the other. As shown by Crimp et al. (2007), this offset is evident in simulated mean wheat yields. We were not aware of this being shown for the 100 point distribution of yields from poorest to best seasons. Figure 2 shows using Orroroo climate (in upper north of grains belt see Figure 1) that a 10% drying can be off-set by an increase in carbon dioxide across the distribution. The panel on the left shows that this is a reasonably tight relationship on a year by year comparison (in the case of 480 ppm, $R^2$=0.99, root mean square error (RMSE) 0.19 t/ha). To assess future risk profiles a percentile point against percentile point comparison is more instructive than a year by year comparison. As shown in the panel on the right side of Figure 2, the percentile by percentile comparison is a closer fit (RMSE 0.07 t/ha).

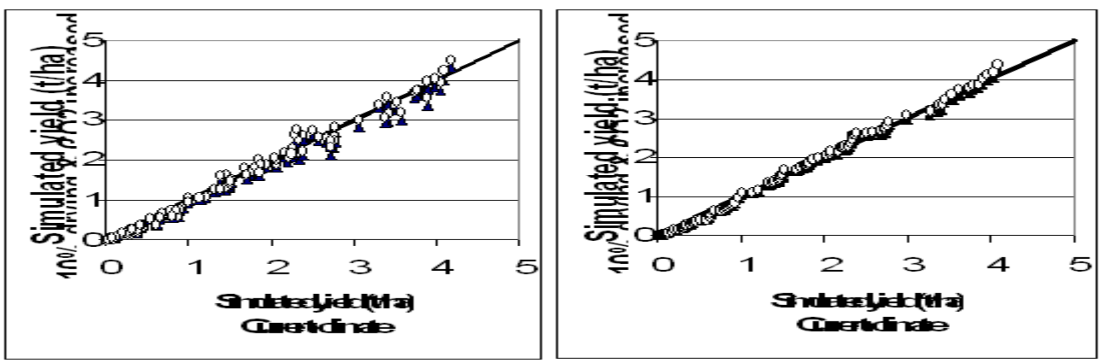


**Figure 2: APSIM simulated wheat yields for Orroroo comparing current climate (1900-2009) with a future climate that is 10% drier and $CO_2$ concentrations of 430 ppm (triangles) and 480 ppm (open circles). The left hand panel is year by year comparisons, the right hand panel shows percentile point comparison.**

It is important to note that this analysis had a fixed sowing time, so the emphasis is on water used for crop growth. Under a drier climate there will be less sowing opportunities and there is no carbon dioxide benefit that will off-set the sowing opportunities. Figure 2 shows the relatively small difference between 430 and 480ppm of carbon dioxide. It must also be remembered that this is a simulation analysis and there are many complexities and unknown factors in the response of crops to carbon dioxide fertilisation (Gifford 2004). Nevertheless APSIM is the currently available tool and widely used to investigate questions of carbon dioxide fertilisation (Crimp et al. 2008).

Booleroo is about 30km South West from Orroroo. Orroroo gets about 17% less in-crop rainfall than Booleroo. A reasonable question is whether Orroroo is a spatial analogue for Booleroo at 17% less rainfall (or some combination of rainfall reduction and carbon dioxide fertilisation).

Figure 3 shows that on a year by year comparison there is a noisy relationship ($R^2$=0.76 RMSE 0.45 t/ha) but when this is expressed as a percentile by percentile comparison (shown on the left panel) the relationship is much tighter ($R^2$=0.99, RMSE 0.12 t/ha). This suggests that using APSIM as an analytical tool for spatial analogues for drying is valid at least within relatively close sites and modest amounts of drying.

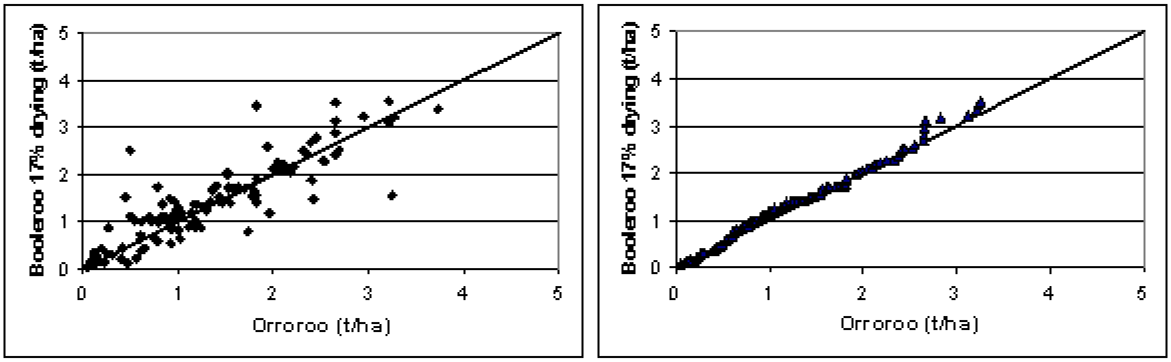


**Figure 3: APSIM simulated wheat yields comparing Orroroo climate (1900-2009) to Booleroo climate (1900-2009) with rainfall reduced by 17%. The left hand panel is year by year comparisons, the right hand panel shows percentile point comparison.**

*Framework comparing regions*

Table 1 provides a summary of the characteristics of farming systems in rainfall zones on the Eyre Peninsula. Similar summary tables for the Northern and Yorke region and these allow comparison across rainfall zones. In the Northern and Yorke region land values in the medium and higher rainfall zones are higher due to soil types and proximity to a capital city. In the run of recent poor seasons farmers in the low rainfall regions of the upper north with heavier soils have suffered more than the low rainfall farmers on Eyre Peninsula or Murray Mallee.

**Table 1. summary of key characteristics on Eyre Peninsula. Wh = wheat, Bar = barley, FPea = field pea, Cn = Canola, Past = pasture, in most cases volunteer pasture. Farm size and land value are broad estimates with many exceptions.**

| Rainfall (annual) | **Low**<br>**300-325** | **Medium Low**<br>**325-375** | **Medium High**<br>**375-450** | **High**<br>**450-600** |
|---|---|---|---|---|
| Typical sequence | Wh-Bar-Past | Wh-Bar-FPea-Past –Wh | Cn-Wh-FPea-Cn-Wh-Bar | Wh-Bar-Lup-Wh Past-Past |
| Break crops | Very limited | Limited | Canola common | Range of break crops-soil limit rather than climate |
| Soils | Sandy | Sandy | Heavy soils | Heavy soils, often shallow |
| Climate limit | Very hot dry springs | Hot dry springs | Sufficient rain to cover high inputs | Waterlogging |

| | | | | |
|---|---|---|---|---|
| | | | and risky crops | |
| Dominant constraints & challenges | Low unreliable rainfall and hostile subsoils | Unreliable rainfall, getting crop/stock balance right | Herbicide resistant weeds. High cost structure. | High cost structure, Herbicide resistant weeds and foliar diseases |
| Farm size (ha) | 3,500 | 2,500 | 1,500 | 1,000 |
| Land Value ($/ha) | 500 | 1000 | 3000 | 4000 |
| Variable cost ($/ha) | 80 | 120 | 250 | 300 |
| Wheat yield (t/ha) Poor Avg Good | 03 1 1.5 | 1 2 2.5 | 2 3 5 | 2 3.5 5 |

Discussion with farmers in medium rainfall regions indicate that in recent dry seasons they tend to drop canola and pulse crops from their farming system and rely on cereals and in some cases are running lower input cereal operations like the drier regions. Unless there is a substantial change to the economics of grain farming, a warming drying trend will hasten the trend to fewer, larger farms (Barr 2009). There are some advantages from a drying trend in the wettest parts of the state that currently suffer water-logging.

The use of space as a proxy for time and the use of recent droughts as temporal analogues are useful ways to engage farmers, advisers and policy makers in thinking about climate change. The advantage of temporal analogues is that the soil and farming system is held constant; a limit to this approach is that it is very dependent on the particular run of seasons and how these have interacted with commodity prices. An advantage of spatial analogues is that it allows comparisons of farming systems and this points to some of the system changes that are likely. Spatial analogues must be used carefully as there are many factors other than climate that define a farming system, for example soil types. A feature of many successful low rainfall farming enterprises in recent times has been the use of light textured soils that have much lower amounts of water lost as soil evaporation. The main advantage of spatial and temporal analogues is that farmers and their advisers already use them in their thinking about adaptation. Used thoughtfully, these are simple but powerful tools, and using APSIM as a sophisticated climate analyser we could only find support for this approach.

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