# FutureSheep – What will pasture production look like in south-west Western Australia in 2050?

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## Abstract
The south-west agricultural region of Western Australia (WA) has become drier and hotter since the 1970's and future projections indicate this trend will continue – presenting challenges for pasture and livestock production. To help producers adapt to this change in climate, we used the GrassGro™ simulation model to predict pasture productivity in 2050 for eight farming locations in WA. Climate data for 2050 was generated for two greenhouse gas (GHG) pathways, RCP 4.5 and RCP 8.5 (Representative Concentration Pathways), using change factors from the Climate Change in Australia website. Using these factors, daily rainfall and temperature for 2050 was calculated using historical 2002-2021 data. Atmospheric $CO_2$ levels were set at 395 ppm for the current climate, 500 ppm for 2050 RCP 4.5 and 610 ppm for 2050 RCP 8.5. All model simulations were conducted on ungrazed annual pastures run for 20 years. GrassGro™ was validated for each of the case study sites using the Pastures from Space ™ data for the period 2004 to 2021. The resulting simulations suggest that all sites will experience a loss in annual pasture yield by 2050, with the lower emission pathway (RCP 4.5) resulting in the least reduction in most cases. With an RCP of 4.5 the yield at low to medium rainfall sites is expected to decline by an average of 20% compared to only 6% at higher rainfall sites. The results also suggest that the growing season in 2050 will be shorter at all sites. To maintain current pasture productivity in 2050 will require feedbase adaptation such as increased soil fertility, the adoption of annual or perennial pasture species that can produce similar amounts of dry matter with less rainfall in a shorter growing season and the introduction of summer-active forages.

## Keywords
Future climate, forage biomass, plant growth, simulation modelling, mediterranean climate.

## Introduction
The climate in southern Australia has become warmer and drier. In the south-west cereal-livestock farming region of WA, typically classified as a 'Mediterranean' climate, rainfall has declined approximately 15% between the April to October growing season since 1970 (CSIRO and Bureau of Meteorology 2022). This trend is predicted to continue with this region becoming even hotter with less rainfall particularly in winter and spring (CSIRO and Bureau of Meteorology 2022). Consequently, maintaining pasture and livestock production in the future could be quite challenging in a region that supports 20% of the nation's sheep population (Pritchett 2023). Our research is investigating how producers can adapt their grazing systems to this change in climate. In this paper we predict the magnitude in the decline of current pasture production in 2050 for two greenhouse gas (GHG) pathways using simulation modelling. The findings help to determine the extent of adaption required to maintain or improve pasture productivity in the future.

## Methods
Pasture yield data for eight farming locations in WA (Figure 1.) was generated using GrassGro™ version 3.3.11 (Moore et al. 1997) using the standard parameter sets for annual pasture species (*Trifolium subterraneum*, *Lolium rigidum*, *Arctotheca calendula*). Soil type was chosen based on the dominant soil type within the catchment the site was located and soil parameters were based on GrassGro™ soil type default values. To generate 2050 climate data under two greenhouse gas representative concentration pathways (RCP) 4.5 and 8.5, a change factor was obtained from the Climate Change in Australia website. Using this change factor daily rainfall and temperature data using historical 2002-2021 data were calculated as described by Harrison et. al. (2016). Current climate is the historical period from 2002-2021 obtained from SILO (Jeffery et al. 2001). Based on the Intergovernmental Panel on Climate Change (IPCC) representative concentration pathways atmospheric $CO_2$ levels were set at 395 ppm for the current climate, 500 ppm for 2050 RCP 4.5 and 610 ppm for 2050 RCP 8.5. All simulations were ungrazed permanent pastures run for 20 years. The model was validated for each of the locations using the Pastures from Space™ data for the period 2004 to 2021 (Mata et al. 2004).


**Figure 1. Location of the eight farming sites in WA.**

## Results and Discussion

*Change in annual rainfall in 2050*

Irrespective of future GHG emissions all sites are expected to experience a decline in rainfall by 2050 the only possible exception being Dongara (Table 1). For the most likely scenario of RCP 4.5 which includes a significant adoption of renewables the average decline in annual rainfall across sites was 8%. Assuming no decline in the rate of GHG emissions going forward, represented by an RCP of 8.5, sites could expect to experience an average decline of 13% in annual rainfall by 2050.

**Table 1. Annual rainfall for current climate and simulated climate in 2050 with an RCP of 4.5 or 8.5 for the 8 locations.**

| Location | Current rainfall (mm) | Rainfall RCP 4.5 2050 (mm) | Rainfall RCP 8.5 2050 (mm) |
|---|---|---|---|
| Bruce Rock | 294 | 267 | 251 |
| Varley | 318 | 304 | 271 |
| Kumminin | 329 | 296 | 279 |
| Corrigin | 348 | 314 | 295 |
| Dongara | 366 | 369 | 355 |
| Wagin | 392 | 350 | 333 |
| Mobrup | 538 | 476 | 458 |
| Westbourne | 629 | 557 | 533 |

*Change in annual pasture yield by 2050*

Simulated annual pasture yield for the eight farm locations is presented in Figure 2. Average simulated yields for the current climate ranged from 2100 to 9000 kg DM/ha/yr. While the simulations suggest that all sites will experience a loss in pasture yield by 2050, the lower emission pathway (RCP 4.5) generally resulted in the least reduction, with yield at low to medium rainfall sites expected to decline by an average of 20% compared to only 6% at higher rainfall sites. For example, the site at Kumminin may experience a loss in yield of 34% under the most likely emissions pathway of RCP 4.5. By contrast, higher rainfall pastures at Mobrup and Westbourne (Figure 2) are predicted to lose only 6% of their yield. This finding is consistent with the numerous studies that have simulated the impact of future climate on pasture yield (e.g. Cullen et al. 2009; Moore and Ghahramani 2013).

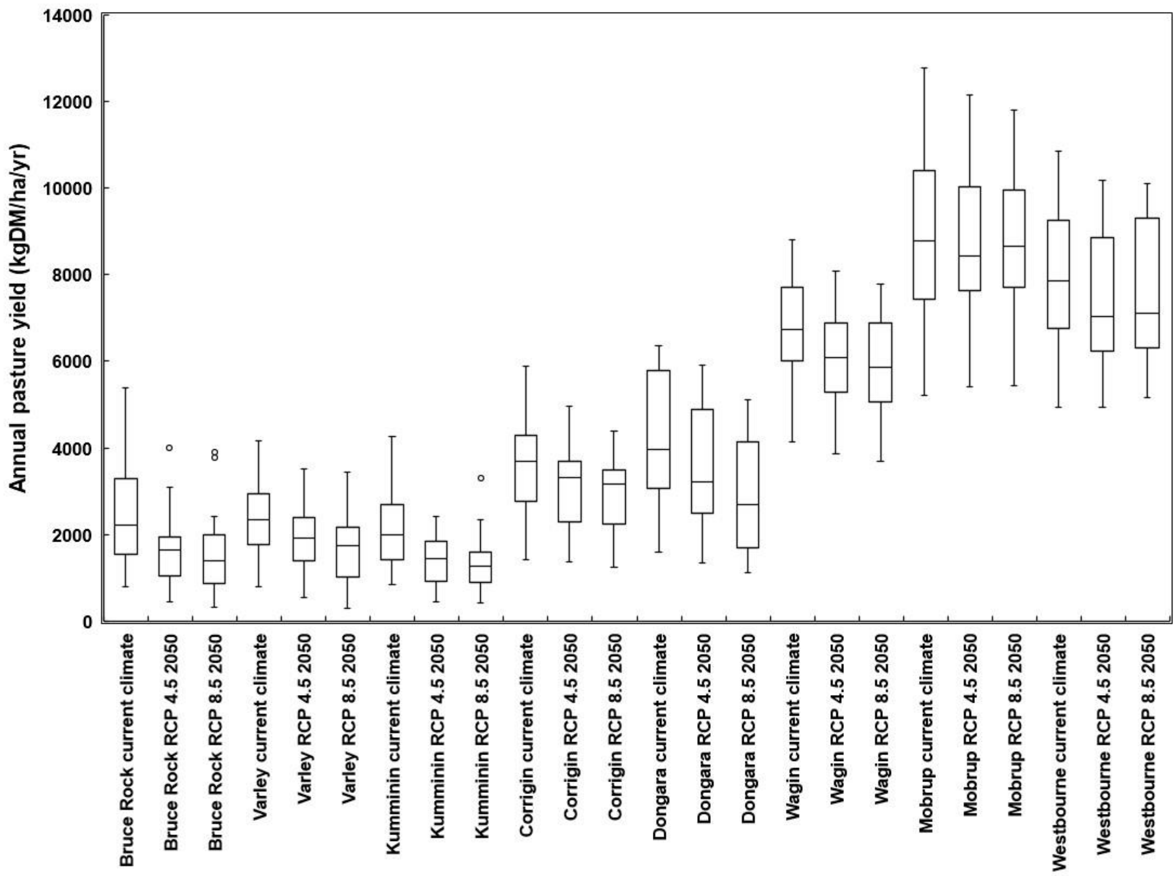


**Figure 2. Simulated annual pasture yield (kg DM/ha/yr) for Bruce Rock, Varley, Kumminin, Corrigin, Dongara, Wagin, Mobrup and Westbourne in WA with the current climate, RCP 4.5 2050 and RCP 8.5 2050. The 'boxes' in the boxplots show the upper and lower quartile and median (horizontal line) values, while the 'whiskers' show the range excluding 'points' (open dots) considered outliers.**

*Change in monthly pasture production by 2050*

Table 2 presents the change in monthly pasture production in 2050 compared to current yields. At the sites with less than 400 mm of annual rainfall (Bruce Rock, Varley, Kumminin, Corrigin and Dongara) almost every month of the year in 2050 is likely to experience a loss in pasture production compared to current yields (Table 2). At higher rainfall sites (Wagin, Mobrup and Westbourne) the simulations suggest that winter and early spring growth will increase in 2050 (Table 2) most likely due to warmer temperatures. However, even in these environments the growing season may be shortened because of less growth in autumn and late spring due to lower rainfall and higher temperatures. Interestingly, Cullen et al. (2009) predicted the same changes in the high rainfall zone of south-eastern Australia. Furthermore, Moore and Ghahramani (2013) suggested the same difference between the low rainfall and high rainfall areas of southern Australia in how they may respond to future climate change projections, with the impact being greater in the low rainfall zone.

*Adaptation*

In their review of climate impacts and adaptation for pasture-based industries, Cullen et al. (2021) summarised a range of possible farming system adaptations. These were grouped broadly into feedbase, livestock management, technology and infrastructure and diversification. The most promising adaptations in the feedbase category were an increase in soil fertility, adoption of drought and heat tolerant temperate species, introduction of summer-active forages and forage crops to fill feed gaps. The next step in this research is to predict how a number of these strategies would perform at the eight locations in 2050 using GrassGro™ simulations.

**Table 2. Change in average monthly yield (kgDM/ha) for the eight locations at the two greenhouse RCP's of 4.5 and 8.5. Note locations progress from low to high rainfall.**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bruce Rock RCP 4.5 | -3 | -2 | -10 | -30 | -57 | -73 | -164 | -173 | -83 | -106 | -37 | -1 |
| Bruce Rock RCP 8.5 | -5 | -7 | -16 | -41 | -102 | -113 | -215 | -207 | -76 | -114 | -75 | -4 |
| Varley RCP 4.5 | -4 | -6 | -10 | -41 | -64 | -92 | -86 | -50 | -21 | -35 | -3 | -3 |
| Varley RCP 8.5 | -5 | -7 | -10 | -35 | -68 | -112 | -117 | -136 | -70 | -81 | -2 | -3 |
| Kumminin RCP 4.5 | -4 | -2 | -8 | -19 | -77 | -121 | -158 | -179 | -103 | -40 | -3 | -3 |
| Kumminin RCP 8.5 | -2 | -1 | -8 | -19 | -72 | -138 | -181 | -195 | -107 | -52 | -2 | -3 |
| Corrigin RCP 4.5 | -7 | -15 | -27 | -72 | -79 | -39 | -6 | -40 | -123 | -83 | -23 | 0 |
| Corrigin RCP 8.5 | -6 | -17 | -32 | -84 | -104 | -90 | -28 | -31 | -111 | -102 | -24 | -3 |
| Dongara RCP 4.5 | 0 | +1 | 0 | -3 | -84 | -138 | -89 | -119 | -121 | -110 | -43 | +3 |
| Dongara RCP 8.5 | 0 | 0 | 0 | -3 | -105 | -243 | -202 | -183 | -234 | -188 | -39 | -4 |
| Wagin RCP 4.5 | -34 | +9 | -82 | -11 | -42 | -52 | 26 | -6 | -216 | -243 | -20 | -15 |
| Wagin RCP 8.5 | -48 | -1 | -102 | -97 | -108 | -51 | +48 | +20 | -226 | -309 | -19 | -18 |
| Mobrup RCP 4.5 | -34 | 34 | -25 | -62 | -77 | -10 | +57 | +103 | 19 | -149 | -259 | -40 |
| Mobrup RCP 8.5 | -59 | -13 | -52 | -108 | -74 | +35 | +123 | +189 | +67 | -99 | -235 | -29 |
| Westbourne RCP 4.5 | -43 | -13 | +7 | -43 | -46 | +7 | +68 | +125 | +52 | -164 | -246 | -1 |
| Westbourne RCP 8.5 | -66 | -35 | -37 | -88 | -93 | +5 | +109 | +210 | +112 | -72 | -194 | -8 |

## Conclusion

By 2050 without adaptation, it is likely that pasture yields in the cereal-livestock farming region of WA will be less and the growing season shorter. The severity of these changes will be far greater in rainfall environments receiving less than 400 mm of annual rainfall.


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