# Predicted frequency of wet and dry soil conditions in Tasmanian dairy regions under future climate scenarios

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## Abstract
Durations of wet and dry periods are significant factors that influence pasture management on dairy farms. Historical and future simulated daily climate data for two dairy regions of Tasmania (Flowerdale and Ringarooma) was accessed from the 'Climate Futures for Tasmania' project and used to simulate a perennial ryegrass sward growing on a clay loam soil. The simulated soil moisture content to a depth of 400mm was used as the criteria for determining number of wet (soil moisture > 160mm) and dry (soil moisture <120mm) days per annum. The predicted mean number of dry and wet days for each region for six general circulation models (GCMs; CSIRO-Mk3.5, ECHAM5, GFDL 2.0, GFDL 2.1, MIROC3.2 and UKHad), was computed for the baseline period (years 1971 to 2000) and three future climate periods (years of 2001 to 2030, 2031 to 2060 and 2061 to 2090). By years 2061 to 2090, the predicted mean number of wet days at Flowerdale and Ringarooma is predicted to decline by 8.5 and 4.5 days per annum, respectively. In contrast, the mean number of dry days for Flowerdale and Ringarooma is predicted to increase by 7.5 and 4.8 days, respectively. While there was little change in the mean number of wet and dry days when averaged over each GCM, there was substantial variation between GCMs for any particular period and region. This paper discusses the implication of these results and also highlights the potential influence of inter-annual climate variability on dairy farming systems.

## Key Words
Climate Futures for Tasmania, climate change, field capacity, readily available water, Flowerdale, Ringarooma

## Introduction
Climate is an important driver of pasture production and the intra-annual variability in climate results in different patterns of pasture production which needs to be managed to meet feed demands on dairy farms. In recent decades, south eastern Australia has experienced a decline in total annual rainfall (Australian Bureau of Meteorology 2008), with the most substantial reduction occurring in autumn (Gallant *et al.* 2007). General Circulation Models (GCMs) provide the best estimates for assessing potential changes to the climate on a global scale however projections of climate change are not evenly distributed over the globe. This means that local or regional climate projections are required to quantify local or regional climate impacts (Corney *et al* 2010). The Climate Futures for Tasmania (CFT) project generated climate projections specific to Tasmania through a dynamical downscaling approach (Grose *et al.* 2010). This downscaling approach increased the spatial resolution from 2° to 3° grid cells (~200 to 300km) in the GCMs down to a 0.1° grid (~10km) for Tasmania, thus capturing regional and sub-regional differences allowing the projected climate change impacts to be quantified on a local scale (Corney *et al* 2010).

Extended periods of both wet and dry soil conditions can strongly influence the managerial operations of a pasture-based dairy system. For example, extended periods with wet soil moisture conditions can result in pugging of pasture, increased lameness and an increase incidence of mastitis, whilst extended dry soil conditions often result in lower pasture production, reduced pasture persistence and an increased reliance on purchased feed. This study examined the predicted changes in the frequency of wet and dry days per annum for two dairy regions of Tasmania out to 2090 using climate projection data from the CFT project.

## Methods
Daily climate data developed from the CFT project (https://dl.tpac.org.au/) was accessed for Flowerdale (41.0°S, 145.6°E) and Ringarooma (41.3°S, 147.7°E). For both regions, six down-scaled A2 (i.e high on the scale of worst case scenarios based on regionally oriented economic development, increasing population and self-reliant nations; Corney *et al* 2010) emissions scenario GCM files (CSIRO-Mk3.5, ECHAM5, GFDL 2.0, GFDL 2.1, MIROC3.2 and UKHad) were used, in combination with the biophysical model DairyMod (Johnson *et al.* 2008), to simulate a rain-fed perennial ryegrass pasture sward using a generic clay loam soil.

Each GCM predicts varying increases or decreases in mean annual rainfall for future climate periods for Flowerdale (Figure 1a) and Ringarooma (Figure 1b) compared to its corresponding baseline period. The simulated soil moisture content to a depth of 400mm was used as the criteria for determining number of wet (soil moisture > 160mm) and dry (soil moisture <120mm) days per annum. The number of wet days represents when the soil is above field capacity and the number of dry days represents the point where water in the soil profile is no longer readily available to the pasture sward, and evapotranspiration falls below its potential rate. The mean number of dry and wet days for each region, averaged across the six GCMs, was computed for the baseline period (years 1971 to 2000) and three future climate periods (years 2001 to 2030, 2031 to 2060 and 2061 to 2090). In addition, a ten-year moving mean number of wet and dry days and the associated coefficient of variation (CV%) for each region and GCM were calculated (mean of years 1971 to 1980 = 1980 value).

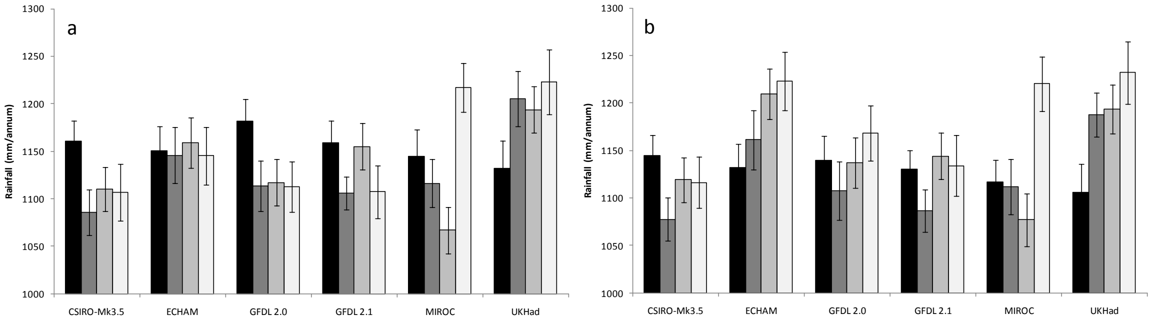


**Figure 1. Mean annual rainfall for Flowerdale (a) and Ringarooma (b) for the climatic periods of years 1971 to 2000 (■), 2001 to 2030 (□), 2031 to 2060 (■) and 2061 to 2090 (□) according to six general circulation models (vertical bars indicate the standard error of the mean).**

## Results

*Wet days*

The mean number of wet days, averaged over the six GCMs, was predicted to decline by 8.5 days per annum at Flowerdale and 4.5 day per annum at Ringarooma (Table 1). While there was little variation in the mean number of wet days between GCMs during the baseline period, each GCM predicted varying changes in the number of wet days per annum for three future climate periods. At Flowerdale, five of the six models predicted a reduction in the mean number of wet days per annum by years 2061 to 2090 when compared to the baseline period of years (Table 1). The only exception was the UKHad model with a predicted increase in the mean number of wet days per annum by years 2061 to 2090 when compared the baseline period of years (Table 1). At Ringarooma, all models predicted either no change (i.e. ECHAM model) or a decline in the mean number of wet days per annum by years 2061 to 2090 when compared to the baseline period of years (Table 1).

**Table 1. Mean number of wet days (soil moisture > 160mm) per annum for Flowerdale and Ringarooma using six global climate models for a baseline period (years 1971 to 2000) and change in the mean number of wet days per annum for three future climate periods (years 2001 to 2030, 2031 to 2060 and 2061 to 2090) compared to the baseline period.**

| Region | General Circulation Model | 1971 to 2000 | 2001 to 2030 | 2031 to 2060 | 2061 to 2090 |
|---|---|---|---|---|---|
| Flowerdale | CSIRO-Mk3.5 | 123.9 | -11.8 | -15.3 | -20.6 |
| | ECHAM5 | 121.6 | +0.5 | -3.0 | -7.3 |
| | GFDL 2.0 | 122.4 | -4.5 | -8.7 | -13.4 |
| | GFDL 2.1 | 119.9 | -6.5 | +1.3 | -5.4 |
| | MIROC3.2 | 122.3 | -6.7 | -18.1 | -5.4 |
| | UKHad | 118.2 | +9.2 | +3.0 | +1.3 |
| | Overall mean | 121.4 | -3.3 | -6.8 | -8.5 |
| Ringarooma | CSIRO-Mk3.5 | 115.7 | -10.1 | -10.4 | -16.6 |
| | ECHAM5 | 116.1 | -2.6 | -1.4 | 0.0 |
| | GFDL 2.0 | 114.6 | -5.3 | -5.2 | -6.3 |
| | GFDL 2.1 | 111.9 | -3.3 | +1.2 | -0.8 |
| | MIROC3.2 | 115.3 | -9.6 | -16.1 | -1.4 |
| | UKHad | 113.6 | +5.2 | +1.3 | -2.1 |
| | Overall mean | 114.5 | -4.3 | -5.1 | -4.5 |

There was substantial inter-annual variability in the number of wet days both within GCMs over time and between GCMs during the same timeframe (only limited data shown). The CSIRO-Mk3.5 model predicted a decline in the moving ten-year mean number of wet days per annum over time for Flowerdale (2.0 days per decade decline; Figure 2a). In contrast, the UKHad model predicted only a very small reduction in the moving ten-year mean number of wet days per annum over time (< 0.01 days per decade decline; Figure 2b). There also appears to be a trend towards increasing year-to-year variability in the number of wet days per annum as evidenced by the increase in CV% over time, especially with the CSIRO-Mk3.5 model.

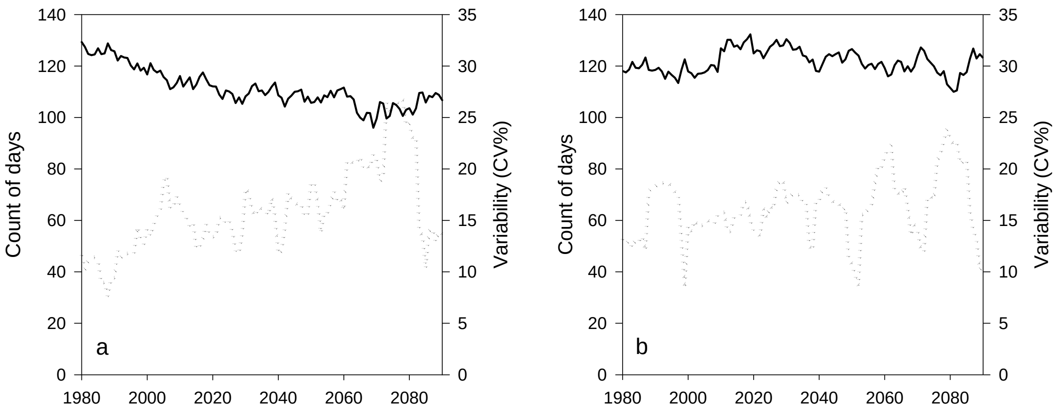


**Figure 2. Moving ten-year mean number of wet days (solid line), defined as soil moisture > 160mm in the top 400mm of soil profile, and its associated coefficient of variation (CV%, broken line), from years 1980 to 2090 for Flowerdale using the CSIRO-Mk3.5 (a) and UKHad (b) general circulation models.**

*Dry days*

The mean number of dry days, averaged over the six GCMs, was predicted to increase by 8.0 days per annum for Flowerdale and 7.2 days per annum for Ringarooma in the period of years 2031 to 2060 (Table 2). There was little variation in the number of dry days between GCMs during the baseline period. However, post the baseline period, there was substantially more variation between the climate models. For example, the CSIRO-Mk3.5 model resulted in Ringarooma having, on average, an additional 19.5 dry days per annum in the period of years 2061 to 2090 compared to the baseline period of years while the ECHAM model predicted a decline of 1.4 dry days per annum in the period of years 2061 to 2090 compared to the baseline period of years (Table 2).

**Table 2. Mean annual number of dry days (soil moisture < 120mm) per annum for Flowerdale and Ringarooma using six global climate models for a baseline period (years 1971 to 2000) and change in the number of dry days per annum for three future climate periods (years 2001 to 2030, 2031 to 2060 and 2061 to 2090) compared to the baseline period.**

| Region | General Circulation Model | 1971 to 2000 | 2001 to 2030 | 2031 to 2060 | 2061 to 2090 |
|---|---|---|---|---|---|
| Flowerdale | CSIRO-Mk3.5 | 157.9 | +7.6 | +12.5 | +13.0 |
| | ECHAM5 | 156.8 | -3.4 | +2.8 | +5.7 |
| | GFDL 2.0 | 155.5 | +7.6 | +13.5 | +19.7 |
| | GFDL 2.1 | 160.2 | +1.6 | +5.4 | +6.4 |
| | MIROC3.2 | 160.7 | +0.4 | +11.9 | +2.6 |
| | UKHad | 157.9 | -4.9 | +2.0 | -2.7 |
| | Overall mean | 158.1 | +1.5 | +8.0 | +7.5 |
| Ringarooma | CSIRO-Mk3.5 | 161.0 | +5.4 | +11.9 | +19.5 |
| | ECHAM5 | 155.7 | -0.3 | +8.5 | -1.4 |
| | GFDL 2.0 | 161.1 | +6.6 | +8.5 | +5.2 |
| | GFDL 2.1 | 163.8 | +2.2 | +4.4 | +0.6 |
| | MIROC3.2 | 162.5 | +1.6 | +9.1 | +5.6 |
| | UKHad | 161.9 | +0.4 | +0.8 | -1.0 |
| | Overall mean | 161.0 | +2.7 | +7.2 | +4.8 |

There was also substantial inter-annual variability in the number of dry days both within GCMs over time and between GCMs during the same timeframe (only limited data shown). For example, Figure 3 shows the moving ten-year mean number of dry days per annum for Ringarooma using the CSIRO-Mk3.5 and ECHAM models. The CSIRO model showed a trend towards an increase in the moving ten-year mean number of dry days per annum (2.0 days per decade increase; Figure 3a). In contrast, the ECHAM model showed a trend towards a decline in the moving ten-year mean number of dry days per annum (0.1 days per decade decline; Figure 3b). Although there were substantial fluctuations in the year-to-year variability in the number of dry days per annum with both models, there appears to be a trend towards a small decline in the variability with the CSIRO-Mk3.5 model compared to an increase in the variability for the ECHAM model over time.

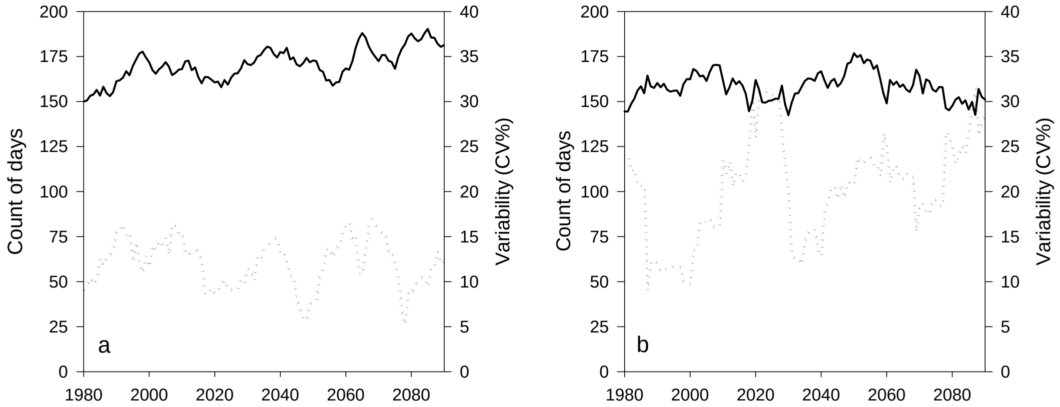


**Figure 3. Moving ten-year mean number of dry days (solid line), defined as soil moisture < 120mm in the top 400mm of soil profile, and its associated coefficient of variation (CV%, broken line), from years 1980 to 2090 for Ringarooma using the CSIRO-Mk3.5 (a) and ECHAM (b) general circulation models.**

## Conclusion

This study concluded that while there was substantial variation between GCMs, over time there appeared to be an upward trend in the predicted number of dry days per annum when available water in the soil profile will limit pasture production for the two Tasmanian dairy regions examined in this study. In addition, inter-annual variability in the number of wet and dry days is predicted to continue to occur and has the potential to also increase in the future. There is currently no conclusive evidence to suggest that for the two dairy regions of Tasmania examined in this study that adaptation strategies for managing extended dry or wet periods are going to be needed any more into the future than they are already today. Managing extended dry periods could include the adoption of deeper rooted pasture species into the feedbase or the implementation of irrigation, whilst managing extended wet periods could include improvements to on-farm drainage or the provision of infrastructure to support a stand-off area for a herd. There will also be a need to quantify the whole of farm biophysical and business performance, beyond just changes in the frequency of wet and dry soil conditions, when adopting such potential adaptation strategies.

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