Opportunities for irrigated pasture and broadacre crops using climate projections for the Meander Valley and Southern Midlands, Tasmania

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Abstract
Projected changes to the Tasmanian climate will have profound impacts on agricultural enterprises at farm, industry and regional scales. This will lead to substantial changes in farm management, choice of crops and land use. Projections of climate variables from the Climate Futures for Tasmania (CFT) project were used to assess the impacts of a changing climate on six different crop enterprises at two locations within north-central Tasmania (Meander Valley and Southern Midlands). Six fine resolution (0.1° grid) dynamically downscaled climate model outputs allow for impacts, to be differentiated between the two sites over the period 1971 to 2065. The mean annual temperature under the A2 emission scenario across both regions is projected to rise by 1.8 to 2.1°C from the baseline (1971–2000) to 2050 (2036 – 2065). Mean annual rainfall is projected to increase slightly at both Meander Valley and the Southern Midlands by 2% and 3% respectively. Agricultural opportunities for the two sites were assessed for three crops under irrigation; wheat, barley and perennial ryegrass. Yield and production impacts were simulated using the projected CFT data and the biophysical models of APSIM and DairyMod. Mean annual pasture yields are projected to increase from the baseline to 2050 largely due to an increase in spring pasture growth. Wheat yields are projected to increase by 6% and barley yields are projected to decrease by 2% by 2050. This study suggests that increased temperatures and elevated atmospheric CO_2 concentrations are projected to impact positively on irrigated cropping and pasture yields, where water availability is not a limiting factor.

Keywords
Cropping, Pastures, Modelling, Irrigation.

Introduction
Agriculture is a major driver of the Meander Valley's and the Southern Midlands economy. The Tasmanian Government's Wealth from Water Programbegan in 2010 and aims to assist farmers and potential investors to develop their irrigation businesses and help make the transition to growing the high value crops best suited to their area. This paper focusses on both the Meander Valley and the Southern Midlands in applying the crop rules developed in the Wealth from Water Pilot Program to modelling the response of pastures and crops in terms of yields and irrigation requirements. Suitable soils and temperate climate in both regions, underpins the level of high quality and quantity of agricultural production from the regions. The two regions have different climates. The Meander Valley climate varies from high rainfall and relatively cool areas in the highland region to the south and west, to warmer and drier areas in the east towards Launceston. In contrast, the Southern Midlands experiences a relatively temperate, maritime climate with mild to warm summers and cold winters. The region is in the rain shadow of the Central Highlands and therefore receives lower rainfall compared to Meander Valley. Mean annual rainfall ranges from 500 to 550 mm in the Southern Midlands, conversely Meander Valley mean annual rainfall ranges from 800 to 1,500 mm (Grose et al. 2010).

Agricultural production in the Meander Valley is largely derived from livestock. Dairy, beef and sheep production accounts for approximately 75% of the total farmed area and contributes 60% of the gross value of agricultural production. The remaining 40% of the gross value of agricultural production is from cropping, with vegetables being the major crop, followed by potatoes, poppies, pasture seed and cereals (AK Consultants 2012). Approximately two thirds of agricultural production in the Southern Midlands is attributable to livestock, with greater than 90% of all agricultural land used for grazing. Horticulture encompasses less than 1% of the land use but represents greater than 30% of total agricultural production, from stone fruit, fruit and vegetables for seed. The availability of additional irrigation water for both the Meander Valley and the Southern Midlands has paved the way to increase production for a range of irrigated dairy, cropping and livestock finishing enterprises (AK consultants 2012). Modelling the potential suitability and yield of crops using land and climate data along with irrigation water availability has not been undertaken before in these regions.

Methods

Two study sites were selected as representative of the wealth from water pilot project and of the regions of Meander Valley and the Southern Midlands. Deloraine in the Meander Valley and Oatlands in the Southern Midlands. Deloraine is characterised by Dermosol and Ferrosol soils and receives an annual rainfall of 834 mm. Oatlands is a low rainfall (551 mm) site in the Southern Midlands region characterised by texture contrast soils (Chromosols and Sodosols).

Climate data from the 0.1° gridded bias-adjusted dynamically downscaled General Circulation Models (GCMs) was obtained from the TPAC portal (https://dl.tpac.org.au/). Six GCMs were used; CSIRO-Mk3.5, ECHAM5/MPI-OM, GFDL-CM2.0, GFDL-CM2.1, MIROC3.2 (medres) and UKMO-HADCM3 under the A2 scenario. Daily climate data were accessed for the period 1st January 1961 to 31st December 2065 for maximum and minimum temperature (°C), rainfall (mm) pan evaporation (mm) and solar radiation ($MJ/m^2/day$). A 30-year climate 'baseline' (1971-2000) and two future 30-year climate periods of 2025 (2011-2040) and 2050 (2036-2065) were selected.

DairyMod (version 4.9.6) (Johnson et al. 2003; 2008) was used to simulate the impact of climate change on irrigated pasture growth at both sites. DairyMod has been shown to realistically simulate monthly and annual pasture production for sites across southern Australia, under a wide range of soil types and pasture management options (Cullen et al. 2008; Lodge and Johnson 2008). The Agricultural Production Systems Simulator (APSIM) (version 7.8) (Keating et al. 2003) was used to simulate the impact of climate change on irrigated wheat (Tennant) and barley (Gairdner), using typical crop management practices. The APSIM model has been shown to competently simulate crop growth and yield, and water and nitrogen balances across a wide range of environments (Keating et al. 2003; Wang et al. 2010). A clay loam surface texture was used for both sites, without any soil nutrient limitation and the same physical and chemical soil parameters were used for both sites as the principle aim was to determine the impact of climatic differences and trends.

Results

Projected climate

The mean monthly and annual values for each 30-year period were calculated for the five climate variables. The projected climate for the Meander Valley and the Southern Midlands shows the observed increase in temperatures during the latter half of the 20th century are projected to continue into the 21st century (Grose et al. 2010). Mean annual daily maximum temperatures are projected to increase by 1.3°C and 1.4°C by 2050, while mean annual daily minimum temperatures are projected to increase by 1.5°C and 1.4°C by 2050 respectively. Mean annual rainfall is projected to increase above the baseline value by 2% at Deloraine and 3% at Oatlands, while mean annual evaporation is also projected to increase by 7% and 6% respectively. Frosts are projected to decrease significantly with a warming climate. At both Deloraine and Oatlands frost-risk days are projected to reduce from approximately 50 to less than 25 by the end of the century, although damaging spring frost may still occur rarely (Grose et al. 2010).

Modelling

The projected climate impacts on irrigated barley, were quantified at Deloraine and Oatlands, with two different sowing times, of May 1 and June 1. The modelling was based on enterprises that are currently operating at their optimum through 'best practice' management. Barley yields are projected to remain relatively stable at Deloraine by 2050 (baseline yield 6.4 t/ha May planting) and (7.4 t/ha June planting) decreasing marginally by 1% (May sowing) with no change observed under the June sowing (Fig. 1*a*). In contrast, at Oatlands barley yields are projected to decrease slightly by 2050 by 2%, under both planting dates (Figure 1*b*) from baseline values of 9.9 t/ha (May) and 11.6 t/ha (June) respectively. There will also be a corresponding reduction in the number of days to flowering at both Deloraine and Oatlands with both planting times.

The effects of the projected future climate on annual irrigated pasture production for both sites are shown in Figure 2. Simulated mean annual pasture yields for 2050 are projected to increase above the baseline (yield 12.9 t/ha) at Deloraine by 38% (model range 31 to 43%) (Figure 2*a*), and at Oatlands by (10.4 t/ha) by 59% (50 to 70%) (Figure 2*b*). The projected increase in simulated annual pasture yields is driven by increased growth from late winter through to spring, with the greatest increase in growth projected to occur in spring.

Irrigation water demand is also projected to increase by 12% at Deloraine and by 11% at Oatlands by 2050 above the baseline values.

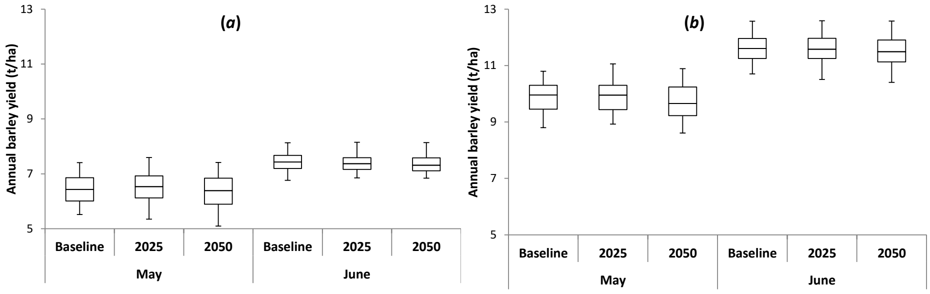

Figure 1. Multi-GCMs annual projected irrigated barley production (t/ha) box plots (5th, 25th, 50th, 75th and 95th percentile) for May 1st and June 1st sowing dates for the baseline, 2025, 2050 at Deloraine (*a*) and Oatlands (*b*).

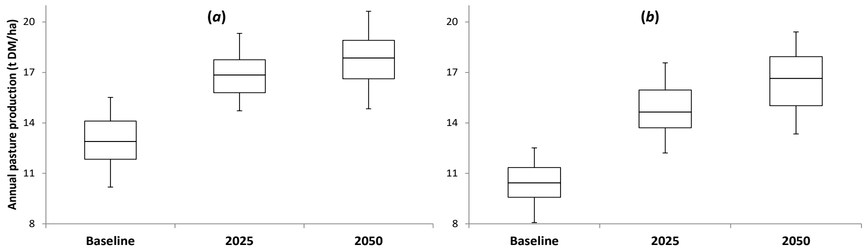

Figure 2. Multi-GCMs annual projected irrigated perennial ryegrass production (t/ha) box plots (5th, 25th, 50th, 75th and 95th percentile) at Deloraine (*a*) and Oatlands (*b*) for the baseline, 2025, 2050 at Oatlands.

The projected climate impacts on irrigated wheat, were quantified at Deloraine and Oatlands, with two different sowing times, of April 1 and May 1. Wheat yields are projected to remain relatively stable at Deloraine by 2050 (baseline yield 8.4 t/ha April planting) and (7.8 t/ha May planting) increasing marginally by 2% (model range 0 to 3%) (April sowing) and 1% (-1 to 5%) (May sowing) by 2050 (Fig. *3a*). In contrast, at Oatlands yields are projected to decrease by 2% (model range -5 to 0%) below the baseline (9.8 t/ha) by 2050 (April sowing) while increase by 3% (-1 to 9%) (baseline 9.1 t/ha) under the May sowing regime by 2050 (Fig. *3b*). There will also be a corresponding reduction in the time to reach anthesis at both sites (9% at Deloraine and 5% at Oatlands.

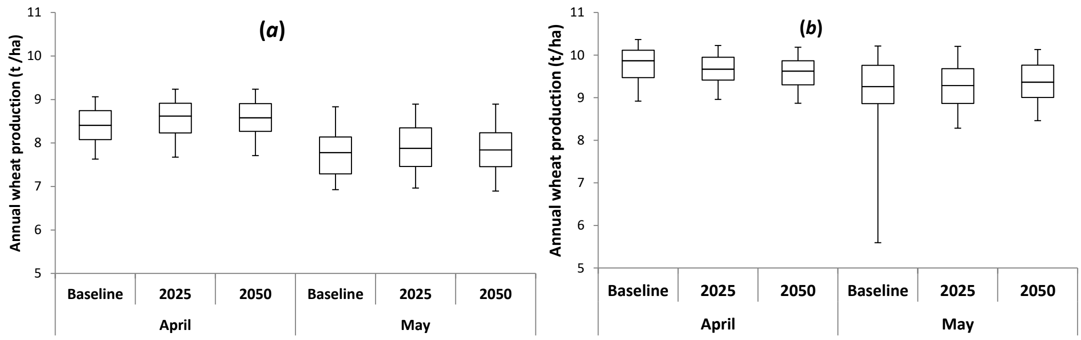

Figure 3. Multi-GCMs annual projected irrigated wheat production (t/ha) box plots (5th, 25th, 50th, 75th and 95th percentile) for April 1st and May 1st sowing dates for the baseline, 2025, 2050 at Deloraine (*a*) and Oatlands (*b*).

Discussion

A future warmer climate will drive an increase in irrigated pasture production, with the majority of the additional growth occurring from late winter through to spring, reflecting warmer winter and spring temperatures with adequate soil moisture. These results are consistent with the findings of Thomas and Norris (1979) and Kemp et al. (1989) that cool temperate pasture production during winter and early spring in temperate regions is severely restricted by low temperatures. This is partly due to frost and other factors such as low daily temperatures and low solar radiation (Holz et al. 2010). Irrigation demand for perennial ryegrass production is also projected to increase by 2050 at both sites, primarily driven by an increase in both spring and early summer irrigation demand. Annual irrigated barley yields are projected to decline slightly at both sites by 2050 consistent with other studies of climate change impacts on broadacre crop production in south-eastern Australia, where without adaptation strategies, yields have been projected to decline under a warming climate (Anwar et al. 2007; Wang et al. 2010). Irrigation water demand for barley production is also projected to decrease at both sites, under both sowing times by 2050. Irrigated wheat yields however, are projected to increase marginally at Deloraine, conversely at Oatlands, wheat yields are projected to decrease when sown in April, while increasing when sown in May by 2050. Irrigation water demand for wheat (data not shown) is also projected to remain relatively stable at Deloraine decreasing by 3% (April sowing) and increasing by 2% when sown in May, from the baseline values of 1.7 ML/ha, (respectively) to 2050. Correspondingly, at Oatlands irrigation water demand is projected to increase by 2% (April sowing) and by 13% (May sowing) from the baseline values of 1.3 ML/ha (respectively) by 2050. Time to wheat and barley crop maturity is also projected to decrease due to increases in both temperature and CO^2 concentrations. The projected promotion of crop development will affect the timing of sowing. The optimum sowing time may shift forward as the climate warms and frost risk at anthesis is reduced, allowing options of planting later maturing cultivars.

Conclusion

Projected climate impacts were quantified for two sites within the Meander Valley and the Southern Midlands, employing biophysical modelling in regards to irrigated pasture production and irrigated cropping. Opportunities for the expansion of agriculture and the development of irrigated pasture and cropping within both the Meander Valley and Southern Midlands from the Wealth from Water initiative are favourable for the crop species analysed. Our results indicate that irrigated pasture simulations were very positive, while irrigated grain crop (wheat and barley) simulations are projected to remain viable, with the future climate scenarios.

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