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Management opportunities for boosting productivity of cool-temperate dairy farms under climate change

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ABSTRACT

Improved knowledge of the effects of climate change on farming systems can help increase long-term production, economic performance, and mitigate risk. Here we assessed the effects of stocking rate and seasonal calving times on pasture and milk production under short and long term climate changes on dairy farms in Tasmania, Australia. Annual and monthly perennial ryegrass pasture production was simulated from 1971 to 2065 to examine trends in pasture productivity, forage requirements, and impacts on milk production in 2015 and 2050. The projected future climate for the study region indicates a mean warming of up to 1.4 °C, with moderate declines in rainfall of up to 5%. Despite lower rainfall, climate change will likely have a positive impact on pasture yields, with annual production increasing by 13–16%, even though summer growth is reduced and inter-annual variability is increased. We found that greater pasture production is conducive to greater forage conservation, and together these factors allow intensification of stocking rates. These effects increase milk yields by 3–16% per annum and reduce reliance on purchased feeds, which together implies greater profitability of cool-temperate Australian dairy systems under future climates. We also found that total milk production in a spring calving system allows greater stocking rates and pasture utilisation compared with an autumn calving system, and whilst milk produced per animal declines under higher stocking rates, milk yield per hectare increases. Overall, our results suggest that global warming and climate change will positively affect pasture growth rates in Tasmania, and that greater production and conservation of home-grown feeds will be conducive to increased farm milk yields, provided that stocking rates are intensified sustainably.

1. Introduction

The dairy industry in Australia is the nation's third largest agriculture sector, accounting for 8% of the total gross value of primary production (Australian Bureau of Statistics, 2013). The dairy industry in Tasmania is the state's largest agricultural sector, contributing 26% of the gross value of agricultural production (Australian Bureau of Statistics, 2013). The predominance of dairy farms is located along the northern coastal areas of the state from Scottsdale in the north-east to Smithton in the north-west, with a smaller number of farms in other regions. The majority of feed production is pasture based, typically with mixed swards consisting of perennial ryegrass (*Lolium perenne* L) and white clover (*Trifolium repens* L). Pasture is generally the cheapest source of feed for dairy cows and there is a strong positive relationship between farm profit and total pasture dry matter (DM) consumed per hectare (Chapman et al., 2009; Rawnsley et al., 2013). In southern Australia, perennial ryegrass is the most widely sown pasture species on dairy farms, supplying 60% to 70% of the diet for lactating dairy cows due to its high nutritional value and digestibility (Armstrong et al., 2010; Chapman et al., 2008; MacDonald et al., 2010). The reliable production of high quality pasture in Tasmania reduces the demand for supplementary feed and provides a competitive advantage for the dairy industry in comparison to mainland Australia and international producers. Whilst the potential impacts of projected climate change on pasture production under future climates in Tasmania have previously been described (Bell et al., 2013; Cullen et al., 2008, 2012; Holz et al., 2010; Phelan et al., 2014), to date there has been little work undertaken to determine how climate change may impact more broadly on whole farm systems, such as effects on herd milk production and farm feed budgeting.

Although perennial ryegrass generally provides high quality forage for most of the year (Garcia and Fulkerson, 2005; Waller and Sale, 2001), pasture based systems regularly fail to meet the feed requirements for lactating dairy cows during late winter and summer in south-eastern Australia. Growth is restricted during winter due to low temperatures and in summer primarily due to insufficient rainfall, occasional heat waves and high vapour pressure deficit (Chapman et al., 2008, 2011, 2012; Cullen et al., 2009; Doyle et al., 2000). In north-western Tasmania, perennial ryegrass is generally most productive in spring as temperatures climb after winter and pastures

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utilise frequent rainfall and soil water that often accumulates over winter. These conditions allow perennial ryegrass to provide a highly nutritional feed, with both high energy and high crude protein concentrations (Rawnsley et al., 2013). The resultant seasonal growth patterns are characterised by feed deficits during summer that need to be filled with supplementary feed, and feed surpluses in spring, which ideally should be managed through feed conservation (Chapman et al., 2009, 2011; Rawnsley et al., 2013). The heavy reliance of the Tasmanian dairy industry on home-grown forage increases farm vulnerability to climate change through its influence on pasture production and persistence and may result in an increased reliance on purchased supplementary feeds, that have variable costs.

The Climate Futures for Tasmania (CFT) project generated climate projections specific to Tasmania through fine-scale climate modelling using a dynamical downscaling approach to the end of the 21st century using general circulation models (GCMs) (Corney et al., 2010). The CFT modelling projections for Tasmania under the A2 emission scenario indicate temperature increases from 2.6 °C to 3.3 °C, and in some regions either positive or negative changes in annual rainfall of up to 100 mm per year (Grose et al., 2010). Previous studies of climate change impacts across the dairy regions of south-eastern Australia have commonly focused on impacts on pasture and fodder crops (Bell et al., 2013; Cullen et al., 2009, 2012; Holz et al., 2010; Pembleton et al., 2013; Phelan et al., 2014). Cullen et al. (2009, 2012) indicated that pasture production in cool-temperate climates would be relatively resilient to climate change, whilst Holz et al. (2010) and Phelan et al. (2014) suggest that the net effect of a warming climate would be beneficial for pasture growth. However, to date there has been little work on how management options such as stocking rates and calving time influence milk production under a changing climate.

The overarching aim of this study was to assess the opportunities for improved management of a temperate grazing dairy system under a changing climate. Specific objectives were to 1) quantify the impacts of climate change on seasonal growth rates and total annual pasture production and 2) evaluate the effectiveness of stocking rates and seasonal calving time on pasture and milk production, and on herd feed demand and supply for two representative dairy farming regions in Tasmania.

2. Materials and methods

2.1. Study sites

Two study sites were selected in the major dairy production regions in north-west Tasmania (Fig. 1). The Woolnorth region (centred on 40.7°S, 144.8°E, 17 m) is characterised by moderate to high rainfall, a cool-temperate climate and predominantly Podosol soils (Isbell, 2002). The Togari region (centred on 41.0°S, 145.3°E, 44 m) is characterised by high rainfall, a cool-temperate climate, and soil orders dominated by Podosols, Ferrosols, and Dermosols (Cotching et al., 2009; Isbell, 2002). Both dairy production systems were simulated on a moderately drained Podosol soil under rainfed conditions. The pasture growing season for both sites is typically from late August to early December, with an additional flush in autumn growth subject to adequate rainfall (e.g. see Fig. 3). Mean annual rainfall at Woolnorth is 974 mm, and the mean annual daily maximum and minimum temperatures are 16.7 °C and 9.7 °C respectively, with few frosts. Mean annual potential evapotranspiration at Woolnorth is 1093 mm. Mean annual rainfall at Togari is 1149 mm, and the mean annual daily maximum and minimum temperatures are 16.4 °C and 9.0 °C respectively, whilst mean annual potential evapotranspiration is 1074 mm.

2.2. Projected climate

The CSIRO-Mk3.5 GCM was chosen for this study, due to its high skill in simulating the climate over south-east Australia (Bennett et al., 2014; Corney et al., 2010). The CSIRO-Mk3.5 model was used because of the need for detailed spatial resolution and downscaling of GCM data. For reasons of both accuracy and convenience, we used work by Corney et al. (2010) that dynamically downscaled these projections for Tasmania. Corney et al. (2010) and Holz et al. (2010) showed that both mean annual temperature projections and total annual rainfall from five other GCMs (ECHAM5/MPI-OM, GFDL-CM2.0, GFDL-CM2.1, MIROC3.2 (medres) and UKMO-HadCM3) were not significantly different to projections from the CSIRO-Mk3.5 model (see online Supplementary material; Appendix S1). Climate data from the 0.1° gridded bias-adjusted dynamically downscaled CSIRO-Mk3.5 were

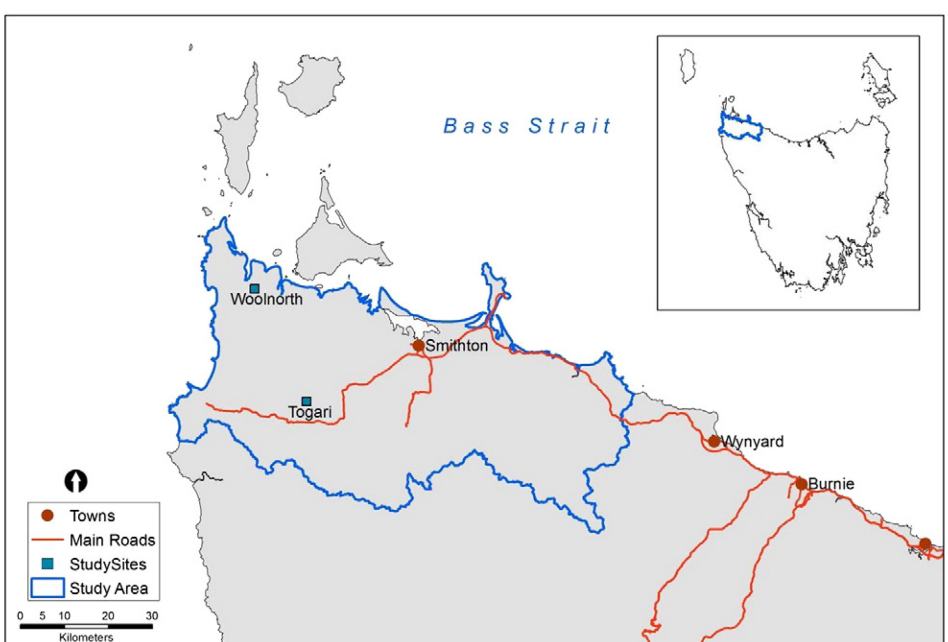

Fig. 1. Study site locations in north-western Tasmania.