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Management options for dairy farms under climate change: Effects of intensification, adaptation and simplification on pastures, milk production and profitability

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ABSTRACT

There are few holistic analyses of agricultural systems that inclusively consider how the combination of gradual climate change and increased frequencies of extreme climatic events influence biophysical variables as well as economic returns. Here we examine how climate change to 2040 influences pasture growth rates, grazed pasture harvested (PH) and profitability of three case study (baseline) farms in southern Australia. We applied 'development options' (or adaptations) to baseline farms in each region that either intensified, simplified or modified the seasonal distribution of feed supply (*Intensify*, *Simplify* or *Adapt*, respectively) by manipulating several components of the farm system simultaneously, including herd size, liveweight and farm assets.

In general, climate change reduced annual pasture produced. On dryland farms, hotter, drier conditions reduced growing durations through later autumn breaks and earlier finishes to spring growth, although winter growth rates were enhanced. On irrigated farms, the magnitude and inter-annual variability of PH was less influenced by climate change. Overall, climate change reduced milk production and income, and increased costs due to additional fodder conservation and more purchased feed.

Current climate variability caused far greater inter-annual variation in PH and profit compared with the long-term impacts of climate change. This suggests that farm outcomes may be improved by tactically managing for short-term climatic variability, rather than by making long-term strategic changes in preparation for climate change.

Future work on adapting dairy businesses to climate change should examine development options that help maintain or extend growing season length and/or harness the additional winter growth. Our study indicates that climate change impacts on dairy systems will be regionally-specific; no individual development option was universally effective in reducing pasture losses to climate change across regions and development options, and no option consistently increased or decreased PH across sites. Future adaptation strategies should thus take into account not only local climate variability as well as climate change, but also the existing farming systems already operating at each site.

1. Introduction

Increasing global demand for animal products will require strategies to increase future livestock production. By 2050, consumption of meat and dairy is expected to have respectively risen by 76% and 65% against a 2005–07 baseline, compared with 40% for cereals (FAO, 2012). Currently, the major dairy consumers are China, India, the EU and the United States; India and China together consume almost 100 million tonnes of milk products per year (Bailey et al., 2014). Australian dairy is a $13.5 billion farm, processing and export industry employing an estimated 39,000 people (DA, 2015). An important sector of the dairy industry is based in south-eastern Australia, where the majority of production occurs. Similar to their New Zealand counterparts, the Australian industry remains predominately pasture-based with an estimated 70–75% of feed requirements met from grazed pasture under 'normal' seasonal conditions (DA, 2015), largely because grazed pasture is generally the cheapest source of feed (Chapman et al., 2014a). However, dairy production systems in this region are diverse, with some systems implementing grain or alternative concentrate feeding during milking, and others operating similar systems to those

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in Europe and North America, where cows are housed and fed total mixed rations for most or all of the year (Ho et al., 2013). While pasture growth is a key driver of profit in pasture-based dairy farms, in practice farms are complex ecosystems (Bryant and Snow, 2008) with biophysical, management and financial components (Kalaugher et al., 2017).

Pasture production is highly dependent on seasonal climatic conditions, with the amount and timing of rainfall being a key factor in the seasonal and annual variability of pasture growth (Chapman et al., 2009). Drought conditions have a substantial impact on farm financial performance because low pasture growth rates reduce pasture intake, leading to greater reliance on purchased feeds (grain, concentrates, hay and silage), which also tend to be more expensive during such times (Armstrong et al., 2005; Chapman et al., 2014b). Projections for climate change in south-eastern Australia indicate that temperatures will increase and rainfall is likely to decrease, although large uncertainty exists in rainfall projections (CSIRO, 2015). Previous studies have shown that warmer and drier climates will lead to increases in pasture growth rates in winter and early spring, but with contraction of the spring growing season (Cullen et al., 2009; Moore and Ghahramani, 2013). However, the future climate scenarios used in those studies did not capture either (1) the projected effects of rainfall patterns, with more rain forecast to fall in fewer, larger events and longer dry spells between events (CSIRO, 2015), or (2) the increase in temperature extremes, including heat waves of greater frequency and magnitude (White et al., 2010). Recent work accounting for extreme climatic events have revealed an additional detrimental impact to pasture production and farm financial performance compared with analyses using only gradual changes in climate (Harrison et al., 2016), with impacts likely to vary regionally and according to the type of farm system implemented.

Existing climate change research related to dairy production has mainly focused on climate impacts rather than adaptation (e.g. Klinedinst et al., 1993). For instance, climate projections for South Africa suggest that dairy cattle over most of the country are likely to be severely heat stressed at peak annual temperature-humidity index from the year 2046 onwards (Nesamvuni et al., 2012). Although there has been some research of dairy farm adaptation to climate change in other countries (e.g. New Zealand (Kalaughter et al., 2017) and Ireland (Fitzgerald et al., 2009)), there has been little in Australia. What has been done focuses on adaptation of specific attributes of the farm systems, such as changes to single factors including pasture characteristics (Cullen et al., 2014), stocking rates and/or calving dates (Harrison et al., 2014a; Phelan et al., 2015). Such options do not address broader questions about future options for the dairy industry by considering, for example, how whole of farm system changes influence production and profit resilience to climate change. For example, adaptations that aim to intensify production may consider not only increasing stocking rates and concentrate feeding per animal, but also farm infrastructure investment and total debt.

In this study, the impact of future climate scenarios was examined in three dairy regions of south-eastern Australia. Case study farms were modelled as representative baselines in each region, along with three contrasting development options. These represented regionally relevant systems that (1) *Intensify* (increased stocking rate with greater reliance on off-farm resources and farm infrastructure), (2) *Simplify* (reduced stocking rate, fewer inputs such as fertiliser and less reliance on feed resources produced external to the farm) or (3) *Adapt* (re-organise resources around expected changes in pasture growth patterns) of each case study farm. A participatory action research (PAR) approach was used with regional working groups integral to describing, modifying and validating the modelled results. This paper addresses the impacts of climate change on the production and profitability of the case study farms, while in a future study we address the impact of climate change in relation to inherent climate variability in wet and dry periods, the transition from the base farm to each development option, and other sources of variability in the farm business, notably milk prices and feed costs. The aims of the current paper were

1. To examine the effect of climate change on (a) seasonal pasture growth rates, (b) pasture intake per animal and harvested and (c) profit of three case study dairy farms, and
2. To examine the influence of climate change on PH and profit if either of three development options that *Intensified*, *Simplified* or *Adapted* the baseline farm were applied in each of the three regions.

2. Methods

2.1. Overview

An earlier publication detailed the influence of climate change to 2080 and extreme climatic events on dairy farm production and profitability (Harrison et al., 2016), as well as the new approach used to generate the climate data. Here, we first quantify the influence of climate change between the present and 2040 on pasture production, purchased fodder requirement, milk production and profitability, then elucidate the ability of different farm system adaptations in mitigating or reversing adverse effects of climate change. We simulated these systems using 38 years of either historical or future climate data and assessed Low, Medium and High climate change trajectories. To enable a more complete insight into the influence of climate change on production and profit, we held other variables constant where possible, such as milk prices and feed costs. In a subsequent report, we will further examine the impacts of implementing farm system adaptations at the beginning of wet or dry decades for the historical and future climates, and also incorporate variability in milk and supplementary feed prices. Full details of the methods used to create the future climate data are provided in Harrison et al. (2016).

2.2. Historical climate data, regional working groups and site characteristics

Australian dairy farming occurs across diverse climatic zones, but the bulk of milk production occurs in south-eastern temperate regions. We undertook case studies of three farms located in regions representing the breadth of dairy farming in this region. These were situated in the Fleurieu Peninsula (Parawa, South Australia), Gippsland (Moe, Victoria) and North West (NW) Tasmania (Wynyard). An expert working group was established in each of the regions, which comprised farmers and local service providers. These groups defined the criteria for selecting the case study farm, the farm development options to be analysed, and provided input into the assumptions used when analysing farm system changes. Regional working group members also contributed to the interpretation of the results to ensure that the analyses were subjected to informed feedback and that a broad range of perspectives were considered. Historical daily weather data for each site were sourced from meteorological archives (http://www.longpaddock.qld.gov.au/silo), with baseline data measured from 1 January 1975 to 31 December 2013. Annual average rainfall of the historical periods at the three sites ranged from 937 to 995 mm, with a winter-dominant pattern (Fig. 1). In winter, historical minimum and maximum daily temperatures vary from 4 °C to 15 °C, respectively, and from 10 °C to 26 °C, respectively, in summer (Fig. 1). All simulations using historical data assumed a baseline atmospheric CO_2 concentration of 380 ppm. Case study farms used as baselines were located in cool temperate regions 12–361 m ASL with Grey Dermosol or Red Ferrosol soils (Isbell, 2002) and plant available water capacities of 32–80 mm (Table 1). Pasture species mainly consisted of perennial ryegrass (*Lolium perenne*), and were simulated as such in this study. Further site characteristics are provided in Table 1 in Harrison et al. (2016), and historical climate details are shown in Fig. 1.