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Temporal and spatial water use on irrigated and nonirrigated pasture-based dairy farms

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ABSTRACT

Robust information for water use on pasture-based dairy farms is critical to farmers' attempts to use water more efficiently and the improved allocation of freshwater resources to dairy farmers. To quantify the water requirements of dairy farms across regions in a practicable manner, it will be necessary to develop predictive models. The objectives of this study were to compare water use on a group of irrigated and nonirrigated farms, validate existing water use models using the data measured on the group of nonirrigated farms, and modify the model so that it can be used to predict water use on irrigated dairy farms. Water use data were collected on a group of irrigated dairy farms located in the Canterbury, New Zealand, region with the largest area under irrigation. The nonirrigated farms were located in the Manawatu region. The amount of water used for irrigation was almost 52-fold greater than the amount of all other forms of water use combined. There were large differences in measured milking parlor water use, stock drinking water, and leakage rates between the irrigated and nonirrigated farms. As expected, stock drinking water was lower on irrigated dairy farms. Irrigation lowers the dry matter percentage of pasture, ensuring that the amount of water ingested from pasture remains high throughout the year, thereby reducing the demand for drinking water. Leakage rates were different between the 2 groups of farms; 47% of stock drinking water was lost as leakage on nonirrigated farms, whereas leakage on the irrigated farms equated to only 13% of stock drinking water. These differences in leakage were thought to be related to regional differences rather than differences in irrigated versus nonirrigated farms. Existing models developed to predict milking parlor, corrected stock drinking water, and total water use on nonirrigated pasture-based dairy farms in a previous related study were tested on the data measured in the present research. As expected, these models performed well for nonirrigated dairy farms but provided poor predictive power for irrigated farms. Partial least squares regression models were developed specifically to simulate corrected stock drinking water, milking parlor water, and total water use on irrigated dairy farms.

Key words: water use, water efficiency, irrigation, milking parlor, pasture system

INTRODUCTION

The area of land under irrigation doubled from 1950 to 2000 (Molle et al., 2010), and global water use for irrigated agriculture now accounts for approximately 70% of total freshwater withdrawals (United Nations Educational, Scientific and Cultural Organization, 2015). Water scarcity is an issue in many water basins (Smakhtin et al., 2004; Molle et al., 2010), and 20% of the world's aquifers are being overused (Gleeson et al., 2012). Therefore, the focus on optimizing and managing agricultural water usage is increasing (Scarsbrook and Melland, 2015; Dillon et al., 2016). This focus is needed because the world population is estimated to reach 9.7 billion people by 2050. The amount of food produced will need to increase by 70% to feed this population (FAO, 2009; United Nations Department of Economic and Social Affairs, 2015); therefore, the pressure on water resources will increase further.

Dairy cow water intake studies have concentrated on confinement systems (Murphy et al., 1983; Meyer et al., 2004; Cardot et al., 2008), and only recent articles are available on pasture-based dairy farms (Higham et al., 2017; Murphy et al., 2017). Significant data are available on the amount of water used for irrigation (Armstrong et al., 2000; Doll and Siebert, 2002), and water use on nonirrigated pasture-based dairy farms in New Zealand has been quantified (Higham et al., 2017). However, data for other water uses on irrigated

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dairy farms, including stock drinking water (**SDW**), and milking parlor water use (**MPW**) remain limited.

The study of Higham et al. (2017) showed the seasonal nature of water use on pasture-based farms (milking from spring to autumn) and the importance of milk production and climatic variables as drivers of water use. However, further research is needed on the water requirements of dairy farms that use irrigation. As the models developed by Higham et al. (2017) do not include or account for DM percentage in the feed (and therefore ingested water), we do not expect them to reliably predict water use on irrigated farms.

As the allocation of water resources gets close to available limits in waterways in dairying regions, accurate water use figures for SDW and MPW are required. This information is needed to minimize the risks of underestimating water used (where not enough water is left to maintain environmental water flows) or overestimating water used (where the water resource is underused). Water use data are also required for water footprinting studies (Ridoutt and Pfister, 2010; Zonderland-Thomassen and Ledgard, 2012), which can be used to calculate abstractive and consumptive water use for analysis of the water "embedded" in milk products. This also allows the effect of current and future water extraction patterns to be assessed. The objectives of the current study were to evaluate the accuracy of previously described water requirement models and to develop new models for predicting water requirements on irrigated dairy farms.

MATERIALS AND METHODS

Water use was measured on 20 irrigated dairy farms in the Canterbury region (−43°S, 172°E) and 22 nonirrigated dairy farms in the Manawatu region (−40°S, 176°E) of New Zealand. Dairy farms with water meters, telemetry, and data loggers already installed (as required by regional council rules) were selected, and, where appropriate, additional water meters and data loggers were installed as piping infrastructure allowed. In this manner, as many different water uses as possible were monitored. A complete set of total water [**TW**, calculated as MPW + SDW; irrigation water (**IW**) is excluded from TW] use, MPW, and SDW data were recorded on 3 farms in the Canterbury region and 10 farms in the Manawatu region. In addition, individual MPW, SDW, and TW values were measured on 11, 1, and 7 farms in the Canterbury region and 5, 1, and 3 farms in the Manawatu region, respectively. The IW use data were available on 10 of the Canterbury farms as the rest were not telemetered. A total of 29 and 23 years of data (not including submetering) was collected from the irrigated and nonirrigated farms, respectively.

Table 1. Characteristics (SD in parentheses) of the dairy farms used for water use analysis

Region and variable[1]	No. of farms	System type,[2] no.			Cow breed[3]	Average no. of cows	Average daily milk yield, kg/d	Average daily milk fat + milk protein, kg/d	Average effective area, Ha	No. of rotary parlors[4]	Average no. of bales	Cow:bale ratio	Average no. of houses on SDW line
		1–2	3	4–5									
Nonirrigated													
SDW	11	3	7	1	0.65 (0.261)	454 (160.4)	12.8 (7.71)	1.14 (0.649)	182 (80.3)	2	37.4 (11.25)	12.2 (2.01)	0.6 (0.97)
cSDW	8	3	4	1	0.58 (0.258)	499.3 (140.3)	13.0 (8.01)	1.16 (0.678)	201 (83.6)	2	40.8 (10.08)	12.5 (2.07)	0.3 (0.49)
MPW	15	4	8	3	0.66 (0.198)	419 (172.1)	12.6 (7.65)	1.11 (0.639)	170 (83.9)	2	34.1 (12.40)	12.4 (1.90)	N/A[5]
TW	14	5	8	1	0.68 (0.201)	448 (152.7)	12.1 (7.44)	1.07 (0.624)	179 (72.9)	3	35.9 (11.04)	12.6 (1.91)	N/A
Irrigated													
SDW	4	0	2	2	0.41 (0.188)	733 (112.4)	13.1 (7.99)	1.21 (0.702)	196 (30.7)	4	54.5 (4.12)	13.4 (1.22)	0 (0.0)
cSDW	4	0	2	2	0.41 (0.188)	733 (112.4)	13.1 (7.99)	1.21 (0.702)	196 (30.7)	4	54.5 (4.12)	13.4 (1.22)	0 (0.0)
MPW	14	0	10	4	0.46 (0.116)	772 (163.8)	11.8 (7.44)	1.07 (0.462)	216 (50.3)	12	48.4 (7.07)	15.9 (2.28)	N/A
TW	9	0	5	4	0.50 (0.000)	776 (102.8)	13.9 (8.10)	1.26 (0.698)	210 (23.0)	7	51.1 (6.33)	15.2 (1.73)	N/A
IW	9	2	6	1	0.50 (0.000)	763 (175)	12.8 (7.70)	1.18 (0.672)	201 (42.4)	6	48.7 (5.74)	15.6 (3.13)	N/A

[1] SDW = stock drinking water; cSDW = corrected stock drinking water; MPW = milking parlor water use; TW = total water use; IW = irrigation water.

[2] System type based on the DairyNZ (Hamilton, New Zealand) 1-to-5 classification system: 1 = all pasture; 2 = 4 to 14% of feed imported; 3 = 10 to 20% of feed imported; 4 = 20 to 30% of feed imported; 5 = 25 to 40% of feed imported (Ramsbottom et al., 2015).

[3] 1 = Friesian; 0.5 = Friesian-Jersey cross; 0 = Jersey.

[4] Rotary parlors (Reinmann, 2003); all other parlors were herringbone swing-over milking parlors.

[5] N/A = data not collected.