Water use on pastoral dairy farms in New Zealand: An analysis of measurements, predictions, and water footprinting

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Abstract

Current water use guidelines for pastoral dairy farms across New Zealand are based on a 1964 study suggesting 70 L per cow per day for stock drinking water (SDW) and 70 L per cow per day for milking parlour water (MPW) use. However, dairy cows and milking parlours have changed significantly over the last half century. This thesis combined detailed monitoring of water use on more than 100 farms in the Waikato, Manawatu, and Canterbury regions with predictive modelling to; set benchmarks for SDW and MPW, analyse temporal and spatial variations of water use for irrigated and non-irrigated dairy farms, and assess the likely impact of climate change on future water demand of pastoral dairy farms across New Zealand. Finally, the thesis applied and evaluated different water footprint methods (the Water Footprint Network method, the Stress-Weighted Water Footprint method, and the Availability WAter REmaining (AWARE) method) to assess the impact of dairy water use on local water resources across different regions of New Zealand. In particular, the effects of varying the accuracy of data sources (local verse global) and the scale of the analysis (regional verse catchment) on the water footprints were investigated.

From this study, in the Waikato region, the mean SDW is 60 L/cow per day and the mean MPW is 49 L/cow per day. In the Manawatu region, the mean SDW is 74 L/cow per day and the mean MPW is 50 L/cow per day. In the Canterbury region, the annual mean SDW is 28 L/cow per day and mean MPW is 64 L/cow per day. For the first time, leakage rates in the supply of SDW were estimated for pastoral dairy farm systems. Average leakage rates were estimated to be approximately 26% in the Waikato region, 47% in the Manawatu region, and 13% in the Canterbury region. Through climate change modelling requirements for

irrigation water were estimated to increase by 17-24%, with the largest increase in Canterbury. Approximately 99% of the volumetric (total volume of water used) water footprint (L/kg fat and protein corrected milk) is associated with the green (from rainfall) and blue (from surface water) water consumed in the growth of pasture and feed at the study farms.

The use of global data sources, as compared to the local data, resulted in underestimation of the volumetric green water footprint (L/kg FPCM) by 12 to 30%, and overestimation of the volumetric blue water footprint (L/kg FPCM) by 3 to 141% in the study regions. Likewise, the water footprint of dairy farming was found to vary markedly with the scale at which this analysis is conducted. The use of local data at a catchment scale gave the most reliable water footprints.

Overall, water use on New Zealand dairy farms has been demonstrated to be much more complex than simple, historic guidelines indicate. The water use values produced in this study can serve as updated industry and policy guidelines, as the industry addresses limits to water availability and future increases in water use requirements for stock drinking water on non-irrigated dairy farms associated with predicted climate change.

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ADD	Average daily demand
AMD	Availability minus demand
AWARE	Available WAater REmaining
Brd	Breed
CF	Characterisation factor
CowBail	Cow to bail ratio
cSDW	Corrected stock drinking water
DM	Dry matter
DM%	Dry matter %
DMI	Dry matter intake
EFR	Environmental flow requirements
ET	Evapotranspiration
ET_{blue}	Blue evapotranspiration/irrigation water
ET_c	Crop specific evapotranspiration
ET_{green}	Green evapotranspiration
ET_o	Reference evapotranspiration
Evap	Potential evapotranspiration
FPCM	Fat and protein corrected milk
IW	Irrigation water
JD	Julian day
K_c	Crop coefficient
LCA	Life cycle assessment
MAR	Mean annual runoff
MeanT	Average daily temperature
Milking	The number of milkings in a day
MilkSol	Milksolids
MilkVol	Milk volume
MinT	Minimum daily temperature
MPW	Milking parlour water
MY	Milk yield
Na	Sodium
NPS-FM	National Policy Statement for Freshwater Management
NSE	Nash-Sutcliffe efficiency
PBIAS	Percentage bias
PDD	Peak daily demand
P_{eff}	Effective precipitation
PKE	Palm kernel expeller
PLS	Partial Least Squares
Rad	Solar radiation
RCPs	Representative concentration pathways

RF	Rainfall
RMA	Resource Management Act
RMSE	Root mean square error
R_{nat}	Natural runoff
RSR	RMSE-observations standard deviation ratio
SDW	Stock drinking water
SRF	Strongly regulated flows
STe_i	Surface time equivalent
SU	Stock unit
TMax	Maximum daily temperature
TMin	Minimum daily temperature
TW	Total water/bore water
VF	Variation factor
VWI	Voluntary water intake
WA	Water availability
WA_{blue}	Blue water availability
WF_{blue}	Blue water footprint
$WFII_{blue}$	Water footprint impact index
WFN	Water Footprint Network
WS_{blue}	Blue water scarcity
WSI	Water stress index
WU	Water withdrawal
WULCA	Water use in Life Cycle Assessment