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

A thesis presented in partial fulfilment of the
requirements for the degree of

Doctor of Philosophy

in

Environmental Sciences
at the Institute of Agriculture and Environment

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Caleb David Higham

2017
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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<tr>
<td>ADD</td>
<td>Average daily demand</td>
</tr>
<tr>
<td>AMD</td>
<td>Availability minus demand</td>
</tr>
<tr>
<td>AWARE</td>
<td>Available WAater REmaining</td>
</tr>
<tr>
<td>Brd</td>
<td>Breed</td>
</tr>
<tr>
<td>CF</td>
<td>Characterisation factor</td>
</tr>
<tr>
<td>CowBail</td>
<td>Cow to bail ratio</td>
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<tr>
<td>cSDW</td>
<td>Corrected stock drinking water</td>
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<td>DM</td>
<td>Dry matter</td>
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<tr>
<td>DM%</td>
<td>Dry matter %</td>
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<tr>
<td>DMI</td>
<td>Dry matter intake</td>
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<td>EFR</td>
<td>Environmental flow requirements</td>
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<tr>
<td>ET</td>
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<td>Crop specific evapotranspiration</td>
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<td>ET$_{green}$</td>
<td>Green evapotranspiration</td>
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<td>ET$_o$</td>
<td>Reference evapotranspiration</td>
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<tr>
<td>Evap</td>
<td>Potential evapotranspiration</td>
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<td>Fat and protein corrected milk</td>
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<td>IW</td>
<td>Irrigation water</td>
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<td>Julian day</td>
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<td>K$_e$</td>
<td>Crop coefficient</td>
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<td>LCA</td>
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<td>The number of milkings in a day</td>
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<td>RF</td>
<td>Rainfall</td>
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<td>Root mean square error</td>
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<tr>
<td>RSR</td>
<td>RMSE-observations standard deviation ratio</td>
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<td>Strongly regulated flows</td>
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<td>$S_{Te1}$</td>
<td>Surface time equivalent</td>
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<td>Stock unit</td>
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<td>Minimum daily temperature</td>
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<td>Total water/bore water</td>
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