Original papers

Multiple linear regression modelling of on-farm direct water and electricity consumption on pasture based dairy farms

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ABSTRACT

An analysis into the impact of milk production, stock numbers, infrastructural equipment, managerial procedures and environmental conditions on dairy farm electricity and water consumption using multiple linear regression (MLR) modelling was carried out. Electricity and water consumption data were attained through the utilisation of a remote monitoring system installed on a study sample of 58 pasture-based, Irish commercial dairy farms between 2014 and 2016. In total, 15 and 20 dairy farm variables were analysed on their ability to predict monthly electricity and water consumption, respectively. The subsets of variables that had the greatest prediction accuracy on unseen electricity and water consumption data were selected by applying a univariate variable selection technique, all subsets regression and 10-fold cross validation. Overall, electricity consumption was more accurately predicted than water consumption with relative prediction error values of 26% and 49% for electricity and water, respectively. Milk production and the total number of dairy cows had the largest impact on electricity consumption while milk production, automatic parlour washing and whether winter building troughs were reported to be leaking had the largest impact on water consumption. A standardised regression analysis found that utilising ground water for pre-cooling milk increased electricity consumption by 0.11 standard deviations, while increasing water consumption by 0.06 standard deviations when recycled in an open loop system. Milk production had a large influence on model overprediction with large negative correlations of −0.90 and −0.82 between milk production and mean percentage error for electricity and water prediction, respectively. This suggested that overprediction was inflated when milk production was low and vice versa. Governing bodies, farmers and/or policy makers may use the developed MLR models to calculate the impact of Irish dairy farming on natural resources or as decision support tools to calculate potential impacts of on-farm mitigation practices.

1. Introduction

GDP (Gross Domestic Product) growth within developing countries is fuelling a forecasted 20% increase in global consumption of milk and dairy products by 2050 (Bruinsma and Alexandratos, 2012). In preparation for the abolishment of the European Union milk quota system in April 2015, the Irish government identified the potential for a 50% increase in milk production by 2020 over 2007–09 levels (DAFM, 2016). With dairy products and ingredients valued at €3bn to the Irish economy in 2014, the increased production should be sensitive to the use of natural resources to ensure the sustainable growth of Ireland’s dairy industry (DAFM, 2016). The related impact is twofold: (1) much of Ireland’s dairy farm water is supplied by groundwater boreholes to safeguard a consistent, reliable supply of adequate pressure (O’Connor and Kean, 2014). Since 7.42 L of water per litre of milk are consumed on average (Shine et al., 2018), the water demand will rise dramatically in line with milk production which may cause local water shortages during periods of little rainfall, thus placing additional pressure on the public water supply. (2) In Ireland, a strong positive correlation exists between milk production and electricity consumption with 38.84 watt-hours (Wh) per litre of milk consumed on average (Shine et al., 2018). Similarly, the electricity consumption of three Finnish dairy farms varied between 37 and 62 Wh kg\textsuperscript{−1} milk, with milk cooling and milk harvesting being the two largest energy consuming processes (Rajaniemi et al., 2017). Without an effective mitigation strategy, dairy farm electricity costs per litre of milk may increase, as dairy farm infrastructure may not be optimally configured for the increased milk production levels. Similarly, increased electricity consumption during daytime or peak hours may have negative effects on national grid loads as well as on dairy farm electricity costs in a dynamic pricing

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Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Min</th>
<th>Mean</th>
<th>Median</th>
<th>Max</th>
<th>IQR</th>
<th>SD</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield</td>
<td>Litre</td>
<td>213</td>
<td>51,421</td>
<td>48,016</td>
<td>204,756</td>
<td>42,407</td>
<td>32,452</td>
<td>863</td>
</tr>
<tr>
<td>Dairy cows</td>
<td>n</td>
<td>28</td>
<td>114</td>
<td>102</td>
<td>300</td>
<td>50</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td>Electricity</td>
<td>kWh</td>
<td>199</td>
<td>2,094</td>
<td>1,818</td>
<td>7,786</td>
<td>1,350</td>
<td>1,094</td>
<td>31</td>
</tr>
<tr>
<td>kWh Lw Lm−1</td>
<td></td>
<td>8.10</td>
<td>73.19</td>
<td>39.82</td>
<td>3,314.64</td>
<td>31.68</td>
<td>164.97</td>
<td>4.70</td>
</tr>
<tr>
<td>kWh Cow Lw Lm−1</td>
<td></td>
<td>1.98</td>
<td>18.35</td>
<td>18.14</td>
<td>45,36</td>
<td>7.78</td>
<td>6.02</td>
<td>0.17</td>
</tr>
<tr>
<td>Water</td>
<td>m³</td>
<td>51</td>
<td>361</td>
<td>308</td>
<td>1,575</td>
<td>217</td>
<td>218</td>
<td>7</td>
</tr>
<tr>
<td>m³ Lw Lm−1</td>
<td></td>
<td>1.67</td>
<td>13.42</td>
<td>6.63</td>
<td>542.22</td>
<td>6.82</td>
<td>34.18</td>
<td>1.14</td>
</tr>
<tr>
<td>m³ Cow Lw Lm−1</td>
<td></td>
<td>0.51</td>
<td>3.29</td>
<td>2.95</td>
<td>23.50</td>
<td>1.83</td>
<td>1.90</td>
<td>0.06</td>
</tr>
</tbody>
</table>

IQR = Inter-quartile range, SD = Standard deviation, SEM = Standard error of the mean.

Wh Lw Lm−1 = Watt-hours per litre of milk. kWh Cow Lw Lm−1 = Kilowatt-hours per dairy cow. Lw Lm−1 = Litres of water per litre of milk. m³ Cow Lw Lm−1 = Cubic meter of water per dairy cow.
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