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Measuring spatial and temporal variation in lactating dairy cow placement on diverse grazing system farms

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ABSTRACT

The locations dairy cows visit on grazing system farms can have important implications for nutrient management. Excreted nutrients can be directly returned to pasture paddocks, or returned to places where these nutrients can either be collected for reuse, or are not collectable and therefore lost. Previous research has shown that nutrient accumulation was related to the time cows spend in places on farms, but there is little literature describing the spatial or temporal variation in the locations lactating dairy cows visit on grazing system farms. We developed a methodology to quantify the time lactating cows spend in different places on 43 representative grazing system farms to better understand the potential for excreta deposition and collection. These farms were diverse, with the herds visiting a wide variety of places where they spent differing lengths of time. The lactating dairy herds spent the majority of their time on pasture paddocks (74.2%; 0 to 97.6%), and only 10% (1 to 25%) of their time in locations where nutrients are routinely collected for storage and re-use, (i.e. the dairy shed (milking parlour) and associated yards). However, the paddocks where the cows were placed were not uniformly distributed around the farm, with significantly more time spent in paddocks overnight, that were located an average of 118 m closer to the dairy shed than paddocks the cows visited during the day. Feedpads and holding areas were the other places on farms that cows often visited, and where they spent 9.5% and 18.2% of their time respectively. However, only half of the feedpads in this study were concreted to facilitate collection of excreted nutrients for redistribution. Using excretion rates from the literature and data collected in this study, an estimated 1.0, 7.3 and 5.1 t of P, N and K respectively would be deposited within 100 m of the dairy shed by a 326 cow herd over a 300 day lactation on a grazed dairy farm. Up to 50% of the nutrients deposited near the dairy shed are potentially not collected and recycled. These results suggest that quantifying animal numbers and the time they spend in various locations are essential to determine nutrient deposition within dairy grazing systems and to improve farm nutrient use efficiencies.

1. Introduction

Improving nutrient management is a key requirement of dairy production systems globally, particularly in light of the on-going increase in fertiliser and feed nutrient importation onto farms and the surpluses and positive nutrient balances associated with greater milk production (Neeteson et al., 2003; Kristensen et al., 2005; Fangueiro et al., 2008; Kobayashi et al., 2010; Gourley et al., 2012b; Oenema et al., 2014). Consequently, a wide variety of nutrient management systems have been developed, ranging from simple input-output farm gate balances to more detailed assessment of internal transformations, storages, and distribution of nutrients within the farm (Öborn et al., 2003; Gourley et al., 2007). An essential component of these tools is the quantification and management of dairy cow excreta. In the United States for example, concentrated animal feeding operations are required to develop nutrient management plans, such as the Manure Management Planner (MMP, 2014), which details the collection, storage and application of manure (Nennich et al., 2005). Nutrient accounting systems such as MINAS were created in response to the European Union Nitrates Directive, for use in the Netherlands to improve management of animal manure (Oenema et al., 2006). Nutrient management plans are also required of New Zealand grazing system dairy farms located in catchments that are particularly sensitive to nutrient losses (Monaghan et al., 2007). It is expected that by ensuring that excreted nutrients are accounted for and used to produce fodder, farmers could reduce the use of imported fertiliser nutrients and minimise environmental impacts of nutrient loss in both grazing and confinement systems (Nennich et al., 2005; Oenema et al., 2006; Monaghan et al., 2007).

In the largely confinement production systems in Europe and the US

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dairy cows are housed in barns and other structures for much of the year, while grazing system dairy cows spend most of their time away from facilities where excreted nutrients can be collected for re-use. For example, in a study comparing manure management practices in contrasting dairy production systems, Gourley et al. (2012a) reported that between 51 and 89% of estimated manure N was deposited by cows to pastures in grazing systems, while less than 43% of excreted N was deposited on pasture in confinement systems. However, in a survey of Canadian dairy farms lactating cows spent on average 19% of their time on pasture in summer, although in some regions and on smaller farms as much as 17 h per day was recorded (Sheppard et al., 2011).

The return of excreta by animals to pasture can lead to considerable between paddock spatial heterogeneity in soil nutrient levels observed in grazing system dairy farms (Gourley, 2004; Lawrie et al., 2004; Gourley et al., 2007, 2015; Fu et al., 2010; Aarons et al., 2015). Fu et al. (2010) observed higher soil P levels near the farmyard and where slurry had been applied. Likewise paddocks closer to the farmyard and dairy shed had significantly greater soil P and K levels (Aarons et al., 2015) while those regularly receiving effluent had higher K levels (Gourley et al., 2015). By contrast, paddocks frequently harvested for fodder (eg silage removal and fewer visits by animals) had lower soil K (McCormick et al., 2009; Gourley et al., 2015). These data indicate that soil nutrient levels could be influenced by daily farm management decisions that determine which pastures dairy cows graze, which pastures are used for fodder production, and the location and time animals spend in places around farms. For example, dairy cows can be placed closer to the dairy shed at night to minimise the travel time for the morning milking (Wardrop, 1953). Herds can be held in standing/exercise yards for up to 12 h on grazing system farms (Sheppard et al., 2011). By contrast certain paddocks can be routinely withheld from grazing for silage or hay production (McCormick et al., 2009). Despite this, little research is reported documenting the locations that cows visit and the time spent there on grazing system farms. Spatial and temporal analysis of cow locations has typically focussed on measuring within paddock variability in excreta deposition (e.g. White et al., 2001; Hirata et al., 2011; Moir et al., 2011). In addition, these studies have not quantified the locations of commercial dairy cows to better understand within farm factors influencing herd placement decisions.

The objective of this study was to quantify the spatial and temporal variability in where dairy cows spend time in grazed production systems to better understand within farm nutrient flows. We aimed to identify the typical places visited by lactating cows on commercial dairy farms and the time the herds spent in these locations. We then examined the farm management and environmental factors associated with differences in the distribution of time spent in these places. Finally, we used data from the literature to estimate nutrient loads deposited, to quantify the flows of excreted nutrients through the herds around these farms and the potential for collection of excreta, then conclude by describing the implications of these returns.

2. Material and methods

2.1. Grazing system farms

Data quantifying the spatial and temporal variability in the location of cows were collected on 43 commercial dairy farms representative of Australian grazing systems (Gourley et al., 2012b). The participating dairy farms were located in temperate, Mediterranean, sub-tropical and tropical environments across the major dairy regions (Fig. 1 and Table 1), and reflected the relative proportion of the national industry in each region (Gourley et al., 2012b). Most of these pasture-based grazing system farms were managed conventionally, with four organic dairy farms also included in the study. In all study farms the cows were not housed and grazed year-round, generally travelling each day along laneways between paddocks and to and from the dairy shed where they were milked. Cows were often held in concreted dairy yards before or after milking. Cows may also have been confined in other locations (holding areas and feedpads) on the farms for feeding or other reasons. While feedpads may be concreted, holding areas were most commonly a paddock or a part of a paddock where cows were held. Paddocks that the cows were collected from in the morning or returned to at night were categorised in this study as 'night' paddocks, as distinct from 'day' paddocks where the cows grazed during the day.

2.2. Spatial and temporal data collection

The participating farms were visited on five occasions (summer; February/March 2008, autumn; May/June 2008, winter; August 2008, spring; November 2008 and summer; February/March 2009) and the farmers interviewed by trained interviewers using a structured questionnaire. An initial meeting was also held with the farmers where they were informed of the questions to be asked at each interview, to ensure they were prepared to provide the required information. At each interview, the farmers were asked to identify the places on the farm the lactating dairy cows had been placed over the preceding 24 h, and the time animals spent in those places. The interview dates were selected to represent each season and the farmers indicated that their management of the cows was typical for each season.

To calculate the areas of places visited and the distances walked along laneways, farms were mapped in detail (ArcView GIS 3.3, Environmental Systems Research Institute) using schematics provided by the farmers and aerial photographs that were available (see Gourley et al., 2015 for more details). All paddocks, buildings and other infrastructure, ponds and dams, laneways, and areas not used as part of the production system (such as woodlands and water courses) were identified and dimensions assigned. Distances to the dairy shed were measured from the gate entrance of each paddock.

2.3. Data and statistical analysis

After reviewing the dairy cow data recorded at all farm interviews (2964 records), the places visited were categorised as one of seven locations ('night' or 'day' paddocks, laneways, dairy shed, yards, feedpads, holding areas). The time (in hours) each cow spent in each location over 24 h was used to calculate the percentage of time spent there for analysis of time in locations.

The structure of the data necessitated a number of manipulations for data and statistical analysis. While dairy sheds, yards and laneways were identified on all farms at all interviews, only some farms had feedpads and/or holding areas, and paddocks were not visited on some farms on at least one interview date. The unbalanced design where all factor combinations were not present at all interview visits resulted in a total of 1273 'location' records for each herd on each farm at each visit, or 1673 records when the seven locations are included for all farms.

For further analysis, the locations 'night' and 'day' paddocks were pooled into a single class (paddock) to give six management units (paddocks, laneways, dairy shed, yards, feedpads, holding areas) and the time spent in these management units were then compared. Grouping the locations into the six management units resulted in 1464 or 1162 'management unit' records depending on whether all factor combinations were present or not, respectively. The non-normal distribution of data required logarithmic or angular transformation for statistical analysis, while the repeated measures nature of the data collection (ie data collection on a number of occasions on each farm) was suited to REML (Residual Maximum Likelihood) analysis.

After preliminary graphical analysis (R program, Version 2.11.0 R Foundation for Statistical Computing) the data were statistically analysed using Genstat Release 17.1; VSN International Ltd, 2014 to summarise the data (mean, median, ranges) and to investigate the effects of fixed and random terms. The time in hours, spent in the seven location categories, the distance of the locations from the dairy shed, as well as the area of these locations were compared by REML mixed