Urine patch area coverage of an intensively stocked dairy pasture

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Abstract
The urine patch of the grazing cow has been identified as the key source of N loss from pasture-based dairy systems. Although critical to N modelling, quantitative data on the annual area coverage of urine patches in pastures is scarce. A new technique using survey-grade global positioning system (GPS) technology was developed to measure the paddock area coverage of dairy cattle urine and dung patches. A four year study was conducted on an intensively stocked (4.3 cows/ha) dairy farm in Canterbury, New Zealand. Twelve field plots on typical grazed pasture were monitored over a four year period, sampling at 12 week intervals. Urine and dung deposits within the plots were visually identified, the pasture response area (radius) measured and position marked with survey-grade GPS. Spatial geographic information system (GIS) software was used to analyse the data. The mean urine patch pasture response area was 0.35 m^2. It was calculated that the mean area covered by urine patches on an annual basis was 23.1 ± 2.2 % for the given stocking density and grazing management regime.

Key Words
Nitrogen, urine, area coverage, dairy, grazed pasture, GPS.

Introduction
Urine and dung deposited by grazing animals causes high nutrient loading to a relatively small proportion of the total grazed area (Haynes and Williams 1993). The high N loading rate (1000 kg N ha^{-1}) of the dairy cow urine patch exceeds pasture N demand (Moir *et al.* 2007), and hence represents the major source of N loss from intensively grazed pasture systems (Di and Cameron 2002*a*). Much valuable research has been conducted to quantify (Silva *et al.* 1999, Ledgard *et al.* 1999, Di and Cameron 2002*a*) and mitigate (Di and Cameron 2002*b*, 2007) N loss from temperate grazed grassland in New Zealand. However, in order to effectively model and manage N losses from grazed pastures, information on the spatial nature of urine depositions is required. Quantitative research data on the area coverage of urine depositions to grazed pasture is scarce internationally.

The measurement of annual urine patch coverage in grazed pastures is difficult. Short-term observations of grazing dairy heifers were made by Petersen *et al.* (1956), mostly focusing on dung depositions and distribution. These workers concluded that a negative binomial function was in close agreement with measurements of the distribution of dung patches, and probably also urine patches. MacLusky (1960) estimated that the surface area affected by cow urinations was 0.68 m^2/cow/d, which equates to a low annual coverage value of < 10% of the paddock area. Estimates of total urine patch area coverage, are however, unclear in this study. Richards and Wolton (1976) conducted more detailed calculations, based in part on the work of Petersen *et al.* (1956). Assuming that overlapping occurs, they used the negative binomial function and calculated that 23 % of a paddock might be covered by urine patches annually. However, this study did not have the ability to distinguish between old and fresh urine patch response areas, which are a critical aspect of the calculations. Based on values from literature, Williams (1988) calculated that 23% of a pasture would be covered in excreta (dung and urine) in one year. Again using a theoretical calculation, Whitehead (2000) estimated an annual urine coverage area of 21% for grazing dairy cattle. In a more detailed recent study, White *et al.* (2001) measured the frequency and location of urinations and defecations of dairy cows for 5 x 24 hr grazing periods. Taking an average area coverage for urine and faeces based on literature values, they calculated an area coverage of excreta of about 10% of the total paddock area for a stocking density of 2.48 cows/ha. Although the most comprehensive study to date in this field of research, the annual urine patch coverage area value of 10% by White *et al.* (2001) seems low when compared to New Zealand grazing systems.

In a preliminary study, Moir *et al.* (2006) presented a new methodology to overcome these measurement issues. A Real-Time Kinematic Global Positioning System (RTK-GPS) was used to record the temporal and

spatial location and radius of animal urine and dung patches in the field. In this paper we present the full results of this study examining field urine depositions by dairy cattle, using the method of Moir *et al.* (2006). The objective of this study is to quantify the annual area coverage and spatial distribution of dairy cow urine depositions to an intensively stocked grazed pasture system.

Methods

The research was conducted on the Lincoln University Dairy Farm (LUDF), near Christchurch, New Zealand. The trial was four years in duration, commencing in May 2003. The farm is 161 ha (effective) in area with a stocking density of 4.3 cows/ha, and is spray irrigated from November to March. Milk production is 1800 kg milk solids (MS)/ha/yr with cows grazed outdoors year round on a pasture only diet. Most of the dairy herd graze off-farm for 4 weeks during the winter months of June and July. Twelve 10 m x 10 m (100 m^2) plots were established on 'typical' grazing areas of the farm, and sampled at twelve week intervals. Plots were grazed as part of the normal grazing rotation of the farm.

Urine patches were visually identified as being areas of lush, dense pasture growth, typical of a large pasture nitrogen growth response. The location of all animal urine and dung patches deposited on the plots were recorded using a GPS. Survey grade Trimble™ RTK GPS (TNL 5700 rover, plus base unit) was used, giving a position accuracy of ± 0.01 m. Patch positions were marked by placing the GPS pole in the centre of the dung or urine patch and the location recorded in the data logger. In addition, the mean radius of the urine or dung patch was measured by clamping a ruler horizontally to the base of the GPS pole. All measurements were taken at least 14 days after the paddock was last grazed meaning that urine patches were easily observed due to the high pasture mass of the urine patch compared with other areas of the sward.

The field GPS data was ground-truth corrected and geographic information system (GIS) data analysis was performed using *ArcGIS 8.0* (ESRI 2002). Location coordinates were established for urine and dung patches, including patch radius. During data analysis it was assumed that if the centre of a urine patch was within ± 10 cm of another patch, it was deemed as having resulted from the same urination event. Dung patch data was removed from the data set. The data output was then summarised in terms of: (i) number of urine patch observations in each plot per sampling event; (ii) area of the plot (%) affected by urine deposition at each sampling event; and (iii) the mean radius of urine patches.

Results

The average observed urine patch radius and size (area) were very consistent. Mean urine patch radius ranged from 27 cm in the winter of Year 2, up to 40 cm in the summer of Year 3 (Table 1). Urine patch area ranged from 0.31 to 0.50 m^2 (Table 1). Overall, the mean urine patch observed in the field can be described as having a radius of 33 cm and an area of 0.35 ± 0.001 m^2.

Table 1. Mean urine patch radius (cm) and area (m^2) across all years.

Season of Deposition:	Year 1		Year 2		Year 3		Year 4	
	Patch Radius	Patch Area	Patch Radius	Patch Area	Patch Radius	Patch Area	Patch Radius	Patch Area
Winter	33.1	0.34	27.5	0.24	30.6	0.29	38.3	0.46
Spring	35.0	0.38	32.5	0.33	38.3	0.46	29.4	0.27
Summer	30.4	0.29	39.5	0.49	39.7	0.50	30.9	0.30
Autumn	27.6	0.24	30.6	0.29	31.2	0.31	37.8	0.45
Annual Means	31.5	0.31	32.5	0.34	34.9	0.39	34.1	0.37
4 Year Mean		0.35						
SEM		0.001						

The average number of urine patches measured per plot is presented in Figure 1. Mean values ranged from 11.0 to 20.0 urine patches/plot. The number of patches varied between seasons, but no trend in seasonal variation between years was apparent (Figure 1). Mean urine patch numbers across all samplings and all years was 15.2 patches /plot/sampling. This value equates to 1520 urine patches/ha at any one time. On a spatial basis, urine patch area coverage varied from season to season, and between years. Annual area coverage by urine patches varied from 21.6 (Year 2) to 24.4 % (Year 4), with an average value of 23.1 % ± 2.2 % (Figure 2A). Area coverage appeared to be lowest for winter and autumn deposition periods, except in year 4, where the trend was reversed. Spatially, urine depositions were of a random nature (Figure 2B).
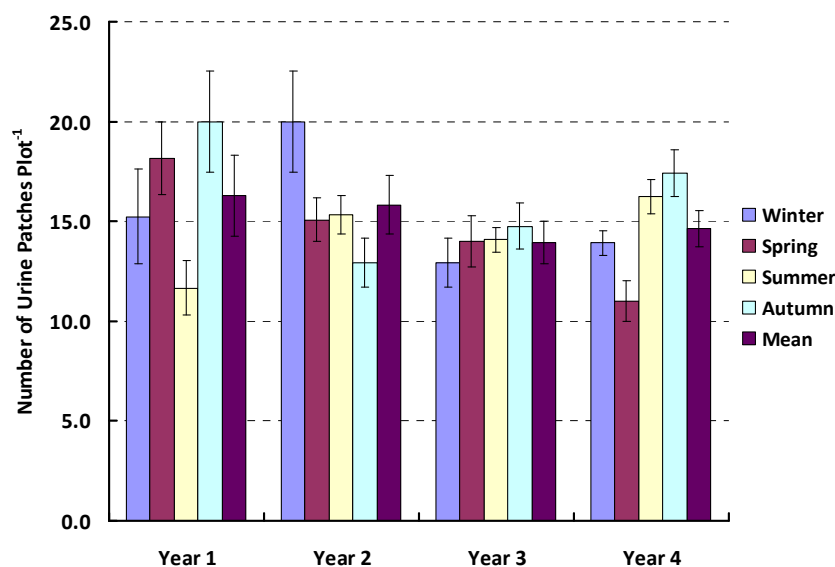
Figure 1. Mean numbers of urine patches observed per plot on a seasonal basis for all years. Error bars represent ± 1 SEM.
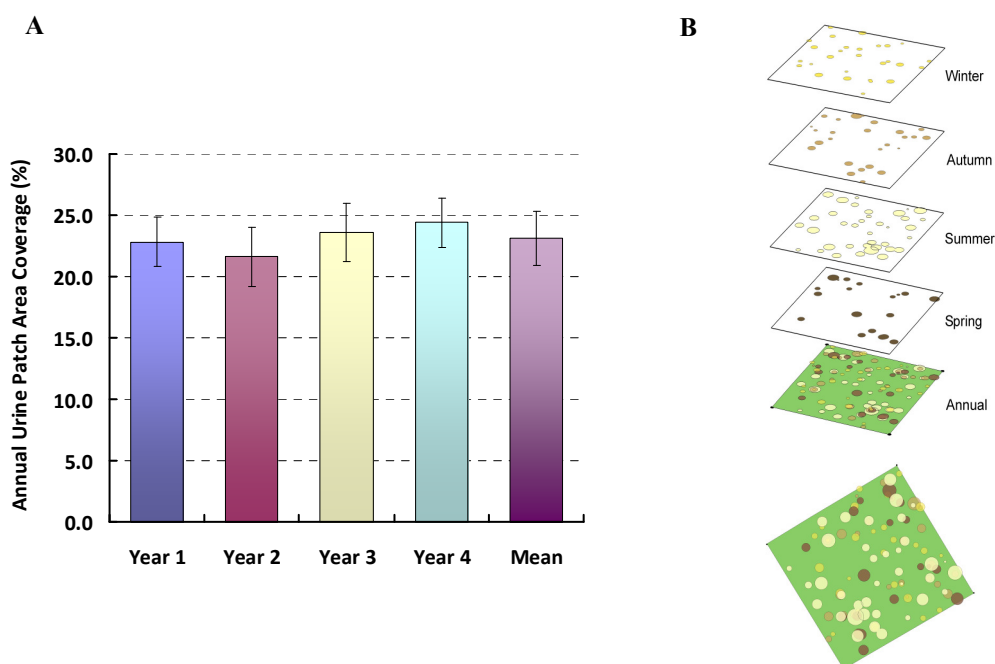

Figure 2. (A) Mean annual area coverage of urine patches from GIS data analysis. Error bars represent ± 1 SEM.; and (B) A graphical example of a GIS data analysis output for cow urine depositions on one field plot for one year. These outputs were used to calculate and map the spatial area coverage of urine patches in the field on a temporal basis.

Discussion

Urine patch radius and area values measured using this new GPS method agree well with values reported by other workers. Petersen *et al.* (1956) reported a mean urine patch area as 0.28 m², Richards and Wolton (1976) reported 0.49 m², while Haynes and Williams (1993) summarised the range as being 0.2 to 0.4 m², with a likely mean value of 0.3 m². The data from our study suggest that in the field environment, the value is likely to be in the region of 0.35 m². Annual urine patch area coverage data presented here provide valuable new information on spatial urine coverage under an intensively stocked dairy system. The mean area coverage value presented here is 23.1 ± 2.2 % of the paddock area covered in urine patches annually. This value agrees strongly with the theoretical calculations of Peterson *et al.* (1956) (23%), Williams (1988) (23%) and Whitehead (2000) (21%). In contrast, the estimates of around 10% coverage by MacLusky (1960)

and White *et al.* (2001) are not in agreement with results from our study. However, the random nature of urine and dung depositions reported here (Figure 2B) do compare well with the results of White *et al.* (2001), and demonstrate the even grazing of pasture, and therefore even urine and dung deposition, that occurs under a high stocking rate.

Conclusions

A new method of accurately measuring and recording the position and area coverage of urine and dung depositions by grazing cattle in the field has been successfully developed in this study. Our detailed results indicate that for dairy pastures with a high stocking density of 4.3 cow ha^{-1}, the average urine coverage of paddocks on an annual basis was 23.1 ± 2.2 %, with a mean urine patch area of 0.35 m^2. It was estimated that on average 1520 urine patches ha^{-1} were present at any time through the year. This is valuable information for those measuring, modeling and mitigating N loss from grazed dairy pasture systems.

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