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Livestock and pasture management on commercial Thoroughbred breeding farms: implications for estimating nitrogen loss

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Abstract

Published data on livestock and pasture management on Thoroughbred breeding stud farms were collated to model and estimate farm-level variables required to estimate nitrogen leaching. On commercial farms, stocking density doubled during the breeding season (August – December). The effective stocking density increased with farm scale (number of resident mares) but decreased with farm size (total effective area). Therefore, farm nitrogen output may fluctuate seasonally and will be influenced by farm size and scale. Farm size and scale independently affected the stocking and grazing management (i.e., paddock rotation interval) for the different equine stock classes (empty, pregnant, mares with foals). Stocking and grazing management influenced the pasture available and subsequently, the grazing behaviour as determined by the difference between pasture mass of lawns and roughs. The difference between pasture mass of lawns and roughs was reduced with increasing stocking density and decreasing pasture availability, and increased under conditions of high stocking density (>2 mares/ha) and low pasture availability (<400 kg DM/ha/horse). Modification of grazing behaviour could affect the nitrogen-leaching potential by modifying the size of manure-deposition area and the N-loading rate on urine and dung patches. The complex relationship between farm, horse and management factors needs to be included when estimating nitrogen leached from equine properties.

Keywords: horse; grass; nitrate; leaching

Introduction

On grazed-pasture systems, nitrogen that is undigested or excess to requirements will be excreted onto pasture in the faeces and urine (Haynes & Williams 1993). Faecal protein and urine contains nitrogen (N) that can be utilised by plants for dry matter production or converted into reactive forms (ammonia, nitric oxide, nitrous oxide, nitrate) which can be volatilised into the atmosphere (ammonia, nitric oxide, nitrous oxide) and leached (nitrate) into ground and surface water (Galloway et al. 2003).

The nitrate leaching loss is dependent on rate and amount of N deposited on pasture (N-loading) in relation to the rate of N removal by plants based on plant fertility requirements. Leaching increases when nitrate accumulates due to N loading exceeding the plant uptake capacity (Di & Cameron 2002). The opportunity for plant to remove N depends on the nitrogen retention capacity of the soil (Di & Cameron 2007). The N-retention capacity is affected by soil type, soil conditions (i.e. erosion, compaction, ploughing), season and climate (Bott et al. 2013; Cameron et al. 2017; Di & Cameron 2002). The main concern of nitrate leaching is the contamination of drinking water and eutrophication of larger water bodies that can affect the aquatic ecosystem (Galloway et al. 2003; Hubbard et al. 2004).

In dairy and sheep pasture-based farming systems, relatively large leaching losses occur with high stocking density, fertiliser application and irrigation (Cameron et al. 2017). A nutrient budget model such as 'OVERSEER' is designed to estimate the balance of nutrient inputs and outputs (available on www.overseer.org.nz). Then, the model uses this information to estimate nitrate leaching losses (Cameron et al. 2017). The component sub-models within 'OVERSEER' that model animal intake and excretion, N distribution and proportion leached were designed using assumptions derived from studies on ruminants, and dairy and beef farming systems (Watkins & Selbie 2015).

On equine Thoroughbred stud farms, there are seasonal fluctuations in stock numbers and grazing management (as determined by paddock-rotation interval). Stocking density increases during the breeding season (August-December) due to an influx of breeding mares (Hirst 2011; Rogers et al. 2007). Grazing management (rotational grazing, semi-set-stocked and set-stocked) varies between farms and mare categories (Bengtsson et al. 2018). Therefore, stocking density and grazing management can alter the grazing intensity. Horses exhibit selective grazing and 'latrine' behaviour where they avoid grazing in areas in which they have previously urinated and defecated in (Bott et al. 2013; Ödberg & Francis-Smith 1976). This grazing behaviour will lead to formation of 'roughs' (areas where horses avoid grazing) and 'lawns' (preferred grazing area) (Bott et al. 2013; Ödberg & Francis-Smith 1976). When grazing intensity is high, pasture in the lawns will diminish, eventually causing defoliation followed by soil erosion and increased soil nutrient losses (Bott et al. 2013). Due to their 'latrine' behaviour, horses exhibit a different faeces and urine deposition pattern on pasture in comparison to ruminants. Thus, in horses, the N-loading rate on urine and dung patches, the size, and the proportion of paddock covered by urine and dung patches could be different compared to ruminants, which could potentially alter the N leaching losses. Variation in N-loading rates creates the potential for different N-leaching losses. This variation has been observed in different types of animal grazing systems (e.g., sheep, dairy, beef) due to a difference in N-loading rates created by variation in animal size, frequency and volume of urination, and pasture quality (Di & Cameron 2007).

When modelling equine Thoroughbred stud-farm systems, the 'OVERSEER' program assumes a horse has the protein utilisation of an upscaled small ruminant, and ignores variables such as the seasonal fluctuations in equine stock numbers and density, grazing management, and the grazing behaviour previously described, which can impact the farm level N-output and N-leaching estimates. The objective is to model and estimate appropriate farm-level variables required to estimate nitrogen leaching on Thoroughbred breeding stud farms.

Methods

To identify and model appropriate farm-level variables required to estimate nitrogen leaching on Thoroughbred breeding stud farms, data were obtained from published literature. This data included; a cross sectional survey of 22 farms (3,069 broodmares ~45% of the active broodmare herd) (Rogers et al. 2007) and two prospective observational trials, one large scale nationwide seasonal study of 22 farms (5,710 broodmares, ~52% of active broodmares) (Hirst 2011), and a smaller more intensive trial of four commercial thoroughbred farms sampled weekly during the spring breeding season of 2017-2018 (Bengtsson et al. 2018). From these studies, data on pasture mass, paddock dimensions, stocking (stocking density, number of mares per paddock) and grazing management (paddock rotation interval), were collated and sorted into a customised database according to farm size (total effective farm area), farm scale (number of resident mares) and season (breeding and non-breeding). The data collected on the four farms during the 2017-2018 season was overlaid and applied within a matrix model to estimate the pasture available (kg DM/ha/horse), and the difference between 'lawns' and 'roughs' during the breeding season (Bengtsson et al. 2018). Paddock sizes (ha) were log transformed. Average paddock rotations were obtained and converted into weeks. Pasture available (kg DM/ha/horse), and the percentage difference in pasture mass between 'lawns' and 'roughs' were calculated as below:

Pasture available (kg DM/ha/ horse) =
pasture DM kg/ha ('lawns')/stocking density (mares/ha)

Percentage difference in pasture mass between lawns and roughs
= [pasture DM kg/ha ('roughs') – pasture DM kg/ha ('lawns')]/pasture DM kg/ha ('roughs')

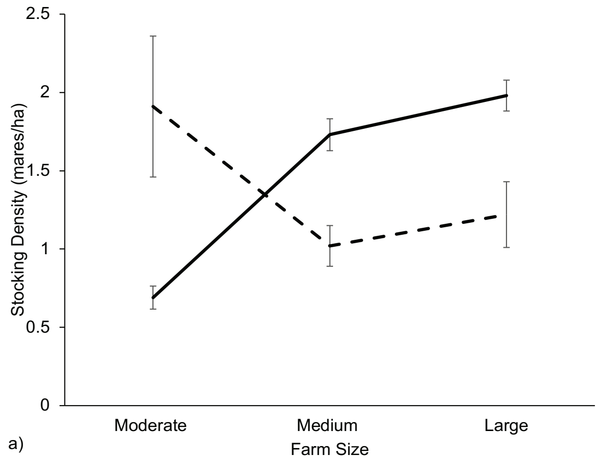
The outputs from the matrix model were then incorporated into the customised database where, (1) the effects of farm size and scale, season, and mare category on stocking density, and (2) the relationship between farm variables (stocking and grazing management), pasture available, and grazing behaviour (difference between lawns and roughs) were modelled.

Results

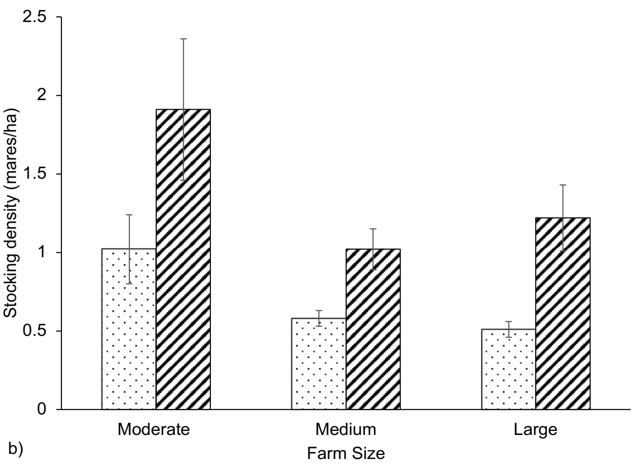
Stocking density

Within the literature (Hirst 2011; Rogers et al. 2007), farms were categorised based on size (total effective size, ha) and scale (number of resident mares) into moderate (<100 ha, <70 mares), medium (100-200 ha, 90-199 mares), and large (>200 ha, >200 mares). A comparison of stocking densities during the breeding season between these farm sizes and scales is presented in Fig. 1. On a farm-size basis, the stocking density (mares/ha; mean±standard error of the mean) during the breeding season was highest (2±0.45) on moderate-sized farms (<100 ha) followed by large sized

Figure 1 a) Stocking density during the breeding season (mares/ha±standard error of the mean) of farms with moderate (<100 ha), medium (100-200 ha) and large (>200 ha) total effective farm area ('dotted' line) and moderate (<70 mares), medium (90-199 mares) and large (>200 mares) scale (number of resident mares, 'solid' line) from Hirst (2011) and Rogers et al. (2007), respectively, and **b)** the stocking density (mares/ha±standard error of the mean) during non-breeding ('dotted' bars) and breeding ('striped' bars) season on moderate (<100 ha), medium (100-200 ha) and large (>200 ha) farms from Hirst (2011).



a)



b)

farms (>200ha) with 1.2±0.21 mares/ha and medium-sized farms (100-200ha) with 1±0.13 mare/ha (Fig 1a). On a farm-scale basis, the stocking density increased with number of resident mares. Stocking density was highest on large (>200 mares) farms (1.98±0.10 mares/ha) followed by medium (100-199 mares) farms (1.73±0.10 mares/ha) and moderate (<70 mares) farms (0.7±0.07 mares/ha) (Fig. 1a). Overall, there was a non-linear relationship between stocking density and farm category and scale. The relationship was reversed when farms were categorised based on size (effective ha) instead of number of resident mares. The stocking densities during the breeding season were two times higher than those during the non-breeding season on all farm categories (Fig. 1b).

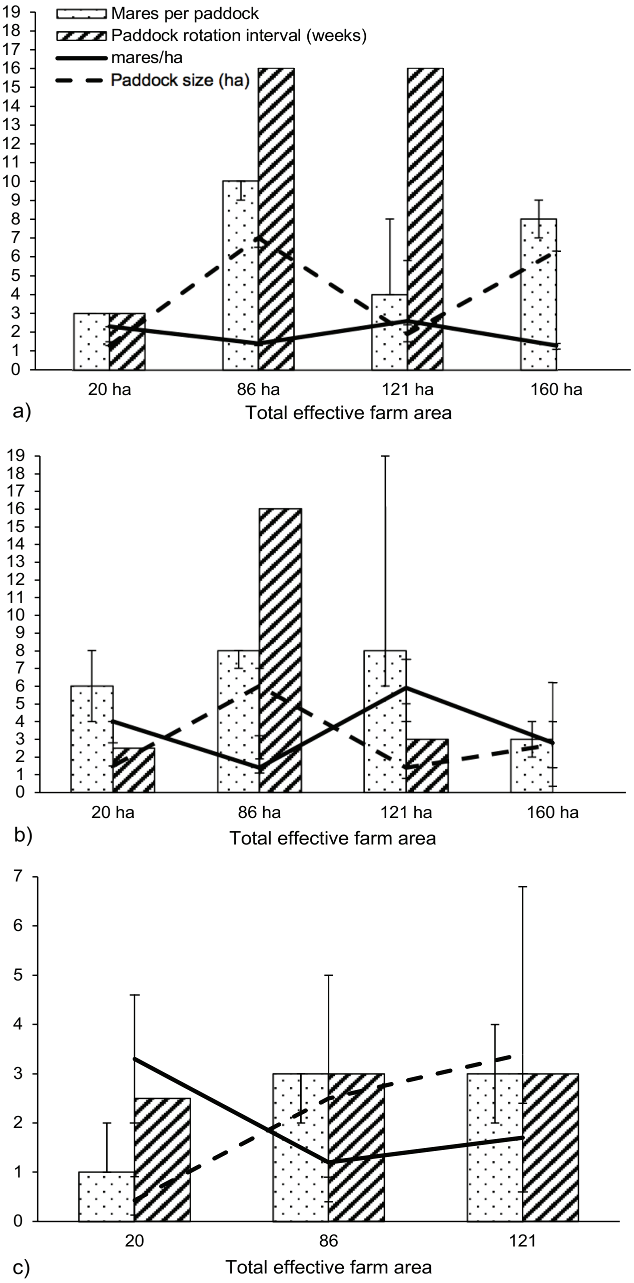
Management of different mare categories (empty mares, pregnant mares, and mares with foals)

The number of mares per paddock was independent of effective farm size for all mare categories but increased with paddock size (Figs. 2a, 2b, 2c). The stocking density decreased when paddock size increased for all three mare categories. The paddock rotation interval of empty mares (three weeks) was shorter on a smaller farm (20 ha) compared to empty mares on larger farms which were semi-set-stocked (16 weeks on 86 and 121 ha farms) or set stocked (160 ha farm) (Fig. 2a). The paddock rotation interval of mares with foals was similar (2.5-3 weeks) regardless of farm size and stocking density and was shorter than that for empty and pregnant mares (Fig. 2c). The paddock rotation interval of pregnant mares varied with stocking density (Fig. 2b). When stocking density was high (4 (IQR 2.8-4) and 5.9 (IQR 4-7.5) mares/ha), the paddock rotation interval decreased (2.5-3 weeks vs 16 weeks-set stocked) compared to lower stocking densities (1.4 (IQR 1.1-3.2) and 2.8 (IQR 1.4-6.2) mares/ha).

Effect of equine stocking and grazing management on grazing behaviour and pasture on offer

On all paddock rotation intervals, pasture availability (kg DM/ ha /horse) decreased when stocking density increased (Fig 3). The pasture on offer decreased by 5% (2.5 weeks), 22% (set stocked), 42% (16 weeks) and 70% (3 weeks). At a given paddock rotation interval, the percentage difference between pasture mass of roughs and lawns reduced with increasing stocking density and decreasing pasture on offer (Figs. 3b, 3c, 3d). However, at high stocking density (>2 mares/ha) and with low pasture DM on offer (< 400 kg DM/ ha /horse), the difference in pasture mass of lawns and roughs increased drastically (Figs. 3a, 3c). Every increase of 1 mare/ha would increase the difference between pasture mass of roughs and lawns by 30% when the paddock rotation was 2.5 weeks, and 10% when the paddock rotation was 3 weeks. Under set-stocked conditions, an increase in stocking density by 1 mare/ha increased the difference between roughs and lawns by 10%. This effect was observed at a higher pasture DM on offer (809 kg DM/ha/horse) (Fig. 3d) compared to shorter paddock rotations (<400 kg DM/ha/horse at 2.5 weeks and 3 weeks) (Figs. 3a, 3b). In summary, changes in difference between pasture mass of lawns and roughs showed a 'U' shaped response towards decreasing pasture availability and increasing stocking density.

Figure 2 Relationship among total effective farm size (farm category, ha), number of mares per paddock ('dotted' block), paddock rotation interval ('striped' block) paddock size ('dotted' line) and stocking density ('solid' line) of (a) empty mares, (b) pregnant mares, (c) mares with foals. From Bengtsson et al. (2018). All data presented as median and interquartile range except for paddock rotation interval. Empty and pregnant mares (160 ha) were set stocked.



Discussion

It has also been reported in a number of studies that the management of commercial Thoroughbred breeding farms in New Zealand appears to be relatively homogenous

Figure 3 The dynamics among pasture available (kg DM/horse/ha, 'striped' bar; mean±sd), percentage difference in pasture mass between roughs and lawns ('dotted' line, 0.5 is 50%), paddock size (log ha, 'solid' line), and stocking density under paddock rotation interval of (a) 2.5 weeks, (b) 3 weeks, (c) 16 weeks, (d) set stocked. From (Bengtsson et al. 2018).

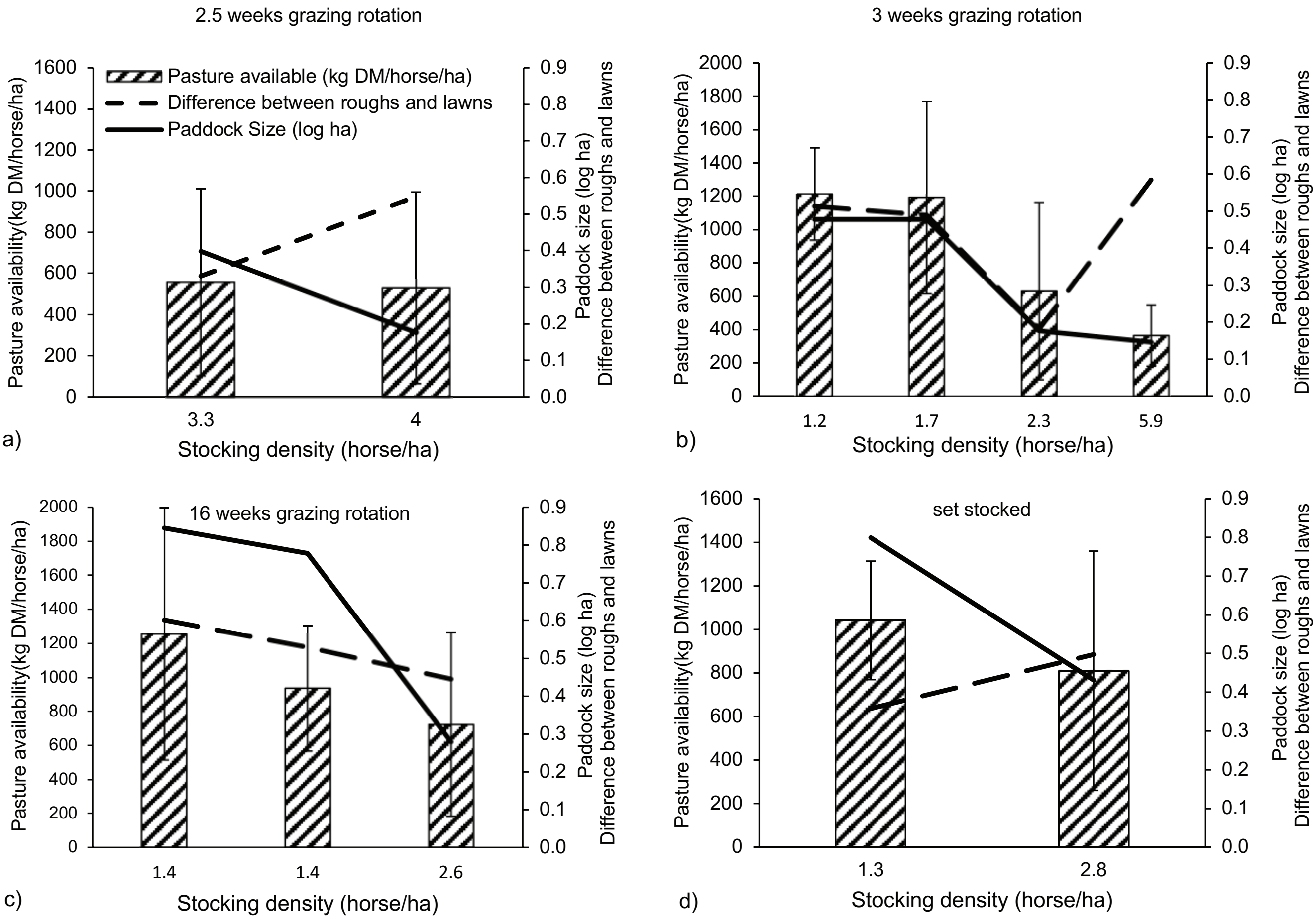
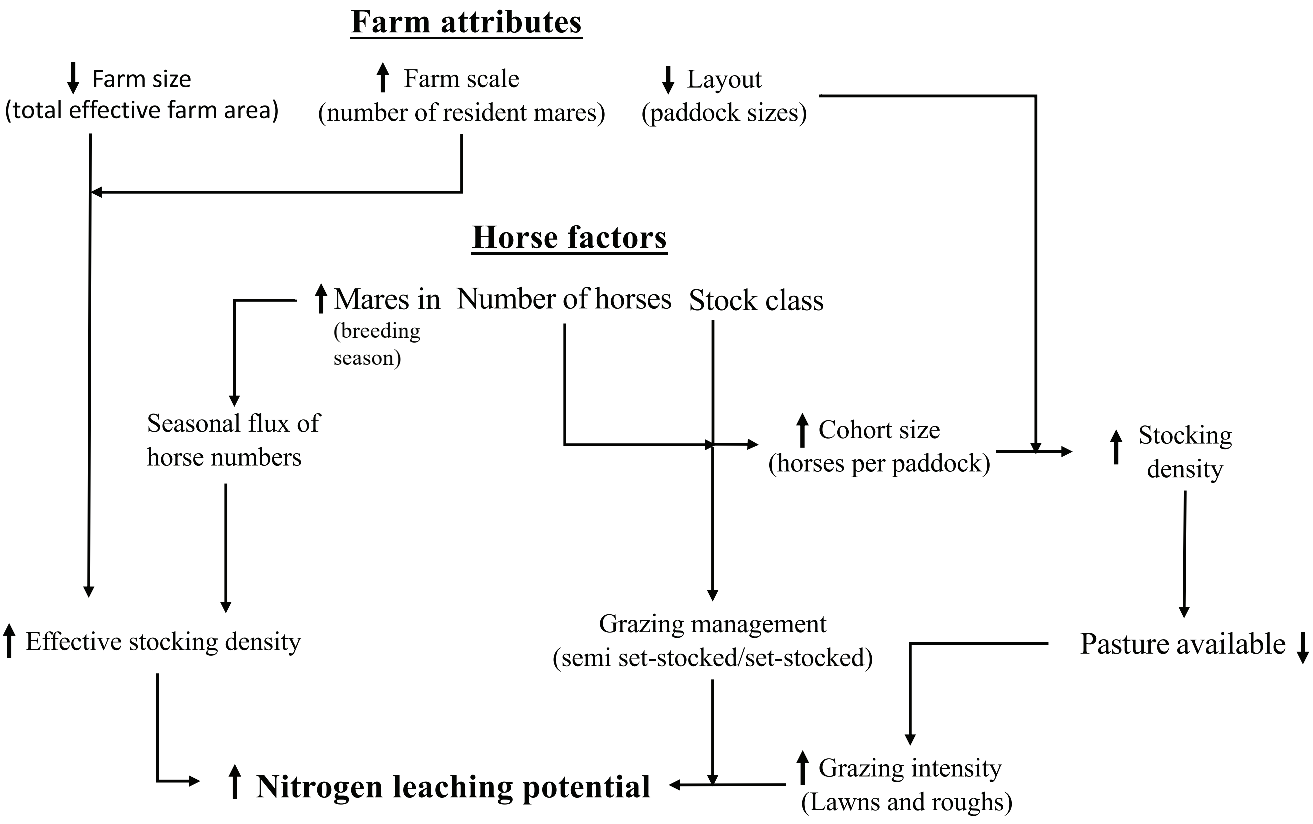


Figure 4 A proposed framework for nitrogen leaching modelling of commercial Thoroughbred breeding stud farms.



(Rogers et al. 2007; Rogers et al. 2017b; Stowers et al. 2009). This observation supports the applicability of our results even though the data was sourced from a limited number of publications. However, two of the studies respectively surveyed the majority of the commercial Thoroughbred farms operations in each season and these were responsible for the management of over 50% of the national broodmare herd. While the detailed breeding season data on rotation lengths, the dry matter of lawns and roughs, and the pasture and grazing management data were obtained from four commercial Thoroughbred breeding farms, over one breeding season, the data from this study was similar to unpublished data collected by the authors across other farms and seasons.

The identification of farms based on size (total effective farm area) or scale (number of resident mares) affected the relationship between stocking density and farm category. Stocking density was highest on moderate sized farms and lower in medium- and large-sized farms. Stocking density was lowest on moderate scaled farms and increased with increasing farm scales. The lack of precision of either measure (farm size or scale) to define the farming operation parameters may be due to inherent variation within each category, as the number of mares varied by 25-80% at a given farm size (Hirst 2011), and the farm size varied up to 80% within a given farm scale (Stowers et al. 2009). Therefore, a matrix approach such as that presented in Fig. 4 may be required to account for between farm and seasonal variation in total nitrogen output.

Regardless of farm category, total mare numbers doubled over the breeding season due to an influx of non-resident mares and thus a 50% fluctuation in farm-level total nitrogen output between the breeding and non-breeding season could be expected. This value may be an over-simplification as during the breeding season there were differences in the stocking density of the different mare categories (pregnant mares (4 mares/ha, empty mares (2-4 mares/ha and mares with foals 2 mares/ha), and these stocking densities were 1-3 times higher than the stocking densities calculated solely based on total effective farm area. Thus, some areas of the farm, particularly those associated with the pregnant mares, may provide greater focal nitrogen output.

During the breeding season the paddock rotation interval of empty mares was influenced by farm sizes (shorter on smaller-sized farms) but remained similar (2-3 weeks) regardless of farm size for mares with foals. The consistency of the rotation interval in this mare category (mares with foals) may be linked to the reproductive cycle of the mare and associated management of re-breeding these mares. In contrast, the primary driver for rotation length with the pregnant mares may have been the feed supply due to the strong association of a shorter rotation interval with higher stocking densities.

Stocking and grazing management affected the pasture on offer and modified the grazing behaviour of mares. There was a ‘U’ shaped relationship between the percentage difference between pasture mass of lawns and roughs, and the pasture availability and stocking density. This result reflects that mares become less selective in their grazing (starting to graze ‘roughs’) when pasture availability decreases which can decrease the area of ‘roughs’. For young stock, the threshold value, or tipping point for grazing of the roughs, appears to be 1500 kg DM/ha (Rogers et al. 2018) and a similar threshold value would be expected for broodmares. Under commercial conditions because of the latrine avoidance behaviour, it has been suggested that the maximal pasture utilisation by horses is 70% of the total pasture dry matter on offer (Rogers et al. 2017a). Therefore, the focal N leaching potential would be greatest for a high stocking rate-low lawn pasture mass situation as this scenario would increase the concentration of dung and urine in the latrine area and the overgrazing would reduce the ability of N to be utilised by pasture. This scenario would only be present during spring with empty mares prior to the spring flush.

The stocking density reported for equine farms of different size and scale during the breeding season ranged between 0.7-2 mares/ha (Rogers et al. 2007) and 1-2 mares/ha (Hirst 2011), respectively. Average nitrogen excretion by Thoroughbred mares on a pasture-based diet was estimated to be 0.27 kg N/day (Chin et al. 2019). Compared to dairy systems, stocking densities reported for systems 1-5 were 2.5-3.5 cows/ha (Shadbolt 2012) and nitrogen excretion reported was 0.31 kg N/day for dairy cows (Luo & Kelliher 2014). Therefore, the nitrogen output per ha would be 0.78-1.08 kg N/ha on dairy properties compared to 0.27-0.54 kg N/ha on an equine stud farm. However, this does not represent the nitrogen-leaching potential on equine stud farms because there are complex farm variables that can influence the nitrogen leaching which needs to be understood with further studies.

Conclusion

The data presented here in this paper was not intended to define and quantify all the parameters that need to be considered in describing potential N loss under commercial equine farms. Hence, the implications discussed in this paper requires confirmation with further studies. From this preliminary study, our findings suggest that farm attributes (farm size, paddock size) and horse factors (mare category, number of mares per paddock) have an influence on stocking and grazing management decisions, which, in turn, modify the grazing behaviour of mares, and ultimately, can affect the nitrogen-leaching potential. Therefore, estimating nitrogen leaching on equine breeding stud farms requires a specific modelling framework (Fig. 4). Using this framework, the greatest nitrogen leaching potential can be expected on large-scale commercial breeding stud farms that operate on a moderate-sized property due to increased effective stocking density and semi-set-stocked conditions.

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