Improving slurry nutrient distribution on dairy farm holdings

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Table of Contents

Executive Summary

1. The Department of Agriculture, Food and the Marine requested Teagasc to complete an assessment of possible ways to improve slurry nutrient distribution on dairy farm holdings. In order to ensure that the nutrient distribution is appropriately managed on both the milking platform and out blocks (mainly used for silage production), a methodology was developed to optimise slurry nutrient distribution on the total dairy farm. Within this report a methodology is described to determine the milking platform stocking rates where different proportions of the slurry (slurry produced while animals were indoors) would be required to be distributed, based on the organic N excretion rate of the herd and the chemical N application rate per hectare.

2. The quantity of the organic N captured per cow per year during the housing period is 18 kg for cows with organic nitrogen excretion rates in Band 2; the corresponding values for Band 1 and Band 3 cows is 17 kg and 21 kg per cow per year, respectively.

3. Where the overall maximum chemical nitrogen allowances is 214 kg/ha; 25%, 50%, 75% and 100% of the slurry should be distributed for herds in Band 1 at milking platform stocking rates of up to 3.8, 4.0, 4.3 and ≥4.5 cows/ha, respectively. The corresponding stocking rates for Band 2 are 3.3, 3.5, 3.6 and ≥3.9 cows/ha, respectively while for herds in Band 3 25%, 50%, 75% and 100% of the slurry should be distributed at stocking rates of up to 2.8, 3.0, 3.2 and ≥3.4 cows/ha, respectively. No slurry is required to be distributed at stocking rates of less than or equal to 3.6, 3.1 and 2.7 for Bands 1 to 3 respectively.

4. Where the overall maximum chemical nitrogen allowances is 241 kg/ha; 25%, 50%, 75% and 100% of the slurry should be distributed for herds in Band 1 at milking platform stocking rates of up to 3.4, 3.6, 3.9 and ≥4.1 cows/ha, respectively. The corresponding stocking rates for Band 2 are 3.0, 3.1, 3.3 and ≥3.5 cows/ha, respectively while for herds in Band 3 25%, 50%, 75% and 100% of the slurry should be distributed at stocking rates of up to 2.6, 2.7, 2.9 and ≥3.0 cows/ha, respectively. No slurry is required to be distributed at stocking rates of less than or equal to 3.2, 2.8 and 2.4 for Bands 1 to 3, respectively.

5. Where the overall maximum chemical nitrogen allowances is 200 kg/ha; 25%, 50%, 75% and 100% of the slurry should be distributed for herds in Band 1 at milking platform stocking rates of up to 4.0, 4.2, 4.5 and ≥4.8 cows/ha, respectively. The corresponding stocking rates for Band 2 are 3.4, 3.6, 3.8 and ≥4.1 cows/ha, respectively while for herds in Band 3, 25%, 50%, 75% and 100% of the slurry should be distributed at stocking rates of up to, 3.0, 3.1, 3.3 and ≥3.5 cows/ha, respectively. No slurry is required to be distributed at stocking rates of less than or equal 3.8, 3.3 and 2.8 for Bands 1 to 3, respectively.

6. Where the overall maximum chemical nitrogen allowances is 150 kg/ha; 25%, 50%, 75% and 100% of the slurry should be distributed for herds in Band 1 at milking platform stocking rates of up to 4.6, 4.9, 5.2 and ≥5.6 cows/ha, respectively. The corresponding stocking rates for Band 2 are 4.0, 4.2, 4.5 and ≥4.7 cows/ha, respectively while for herds in Band 3 25%, 50%, 75% and 100% of the slurry should be distributed at stocking rates of up to 3.5, 3.7, 3.9 and ≥4.1 cows/ha, respectively. No slurry is required to be distributed at stocking rates of less than or equal 4.4, 3.8 and 3.3 for Bands 1 to 3, respectively.

7. The methodology developed in this report requiring varying proportion of slurry (slurry produced while animals are indoors) to be distributed depending on herd organic N excretion rate and chemical N application rate will result in improved nutrient distribution on fragmented dairy farms and improve nutrient use efficiency while reducing nutrient loss to the environment. It is important to note that these requirements do not impact milking platform stocking rates but do affect the quantity of slurry that must be distributed to non-milking grazing platform. The implementation and enforcement of the outcomes of this report could result in a significant challenge at farm level. These changes will require further consideration when planning the implementation process.

1. Background

The Department of Agriculture, Food and the Marine requested Teagasc to conduct 'An assessment of possible ways to improve slurry nutrient distribution on dairy farm holdings'. This report modelled milking platform stocking rates where nutrients must be distributed to other parts of the farm outside the milking platform in order to optimise nutrient use efficiency and reduce potential loss to the environment, based on the platform stocking rates, chemical N application rate and cow banding.

2. Introduction

Irish grass-based systems of milk and meat production rely on the conversion of human inedible forage into highly nutritious and digestible human-edible products. O'Brien *et al.* (2018) reported that the average diet of Irish dairy cows was 81.8% forage, with concentrates constituting just 18.2% of the annual feed budget on a dry matter basis. Of the 81.8% forage, 60.2% was grazed pasture, 19.8% was grass silage, and 1.8% was alternative forages. This is significantly different to farming systems being operated in most other EU countries.

Stocking rate is a key dairy farm-level efficiency factor in successful grazing systems which facilitates the achievement of high levels of grazed pasture utilisation and milk production per hectare (McCarthy *et al.,* 2011, 2012). In defining the optimum stocking rate for resilient, pasture-based grazing systems, pasture production and utilisation is the principle consideration. In Table 1, the optimum stocking rate is defined for farms that produce different amounts of pasture and feed different amounts of concentrate supplement.

It is generally accepted that increasing stocking rate accompanied with increased fertilizer N and concentrate input will result increased nitrogen surplus resulting in increased N leaching, denitrification and nitrous oxide emissions (Murphy et al., 2024). However, on the basis of improved management practices, it is not correct to assume that N losses/ha through leaching increase as grass utilisation increases through increased stocking rate. Both McCarthy et al. (2015) and Roche et al. (2016) reported either stable or declining nitrate leaching with increasing stocking rate; the critical proviso, however, was that strictly no additional N fertiliser or supplements were introduced at higher stocking rate. Additionally, Huebsch et al. (2013) showed that the nitrate-N concentration in groundwater in a free draining soil in Ireland declined over 11 years, despite a 20% increase in stocking rate. The reduction in nitrate-N was associated with changes in several management practices which, included reduced chemical N fertilizer usage, improvements in timing of slurry application, the movement of a dairy soiled water irrigator to areas deemed less vulnerable to N leaching, and the use of minimum cultivation at reseeding. This study has continued to monitor nitrate concentrations and has shown in 2024 that nitrate concentrations are now (2022-2024 period) just 33% of what they were before practices were implemented to reduce nitrate leaching losses.

Table 1. Stocking rate that optimises profit on farms growing different amounts of pasture grown and feeding different amounts of supplement/cow					
	Pasture grown, t DM/ha				
Supplement fed/cow, t DM	12	14	16	18	20
0.00	1.9	2.2	2.6	2.9	3.2
0.25	2.0	2.3	2.7	3.0	3.3
0.50	2.1	2.4	2.8	3.1	3.5
1.00	2.3	2.6	3.0	3.4	3.8
1.50	2.5	2.9	3.3	3.7	4.1

Slurry manure is a valuable source of plant nutrients. The key aim is to maximise the value of slurry. This means getting the most from the phosphorus (P) and potassium (K) content, as well as the nitrogen (N). This will be achieved by making sure that it goes to the right place at the right time and is spread at the right rate. In fragmented dairy farms and depending on soil fertility status, maximising nutrient use efficiency is best achieved by applying the slurry to the area used for silage conservation. By optimizing the efficiency of slurry application, farmers can reduce reliance on chemical fertilizers, improve grassland productivity, and minimise nutrient loss to the environment.

In many Irish dairy farms, the milking platform stocking rates (the area accessible to the milking herd for grazing) are operated at a higher rate than the whole farm stocking rate due to farm fragmentation. As the milking platform stocking rate increases the proportion of winter feed produced on the milking platform reduces while the proportion produced from the area not accessible to the milking herd (outblocks) for grazing increases. On most dairy farms the stocking rate on the milking platform is dependent on the relative proportion of the farm that is accessible to the milking herd for grazing relative to the areas used for other purposes like silage production. Fragmented grazing dairy farms face challenges in slurry nutrient distribution due to multiple land parcels which could be some distances from the milking platform, and this could lead to potential nutrient imbalances.

In the last decade average stocking rates (SR) on Irish dairy farms have only increased marginally from 1.9 to 2.1 livestock units per hectare (LU/ha; NFS, various years), but there has been a significant increase in SR on the milking platform area (i.e. lands adjacent to the milking parlour). Based on available national statistics over this same period (National Farm Survey) milking platform SR has increased on average from 2.0 to 2.7 livestock units per hectare (LU/ha.).

The Department of Agriculture, Food and the Marine requested Teagasc to complete an assessment of possible ways to improve slurry nutrient distribution on dairy farm holdings. In order to ensure that the nutrient distribution is appropriately managed on both the milking platform and out blocks (mainly used for silage production), a methodology was developed to optimise slurry nutrient distribution on the total dairy farm. Within this report a methodology is described to determine the milking platform stocking rates where different proportions of the slurry would be required to be distributed, based on the organic N excretion rate of the herd and the chemical N application rate per hectare.

3. Scenarios simulated and methodology employed

3.1. Scenarios

In all scenarios the platform stocking rates were modelled where 0%, 25%, 50%, 75% and 100% of the slurry were distributed based on the following conditions;

- The overall farm stocking rate was subject to the NAP 5 regulations (SI No. 42 of 2025).
- The maximum N load on the grazing platform was fixed at 500 kg N per hectare (the 500 kg of N per hectare was assumed based on SI No. 605/2017).
- Organic N excretion for herds in Bands 1, 2 and 3 were modelled.
- Maximum chemical nitrogen allowances of 241, 214, 200 and 150 kg/ha were modelled based on consultation with DAFM.

3.2. Organic N excretion banding per cow

DAFM introduced organic N excretion banding as part of the nitrates action programme in 2022. This came into effect in January 2023. The bands included are Band 1 <4,500 kg milk/cow, Band 2 4,500 - 6,500 kg milk/cow and Band 3 >6,500 kg milk/cow. Band 1, 2 and 3 correspond to an organic N excretion rate of 80 kg/cow, 92 kg/cow and 106 kg /cow. The organic N calculations were generated at an animal level based on nitrogen intake in the form of grazed grass, grass silage and concentrate and nitrogen output in the form of milk produced, calves produced and cow live-weight gain. Both calf birthweight and cow live-weight gain were included as outputs in the analysis, with nitrogen content assumed to be 0.029 kg N per kg for calves and 0.024 kg N per kg of live weight for cows. Surplus nitrogen was calculated as the difference between total nitrogen inputs and outputs. Finally, the organic N figure was calculated based on deducting the manure gaseous losses from the surplus nitrogen. Full details of the bands, etc. can be found in 2021 https://www.teagasc.ie/media/website/publications/2021/Nitrates-Modelling-Final.pdf .

3.3. Organic N excretion during the housed period

Table 2 shows the methodology used to calculate both the nitrogen excretion for a dairy cow in Band 2 during the total year and that produced during the housed period. Slurry nitrogen production is calculated by subtracting the dairy cow feed utilized for milk production, live weight gain, and foetal calf growth plus gaseous emissions from the total feed intake of grass silage and concentrate by the animals. Gaseous nitrogen emission loss factor of 30% is applied to account for elevated emissions when animals are housed, as supported by EPA (2023), Misselbrook and Gilhespy (2020), EMEP/EEA (2023), and IPCC (2019). These references reflect the substantially higher gaseous nitrogen losses associated with indoor housing compared to grazing systems. These assumptions were used for the analysis (Table 2).

The calculations show that for Band 2 nitrogen excretion (92 kg N/cow/year), there would be 18 kg N/cow/year excreted over the indoor (stored) period. The corresponding figures for herds with organic nitrogen excretion rates in Band 1 and Band 3 are 17 kg/cow/year and 21 kg/cow/year, respectively.

Table 2. Total Nitrogen excretion for cows in Band 2, and the proportion excreted during the indoor period			
Factors considered in N excretion calculations		**Cow in Band 2 4,500-6,500kg**	**Indoor period**
Grazed grass			
	DM Intake	2,846	
	CP%	18	
	Nitrogen kg	82	
Grass silage			
	DM Intake	1,239	1,150
	CP%	12.7	12.7
	Nitrogen kg	25	23.4
Concentrate			
	DM Intake	945	300
	CP%	18.2	18.2
	Nitrogen kg	28	8.7
Weight gain	Live-weight	40	30
	Nitrogen kg	0.96	0.72
Calves	Live-weight	45	45
	Nitrogen kg	1.31	1.31
Milk			
	Yield Kg	5,428	550
	Protein %	3.49	3.80
	Protein kg	189	20.9
	Nitrogen kg	30	3.9
Nitrogen	Intake kg	135	32.1
	Output kg	32	5.9
	Excretion kg	103	26.2
	Gaseous kg	10	7.9
	Organic N kg	92	18.3

3.4 Total nitrogen load

In order to develop a methodology that could be used to calculate the requirement to distribute nutrients from the milking platform across the overall farm, an overall nitrogen load per hectare was defined and once nitrogen went over that load there was a requirement for manure to be moved to an external block/another part of the farm. In any and all cases, the overall farm stocking rate will be subject to the NAP 5 regulations. The methodology developed in this analysis is designed to increase the levels of nutrient distribution within the overall farm area rather than operating as a stocking rate restriction. The principle focus centres around slurry movement to increase nutrient distribution from the milking platform and therefore there is no stocking rate restriction on the milking platform envisaged as part of this methodology.

The methodology was developed based on the assumption of an overall maximum nitrogen load per hectare (including organic and inorganic N) of 500 kg N. The 500 kg of N per hectare was assumed based on SI No. 605/2017 where the overall maximum N load per hectare within a derogation was 500 kg/ha with a maximum of 250 kg of organic N and a maximum of 250 kg of inorganic N. Within the Dillon *et al.* (2021) report increasing N load above 500kg per hectare resulted in a significant increase in nitrate leaching. Maintaining a maximum nitrogen loading of 500kg/ha on the grazing platform by redistributing slurry to non-grazing areas effectively reduces the impact of increased stocking rates on the grazing platform by preventing excessive nutrient build-up.

4. Results of the modelled simulations

4.1. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with overall maximum chemical nitrogen allowances of 214 kg/ha

Table 3 shows milking platform stocking rates (cows/ha) requiring varying proportion of slurry (slurry produced while animals were indoors) to be distributed for herds with organic nitrogen excretion rates in Band 1, 2 and 3 where the overall maximum chemical nitrogen allowances is 214 kg/ha. For Band 1 herds, 25%, 50%, 75% and 100% of the slurry must be distributed for herds at stocking rates of up to 3.8, 4.0, 4.3 and ≥4.5 cows/ha, respectively. The corresponding stocking rates for Band 2 are 3.3, 3.5, 3.6 and ≥3.9 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. The corresponding stocking rates for Band 3 are 2.8, 3.0, 3.2 and ≥3.4 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. No slurry is required to be distributed at stocking rates of less than or equal to 3.6, 3.1 and 2.7 for Bands 1 to 3, respectively.

Table 3. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with organic nitrogen excretion rates in Band 1, 2 and 3 with overall maximum chemical nitrogen allowances of 214 kg/ha

Band	1	2	3
0% of slurry N distributed SR LU/Ha	≤3.6	≤3.1	≤2.7
25% of slurry N distributed SR LU/Ha	3.8	3.3	2.8
50% of slurry N distributed SR LU/Ha	4.0	3.5	3.0
75% of slurry N distributed SR LU/Ha	4.3	3.6	3.2
100% of slurry N distributed SR LU/Ha	≥4.5	≥3.9	≥3.4

4.2. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with overall maximum chemical nitrogen allowances of 241 kg/ha

Table 4 shows milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with organic nitrogen excretion rates in Band 1, 2 and 3 where the overall maximum chemical nitrogen allowances is 241 kg/ha. For Band 1 herds 25%, 50%, 75% and 100% of the slurry must be distributed for herds at stocking rates of up to 3.4, 3.6, 3.9

and ≥4.1 cows/ha, respectively. The corresponding stocking rates for Band 2 are 3.0, 3.1, 3.3 and ≥3.5 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. The corresponding stocking rates for Band 3 are 2.6, 2.7, 2.9 and ≥3.0 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. No slurry is required to be distributed at stocking rates of less than or equal to 3.2, 2.8 and 2.4 for Bands 1 to 3, respectively.

Table 4. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with nitrogen excretion rates in Band 1, 2 and 3 with overall maximum chemical nitrogen allowances of 241 kg/ha

Band	1	2	3
0% of slurry N distributed SR LU/Ha	≤3.2	≤2.8	≤2.4
25% of slurry N distributed SR LU/Ha	3.4	3.0	2.6
50% of slurry N distributed SR LU/Ha	3.6	3.1	2.7
75% of slurry N distributed SR LU/Ha	3.9	3.3	2.9
100% of slurry N distributed SR LU/Ha	≥4.1	≥3.5	≥3.0

4.3. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with overall maximum chemical nitrogen allowances of 200 kg/ha

Table 5 shows milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with organic nitrogen excretion rates in Band 1, 2 and 3 where the overall maximum chemical nitrogen allowances is 200 kg/ha. For Band 1 herds, 25%, 50%, 75% and 100% of the slurry must be distributed for herds at stocking rates of up to 4.0, 4.2, 4.5 and ≥4.8 cows/ha, respectively. The corresponding stocking rates for Band 2 are 3.4, 3.6, 3.8 and ≥4.1 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. The corresponding stocking rates for Band 3 are 3.0, 3.1, 3.3 and ≥3.5 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. No slurry is required to be distributed at stocking rates of less than or equal to 3.8, 3.3 and 2.8 for Bands 1 to 3, respectively.

Table 5. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with organic nitrogen excretion rates in Band 1, 2 and 3 with overall maximum chemical nitrogen allowances of 200 kg/ha

Band	1	2	3
0% of slurry N distributed SR LU/Ha	≤3.8	≤3.3	≤2.8
25% of slurry N distributed SR LU/Ha	4.0	3.4	3.0
50% of slurry N distributed SR LU/Ha	4.2	3.6	3.1
75% of slurry N distributed SR LU/Ha	4.5	3.8	3.3
100% of slurry N distributed SR LU/Ha	≥4.8	≥4.1	≥3.5

4.4. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with overall maximum chemical nitrogen allowances of 150 kg/ha

Table 6 shows milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with organic nitrogen excretion rates in Band 1, 2 and 3 where the overall maximum chemical nitrogen allowances is 150 kg/ha. For Band 1 herds, 25%, 50%, 75% and 100% of the slurry must be distributed for herds at stocking rates of up to 4.6, 4.9, 5.2 and ≥5.6 cows/ha, respectively. The corresponding stocking rates for Band 2 are 4.0, 4.2 4.5 and ≥4.7 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. The corresponding stocking rates for Band 3 are 3.5, 3.7, 3.9 and ≥4.1 cows/ha where 25%, 50%, 75% and 100% of the slurry is distributed, respectively. No slurry is required to be distributed at stocking rates of less than or equal to 4.4, 3.8 and 3.3 for Bands 1 to 3, respectively.

Table 6. Milking platform stocking rates (cows/ha) requiring varying proportion of slurry to be distributed for herds with nitrogen excretion rates in Band 1, 2 and 3 with overall maximum chemical nitrogen allowances of 150 kg/ha

Band	1	2	3
0% of slurry N distributed SR LU/Ha	≤4.4	≤3.8	≤3.3
25% of slurry N distributed SR LU/Ha	4.6	4.0	3.5
50% of slurry N distributed SR LU/Ha	4.9	4.2	3.7
75% of slurry N distributed SR LU/Ha	5.2	4.5	3.9
100% of slurry N distributed SR LU/Ha	≥5.6	≥4.7	≥4.1

5. Discussion

The methodology developed in this report links organic N and milking platform stocking rate to the amount of slurry that must be distributed to the area of the farm outside the milking grazing platform. It was developed based on a request from DAFM, to improve nutrient distribution on fragmented dairy farm holdings to improve nutrient use efficiency and reduce nutrient loss to the environment.

There are a number of considerations that should be looked at before this methodology is implemented. Distributing a 100% of the slurry (slurry produced while animals were indoors) may not always be best nutrient management practice. Additionally, it is difficult to distribute 100% of the slurry from a logistical perspective. There is possibility that some paddocks in the milking platform being deficient in soil P and K and the application of slurry in these situations would be justified. Therefore, soil fertility status would have to be considered before this methodology is implemented

There has been a huge range of changes implemented as part of SI 113 of 2022 and its subsequent amendments. These changes have had significant implications for some farmers. The changes developed in this report if implemented would add further complexity to the overall process and should be considered as part of the overall implementation plans.

Slurry manure is a valuable source of plant nutrients. The key aim is to maximise the value of slurry. This means getting the most from the P, K and N. This will be achieved by making sure that the slurry goes to the right place at the right time and is spread at the right rate. Additionally, using low emission slurry spreading (LESS) techniques reduces ammonia emissions and improving nitrogen efficiency. While nutrient movement has a cost associated with it (e.g. additional 4 km trip would increase nutrient spreading cost from €2.5 per cubic metre to €5 per cubic metre) (based on 4 loads an hour dropping to 2 loads an hour with a 9 cubic metre slurry tanker), there is value in matching nutrient requirements with nutrient supply.

6. Conclusion

There is a significant proportion of the organic nitrogen excreted by a dairy herd captured when animals are housed. There is potential to utilise the manure that is stored to increase the level of nutrient redistribution where the nutrient load is high in one part of the farm. Optimizing slurry distribution will allow farmers to reduce reliance on chemical fertilizers, improve grassland productivity, and minimise nutrient loss to the environment.

In relation to the manure which is stored;

- The quantity of the organic N captured per cow per year during the housing period is 18 kg for cows in Band 2; the corresponding values for Band 1 and Band 3 cows is 17 kg and 21 kg per cow per year, respectively.
- In order to increase the distribution of nutrients on fragmented farms there is a requirement for some or all of the slurry (slurry produced while animals were indoors) to be distributed from the milking platform as stocking rate increases.
- The milking platform stocking rate methodology which will require varying proportions of slurry to be distributed developed in this report will result in improved nutrient distribution on fragmented dairy farms.
- While this methodology creates an approach to distribute nutrients from the milking platform to the rest of the farm, the overall farm will remain governed by the NAP 5, SI 113 of 2022.

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