LAND APPLYING DAIRY MANURES AND SLURRIES: EVALUATING CURRENT PRACTICE

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Abstract
The intensification of New Zealand dairy farms over the past ten years has resulted in the increased use of off pasture systems. Animal excreta collected from such systems tends to be of higher nutrient concentration yet lower volume than traditional wash down farm dairy effluent (FDE) from parlours. This results in dairy manures and slurries with a higher solids content requiring a different management approach (storage, handling, application and timing) than liquid FDE in order to achieve outcomes that are both agronomically and environmentally positive. Best management practice for manures and slurries needs to take into account the timing of land application with respect to short-term climate and time of year. Direct loss of P, N and faecal microbes is likely to be greatest during winter and early spring when soil moisture regularly exceeds field capacity thereby causing frequent drainage and runoff events. Volatilisation losses from surface applied N (not immediately incorporated) will be highest during summer and early autumn when sunshine hours and air temperatures are high. Indirect drainage loss of N from nitrate leaching will be greatest from autumn applied slurry and manure that has only minimal plant growing days prior to the commencement of the winter/spring drainage period. From a nutrient use efficiency point of view, the application of slurries and manures in late spring provides the optimum window to utilise nutrients for plant growth.

Key words: dairy manure, dairy slurry, land application, distribution uniformity

Introduction

Changing farm practices over the past decade have seen the rapid uptake of farmers using off-pasture facilities such as stand-off pads and wintering barns/animal shelters in order to protect soils and pasture from treading damage. Also, having animals in confined areas has allowed farmers to supplement pasture diets with imported feeds. Both these factors have led to the capture of effluent with greater solids with nutrient concentrations (Longhurst et al. 2012).

Environmental concerns about applying FDE to land when soils are too wet have seen changes in regulatory policies. A number of best management practices for dairy farmers are being promoted: 1) having adequate effluent storage pond capacity to avoid inappropriate land application (Houlbrooke et al. 2004); 2) utilising the newly developed pond storage calculator to determine required storage pond sizes (Horne et al. 2011); 3) the use of low-application rate delivery systems for spreading FDE (Monaghan et al. 2010; Houlbrooke and Monaghan. 2010). Pond storage of FDE on farms is now common practice; however the low application rate delivery systems require smaller irrigation nozzles which are prone to blockages unless a lower solids effluent such as FDE is used. A range of solid separation systems are now available to New Zealand farmers, an area where little is known about the characteristics of the solids produced by these systems.

Overseas research indicates that agricultural manures and slurries have potential to result in nutrient losses to the wider environment including: gaseous N loss, N leaching loss and surface runoff of P and, to a lesser extent, N (Smith et al. 2000 & 2008). Recommended best management practices to mitigate these environmental effects, increase nutrient use efficiency and decrease pasture fouling have focussed on the importance of timing and loading rates of slurry application and the use of advanced spreading technology to avoid surface broadcasting slurry effluents (Smith et al. 2008). However, little is known about the characteristics of these types of wastes, or the risks that they pose in the context of New Zealand's environment and unique pasture dominated production systems. As a result, it is difficult to progress policy work that is urgently needed for the development of best practices for dairy manure and slurry management.

Objectives

The three-fold objective of this two-year project were: i) to better characterise New Zealand's dairy effluent manures and slurries (Longhurst et al., 2012), ii) identify the existing management practices for applying these products to land, and iii) assess and develop guidelines for the land application of manures and slurries. These guidelines can then be used by regulatory authorities and the dairy industry as an extension tool to promote best management practices. Best management practices will be sought that achieve both positive agronomic and environmental outcomes.

Methodology

The outline of the study was described by Longhurst et al., (2012) and the full 22 case studies reported by Houlbrooke et al., (2011). Land applied effluent was captured at 16 sites in a series of collection trays laid out in transects across the path of the delivery system. The volume or weight of effluent was measured so that application depth (mm), application rate (m^3/ha), and nutrient loading (kg/ha) could be determined. The measured data allowed for the spreading distribution pattern to be plotted and the spreading uniformity assessed. The New Zealand dairy industry has recently developed and released a design code of practice for farm dairy effluent (DairyNZ, 2011). One aspect of the code relates to the uniformity of distribution from effluent application systems. In order to encourage acceptable uniformity of application of dairy effluents the code suggests infrastructure should be able to meet a minimum uniformity requirement based upon its distribution uniformity. In particular it suggests an upper quartile distribution uniformity (DU_{uq}) of < 1.25 should be achieved for all liquid effluent application systems. This DU_{uq} is calculated from the mean volume across trays with the 25 % highest depth applied divided by the overall mean depth (DairyNZ 2011).

Effluent characterisation

Know what is being applied

The first step in effluent characterisation is to know what you are applying. When a farmer is faced with the decision to land apply manures or slurries, there are three possible options available to determine the nutrient loading rates:

1) Have the nutrient concentrations in the manures analysed and then adjust the loading rate accordingly. This method is the most accurate but incurs laboratory costs and time delays in getting analytical results back,

2) Use default values Use default values such as produced by Houlbrooke et al. (2011). This method is quick and easy but may not be representative the specific system of interest,

3) Use nutrient budgeting to derive an estimate of the nutrient loading for the proposed application area. The OVERSEER® nutrient budget model (Wheeler et al. 2003) provides an estimate of the nutrient loading but not the nutrient concentration.

Guidelines
Manures are generally characterised into effluents (i.e. FDE), slurries or solids (manures) depending on their solids content. Effluents (0-5% DM) can be pumped as liquids, blockage problems are likely at solid contents above 7% DM. Slurries (5-15% DM) are semi-liquid and can be sprayed, not through irrigation pipes, but under pressure from a slurry tanker. Solid manures can be semi-solids or solid manure that cannot be pumped or sprayed. Solid manures are generally land applied via muck spreaders.

Delivery systems

Spreading systems
In this study three different spreading systems were used for applying the manures and slurries to land: slurry tankers, muck spreaders and a tip truck approach with a tractor fitted back blade for spreading. Slurry tankers usually rely on a vacuum pump to fill slurry tankers and pump slurry effluent out over an inclined splash plate. This creates a spreading footprint typically 10m either side of the passing vehicle. It is important that the splash plate is correctly set up in order to spread the associated spray swath evenly.

Muck spreaders are designed to handle effluents that cannot typically be pumped. Side spreaders typically have a cylindrical body with a PTO driven shaft that runs along its length throwing the manure out the side of the spreader. In comparison a rear discharge spreader has a moving floor comprising of spinning disks or vertical and horizontal beaters that move the product towards the back of the spreader. Some muck spreaders are multipurpose in that they can handle liquid slurries and dryer manures through a side discharge where an auger and closing gate forces effluent onto a spinning impeller.

Spreading uniformity
Of these three delivery systems options, Chambers et al. (2007) suggests that rear discharge spreaders have a more even distribution uniformity and lateral precision compared to side discharge spreaders. The same observation was also made in New Zealand by Pow et al. (2010). Results from spreading distribution patterns in this study confirmed the variability that exists in practice. Figure 1 provides an example of the spreading pattern from a slurry tanker applying wintering barn slurry in Southland.

The DU_{uq} for each each case study and is summarised in Figure 2. In summary, slurry products were more uniformly applied than solids/manures. This is logical considering they behave as a liquid whilst solids come with a wide range of aggregate sizes and different ballistic properties if thrown into the air. Whilst slurry tankers and rain guns had the best distribution uniformity, their DU_{uq} of 1.6 was considerably greater than the value of 1.25 recommended as a design standard for liquid effluent products in the FDE code of practice (DairyNZ 2011). The poor uniformity of the different distribution systems is disappointing; however it does need to be kept in context with the way that cattle dung and urine patches are currently distributed unevenly around grazed paddocks.

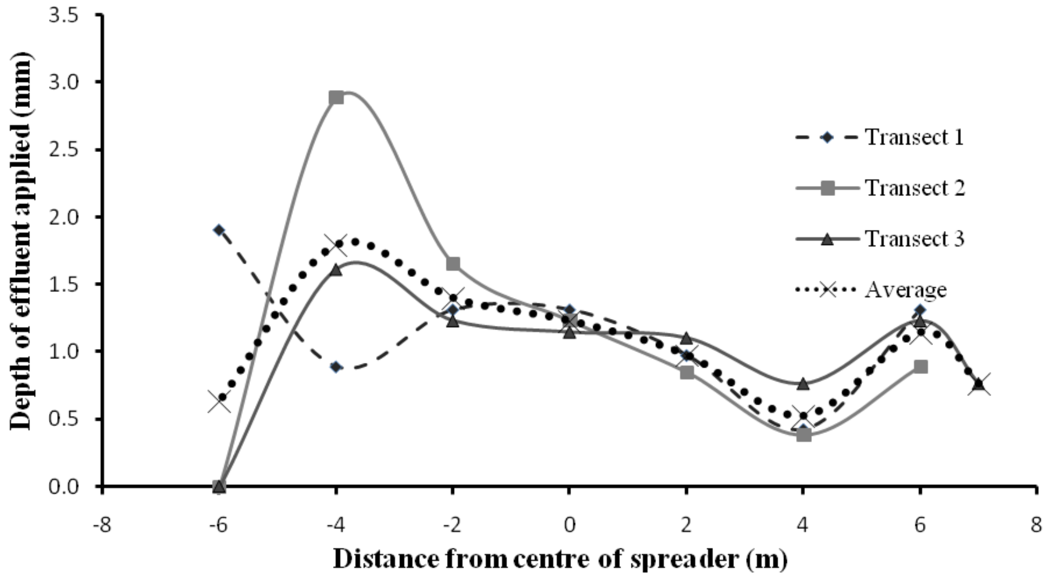

Figure 1: Spreading pattern from three passes of slurry tanker applying wintering barn slurry in Southland.

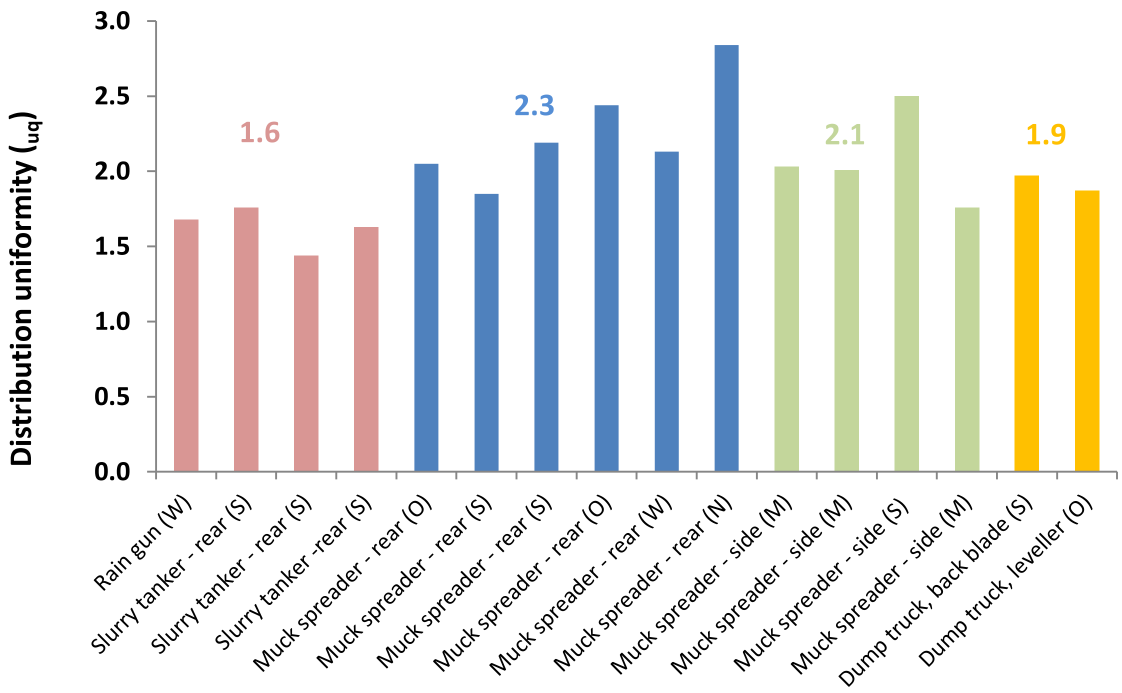

Figure 2: Upper quartile distribution of uniformity for individual spreading systems. General system types are grouped by colour with Red=slurry spreaders , Blue= rear discharge muck spreaders , Green= side discharge muck spreaders , and Yellow= manual back blade operation . The number above each colour is the average for each general system type. In the X-axis labels the description refers to the type of effluent system and the letters refer to N = Northland, W=Waikato, S=Southland, O=Otago and M=Manawatu.

Nitrogen loading rates

Optimum nutrient loading rates will vary depending upon land use. In New Zealand regulatory authorities tend to use a maximum permissible N loading rate of either 150 or 200 kg N/ha/yr for N loading from dairy effluents including slurries and manures. There has been considerable research in New Zealand examining the relationship between N loading rate and N leaching from pastoral-based farming systems. The extent of N leaching is a product of the surplus of mineral N in soil (largely dependent on N inputs), the retention and mobility of N forms in soil (affected by soil properties), and the level of drainage (determined mainly by rainfall).

From the 16 case studies where effluent application volumes/weights were determined, the N loading rate averaged 79 kg N/ha and ranged from 13 to 221 kg N/ha. Only one application (221 kg N/ha) was greater than 150 kg N/ha and in this particular case study the slurry was being applied to pasture prior to being cultivated for growing a high nutrient use crop in the form of maize silage. Therefore the data collected from the case studies suggests that the slurry and manure application volumes/weights were generally well managed with regards to N loading rate.

It is important to note that the nutrient loading rate may not always be set based on reaching N loading limits. In liquid waste streams potassium (K) is typically the limiting nutrient i.e. plant requirement is exceeded before other macronutrient limits are met (Longhurst et al. 2012). However separated solids will be relatively low in K compared to non separated effluent because it is very mobile and therefore will likely be found in greater proportion in the liquid fraction.

Timing conundrum

The application of slurries and manures to land can pose different forms of environmental risk: nitrate leaching, overland flow carrying nutrients and faecal microorganisms or gaseous emissions depending on the time of year. Where animal effluents are applied to crops or cut and carry farm systems then effluent N will be the predominant source of N input. European research (Smith et al., 2008) demonstrated that the risk of N leaching from applied animal effluents is strongly related to timing (i.e. month of application).

Another driver of nitrate leaching from slurry/manure applications relates to the N content and form of the effluent applied. Chambers et al (2007) demonstrated a decreased risk of nitrate leaching when applying farm yard manure (scraped barn floor manure) compared to slurry. This is because farm yard manure has a much larger proportion of organic N than slurry which has greater mineral N contents. Given our knowledge of New Zealand farming systems, soil types and climate in combination with finding from international literature we have summarised the seasonality, risks and potential mitigations available in Table 1.

Table 1: Season of effluent application, risks identified and potential mitigations available from land applying manures and slurries.

Application season	Environmental risks	Possible mitigation
Summer/early autumn	N volatisation	Timing with weather, N form
Autumn	N leaching	Nitrification inhibitor, N form
Winter/early spring	P & N runoff	Storage
Late spring	Optimum window	

Recommended best practice
International literature suggests that the environmental risk of contaminant transfer is considerable if surface runoff events caused by rainfall are generated within 2 days of surface application of effluent solids that do not percolate into the soil or are manually incorporated. The recommendation by Smith et al. (2008) is that a 10 day period is required to adequately mitigate the risk of contaminant movement. Our recommended best management practices relating to land application of manures and slurries are summarised in Table 2.

Table 2. Recommended best management practices for land application.

Practice	Recommendation
Characterisation	Choose 2 from: laboratory tests, default values, OVERSEER® nutrient budget
Application volume	< 50m^3/ha (slurry*); < 3t DM/ha (manures)
Soil moisture at application	Soil type and effluent dependant [b]
Maximum N loading (kg/ha/yr)	150 N (pasture); site/crop dependant (cropping)
Tactical timing if not incorporated	> 10 days until runoff event (minimum 2 days)
Minimum soil temperature	4^o C
Optimum time of year	Late spring

[a] 6% DM slurry, 3,000mg N/L at 50m^3 = 150 kg N/ha, [b] Slurries and liquids should use the FDE soil risk framework to determine scheduling (Houlbrooke and Monaghan 2010)

New technology
Much of the new technology in land application of manures and slurries, applicable to New Zealand, comes from the United Kingdom and Europe. One such emerging technology is the use of trailing shoes to band spread effluent directly to soil. Advantages of such technology are that there is minimal pasture contamination, ammonia-N losses are greatly reduced, N use efficiency is increased, and there is more control over loading rates and spreading uniformity (Misselbrook et al. 2002).

Conclusions
Data gathered from case studies around New Zealand shows that spreading uniformity of applied slurries and manure was generally poor. However their performance should be kept in context with the manner with which animal excreta is spread around paddocks. Slurry spreading systems appear to be more accurate than muck spreading systems as their ballistic behaviour is less affected by solid clumping and size variability. Nitrogen loading rates were generally well managed within regulatory requirements, however, on some sites excessive amounts of K were applied. International literature suggests that recommended application rates are: < 50m^3/ha for slurries and 3t DM/ha for manures. Our case studies suggest that a little over half of our measured sites were applying dairy solids within these recommended limits. Furthermore, international research also suggests that a ten day period is required between land application and surface runoff to minimise environmental risks. Given the range of different potential environmental risks associated with land applying dairy effluent solids we recommend that the optimal time for land application of manures and slurries is in late spring.

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