Manure management facilities on farms and their relevance to efficient nutrient use

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Introduction

The agricultural livestock sector produces large amounts of manure that have substantial fertilizing value when used appropriately. In 2003 the national cattle herd of 6.3 million animals produced 37 million tonnes of manure over the winter housing period, 29.3 million tonnes (t) of which was slurry with the remainder as solid manure. This represents a nutrient value of approximately 130,780 t, 23,714 t and 158,190 t of total nitrogen (N), phosphorus (P) and potassium (K), respectively. Dairy cows accounted for 28% and 7% of the slurry and solid manure production totals, respectively. As slurry accounts for approximately 80% of the manure the objectives of this paper are firstly to identify why slurry is currently not considered as a valuable source of nutrients, secondly to identify how the agronomic utilisation of this valuable nutrient source can be realised and thirdly its economic value.

The extent to which manure nutrients are utilised in Irish agriculture is difficult to estimate. Recent studies suggest that little or no account is taken of the nutrient value of manures with indications of N, P and K overuse. In general, it is advised that cattle slurry be applied to the silage area. This represents for a typical 33 t ha^{-1} (3,000 gallons ac^{-1}) application to first cut silage of a 6.9% dry matter slurry, approximately 120 kg, 20 kg and 142 kg of total N, P and K, respectively. This does not appear to be reflected in fertilizer use statistics. Current Teagasc advice for soils at Index 2-4 states that the P and K content of slurry is as available as fertilizer P and K regardless of the time of application. However, it is not as clear cut for N. The N in slurry is currently considered to be less available than that of fertilizer N. The availability of N depends on both the fraction of the N that is in the available (ammonium form) and the fraction that is slowly available (organic form). In addition the time of year when slurry is applied also influences N availability.

Almost 100% of slurry in Ireland is spread using the conventional “splashplate”, however alternative techniques are available. One example, the “trailing shoe” provides a number of benefits, namely the application of slurry directly to the soil surface underneath the crop canopy, thereby reducing the loss of ammonia (NH_3) to the atmosphere which in turn increases nutrient uptake by the grass crop. The other advantage of the methodology is an increase in the spreading window for slurry in the spring which is particularly important on heavy soils in the wetter parts of the country.

Efficient manure nutrient use

Nutrient management planning

Nutrient management planning is based on the concept of "nutrient recycling" rather than "waste disposal", the latter approach having evolved during a time when increasing agricultural output was the sole objective, without due regard to environmental impact. Under nutrient management planning, nutrient management must be accepted as being on par with other production functions, such as animal or crop health management. This approach is required because reducing nutrient losses associated with the landspreading of manure is as essential to long-term sustainability as is profitably producing high quality food. Nutrient management planning involves several steps: assessment, analysis, decision-making, evaluation and refinement. The assessment step involves the evaluation of farm resources that will influence nutrient management, especially potential spread lands, numbers and types of animals, and the condition of the farmyard. The analysis step determines the nutrient supply and crop nutrient needs. The decision-making step involves deciding on the quantities of manure/slurry and/or fertilizer to apply to each field and preparing a simple and practical plan. Accurate record keeping is essential to successful nutrient management as it is to other aspects of farm operations (Carton and Magette, 1999). The process of nutrient management planning has been accepted at policy level in Ireland, but its implementation at farm level has been slow except where it is mandated as part of another programme (e.g. REPS or Integrated Pollution Control licensing of the pig and poultry sectors by the Environmental Protection Agency).

The landspreading of slurry should follow Code of Practice (e.g. DAFF and DOE, 1996). The timing of application should coincide with periods of vigorous crop growth. For grassland and especially conserved grassland, this is achieved earlier rather than later in the year. The efficient recycling of nutrients also requires properly and well maintained equipment. The typical equipment used in the majority of slurry applications is the vacuum tanker fitted with a "splashplate". This system can transport and apply large volumes of slurry relatively cheaply.

Currently utilisation of cattle slurry on Irish farms

Fertilizer use

The extent to which slurry/manure nutrients are utilised on Irish farms is difficult to estimate, however there are some indicators as to its use. Coulter *et al*. (2002, 2005) suggest that actual fertilizer N usage for silage shows that farmers either slightly overused N, did not appreciate the N in slurry or that not all slurry was applied to the silage crop. In addition current Teagasc P and K advice for silage assumes that the slurry or manure produced from the silage ground is returned to the soil (Coulter 2001, 2004). When a comparison is made between advice and P and K fertilizer use, it would suggest that fertilizer use is midway between that of the advice given where slurry is applied and advice where it is not applied to the silage ground.

Farm facilities

A Farm Facilities Survey (FFS) was undertaken in 2003 to establish baseline data on manure management facilities and management practices on Irish farms. In order to collect and record farm data a 54 page questionnaire was prepared which represented the six farm types and seven farm classes used by the National Farm Survey (Connolly *et al*., 2004). The survey forms were completed by Teagasc advisory staff who interviewed the farmer or farm manager during visits to 401 farms in 25 counties during 2003. Information in relation to the number and type of animals present on the farm, length of housing and grazing periods, housing type, manure storage and method and timing of manure application was collected. The data from the survey forms was inputted to an MS ACCESS database and analysed using SAS Means and Tabulations procedures (Carton *et al*., in prep).

Slurry storage

In the FFS slurry storage systems were divided into eight sub-categories (Tank in roofed slatted area; Other covered underground tank; Uncovered underground tank (including unroofed slatted tank); Uncovered tank overground; Covered tank overground; Lined lagoon; Unlined lagoon; and Other). Details on 716 slurry tanks and the dimensions of each tank were recorded from 367 farms. Covered underground or over ground tanks accounted for 74% of slurry storage systems on farms with uncovered underground and over ground tanks accounting for almost 22%. Lagoons and other systems accounted for the remaining 4%. (Figure 1).

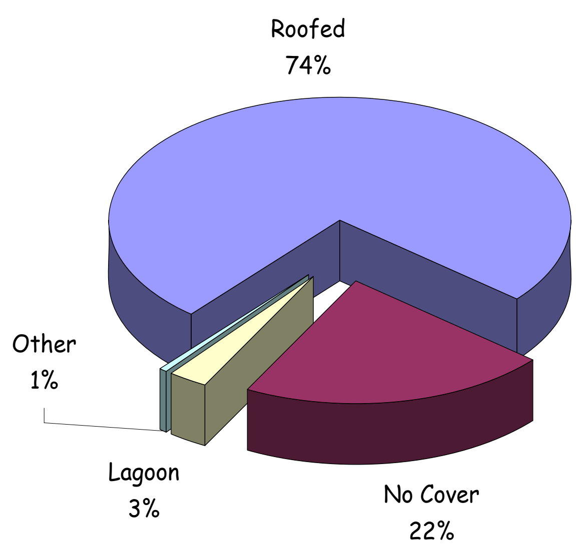

Figure 1: Slurry storage systems

Available slurry storage capacity for each farm was calculated based on the dimensions of the store(s) on each farm and compared with the estimated manure production (DAFRD, 2000) by the animals present on each farm. This data was then used to estimate storage requirements on a national basis to indicate compliance with the measures set out in the EU Nitrates Directive (91/676/EEC) Action Programme. This Action Programme has set minimum slurry storage requirements (in weeks) on farms dependent on the number and type of animals present on the farm and the situation of the farm in respect to one of three regions. Storage surpluses/deficits were then calculated as the difference between the slurry storage requirement and the capacity available. On this basis it was identified that nationally that there is a 21% and 31% storage deficit for a 16 week and 22 week storage period, respectively. However, these calculations require further investigation.

Landspreading

In the FFS, farmers were asked to record the proportion of slurry spread to conservation land (silage area), grazing, maize and tillage and the time of year in which it was spread using the divisions: Spring (February, March and April); Summer (May, June and July); Autumn (August, September and October) and Winter (November, December and January). It was found that 83% of cattle slurry is spread on the silage area, 13% is applied to the grazing area and the remaining 4% to the maize and tillage areas. Of the total slurry applied to conservation land, 31% is applied in spring, 52% in summer, 13% in autumn and 4% in winter (Table 1).

Table 1: The percentage of cattle slurry applied to different land uses and the season in which it is spread.

	Spring	**Summer**	**Autumn**	**Winter**	**Total**
Conservation land	26 (31)*	43 (52)*	11 (13)*	3 (4)*	83
Grazing land	5	4	2	2	13
Maize	2	1	0	0	3
Tillage	1	0	0	0	1

* The percentage of slurry applied in each season relative to the total spread on conservation land is shown in parenthesis.

The data presented in Table 1 has important implications for the efficient use of cattle slurry as a nutrient source. The utilisation efficiencies of the nutrients N, P and K in cattle slurry are presented in Table 2. Current Teagasc advice suggests that for soils at Index 2-4 that the P and K in cattle slurry is as available as that of purchased P and K fertiliser (Coulter, 2001; 2004). However for N, its availability is dependent on the fraction of N that is in the available (ammonium) form, the fraction that is in the slowly available (organic) form and the time of year in which it is spread.

Table 2: The utilisation efficiency of nitrogen, phosphorus and potassium in cattle slurry as affected by the time of year in which it is applied.

Nutrient	**Spring**	**Summer**	**Autumn**	**Winter**
N	25	5	0	0
P	100	100	100	100
K	100	100	100	100

When Table 1 is compared with Table 2 it is evident that approximately 70% of the cattle slurry applied to the silage area is applied when the utilisation efficiency of N is low or zero. However, there are a number of possible explanations for the apparent low use of cattle slurry in spring, which are discussed in the following section.

Reasons for the apparent low utilisation of cattle slurry in spring

Calculated slurry storage deficits on a national basis suggest that there are 21% and 31% storage deficist for 16 week and 22 week storage periods, respectively. Current data on the timing of slurry spreading suggests that only 4% of slurry is spread during the winter months (November, December and January). It is therefore difficult to reconcile these two datasets as a storage deficit would imply that more slurry would be spread during the winter months.

It is recommended that slurry for first-cut silage can be applied up to the end of March or early April depending on the cutting date, with a minimum of six weeks between slurry spreading and harvesting. However there are a number of issues which have to be taken into account.

Soil and weather conditions

Average precipitation ranges from just under 800 mm per annum on the east coast, to over 1200 mm on the west coast (Collins and Cummins, 1996). This has a major influence on the number of days on which the landspreading of slurry can be undertaken or which the trafficability of soil is suitable. Earl (1997) observed that for a range of soil types in the UK, a threshold soil moisture deficit (SMD) of c. 10 mm was required to allow traffic without undue sinkage slippage or adhesion of soil to the machine tyres. Schulte *et al.* (2005) suggest that the number of days that soils have SMD's greater than 10 mm amounts to almost half a year on the well drained soils in the east of Ireland and that there are as few as 60 to 80 trafficable days on wet soils in the west. It was also found that differences between years are even more pronounced: in "dry years", the number of trafficable days is higher and almost equal for well-drained and poorly-drained soil associations. In "wet years", however, the number of days on which soils can be safely trafficked on ranges from 120 in the east to 25 or less in the far west.

Sward contamination

Almost 100% of slurry is surface spread using the conventional splashplate methodology whereby the slurry is discharged from the tanker under pressure via a nozzle and splashplate. This practice may result in large emissions of NH_3, offensive odours and contamination of herbage. On grassland farms, so as to avoid rejection of herbage by grazing animals, slurry is commonly applied to grassland during autumn or on the silage area immediately after the first-cut in summer. At farm level it is generally thought the physical contamination of the silage crop with slurry gives rise to poor fermentation of the silage if applied close to harvest.

Well preserved silage is characterised by a high concentration of lactic acid and adequate levels of water-soluble carbohydrates to encourage the growth of lactic acid bacteria and the production of lactic acid. A low pH is therefore required, which will also inhibit clostridial activity (McDonald, 1981). This is the most important risk when slurry is applied to grass crops prior to ensiling. Clostridia are ingested by animals in soil contaminated forage and fodder crops and, when added to crops for silage, ferment sugars and lactic acid to produce butyric acid and other undesirable fermentation by-products (Laws *et al*., 2002). This undesirable fermentation process is indicated by a rise in pH and NH_3-N contents and a reduction in lactic acid content (McDonald, 1981).

Spreader availability

A census of agriculture was conducted in 2000 (C.S.O., 2002). The objective of which was to identify every operational farm in the country and collect data on agricultural activities undertaken on them and the machinery used on farms. The results of the census suggest that in 2000 there was 124,108 livestock farms where the agricultural area used for farming was at least 1 ha or above. However, to compare the use of machinery on farms it is more realistic to suggest that a farm which is greater than 20 ha would either own or use farm machinery on a regular basis. The number of farms where the agricultural area was 20 ha or more is 72,368. The census identified that nationally 31,046 farms either owned or share the use of a slurry tanker. It also suggests that 35,281 farms either hire (using a contractor) or borrow slurry tankers. Given that slurry spreading is to a large extent carried out by contractors there will be some overlap in these figures. Preliminary analysis of the FFS carried out in 2003 provides further evidence to support this.

Farm fragmentation

The time required for field application of slurry depends on a number of important factors including field area and layout, machine operational speed, machine width and the distance from the slurry store. Details of land fragmentation on farms were recorded in the FFS in terms of the number of fragments, the area of each fragment and distance of each fragment from fragment 1 or the farmyard holding, i.e. main farmyard and adjacent lands. It was found that approximately 27% of all farms surveyed consisted of a single farm holding while a further 31% of farms had four or more fragments. The mean distance of fragments 2, 3, 4, 5 and 6 from fragment 1 was 2.9, 2.9, 4.1, 6.6 and 4.9 km, respectively (Figure 2).

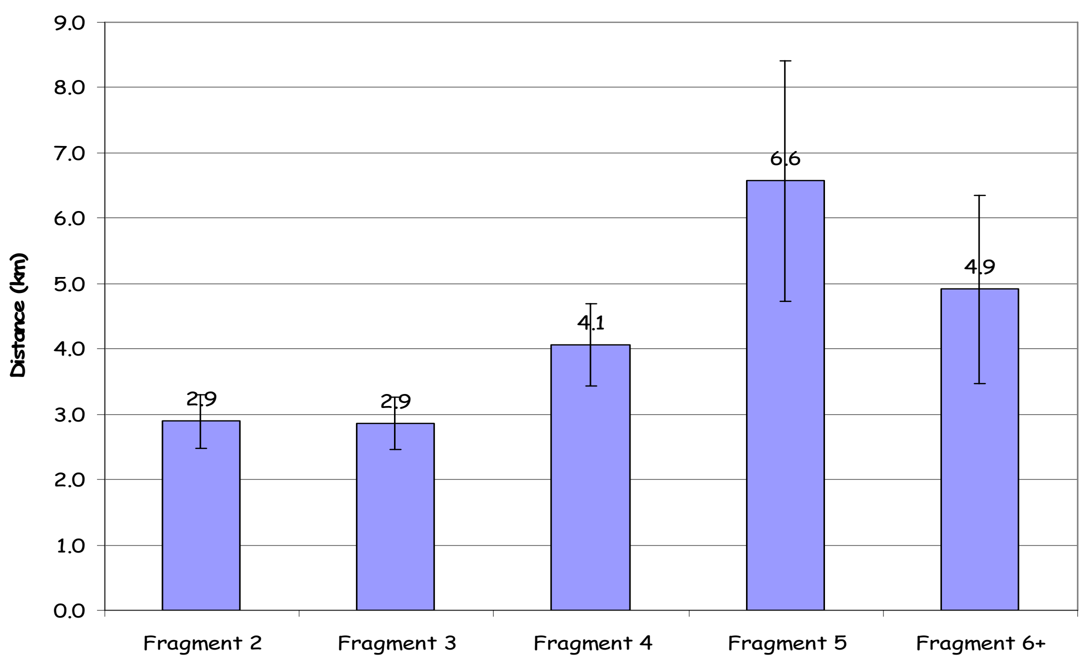

Figure 2: The distance of farm fragments from the main farm holding.

There is a general trend for the distances to be greater in Connaught and Ulster compared with Muster and Leinster. This has important implications for the efficient utilisation of slurry due to the transport costs of slurry to land fragments away from the main holding and the distance which has to be travelled.

Nutrient availability in cattle slurry

Nitrogen is usually the first consideration in a fertiliser plan. Phosphorus and potassium are easier to manage, particularly where the soil P and K status is at Index 2 or above, and they are largely only required for the maintenance of soil reserves. In this situation the P and K in cattle slurry is regarded as been as available as that of fertilizer P and K, as shown in Table 2. However, it is not as clear cut in terms of N. The N in slurry is in two main forms: (1) the available (ammonium) form and (2) the slowly available (organic) form, which is the solid fraction of the slurry, such as undigested silage etc. The available (ammonium) form accounts for 50% of the total N in slurry and the solid fraction accounts for the other 50%. Once slurry is applied the ammonium is available for uptake by the sward. The N in the organic or solid material only becomes available after it breaks down in the soil and is mineralised.

Once applied however, the ammonium in slurry can be lost through NH_3 volatilisation, which is the process whereby ammonium is converted to NH_3 gas and emitted into the atmosphere from the soil as a result of biological, chemical and physical processes. Soil conditions, prevailing weather conditions and cropping procedures influence the amount that is emitted. Higher emissions are associated with dryer soils and warmer weather conditions such as those found in the summer months. When slurry is applied to bare silage stubbles under dry conditions in the summer months, virtually all of the ammonium in slurry is lost by NH_3 volatilisation. In addition the application of slurry with the conventional splashplate technique promotes the process of volatilisation as it covers the soil surface and provides a large surface area from which NH_3 volatilisation can occur. Ammonia loss occurs during and immediately after application and as a result virtually all the ammonium in slurry can be lost within a short period after application. As a result only 25% of the total N in slurry is available for crop sward uptake in spring and 5% is available in the summer under current recommendations (Coulter, 2001; 2004).

Based on recommendations for the application of fertilizer N to silage crops, approximately 120,000 t of fertilizer N was applied to the national silage crop in 2003. The total N in slurry produced in the 2002/2003 housing period calculated on the basis of manure production figures for each category of animal on livestock farms (DAFRD, 2000; DAF 2003) and the census of animals present on livestock farms over the housing period (C.S.O., 2004), and the typical nutrient content of cattle slurry (Table 3), is estimated at approximately 105,000 t. As 50% of the N in slurry is readily available approximately 52,500 t of N is available. Where all this slurry is applied in spring, following current recommendations and splashplate application, approximately 26,500 t of N in cattle slurry may be utilised. However, based on the results presented in Table 1 which states that only 31% of the total slurry applied to silage areas is in spring, approximately 7,000 t of the N in cattle slurry was utilised (Figure 3).

Table 3: Typical dry matter, N, P and K content in cattle slurry

	Dry matter(%) *	N (kg/t)			P (kg/t)	K (kg/t)
		Total	Spring	Summer		
Cattle slurry	6.9	3.6	0.9	0.2	0.6	4.3

*Dry matter content varies and this determines the nutrient contents

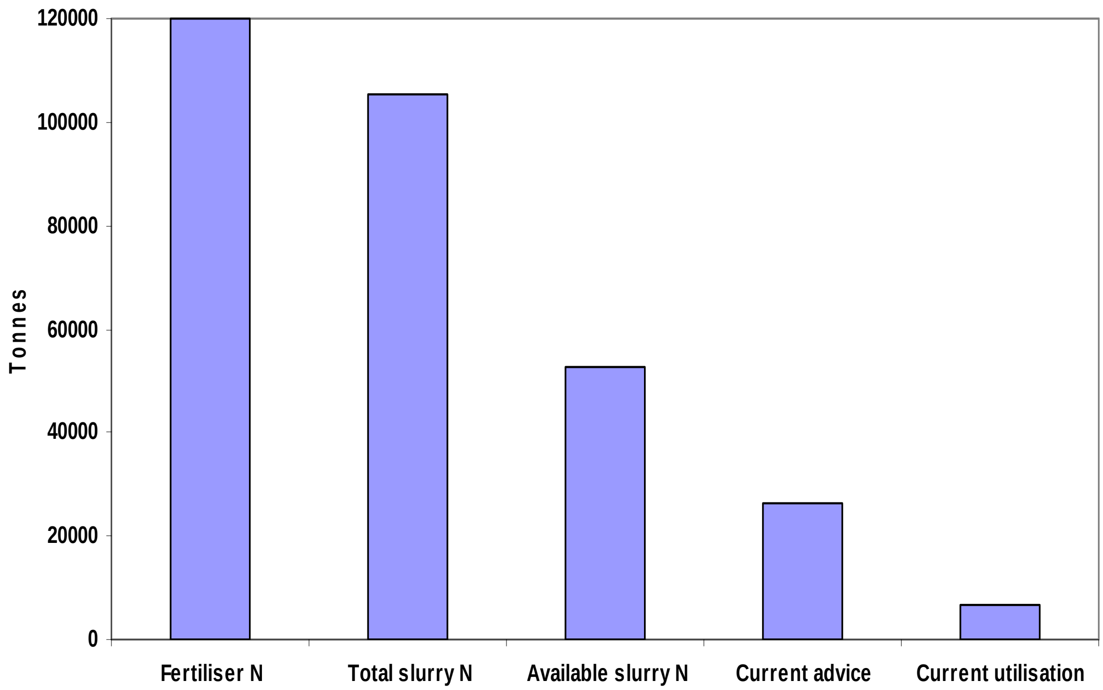

Figure 3: A comparison of the fertilizer N used on the national silage crop, the N content of total slurry produced its current utilisation on farms.

Efficient utilisation of the nutrient value of cattle slurry

To realise an acceptance of the nutrient value of slurry especially in terms of its N content and a reduction in purchased fertilizer through its use as a nutrient source, a number of issues need to be addressed such as a change in the spreading date of slurry to spring application, the method of application and the soil/weather conditions.

The recovery of slurry N in the silage crop can be improved by using low NH_3 emission spreading techniques such as the trailing shoe. Research results in Europe have shown that the recovery of the total N in slurry can be improved from the current 25% in spring to up to 50%. The trailing shoe applicator consists of a boom attached to the back of a tanker on which a number of hoses distribute slurry to the soil surface in narrow bands. The slurry is discharged from the hoses via a “shoe” device which parts the crop canopy allowing slurry to be deposited onto the soil surface below the canopy. Slurry is fed to the hoses via a rotary distribution manifold, which controls the flow of slurry evenly to each hose outlet. A schematic comparison of the trailing shoe technique with the conventional splashplate application is shown in figure 4.

(a) (b)

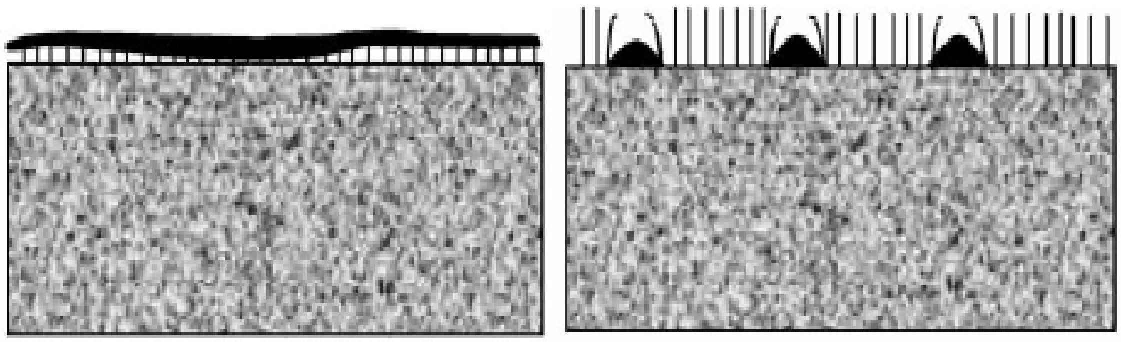

Figure 4: A schematic representation of the conventional splashplate application (a) whereby slurry covers the grass sward; and (b) trailing shoe application whereby the grass canopy is parted and slurry is applied to the soil surface.

The main effect of this new slurry application technique is to reduce the peak NH_3 emission rate that is normally observed in the first few hours after slurry application, with differences in emission rates on subsequent days being of less significance. As upward of 50% of the NH_3 lost after slurry application using conventional techniques is lost in the first few hours after application, it can lead to an appreciable difference in total cumulative emissions (Misselbrook *et al*., 2002). The work of both Misselbrook *et al*. (2002) and Smith *et al*. (2000) suggest that significant reduction sin NH_3 emissions are achievable with trailing shoe application of slurry, when compared with broadcast/conventional spreading.

An important additional benefit is that there is a significant reduction in contamination of the grass with slurry solids. Joint IGER-ADAS research in the U.K. has shown that slurry can be applied much later i.e. closer to cutting without affecting silage quality. Good quality grass silage was made, even under extreme conditions, when slurry was applied just two weeks before harvesting (Laws *et al*., 2002). In comparison, silage made after surface broadcasting at the time was badly contaminated with slurry and fermentation was poor. There was a significant decrease in lactic acid content and an increase in pH as a result. Laws *et al*. (2002) further suggest that the indicate that silage quality is unlikely to be compromised by slurry applications made in early spring, during February, March or even in April, when applied at agronomically sensible rates. This will lead to better utilization of slurry N, reduced risks of nutrient loss via leaching and surface runoff and a reduction in NH_3 emissions to the atmosphere. Furthermore, it increases the flexibility of slurry management by extending the window of opportunity for spreading, allowing more immediate spreading before silage harvesting than with conventional splashplate spreading without a deterioration in silage quality. This has important consequences for the application of slurry to silage swards on the heavier soils in the wetter parts of the country. Therefore where the heretofore accepted time between slurry spreading and silage harvesting is compromised, as a result of high farmer workload in the spring of adverse weather conditions, the application of slurry in narrow bands with the trailing shoe below the grass canopy may be advantageous.

The economic value of cattle slurry

The price of purchased fertilizer currently stands at approximately € 0.56, € 1.35 and € 0.36 per kilo of N, P and K, respectively (J. Humphreys pers. comm.). Based on the application of approximately 120, 000 t of N to the national silage crop in 2003, this equates to a cost to the farmer of € 67.2 million, before P and K are taken into account. The economic value of cattle slurry in respect of the total N, P and K that it contains is approximately € 128.1 million, of which € 59.1 million is N, € 23.7 million is P and € 45.4 million is K. However one must take into account the availability of N in cattle slurry, its current utilisation and the availability of P and K. In this regard the current utilisation of 7,000 t of N in slurry in spring equates to an economic value of € 3.8 million. Under current recommendations where it is advised to spread all cattle slurry to the silage area in spring and assume a 25% utilisation of N, the value of cattle slurry is estimated to be € 83.9 million, € 14.8 million of which is attributable to N.

If one were to assume that with the use of trailing shoe slurry application of all cattle slurry to the silage area in spring and a 50% utilisation of the total N in slurry the economic value is estimated to be € 98.7 million, € 29.5 million of which is attributable to N. In practise however, the actual value that could be realised lies between € 83.9 million and € 98.7 million, with a tendency towards the latter as a result of the implementation of the use of trailing shoe application of all cattle slurry to the silage area in spring.

Summary and Conclusions

In 2003, the national cattle herd of 6.3 million animals produced 37 million t of manure over the winter housing period, 29.3 million tonnes of which was slurry. This represented a nutrient value of 130,780 t, 23,714 t and 158,190 t of total N, P and K, respectively. Current recommendations suggest that slurry is applied to silage areas in spring. However, the percentage of cattle slurry that is utilised in this manner is 26% (31% of total applied to silage area) of the total slurry landspread. In addition there are indications that little or no account is taken of cattle slurry applied in spring. It is suggested that there are a number of reasons why this is the case.

The distribution of and quantity of rainfall has a large impact on the trafficability of soils. Schulte *et al*. (in press) suggest that while the number of trafficable days on the drier well drained soils in the east of Ireland may amount to almost half a year, that there may be as few as 60 to 80 trafficable days on the wetter, heavier soils in the west. Another factor to the low utilisation of cattle slurry in spring is the risk of sward contamination with slurry solids as a result of slurry application during the accepted period of time between application and silage harvest. This can give rise to clostridial activity which increases the pH and NH_3-N content of the fermenting silage crop and an increase in lactic acid production leading to poor fermentation. Spreader availability is a issue in terms of the time of slurry application, with a large majority of farmers opting for the use of contractors to spread slurry. The time required to spread slurry is largely dependent on the distance of spread lands from the main farm holding. It was found that approximately 27% of farms survey in a farm facilities survey in 2003 consisted of one holding with a further 31% having four or more fragments. The average distance of fragments from the main farm holding varies from 2.9 km to 6.6 km for farms with two or more fragments.

Nitrogen is the most important consideration in a fertilizer plan. The P and K in slurry is considered to be as available as purchased fertilizer based on current agronomic advice. The availability of N in cattle slurry is dependent on both the fraction of N that is available for crop uptake and the fraction that is slowly available, and on the time of year in which the slurry is spread. The N in slurry is currently considered to be only 25% available in spring and 5% in summer and is considered to be unavailable in autumn and winter. This has important implications for the efficient utilisation of cattle slurry given that 65% of the slurry applied to the silage crop is applied in summer and autumn.

The recovery of slurry N in the silage crop can be realised by the use of low NH_3 emission landspreading techniques. One such technique is particularly suitable to Irish soils. The main advantages of its use are reductions in NH_3 emissions to the atmosphere which are largely responsible for the low utilisation of slurry N under dry soil/weather conditions in the summer months. Additional advantages of its use are significant reductions in the contamination of grass swards with slurry solids as the slurry is applied to the soil surface. Research has shown that good quality grass silage was made, even under extreme conditions, when slurry was applied just two weeks before harvesting, where agronomically sensible rates were applied. Flexibility of slurry management is therefore facilitated, allowing for more immediate spreading of slurry to silage swards than would have heretofore practised.

The nutrient value of manure when used at agronomically sensible rates to the silage crop in spring can realise significant savings in the cost of purchased fertilizer nutrients. This potential can only be realised through a change in spreading date to spring applications to the silage crop and a change from the current conventional splashplate application of slurry to the use of the trailing shoe. It was calculated that in 2003 spent approximately € 67.2 million on the purchase of fertilizer N for silage production. The value of cattle slurry in respect of its total N, P and K content was estimated to be approximately € 128.1 million. A change in the time of application to spring and a change in application technique to the use of the trailing shoe the value of cattle slurry was estimated to be as much as € 98.7 million.

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