Efficient use of slurry on grassland - the Dutch experience

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Introduction

Dairy farmers in The Netherlands manage 1 million hectares (ha) of grassland. For each 10 ha of grassland, their farms comprise, on average, 1 ha (peat and clay soils) to 4 ha (sandy soils) of silage maize. Annual milk production averages 13,000 litres per ha, implying that around 250 kg total manure-N per ha is produced as well (Aarts et al., 2008). Due to restricted grazing around 75% of this manure is collected, almost entirely as cattle slurry. So, 40-50 m^3 per ha has to be spread annually on each ha of grassland. This slurry typically contains 9% dry matter (DM), 0.45% nitrogen (N), 0.07% phosphorus (P), and an ammonium N to total N ratio of 0.50.

Both farmers and policy makers want nutrients to be taken up and harvested in crops. The amount of nutrients captured by crops is the product of:

1. the applied rates (A, kg per ha) of various nutrient sources,
2. the fertilizer value (V, kg per kg) of each of these sources,
3. the ability of a crop to recover these available nutrients (R, kg per kg), and
4. the extent to which recovered nutrients are eventually harvested (H, kg per kg).

Each of these terms A, V, R and H offers clues on how to reduce losses to the environment. This paper intends to give an overview of the values that farmers, scientists and policy makers in The Netherlands have assigned to A, V, R and H and why.

A: Application rates

Intensive dairy farms import sufficient P via concentrates to fully compensate the P exported in milk and meat. On most soil types, additional mineral fertilizer P supplements are not needed as the P applied in manure is adequate. The inputs of manure and mineral fertilizer N should be balanced to the crop outputs so that the resulting surplus does not lead to N and P concentrations in water that exceed targeted levels. Justifiable N surpluses depend on the soil type, as the denitrifying capacity of soils varies. Currently permitted P surpluses are close to zero but will in the near future become negative on soils with a high P status. Many interacting factors determine which combination of manure and mineral fertilizer N complies with these requirements. A simple model has been developed to handle this complexity (Schröder et al., 2009). Calculations have indicated that a full recovery of manure-P depends on the availability of sufficient N: without N supplementation via mineral fertilizer or biologically fixed N, accumulation of manure P is generally inevitable. This also implies that the N to P ratio of manures is important when considering the potential to meet crop demands with manure instead of mineral fertilizer N. Reduced P contents of diets or the export of the solid fraction resulting from the mechanical separation of manure can widen the N to P ratio of the (remaining) manure. This reduces the need for fertilizer purchase and expenditures on the export of (bulky) untreated slurry. Calculations have shown that permitted manure rates should, ideally, also be differentiated for soil type, crop type, rotation and harvest regime, growing conditions and management quality (Schröder et al., 2009). Figure 1 illustrates the impact of the factors soil type and manure composition.

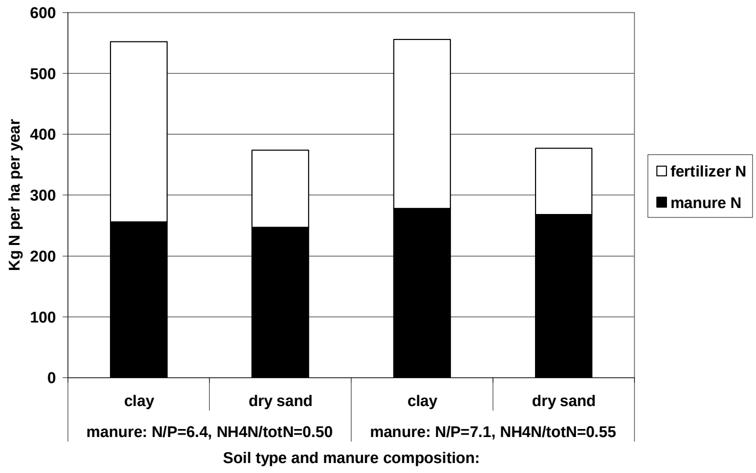

Figure 1. Simulated permissible manure and fertilizer N rates on grassland, as affected by the soil type and the N/P ratio and the ammonium-N/total N ratio (NH4N/Ntot) in manure (fairly good growing and management conditions, mixed use of cutting and restricted grazing, P surplus = 0 kg per ha per year, average leaching risk, N concentration target = 11.3 mg per litre (Schröder et al., 2009)).

Policy makers have obviously tried to find a compromise between the need for differentiation and the need to define a level playing field for all dairy farmers (Schröder & Neeteson, 2008). By now the nutrient inputs per ha in The Netherlands are limited by three types of application standards: a permitted P rate (manures + mineral fertilizer), a permitted manure-N rate, and a permitted rate of plant-available N. Table 1 shows some numbers for grassland and silage maize.

Table 1. Application standards for nutrients (kg per ha per year) in 2010

Permitted P (manure + mineral fertilizer)	Grassland	41
	Silage maize	35
Permitted manure-N on dairy farms		250*
Permitted plant-available N	Grassland, clay soils	310 / 350**
	Grassland, peat soils	265 / 300**
	Grassland, sandy soils	250 / 320**
	Silage maize	150

* total N per ha farmland, including N excreted during grazing; left up to farmer how to split this budget over individual crops on his farm
** farms with mixed use of cutting and grazing / farms with cutting only

From the application standards, farmers can calculate the permitted mineral fertilizer N supplements, taking account of the legal default values for the relative N fertilizer replacement value (NFRV) of manures. Default NFRVs are 0.45 (cattle slurry or FYM on farms with mixed use of cutting and grazing), 0.60 (cattle slurry or FYM on farms with cutting only), and 0.80 (liquid fraction from separated slurry) kg N per kg N applied. Permitted fertilizer N rates thus equal: permitted plant available N - (manure-N x NFRV). Table 2 shows examples of these permitted fertilizer N rates for grassland on dairy farms using cattle slurry.

Table 2. Permitted mineral fertilizer N rates on grassland (rounded, kg per ha per year in 2010).

Harvest regime	Soil type	Cattle slurry rate* (kg total N per ha)		
		200	250	300
Cutting + grazing	Peat	175	155	130
	Sandy	160	140	115
	Clay	220	200	175
Cutting only	Peat	180	150	120
	Sandy	200	170	140
	Clay	230	200	170

* including N excreted during grazing

Dutch dairy farmers have successfully applied for derogation from the 170 kg manure-N per ha threshold stipulated by the EU Nitrates Directive. Currently, the Dutch government is seeking prolongation of the current derogation of 250 kg manure-N per ha for another four years (2010-2013). Derogation requests were and will be based on the objective criteria listed in the Nitrates Directive: a long growing season, a large crop N uptake, and a high denitrifying capacity of the soil. (Schröder et al., 2007a; 2009). Obviously, derogations save dairy farmers the costs of slurry disposal and substitution of mineral fertilizer N for slurry N.

V: Fertilizer value of manure

According to conventions the NFRV is the fertilizer value of manure relative to an efficiently applied mineral N fertilizer, i.e. the ratio the effect of one kg of manure N on the N (or DM) yield and the effect of one kg of mineral N on the N (or DM) yield (Schröder et al., 2007b). So, NFRVs must not be mistaken for the fraction of manure N that can be recovered by a crop, which is, by definition, less.

About half of the N in cattle slurry is ammoniacal. This type of N is directly available to plants, which is generally advantageous, but also easily lost to the environment if the slurry is improperly placed (Table 3). From the mid 1990s Dutch authorities therefore decided to ban the surface spreading (SS) of cattle slurry on grassland. Instead slurry had to be injected. The initial deep injection (15-20 cm) has been gradually replaced by shallower techniques such as sod injection (SI, 5-10 cm) or trailing shoes (TS, from 2012 only permitted on clay and peat soil) in order to reduce the need for tractor power, limit crop damage, and to improve the utilization of slurry-N. Note, that almost all land in The Netherlands is flat, without stones, and at least moderately well drained. In combination with an average annual rainfall of only 780 mm, this type of land is supportive to techniques by which slurry can be applied early if not right at the start of the growing season via SI or TS.

Table 3. Ammonia loss (kg NH_3-N per 100 kg total ammoniacal-N applied) of cattle slurry applied to grassland and arable land, as affected by the application technique (Huijsmans et al., 2008).

Land use	Technique	Loss (kg N/100 kg TAN)
Grassland	Surface spreading	74
	Trailing shoes	26
	Sod injection	19
Arable	Surface spreading	69
	Shallow incorporation (e.g. rigid tine)	22
	Thorough incorporation (e.g. injection, rotavator)	2

The legal obligation to use SI of TS is yet criticized by a minority of farmers. These farmers argue that SI and TS forces them to source out work to expensive contractors using heavy equipment. In their view heavy equipment reduces crop yields via negative impacts on the physical and biological soil fertility and calls at least for a more intensive drainage. If crop yields would not suffer, then at least meadow birds will via destroyed nests and a reduced availability of food. These critical farmers claim that ammonia emission could be reduced as effectively with SS if combined with low-protein diets, the use of bedding material rich in carbon (C), and the right weather conditions for the moments of manure spreading. As for the latter: warm, sunny and windy conditions stimulate ammonia volatilization.

The complaints of this group of farmers have been addressed in both experimental work and desk studies. This work has indicated that the pressure exerted by wheels does indeed deserve attention, however regardless whether SS, SI or TS is used. Recent trials once more showed that SI yields higher NFRVs than SS (Figure 2) and thus helps to reduce the loss of ammonia.

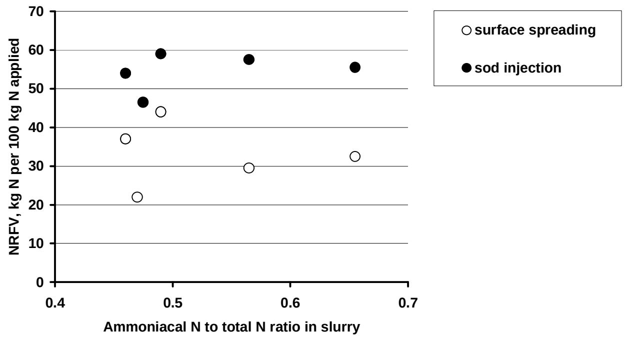

Figure 2. Nitrogen fertilizer replacement value (NFRV) of cattle slurry applied to cut grassland, as affected by the application method and the ammonium N/total N ratio in manure (pooled data of Geurink & Van der Meer, 1995; Schils & Kok, 2003; Schröder et al., 2007).

All the evidence allows us to conclude that the introduction of SI and TS generally had no negative impact on soil fertility and on grassland yield. The drastic decline of meadow bird numbers can mainly be attributed to intensified drainage of grassland and fertilizer use, and the consequential earlier date of first cuts. SI or TS as such are generally not to be blamed for it, unless breeding seasons and spreading seasons coincide in extremely wet years. It is also worth noting that SS is not necessarily harmless to the clutches of meadow birds either (Huijsmans et al., 2008). As for the alleged alternatives, research has indicated that the theoretical effects of combinations of low-protein diets, C-rich bedding, and the right weather during spreading (Figure 3), are hard to achieve in practice (Sonneveld et al., 2009).

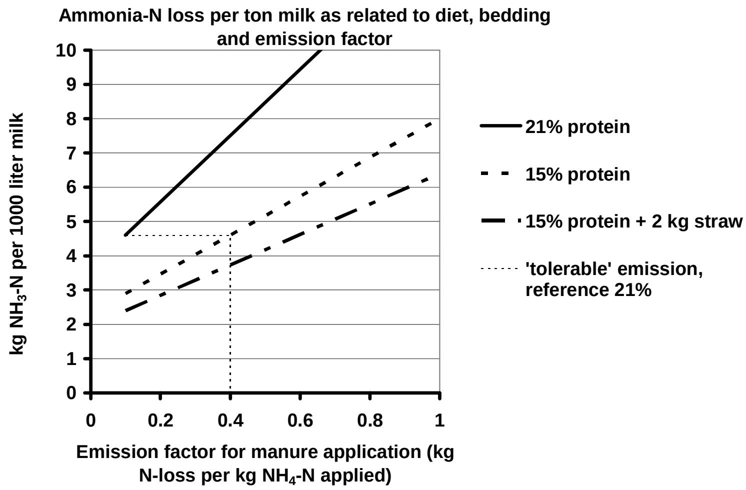

Figure 3. Simulated ammonia-N loss per ton milk, as related to diet composition, the use of straw bedding (2 kg per cow per day) and the emission factor (=kg NH_3-N loss per kg total ammoniacal-N applied, cf. Table 3) (after Schröder et al., 2004).

The legally imposed NFRVs (45-60-80%) should stimulate farmers to manage manure in such a way that they tend to exploit its ability to replace fertilizers as much as possible. Therefore additional means-oriented legislation prescribing do’s and don’ts should not be needed. However, legislation in The Netherlands still contains regulations on spreading times (currently: 1 February- 1 September on sandy soils, 15 September on clay soils; as from 2012: 15 February – 1 September on all soil types), on slurry storage capacity (as from 2012: 6-7 months) and on application methods.

NFRVs may seem ambitious as far as the value of slurry in the first year of its application is concerned. However, slurry is applied regularly if not annually and residual N effects of former applications can be added to the first year NFRVs. These residual contributions are logically larger for FYMs and somewhat smaller for anaerobically digested slurries (Figure 4). The studies underpinning the application standards (e.g. Schröder et al., 2009) have implicitly taken account of these long-term NFRVs. The slurry-mineral fertilizer N combinations evolving from these studies have subsequently been translated into application standards for available N (Table 1) using first year instead of long term NFRVs, as farmers and extension services are most familiar with first year NFRVs. Any upward adjustment of NFRVs defaults in future legislation would hence allow a simultaneous upward adjustment of the permitted rates of available N.

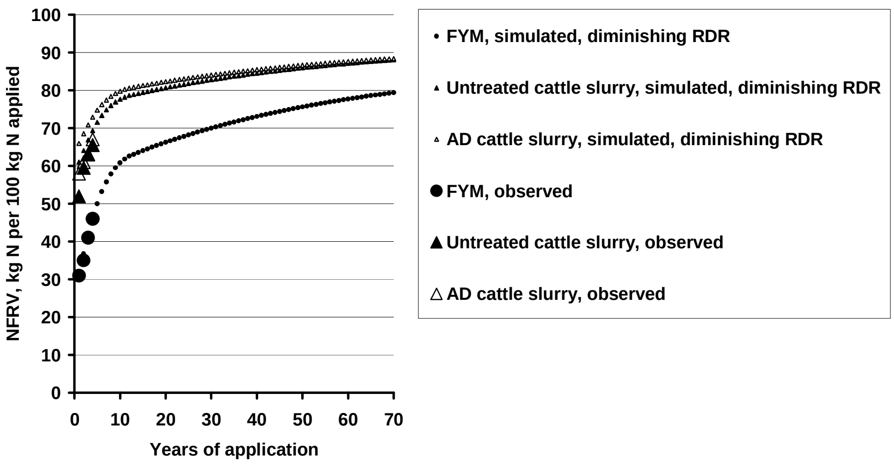

Figure 4. Observed and simulated nitrogen fertilizer replacement value (NFRV) of farm yard manure (FYM), untreated cattle slurry and anaerobically digested (AD) cattle slurry applied to cut grassland, assuming a diminishing relative decomposition rate (RDR) for the organic N in manure, as affected by the number of consecutive applications (Schröder et al., 2007).

R x H: Nutrients recovered in harvests

Finding the proper balance between N and P inputs and outputs is, among other factors, determined by the way the grass is harvested i.e. via cutting or grazing. Ammonia losses from the dung and urine excreted during grazing are lower than the ammonia losses from slurry (Velthof et al., 2009), even when the slurry is injected, implying that less N excrements can be applied to grassland via grazing than via mechanical spreading at a given level of permitted N leaching. Secondly, more crop material is lost due to trampling of grazing animals than during wilting and mechanical harvesting. The net removal of nutrients from grassland is hence less when grazed, implying that less excrements should be applied. Finally, dung and urine are unevenly distributed as a result of which crops utilize the N from these patches less efficiently than N from mechanically spread slurry. This means that per kg N applied, more of it ends up in water bodies under a grazing regime than under a cutting regime. Therefore, more manure and in particular mineral N can be applied to grassland when animals are kept indoors for most of the day (Figure 5). Nevertheless the Dutch government has decided only to extend the permitted mineral fertilizer N rates for zero-grazing farms on sandy soils (Table 2).

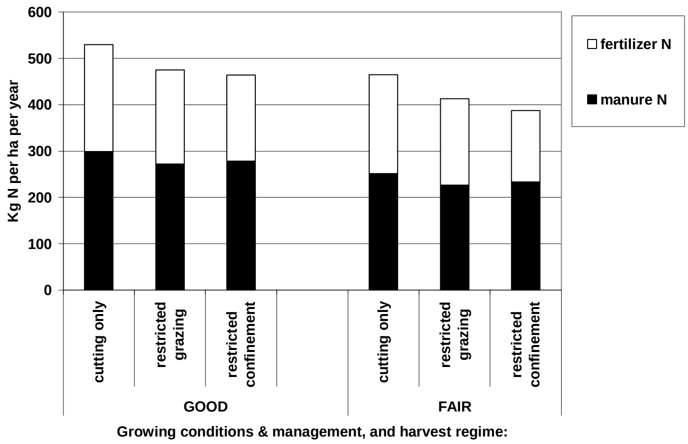

Figure 5. Simulated permissible manure and fertilizer N rates on grassland, as affected by harvest regime (cutting or grazing) and the growing conditions and management (wet sandy soil, conventional slurry composition, P surplus = 0 kg per ha per year, average leaching risk, N concentration target = 11.3 mg per litre (Schröder et al., 2009)).

Conclusion

From the early 1990s dairy farmers in The Netherlands have been confronted with a gradual tightening of legislation, pertaining to the timing and method of fertilizer and manure application and the rates of application. As for these rates, the early legislation required dairy farmers to balance N and P imports (i.e. mainly mineral fertilizer and concentrates) with exports (i.e. milk and meat) so that the surplus per ha would stay below required levels. However, the EU commission did not accept this balance approach, called MINAS, for various reasons including the insufficient improvement of the water quality (Schröder & Neeteson, 2008). National legislation was then as yet tailored to European Directives which, for that matter, were all based on democratic decisions supported by consecutive Dutch governments. Although measures were not at all welcomed by Dutch farmers, they have drastically improved the NFRVs of manures and reduced mineral fertilizer rates accordingly. As a result, the N surplus of dairy farms dropped by an annual rate of circa 7 kg N per ha per year between 1982 and 2005 (Van den Ham et al., 2007). Obviously this has cost money, if not via yield penalties then at least via required investments into equipment or the export of surplus slurry. The quality of water bodies (P, NO_3-N) and air (NH_3-N) has meanwhile improved (Anonymous, 2009), so regulation apparently works. Regionally, however, additional regulations may be needed to achieve environmental targets.

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