Effectiveness of Nitrate Policy in Flanders (1990-2003): Modular Modelling and Response Analysis

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Abstract

The impact of current nitrate policy measures in Flanders is estimated. A modular modelling system has been developed for comparing response and pressure indicators and for decomposing the response impact of policy measures. Compared to 1990, the internalised manure surplus is reduced to zero, whereas the distance to target of the soil surface balance to the water quality standard dropped only with 58%. Source-linked and sink-related measures each account for about the half of the manure surplus reduction. The impact of abatement technologies is minor. The modular approach helps to unravel the discrepancy between pressure and response and to propose policy alternatives.

Keywords: abatement technology, DPSIR scheme, nitrogen pollution reduction

JEL classification: B41; C51; H21; K32

1. Introduction

Comparable to other European regions with similar high livestock densities, Flanders faces a manure surplus problem (EUROSTAT, 2003). Almost simultaneous with the enactment of the European Nitrate Directive, manure policy in Flanders started in 1991 aiming at the reduction of the distance to target of the nitrogen soil surface balance and the improvement of the socially imposed water quality standards (European Council, 1991). This manure policy is mainly based on the instalment of maximum manuring limits, thus restricting the use of manure as a fertiliser. The effect of this internalisation is a nutrient surplus at farm level. When, at the regional level, the total farm-level manure surplus supply exceeds the recycling possibilities as fertiliser, alternative abatements have to be found.

As the local nitrate policy proved not to yield the expected result in the course of the nineties, a so-called three-pillar policy has been adopted. The first pillar is linked to the production of manure as a by-product of livestock production. These source-linked measures imply conventional technological progress (mainly in dairy), livestock decrease, whether or not supported by public buyout measures and efficiency increases (mainly feed composition). The second pillar constitutes of the sink-linked recycling possibilities. These imply an increase of utilised agricultural manure and substituting manure for inorganic fertiliser. Finally the third pillar was drawn on the mere technological abatement, treatment and/or processing. Although this is the most expensive option for surplus reduction, this pillar was expected to account for about half of the surplus reduction.

Manure policy is now in a stage of "mid-term" evaluation and will be re-drawn in 2005. The ongoing political debate, with the policy makers, administrative services and farmers' unions as the main stakeholders, shows there are different perceptions on the effectiveness of past policy measures. In particular, it stays unclear to what extent the policy has been effective and, depending on the answer, on what kind of policy measures the future policy should be based.

The aim of this study is to evaluate, whether, to what extent and which measures have proved to be effective. However, to efficiently perform this kind of policy evaluation, some theoretical and methodological elaborations are necessary. First of all, a clear system analysis is necessary in order to allow differentiating the effectiveness evaluation into a pressure-oriented and the response-oriented component. Next, a modular modelling system to make the system analysis operational proved to be indispensable.

The paper is organised as follows. First, a system analytic description of nutrient flows and their internalisation is given in order to provide a more theoretical basis of the indicators to be estimated (section 2). Next, in section 3, the two used methods to evaluate the nitrate policy are explained: the first compares the response component, nutrient surplus, with the pressure component, distance to target, and the second estimates the impact of each policy response measure. For a flexible operationalisation, MIRANDA (MIRA Nutrient Disposal Area), a modular calculation model, is developed (Sanders et al., 2004). Finally, results of the pressure- and the response-effectiveness are given in section 4 and the response analysis of the various policy measures is given in section 5. Section 6 concludes.

2. System analytic description of nutrient flows and their internalisation

Nutrient flows in agriculture are visualised in figure 1. Inputs to the soil are inorganic fertilisers, manure supply, other organic fertilisers, seeds and planting material, atmospheric nitrogen deposition and biologic N fixation. Manure supply is here interpreted as the net supply: manure production – (export – import) – treatment. Outputs from the soil are harvested crop and fodder production. Total nutrient emission is the difference between inputs and outputs. The soil surface balance is then derived through subtracting ammonia emissions from total nutrient emission. The agricultural balance takes all emissions to soil, water and air into account. For monitoring purposes in Flanders, also the co-products from combustion processes are included (agricultural balance = nutrient emission + combustion co-products).

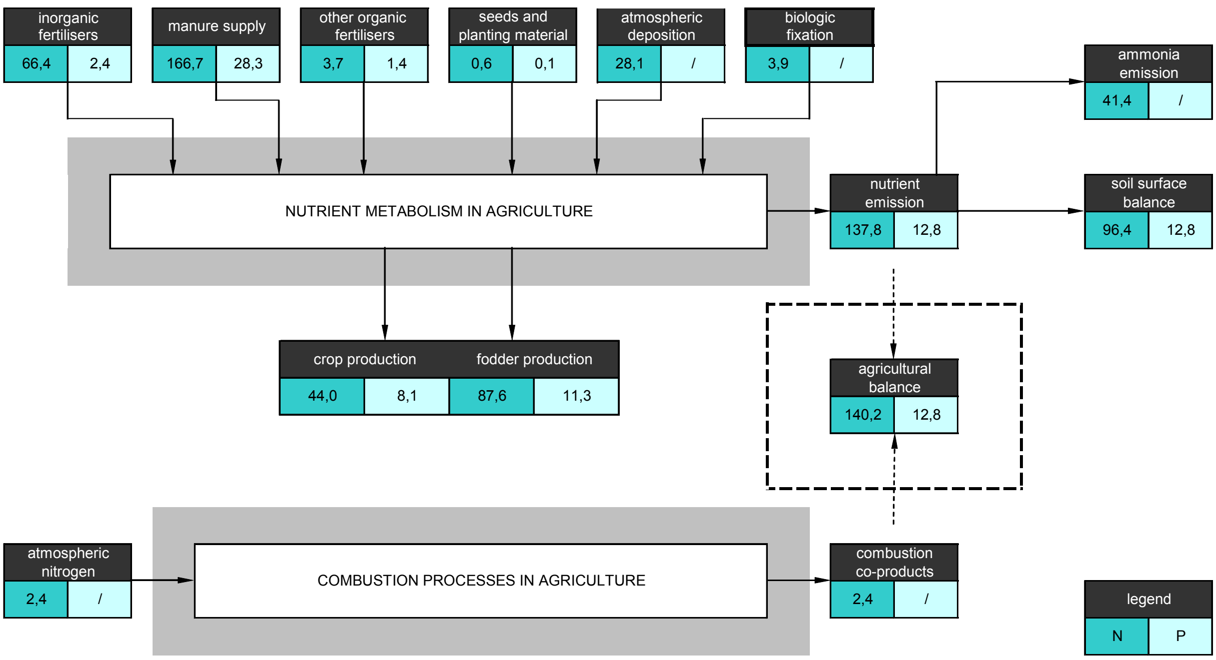

Figure 1. Nitrogen and phosphorus flows in Flemish agriculture in 2003 (million kg).
Source: MIRA, 2004.

Some institutions have a different perception of a soil surface balance for nitrogen, e.g. the EEA (IRENA, 2004) describes a gross nutrient balance that doesn't take into account other organic fertiliser use, seeds and planting materials and ammonia emissions. The OECD nitrogen balance is very similar to the soil surface balance described above (OECD/EUROSTAT, 2003). Also different perceptions and coefficients are used in Flemish institutions for nutrient surplus (MB – CAE) and N production (VMM – CAE – MB).

Another issue is whether to use the pressure oriented 'environmental' point of view or the response oriented 'legal' point of view. The difference between the two arises from the fact the legal standards used for making the surplus explicit, and thus to provide a basis for internalisation, are a simplification of the figure 1 scheme. At the input side only inorganic fertilisers, manure supply and other organic fertilisers are considered. At the output side fertilisation limits are used as a proxy for nutrient removal and ammonia emission is fixed at 15% of livestock N production. Still further simplification is possible by only using manure supply and fertiliser limits for manure. Moreover, simplification also concerns the assumptions on the amount of nutrients produced per livestock unit.

3. Methods to evaluate the nitrate policy

3.1. A modular calculation model

As already shown in the previous section, various perceptions of the nutrient surplus are used. Moreover, technical change, independently or as a result of policy measures, implies changes in assumed parameters of this system. Performing an effectiveness analysis throughout a 14-years period, considering different perceptions of the problem and aiming at the decomposition of the response effectiveness according to the various policy measures, will need an efficient research organisation. This is reached with a modular modelling system.

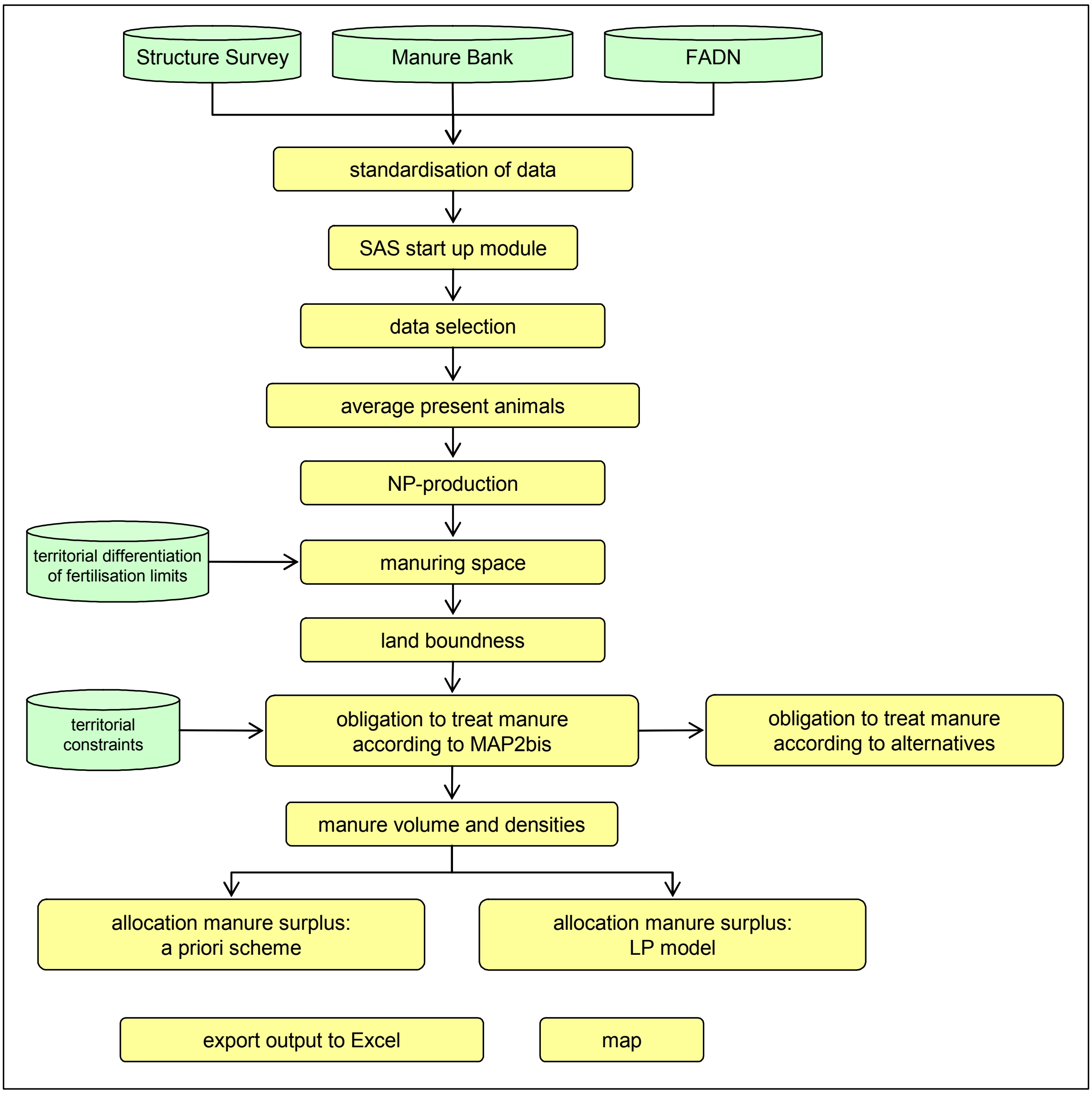

Figure 2. Modular approach of MIRANDA.
Source: Sanders et al, 2004.

All calculations are based on the modular MIRANDA calculation model (MIRA Nutrient Disposal Area, with MIRA standing for the Flemish environmental monitoring agency) (Sanders et al, 2004). It is developed to estimate the nutrient surplus with a combinatorial high number of assumptions. The following parameters can be chosen and filled in with a set of assumptions:

- livestock nutrient excretion coefficients;
- percentage of ammonia emission;
- manuring limits;
- degree of manure-inorganic fertiliser substitution;
- command-and-control measures, such as obliged manure treatment;
- etc.

Accounting for this assumptions' re-combination has been made possible with a modular elaboration of the model presented schematically in figure 2. The basic components of the system analytic scheme are not monitored as such but have to be calculated and grouped into certain categories: livestock (average present animals per year) and cropping plan (ha).

3.2. Assumptions for comparing the P and R indicator

The pressure indicator is the distance to target or, in other words, the distance between the soil surface balance and an amount of permitted nitrogen leakage that corresponds with internationally accepted water quality standards. As described in section 2, this is the soil surface balance minus the maximum amount of nitrogen that may be emitted from the soil to water in order to comply with water quality objectives (70 kg N/ha).

The nutrient surplus (response indicator) is calculated for three years (1990, 1999 and 2003) according to assumptions for some important components of the modular model, as described in table 1. Also the amount of manure obliged to be treated is derived for those years according to the original Manure Law and according to recent adaptations. In Flanders, a farm must treat its manure surplus when it produced more than 7500 kg phosphate in the year 1997 and when it is located in a municipality with a phosphate production pressure higher than 100 kg P_2O_5 per ha.

Table 1. Assumptions according to the modular approach of MIRANDA.

Components MIRANDA	**Assumptions**
Livestock	livestock numbers of the NIS Census converted to average present animals (APA)
Cropping area	areas of the NIS Census calibrated with Manure Bank registrations
Excretion coefficients	statutory excretion coefficients (MAP2bis) with juridical proved feed efficiency progress, without the potential feed efficiency progress for cattle
Ammonia emission	juridical ammonia loss: 15% of the nitrogen excreted
Manuring limits	juridical manuring limits used at that time (1990: Nitrate Directive assumption; 1999: "MAP2bis; 2003: MAP2bis taking vulnerable area and derogation into account)
MIRANDA procedure:	
- at farm level	with acceptation degree of 100%
- aggregated	without acceptation degree, but with compensation of the aggregation error by only using 95% of the total manuring space

3.3. Basic assumptions for the response impact analysis

For calculating the nitrogen surplus for the response impact analysis, the assumptions for 1990 are kept the same and one by one the evolution is introduced of the driving factors (D) on which a response measure (R) is active.

For this purpose MIRANDA is used at aggregated level, so the nitrogen surplus is calculated as the livestock nitrogen production decreased with 95% of the derived manuring space.

The D indicators that are introduced successively in the calculation model can be grouped according to the three pillars of the so-called three-pillar policy for manure. The data for the third pillar (new abatement technologies), however, are not calculated with MIRANDA, but received directly from the Manure Bank.

Pillar 1: Source related measures (related to production of manure):

- run 1: evolution of animals with production quota and breeding (milk and suckle cows, cattle for breeding less than 2 years old and boars) to show the effect of technologic progress in livestock production;
- run 2: evolution of total livestock;
- run 3: progress in feed efficiency;
- run 4: potential progress in feed efficiency for cattle (not scientifically proved, but used as such by the legislator).

Pillar 2: Sink related measures (concerning the recycling of manure as fertiliser for crop and fodder production):

- run 5: evolution of the total agricultural area;
- run 6: 54% not-vulnerable area of the total agricultural area, where higher manuring limits are allowed;
- run 7: derogation: under certain conditions it is possible to use higher manuring limits in vulnerable areas.

Pillar 3: New abatement technologies:

- net export of manure;
- manure treatment.

For the reference run the nitrogen surplus of 1990 is calculated with the following assumptions:

- the number of average present animals in 1990;
- no feed efficiency improvements;
- no potential feed efficiency progress for cattle of 12% nitrogen;
- the area of 1990;
- (severe) manuring limits based on the objectives of the Flemish Environmental Policy Plan 2003-2007 (2003): 170 kg N/ha.

For the first run the evolution (1990-2003) of the number of breeding animals and animals with production quota is introduced to the reference run. Other driving factors (number of animals, feed efficiency progress, potential feed efficiency progress for cattle, area, and manuring limits) are kept the same. For run 2 the evolution of the other animals is added, while feed efficiency progress, potential feed efficiency progress for cattle, area and manuring limits stay the same as for run 1 and the reference. Runs 3 to 8 are elaborated analogous.

The used manuring limits are shown in table 2. The limits used for run 7, are the ones now used by the legislator.

Table 2. Manuring limits used for the different runs.

	Manuring limit (kg N/ha)			
	Grassland	Maize	Crops with low N need	Other crops
Reference	170	170	170	170
Run 1: Technological progress	170	170	170	170
Run 2: Livestock evolution	170	170	170	170
Run 3: Progress in feed efficiency	170	170	170	170
Run 4: Potential progress in feed efficiency for cattle	170	170	170	170
Run 5: Area evolution	170	170	170	170
Run 6: Vulnerable area (46%)	170	170	125	170
Not-vulnerable area (54%)	250	250	125	200
Run 7: Derogation for vulnerable areas (46%)	230	230	125	200/170*
Not-vulnerable area (54%)	250	250	125	200

Source: Flemish Manure Law.

* For derogation the 'Other crops' are split up in two groups: winter wheat, sugar beets, fodder beets and Brussels sprouts have a manuring limit of 170 kg N/ha, other 'Other crops' have a limit of 200 kg N/ha.

4. Comparison between environmental pressure and internalisation

For the three years 1990, 1999 and 2003, four indicators are calculated (Figure 3 and table 3):

- the manure surplus according to the MIRANDA procedure at farm level;
- the manure surplus according to the aggregated MIRANDA procedure;
- the amount of manure obliged to be treated according to the original Manure Law of 1991;
- the amount of manure obliged to be treated according to the recently adapted Manure Law of 2003.

These results are compared to the distance to target. Also soil surface balance and agricultural balance are shown, calculated according to figure 1. In 1995 the balances are higher than would be expected from the prevailing trend due to a higher inorganic fertiliser use (9,8% higher) while nutrient exportation through crop removal was 4,5% lower than the year before.

Both nutrient surplus and distance to target decrease dramatically. However, there is a systematic discrepancy between the two: while the nutrient surplus is – 0,2 million kg N in 2003, the distance to target is still 51,9 million kg N. The most important reasons for this are:

- the difference between the actual excretion by cattle (without the potential feed efficiency progress for cattle) and the excretion according to the Manure Law (with potential feed efficiency progress for cattle);
- the insufficiently enforced substitution between inorganic fertiliser use and manuring;
- and, the presence of some inputs that are difficult to be submitted to policy measures (atmospheric nitrogen deposition, nitrogen fixation).

The nutrient surplus decreases to nil. However, there is no longer a nitrogen surplus at the Flemish level, a large part of the produced manure is obliged to be treated: 19 million kg N according to the original law, 15 million kg N according to recent adaptations.

Based on the aggregated procedure of the used calculation model, the nitrogen surplus in 2004 is estimated to be - 4,4 million kg N. This is a rather conservative estimate, given that the aggregated calculation procedure slightly overestimates compared to the procedure at farm level.

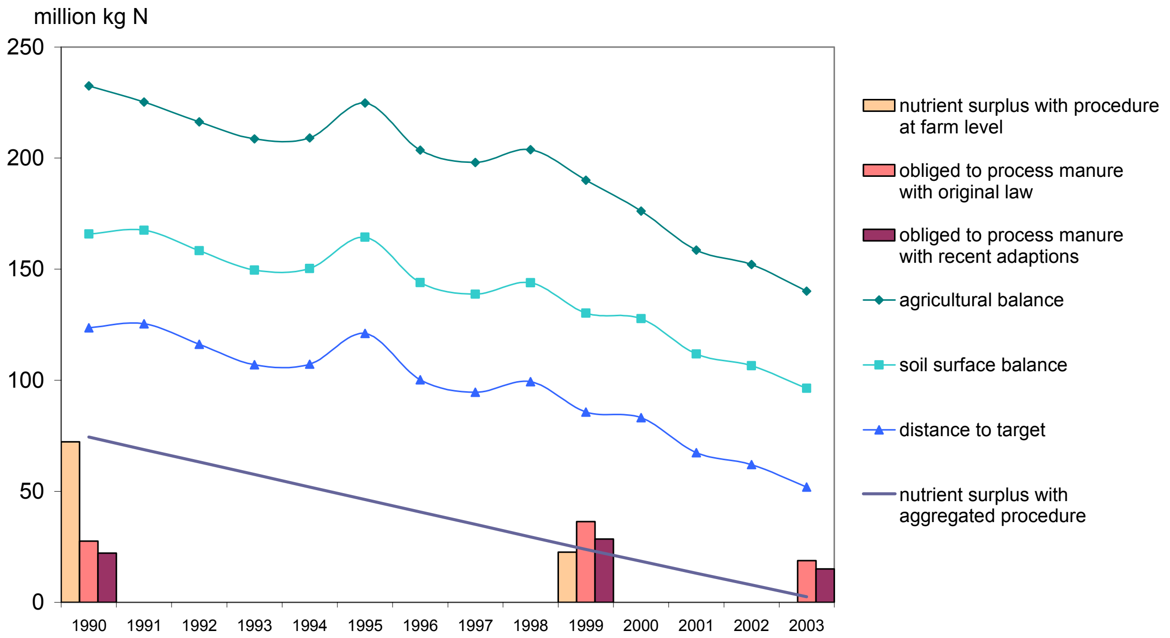

Figure 3. Nutrient surplus (including the amount of manure obliged to be processed) in 1990, 1999 and 2003 and comparison with the distance to target.
Source: NIS and own MIRANDA calculations, see also Vervaet et al, 2004.

Table 3. Results for 1990, 1999 en 2003.

		N (ton)	
	1990	**1999**	**2003**
Supply of manure (= livestock N production – statutory ammonia loss of 15%)	171.976	166.831	139.076
Manuring space	102.662	150.527	143.710
Manure obliged to be treated			
according to the original Manure Law of 1991	27.582	36.384	18.778
according to the recently adapted Manure Law of 2003	22.215	28.509	15.019
Manure surplus			
according to the aggregated procedure	74.446	23.830	2.552
according to the procedure at farm level	72.248	22.668	-222
Agricultural balance	232.445	190.044	140.133
Soil surface balance	165.883	130.254	96.378
Distance to target	123.610	85.701	51.933

Source: NIS and own MIRANDA calculations, see also Vervaet et al, 2004.

5. Impact analysis of response measures

The results of the 7 runs and the Manure Bank data on manure import, export and treatment can be brought together in one graph (Figure 4). The order of the runs and their assumptions are chosen in a way that the calculated nitrogen surplus is lower than the one in the previous run. This doesn't apply from 1993 to 1999 for run 2 (evolution of the livestock). In this period livestock numbers increased spectacularly, which countered the positive effect of technological progress (run 1). Starting from the year 2000, feed efficiency improvements have been taken into account, which is clearly visible in figure 4.

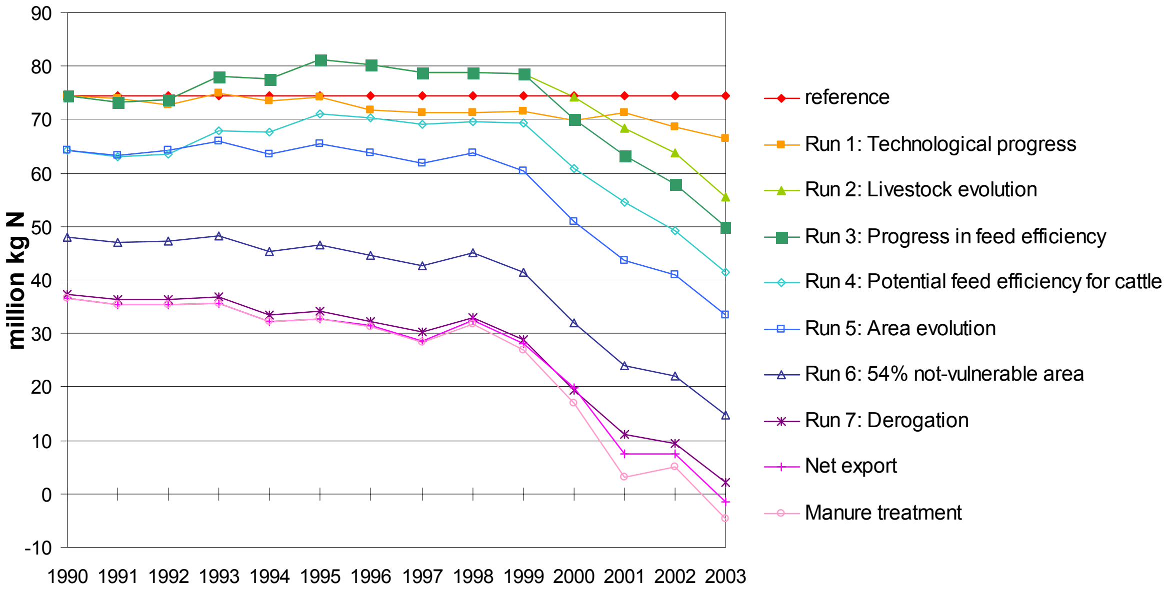

Figure 4. Nitrogen surplus according to the different basic principles (million kg N).
Source: NIS and own MIRANDA calculations, see also Vervaet et al, 2004.

Table 4 lists the impact of each component in 2003 on the referential nitrogen surplus (74,4 million kg N) of 1990. The nitrogen surplus is completely reduced and is even negative: - 4,6 million kg N 'surplus' in 2003 compared to the referential year 1990. Or, the nitrogen surplus in 1990 has been reduced with 6,1% too much in 2003.

Table 4. Impact on the nitrogen surplus of each component in 2003.

	Percentage of the nitrogen surplus in 1990	**Absolute decrease of the nitrogen surplus (tonnes N)**
Technological progress	10,9	8.104
Livestock evolution	14,7	10.910
Progress in feed efficiency	7,5	5.588
Potential progress in feed efficiency for cattle	11,1	8.296
Area increase	10,8	8.006
54% not-vulnerable area	25,3	18.859
Derogation	16,9	12.582
Net export of manure	4,7	3.527
Manure treatment	4,2	3.146
TOTAL	106,1	79.018

Source: NIS and own MIRANDA calculations, see also Vervaet et al, 2004.

With the agricultural structure of 1990 and the manuring limit of the EU Nitrate Directive (170 kg N/ha) there would be a manure surplus of 74,4 million kg N. When this is used as a reference base for the three-pillar nitrate policy in Flanders, the manure surplus should be reduced with source related measures (25%), sink related measures (25%) and new abatement technologies (50%) (Figure 5).

The surplus has been eliminated in 2003, but not according to the postulated percentages. The first pillar had an impact of 32,9 million kg N or 44% (of 74,4 million kg N surplus), the second had an impact of 39,4 million kg N or 53% and the third of 8,9 million kg N or 9%. The third pillar, manure treatment and export, should have had the greatest impact (50%), but have the smallest (9%).

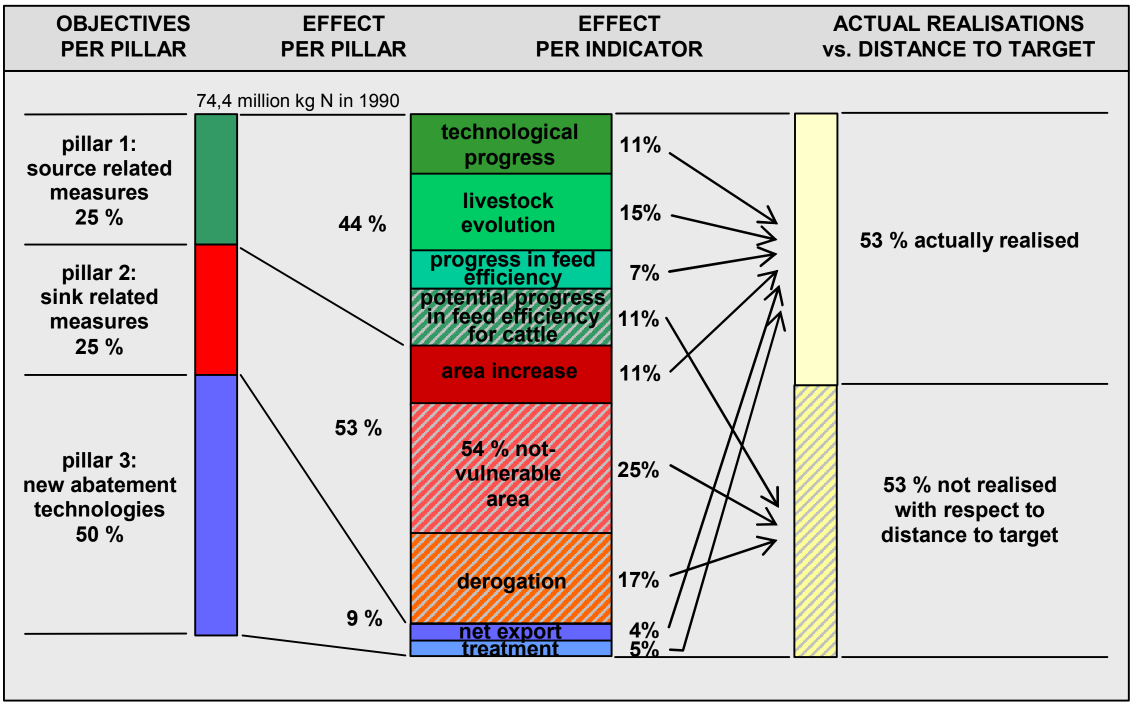

Figure 5: Effects of the nitrate policy in 2003.

Source: NIS and own MIRANDA calculations, see also Vervaet et al, 2004.

Figure 5 also clearly demonstrates what kind of policy measures that helped to resolve the internalised nitrogen surplus problem, but weren't effective for improving the nitrogen soil surface balance. On the one hand, the nitrogen surplus has been reduced with 79,0 million kg N and it would be possible to produce 4,6 million kg N more than produced in 2003. On the other hand, some measures did have an effect on the nutrient surplus (R), but did not decrease the soil surface balance and distance to target (P). For example, the potential feed efficiency progress for cattle (run 4) that causes the calculated nitrogen surplus to decrease, is statutory presupposed, but is not scientifically proved. Also allowing more manuring per hectare by increasing manuring limits (run 6 and 7), does not affect the pressure indicator. The measures without impact on the distance to target are shaded in figure 5.

Concluding, half of the reduced manure surplus is realised through technological progress, decrease of livestock numbers, feed efficiency progress, area increase, manure treatment and export (not shaded). The other half, however, has been "realised" by assuming efficiency progress (feed efficiency progress for cattle and substitution of inorganic fertilisers and manure), which is not effective for the soil surface balance (shaded).

6. Conclusions

The study reports a mid term evaluation of Flemish nitrate policy, but besides the local relevance of some results, some conclusions on methods and policy can be generalised.

The CAE publication concerning the Flemish three-pillar manure policy describes the methodology and results of this analysis more in detail (Vervaet et al., 2004).

Making the nitrogen flows explicit, supported with a sound system analysis and a flexible modular modelling system, allows for a clear conceptual and quantitative distinction between the distance to target (or "surplus" from the ecological point of view) and the manure surplus (the surplus from the farm level, internalised point of view).This inevitably will decrease the information asymmetry, which is now responsible for controversy in the policy debate. Here, in the case of

Flanders, the aggregate impact of policy measures is to be considered to have reached its objectives in full with respect to the internalised manure surplus, but the distance-to-target reduction is still only halfway. This means that the policy was not effective from the ecological point of view. Policy makers now have to search for other internalisation mechanisms.

The study also makes clear that, although the Flemish nitrate policy has succeeded to eliminate the manure surplus, this didn't happen according to the originally postulated shares of the three pillars; 44-53-9 in stead of 25-25-50. Partly due to the success of the first pillar, some incoherence between the pillars arises. Because of the obligation to treat manure, there is still 15 million kg N that must be treated, while there is no longer a manure surplus. When this amount would be actually treated, there would be less manure recycled and thus extra demand for inorganic fertiliser use. This is in conflict with the second pillar, searching for a better substitution of inorganic fertilisers with manure. Moreover, extra nutrient recycling possibilities imply that extra animal places are possible, which is in contradiction with the 'buy out' policy.

The modular research elaboration also helped to identify those policy measures that have proved to be successful in solving the internalised nutrient problem, but without impact on the environmental pressure indicator, namely the distance from the soil surface balance and the water quality target. Not only, as discussed above, information asymmetry between stakeholders may disappear. This will be necessary when conventional paradigms on nitrogen reduction have to be replaced by new strategies. In the case of Flanders, when policy makers want to continue reducing the distance to target, which is still 52 million kg N, the incoherence of the currently used policy measures should be taken into account.

A correct internalisation will create a new manure surplus that will need to be reduced. Ideally, manuring and fertilisation limits should be replaced by nutrient emission limits, that is 70 kg/ha for nitrogen. For this to happen, it is necessary to monitor nutrient flows at farm level with a nutrient account. However, experiences in the Netherlands show that this is not that evident. Nevertheless, when looking to the current policy measures more in detail, the attention should be more focussed on efficiency increases, based on feed efficiency progress and a better substitution of inorganic fertilisers and manure. Even when such an overall efficiency-improving instrument is not possible (for whatever reason), it remains essential to strengthen manuring limits. This is, however, risky from both economic and environmental point of view. Therefore, a simple use of the 170 kg N/ha limit without an economic-ecological optimisation should be avoided. Economic optimisation would become too restricted, and, the risk occurs that the low manuring limit will increase the use of inorganic fertilisers, which is not wanted from ecological point of view either.

Another spin-off of the flexible and transparent method is the accessibility of the nutrient balance and related indicators for several stakeholders in the policy debate, each with different perceptions of reality. Also here the modularity of the modelling system proved to be indispensable. At national and international level, several institutions derive nitrogen related indicators, but often with highly divergent results. It is important for them to communicate efficiently in order to avoid biases.

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