How to Meet the EC-Nitrate Directive in Dutch Vegetable Growing?

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Abstract

To improve nutrient management in Dutch practice, in 2002 a project was started with 33 commercial farms including 9 vegetable farms. Farm-specific fertilization strategies were developed and tested. Nitrogen (N) and phosphorous balances were calculated and soil mineral N content in autumn and nitrate concentration in the ground water were measured. The project was supported by model farm calculations focusing on development of cost-effective sets of measures to improve nutrient management. Results show that on many participating vegetable farms a fertilizer strategy consisting of conventional measures (following recommendations, type and amount of manure, N side dress systems, catch crops) is not sufficient to meet the EC Nitrate directive. Model farm calculations show that extra, less conventional measures, like removal of crop residues or less intensive cropping systems are required. However, this strongly increases costs.

INTRODUCTION

In the Netherlands specialized vegetable farms are characterized by intensive cropping systems. This leads to high nitrogen (N) inputs increasing the risks of nitrate leaching. To reduce leaching N management must be improved. Therefore, in 2000 the Dutch project “Farming for the Future” was started with 33 participating commercial arable and horticultural farms including 9 vegetable farms (Neeteson et al., 2001). The project aims to be a stimulus in on-farm development of sustainable farming systems with emphasis on nutrient utilization. A main question was how to meet current Dutch mineral legislation and also to explore, if groundwater quality would necessitate even stricter rules, which additional measures should be taken by growers. Also other environmental issues like ammonia emission, energy and water use were followed.

To support this project in 2002 a desk study was started focusing on the development of cost-effective packages of measures to improve nutrient utilization. This was done by designing various model farms which were considered representative for the sector.

MATERIALS AND METHODS

Practical Farms

In this paper we present data of the two groups of vegetable farms, located on sandy soils in two vegetable growing areas in the southern part of the Netherlands. Farm characteristics are shown in Table 1. Two farms in the South-West group are specialized in strawberries, for the remaining two farms spinach is the main crop. On the farms in the South-East group predominantly leaf crops are grown like broccoli, leeks, endive, celeriac and Chinese cabbage. Except for the strawberry farms cropping ratio, defined as the ratio of total cropped area and total farm area, is higher than 1 indicating that more than one crop is grown per year.

Based on the registration data (2000-2002) of the farmer a complete N balance on farm level was calculated. Inputs include manure, mineral fertilizers, deposition and plant material like cover straw (strawberry farms), outputs concern harvested products. Deposition levels were derived from regional measurements by the Dutch national institute RIVM. Fixed N-concentrations in harvested products based on literature data

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were multiplied with the measured yields to assess N-removal.

In addition to total N input, effective (i.e. plant available) N input from manure and mineral fertilizers was calculated. Effective N input from manure, expressed as percentage from total N, is derived from current recommendations taking into account N content (especially ratio mineral and organic N), type of manure, application time and method and the N uptake period of the crop. For mineral fertilizers an effective N supply of 100% is assumed.

In the summer of 2002 and 2003 nitrate-concentration in the upper 1 m of the groundwater was measured on each farm by the institute RIVM. In addition, at field level mineral nitrogen content in the soil profile (SMN) at harvest (0-0.6 m) and in autumn (0-0.9 m) was assessed. With these data the effects of farm type and fertilisation strategy on N surplus, SMN at harvest/autumn and nitrate concentration in groundwater could be established.

Project Targets

Participating farmers were asked to comply with the following standards on a farm level:

- Total N input from manure and mineral fertiliser ≤ 225 kg N ha^{-1}. This standard was based on current Dutch mineral legislation (target levels 2003 for dry sandy soils).
- N surplus (complete balance) ≤ 90 kg N ha^{-1}
- Soil mineral N content in autumn ≤ 45 kg N ha^{-1} (0-0.9 m)

Fertilisation Strategies

To achieve project targets farm-specific fertilisation strategies were developed and tested. At first, measures to improve N utilization were identified and, subsequently, they were assorted in a priority sequence (Table 2). As vegetable growers tend to give more N than recommended in order to avoid risks, following the national recommendations is considered as the first measure to be taken when inputs have to be reduced. Subsequently manure type and amount are chosen based on crop demand, organic matter requirement and mineral legislation. In addition mineral fertilizer rates are assessed, based on balance sheet calculations taking into account contributions of various N sources (soil mineral N before planting, effective N input from manure and crop residues). Nitrogen utilization is further improved by measurement of the N status of plant and soil, like the Dutch Nitrogen Budget System (NBS). In this system at regular intervals during the growing period nitrogen content in the soil is measured and, if necessary, supplemented to a target level which depends on crop and crop stage. In addition, measures like placement (for example row application) and type of fertilizer (for example application of ammonium-based fertilisers in late harvested crops) can be taken. If possible, post-harvest measures like growing of catch crops but also less conventional measures like removal of crop residues can be considered. Finally, if the above mentioned measures are not sufficient, adjusting the farms' crop composition (less crops with high N demand, lower cropping ratio) can be necessary.

Model Farms

For vegetable growing on sandy soils three (virtual) model farms were designed (Table 3) (Van der Schoot et al., 2004). Farm 1 and 2 are characterized by intensive growing of leaf vegetables with a cropping ratio of 1.65 and 1.38 respectively. Farm 3 is less intensive (cropping ratio = 1) and is mainly based on a combination of leek and strawberry.

For each model farm a basic fertilization strategy was conducted assuming "Good Agricultural Practice (GAP)". This means that crops are fertilized according to current recommendations. Pig manure, applied in the spring (effective N supply is 70% of total N), is used as organic manure at a level of maximum of 70-80% of crop N demand but not exceeding mineral legislation levels. No efficiency improving fertilization measures (like N side dress systems) are taken and no catch crops are grown. Subsequently, the effectiveness of several additional measures (Table 3) to reduce the nutrient surpluses and their effect on revenues was quantified. For the N surplus the same target level was used as for the practical farms, e.g. 90 kg N ha^{-1}.

RESULTS AND DISCUSSION

Practical Farms

In this paper we focus on the results of 2002 being the most recent year with a complete dataset. Moreover, it may be expected that at that moment the attitude of the participating farmers will be more affected by the project than in the first years.

In 2002 on five of the nine farms total nitrogen input with organic and mineral fertilizers exceeded the 2003-standard for Dutch mineral legislation (Fig. 1). On farms Vg02, Vg03 and Vg10 this is mainly due to the use of relatively large amounts of composts characterized by a low effective N input. This was done to increase organic matter content and, in addition, to reduce heterogeneity of fields. It can be discussed whether such amounts are really necessary, since organic matter supply with crop residues (including press pots used at planting) is generally high on vegetable farms. However, on other farms a strong reduction of N input (Vg07 and Vg08) was realised. For example on Vg07, specialised on endive, this was done by decreasing the input from organic sources combined with the application of the NBS-system reducing the input from mineral fertilizers.

On the farms specialised on strawberries (Vg01 and Vg04) and leek (Vg10) effective N input exceeds recommended levels (Fig. 2). The other farms follow on average recommendations or even fertilise below it. The latter is mainly observed for second crops which can benefit from residues of the preceding crop. On the other hand, late harvested or winter crops are often fertilized above recommendations as risks for N losses are greater than for early harvested crops. For some crops, like strawberries, farmers are doubtful about current recommendations often argued by a higher supposed N demand due to increased yield levels. Finally, besides crop differences, also a risk-avoiding attitude of the farmer plays a role.

Fig. 3 shows the complete N balance. Generally, N output with harvested product is quite low, varying from 25-120 kg N ha^{-1}. Combined with the high N input this results in high N surpluses. Only Vg07 and Vg08 were (almost) able to meet the project standard (< 90 kg ha^{-1}). The other farms realise surpluses ranging from 200 to 400 kg N ha^{-1}. This indicates that following N recommendations is far from sufficient to reduce surpluses to an acceptable level.

As a consequence, on all but one farm SMN in autumn exceeds strongly the project standard of 45 kg N ha^{-1} (Fig. 4). It is therefore not surprising that only at one farm (Vg04) the measured nitrate concentration in the groundwater was below the EC-standard of 11.3 mg N L^{-1}. Finally, Fig. 5 shows that the relation between SMN in autumn 2002 and the nitrate concentration of the groundwater in the succeeding year 2003 is weak (r^2 = 0.20). Nitrate concentration in the groundwater showed no better relation with total N-input or N-surplus. The best relation was found with effective N input (r^2 = 0.40). It must be remarked, that manure history does probably also influence nitrate leaching.

Model Farms

For the model farms three sets of measures were evaluated. The first one concerns the reference strategy (see “Material & Methods”). Set 2 consists of ‘acceptable’ measures like decreasing pig manure rate, substituting pig manure by dairy manure or even composts (if required from the point of view of organic matter supply), applying N side dress systems (NBS) and growing catch crops. When applying the NBS system we assumed that N input can be decreased with 10 and 20% for first and second crops without effects on yield. For catch crops N uptake was assumed to be 100, 80 and 40 kg N ha^{-1} when sown before 15/8, 1/9 and 15/9 respectively. Effective N input from catch crop residues was estimated on 50%. Finally, for set 3 a less conventional measure, e.g.

removal of crop residues, is added.

Fig. 6 shows the N surplus of the model farms for the three sets. For set 1 (reference strategy) N surpluses are comparable (179-181 kg N ha^{-1}). Applying ‘acceptable’ measures (set 2) decreases N surplus with 48-66 kg N ha^{-1}, however, still exceeding the target level of 90 kg N ha^{-1}. The costs increase (Fig. 7) as cheap pig manure is substituted by mineral fertilizer or, if necessary by composts. In addition, extra costs are made for soil sampling and sowing of catch crops. The increased costs are not compensated by a reduced fertilizer input. Addition of a less acceptable measure like removal of crop residues is required to realize a further decrease of N surplus (set 3). However, this strongly increases costs. Moreover, N losses from crop residues are transposed from the vegetable farm to other locations. A more sustainable solution could be composting crop residues and re-use them on the farm. However, environmental gain on a farm level will be lower, as utilization of N from compost is generally low.

CONCLUSIONS

Results show that on many farms a fertilizer strategy consisting of conventional measures is not sufficient to meet the EC Nitrate directive. Main reasons are the intensive cropping system, the relatively large amount of N left in crop residues and the wish of growers to maintain a high organic matter content of the soil. Model farm calculations show that extra, less conventional, measures like removal of crop residues or less intensive cropping systems are required. This strongly increases costs.

Literature Cited

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Tables

Table 1. Characteristics of the participating vegetable farms: farm size, cropped area and the main crops grown as a percentage of the total cropped area for the year 2002 (underlined percentages refer to crops which were double-cropped).

	South-West				South-East				
	Vg01	Vg02	Vg03	Vg04	Vg06	Vg07	Vg08	Vg09	Vg10
Total area (ha)	9.2	9.8	5.2	7.9	16.5	22.0	6.2	12.3	18.4
Total cropped area (ha)	9.2	15.0	12.2	6.8	19.2	39.2	6.4	21.6	18.4
Cropping ratio[1]	1	1.53	2.22	0.86	1.16	1.78	1.03	1.76	1
Contribution crops (%)									
- Strawberry	100			100					
- Spinach		<u>54</u>	<u>42</u>						
- Lollo rossa		27							
- Leeks			<u>23</u>		20	7		25	53
- Chinese cabbage			14		5		35	26	
- Broccoli					<u>28</u>			<u>43</u>	
- Endive						<u>93</u>	<u>28</u>		
- Celeriac									39
- Asparagus					13				
- Potatoes					20				
- Other/fallow		19	21		14		37	6	8

[1]Ratio total cropped area : total farm area

Table 2. Measures to improve N utilization.

1	Following recommendations
2	Manure
	- Type, amount, time and application time
3	Supplementary mineral fertilizer
	- Amount
	* based on balance sheet calculations
	* based on soil and plant analysis
	- Timing, placement and type
4	Post-harvest measures
	- Catch crops
	- Crop residue management (incorporation time, removing crop residues)
5	Crop rotation/cropping system

Table 3. Crop composition model farms representing vegetable growing on sandy soil.

Crop	Relative contribution (%)		
	Farm 1	Farm 2	Farm 3
Leek	33	62.5	47.5
Head lettuce (2 crops)	33		
Spinach (2 crops)	33		
Broccoli (2 crops)		12.5	
Carrots (2 crops)		12.5	
Endive (2 crops)		12.5	
Strawberries			47.5
Asparagus			5

Figures

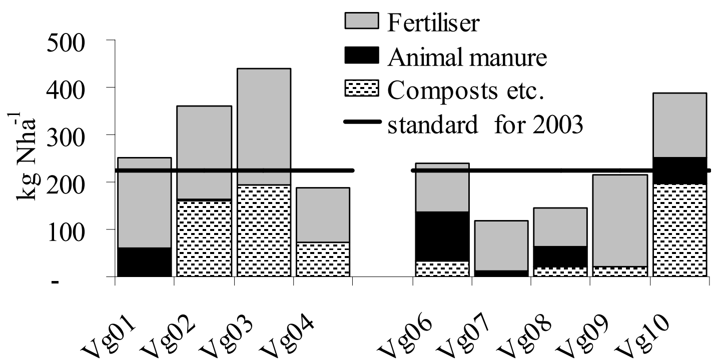

Fig. 1. N input with manure and mineral fertilizers on a farm level in 2002 (practical farms).

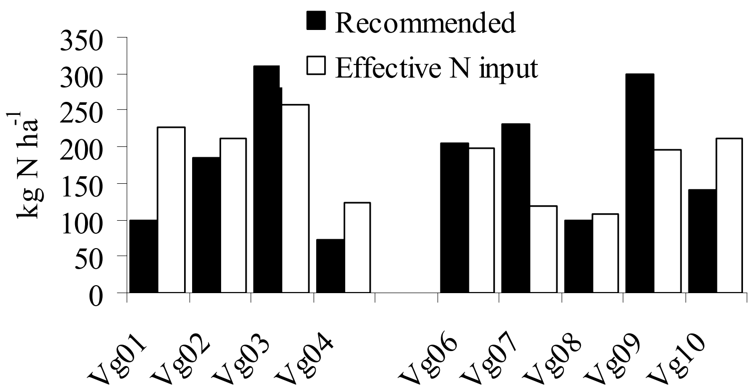

Fig. 2. Realized effective N input compared with recommended N in 2002 (farm level, practical farms).

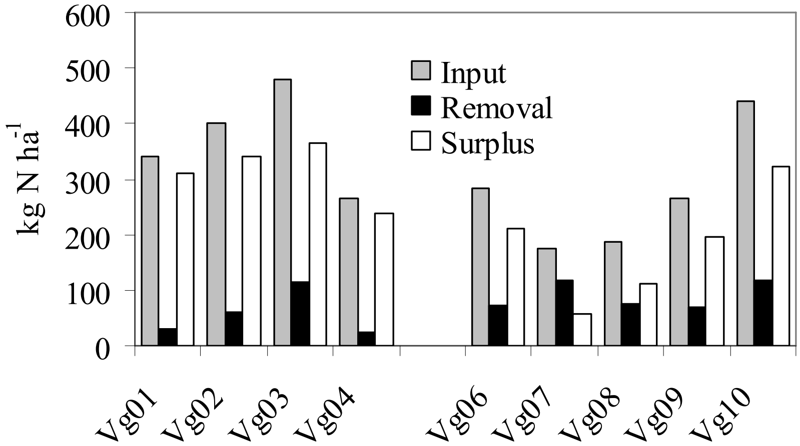

Fig. 3. Total N input (including deposition, plant material, etc.), output (removal with harvested products) and surplus in 2002 (farm level, practical farms).

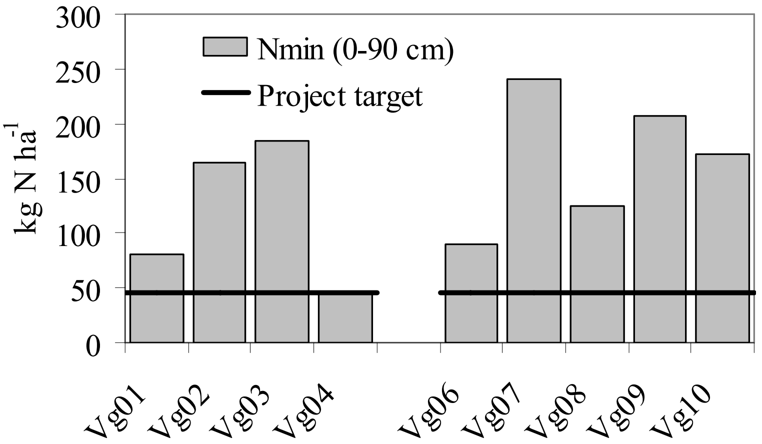

Fig. 4. Soil mineral N content (0-0.90 m) in autumn in 2002 (farm level, practical farms).

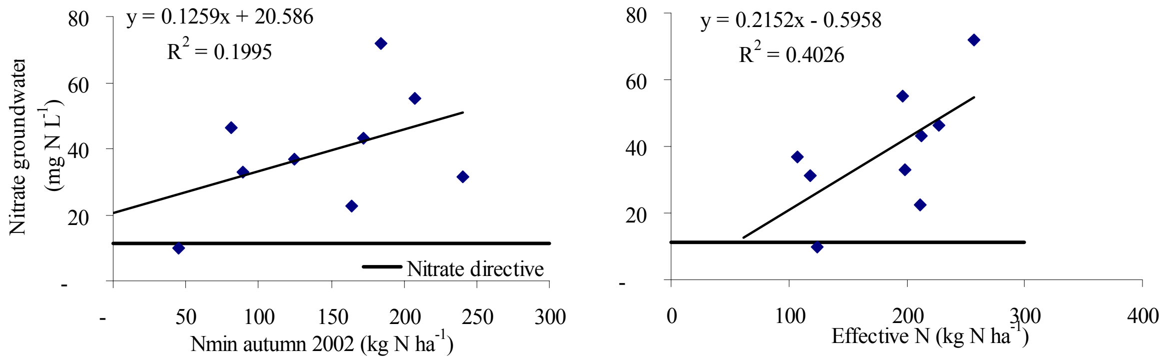

Fig. 5. The relationship between nitrate concentration in groundwater (2003) and soil mineral N (0-0.9 m) (left) and with input of effective N (right) both in 2002.

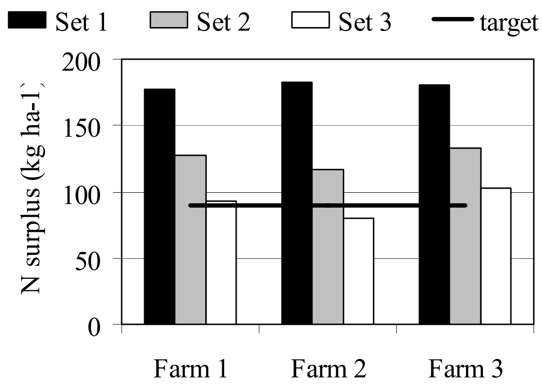

Fig. 6. N surplus (including deposition and plant material, kg ha^{-1}) on the model farms for three sets of measures (set 1 = GAP, set 2 = 'acceptable' measures, set 3 = less acceptable measures).

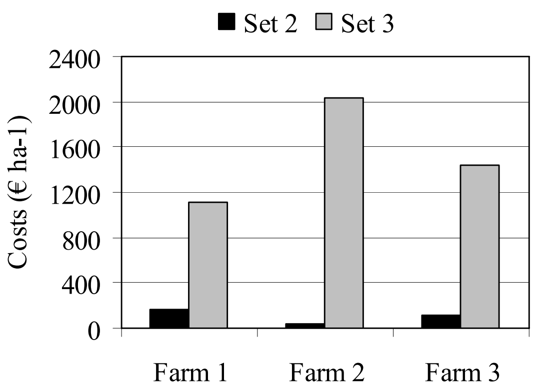

Fig. 7. Extra costs (€ ha^{-1}) of sets of measures 2 and 3 compared to set 1 on the model farms.