Effects Of The EU Nitrate Directive for the Dutch Agricultural Sector: an Application of a Regional Model of Dutch Agriculture Based on Positive Mathematical Programming

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Abstract

This paper applies the Dutch Regionalized Agricultural Model (DRAM) to analyze the effects of Dutch manure and nutrients policies of 2004 for the Dutch agricultural sector and economy as compared to a base of 1996. DRAM can be characterized as a regionalised, environmental, partial equilibrium, mathematical programming model of Dutch agriculture. The model combines the technical detail, including technology options available to farmers in different regions of the Netherlands, of mathematical programming farm models with some market effects at agricultural industry level e.g. land and manure markets. Moreover the mathematical programming model is linked to a mixed input-output model to analyze economy wide effects of changes in Dutch agriculture. A special feature of DRAM is the explicit modeling of manure markets. It is found that through increased manure prices, manure policies specially affects production and profits in the beef and pigs and poultry sectors.

Key words: Positive Mathematical Programming, agriculture, regions, manure markets, manure policies.

1. Introduction

Especially in the Netherlands the future development of the agricultural sector is highly dependent on the EU Nitrates Directive (EC/91/676) and its translation in national manure and nutrients policies. The Nitrates Directive aims to reduce and prevent pollution of surface waters and groundwater by nitrates from agricultural sources, particularly livestock manure and mineral fertilizers. Problems of manure and nutrients surpluses in the Netherlands, especially at livestock farms, are explained by the high intensity of agricultural production and farm and

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regional specialization. In the Netherlands livestock production is concentrated at specialized livestock farms. These farm types are especially concentrated in the sand regions in the south and east. Crop production is concentrated in the clay regions in the north and southwest of the Netherlands. Production in both cattle farming and the intensive livestock industry is largely based on imported concentrates from outside the EU at relatively low prices compared to prices for EU produced feed grains. As a result excess amounts of manure are produced at livestock farms according to prevailing legislation. Part of livestock manure is used at the own farm and excess amounts are transported to neighbouring farms with a lower stocking density. Part of livestock manure is also transported to other regions. Alternatively, excess amounts of manure may also be exported to surrounding countries or may be processed in factories. However, the costs involved in such transport and processing are substantially higher than the costs involved in using manure within the region. Furthermore, arable crop production is based to a large extent on purchased mineral fertilizer because of the relatively low prices for mineral fertilizers. These low prices of mineral fertilizers have also stimulated intensity of the cropping plan at the average arable farm, meaning that in the past low nutrients input crops (e.g. cereals) are substituted by high nutrients input crops (e.g. potatoes and sugar beets).

Since 1985 the Dutch government has implemented several laws and regulations to prevent the growth of livestock production and to reduce and control manure production and use. From 1998 the so-called minerals accounting system (MINAS) became compulsory for farms with high livestock densities (more than 2.5 livestock units per hectare). MINAS calculates the input (e.g. through the purchase of feed, nutrients from mineral fertilizers and animal manure) and the output of nutrients (e.g. through the sales of milk, meat, cereals and manure) at the farm level. Nutrient surpluses above a certain threshold level are taxed. Threshold levels have been sharpened over time and are different per soil type and crop to take into account differences in environmental effects. In 2001 MINAS became compulsory for all farmers including arable farmers and other open-field producers. Moreover, in 2002 the system of manure contracts, known as Mest Afzet Overeenkomst (MAO), was introduced. Under MAO producers of animal manure without sufficient manure application capacity have to contract manure application capacity directly from landowners or indirectly through a middleman (Ministry of Agriculture, Nature Management and Fisheries, 2002a and 2002b).

The objective of this paper is to analyze the environmental and economic effects of MINAS and MAO 2004 standards for the Dutch agricultural sector. For that purpose DRAM (Dutch Regionalised Agricultural Model), a regionalised, environmental, partial equilibrium, mathematical programming model of Dutch agriculture is used (Helming, 2005). The model combines the technical detail, including technology options available to farmers in different regions of the Netherlands, of mathematical programming farm models with some market effects at agricultural industry level e.g. land and manure markets. Moreover the mathematical programming model is linked to a mixed input-output model to analyze economy wide effects of changes in Dutch agriculture (Helming, 2005).

In section 2 of this paper we present a theoretical model of manure markets. Section 3 describes DRAM. In section 4 the scenarios are presented. Section 5 presents and discusses the results. Section 6 gives some discussion on the sensitivity of the results. In this respect we focus on the possible effects of manure policy changes for Dutch agriculture given the changes in the Common Agricultural Policy (CAP) of the European Union (EU). Section 7 concludes this paper.

2. Theoretical model

DRAM is based on the neoclassical economic theory of behavior of economic agents. It is assumed that producers maximize profit and that markets are perfectly competitive. Based on this neoclassical framework of profit maximization, dual price relationships e.g. between nutrients and animal manure demand and supply, can be derived from the primal Lagrange function and applying Kuhn-Tucker conditions (Hazell and Norton, 1986; Howitt, 2002).

To develop a simple mathematical programming model including manure balances we assume that animal manure is a by-product of animal activities (i=1). Moreover, we assume that in the base all the manure is used by the crop activities (i=2). The model can be written as follows.

$$\text{maximize } Z = \sum_{i=1,2}(p_i x_i - \alpha_i x_i - 0.5\beta_i x_i^2) \qquad (1a)$$

$$\text{subject to } \sum_{i=1,2}(\gamma_{ia} - s_{ia})x_i \le 0 \qquad \forall a \qquad [\pi_a] \qquad (1b)$$

$$\sum_{i=1,2} a_{ik} x_i \le b_k \qquad \forall k \qquad [\pi_k] \qquad (1c)$$

$$x_i \ge 0 \qquad \forall i \qquad (1d)$$

Where Z is total profit defined as revenue minus variable costs (1000 Euro), xi is the level of activity i (i=1,2) (1000 hectare or animal), pi is the revenue in Euro per unit of activity i, α_i and β_i are parameters of a quadratic cost function. These parameters are calculated using the approach of Positive Mathematical Programming (PMP) (Howitt, 2005). γ_{ia} is the production of animal manure type a (a=1) by activity i (m3 per animal), sia is the demand of animal manure type a by activity i (m3 per hectare). bk is total available quantity of fixed input k (k=1), aik is quantity of fixed input k demanded by activity i, variable xi is the level of activity i. Restriction (1a) maximizes profit from activities. Restriction (1b) states the production of animal manure should be less than the demand of animal manure. Restriction (1c) states that all activity levels should be greater than or equal to zero. Variable πa associated with restriction (1b) is defined as the shadow price of animal manure type a (Euro per m3). The shadow price provides the increase in the objective function if the input could be made less restrictive marginally. Variable πk associated with restriction (1c) is defined as the shadow price of fixed input k.

The Lagrange function of the above primal mathematical programming problem can be written as follows:

$$L = \sum_{i=1,2} (p_i x_i - \alpha_i x_i - 0.5\beta_i x_i^2 + \pi_a(\gamma_{ia} - s_{ia})x_i + \pi_k(b_k - a_{ik}x_i)) \quad (2)$$

The Kuhn Tucker conditions are:

$$\frac{\partial L}{\partial x_1} = p_1 - \alpha_1 - \beta_1 x_1 + \pi_a \gamma_{1a} - \pi_k a_{1k} \quad (3)$$

$$x_1 \frac{\partial L}{\partial x_1} = x_1(p_1 - \alpha_1 - \beta_1 x_1 + \pi_a \gamma_{1a} - \pi_k a_{1k}) = 0 \quad (4)$$

$$\frac{\partial L}{\partial x_2} = p_2 - \alpha_2 - \beta_2 x_2 - \pi_a s_{2a} - \pi_k a_{2k} \quad (5)$$

$$x_2 \frac{\partial L}{\partial x_2} = x_2(p_2 - \alpha_2 - \beta_2 x_2 - \pi_a s_{2a} - \pi_k a_{2k}) = 0 \quad (6)$$

Using equation (4) one obtains the following marginal cost (inverse supply) function animal manure type a:

$$\pi_a = (\alpha_1 + \beta_1 x_1 - p_1 + \pi_k a_{1k}) / \gamma_{1a} \quad (7)$$

For reason of simplicity assume that a_{1k} equals zero. This means that the marginal cost function of animal manure reduces to:

$$\pi_a = (\alpha_1 + \beta_1 x_1 - p_1) / \gamma_{1a} \quad (7a)$$

Using equation (6) one obtains the following value marginal product (demand) function for animal manure type a:

$$\pi_a = (p_2 - \pi_k a_{2k} - \alpha_2 - \beta_2 x_2) / s_{2a} \quad (8)$$

Figure 1 is a graphical representation of the manure market as described above. The derived marginal costs of animal manure supply is indicated by the upward line MC in figure 1. The downward sloping line MR indicates animal manure demand. Profit-maximizing application of this specific type of animal manure is indicated by the intersection between the lines MR and MC. The market price of animal manure equals π_a and the profit-maximizing demand and supply equals $Q_a = \gamma_{1a} x_1 = s_{2a} x_2$.

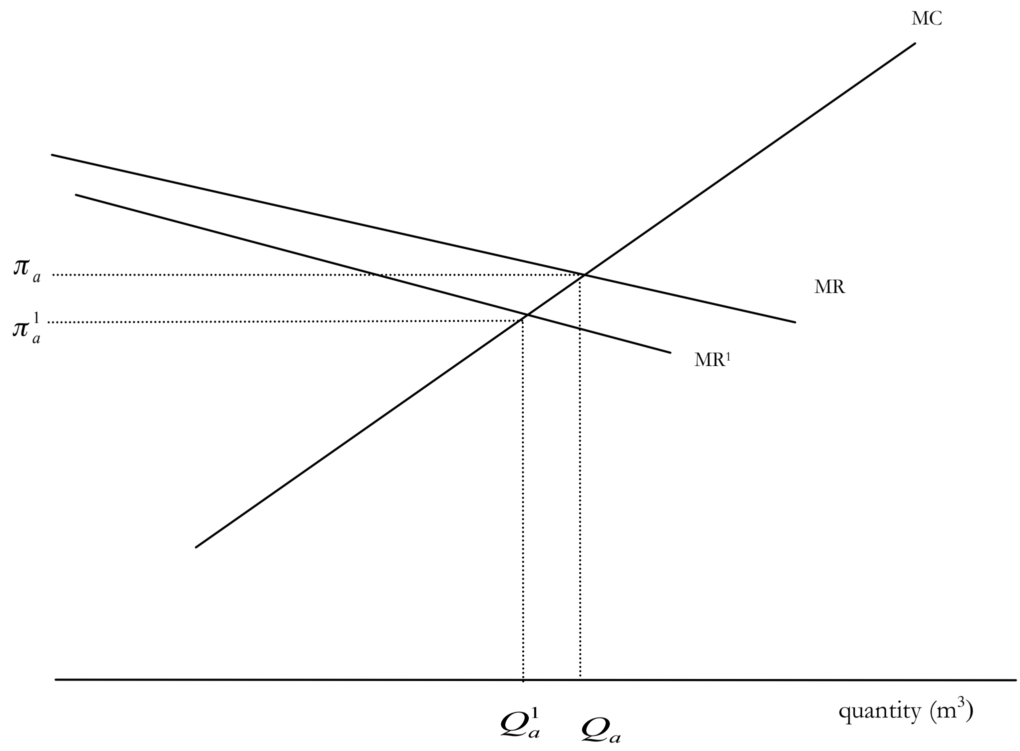

Figure 1. Graphical presentation of manure markets

Now assume that manure policies are tightened such that the demand of animal manure by activity 2 decreases from s_{2a} to $s_{2a}^{'}$. Also assume that this does not affect other variables as yield and output prices. The animal activities can only supply the same amount of animal manure, as a by-product of livestock production, if the allocation of land to the crops increases. However the amount of land available for crop production is limited (see equation (1c)). Hence, land scarcity increases and this translates into higher shadow prices of land. In figure 1, the net result of the increased shadow price of land and decreased application of animal manure per hectare is a shift of the manure demand line from MR to MR^1. Along the line MC, the application of animal manure decreases to Q_a^1 and the price of animal manure decrease to π_a^1. The policy change results in a profit change for the agricultural sector as a whole as indicated by area -(b+c). This loss represents changes in producers' surplus -(a+b) of animal manure production activities (i=1) due to a loss of net production value measured as the area above the line MC and under the price line π_a^1 minus the area above the line MC and under the price line

π_a. The change in the producer surplus of users of animal manure (i=2) is indicated by the area a-c. This is measured as the area above the price line π_a^1 and under the line MR[1] minus the area above the price line π_a and under the line MR. A more detailed description of the modeling of manure markets can be found in Helming (2005).

3. Description of DRAM

Introduction

The model presented in section 2 is a simplified version of DRAM as described in Helming (2005). This section gives a full description of DRAM.

Farm behaviour

The core of the mathematical programming model, described in the middle of figure 2, is an optimisation block which maximizes profits from agricultural activities under the restriction that economic, technical and policy constraints are respected. DRAM assumes that there exists an optimal level of agricultural input use and output production. This optimum allocation of inputs and output production is reached when marginal costs are greater than or equal to marginal revenues for all agricultural activities in the model. This condition for an optimal solution is derived from maximisation of total profits from agriculture. Profits are maximized simultaneously over all farms to take into account the relationship between market effects and farmers behavior.

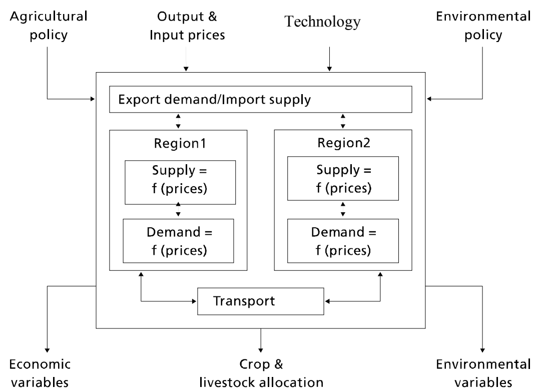

Figure 2. Schematic representation of DRAM.

Regions

To keep the model size manageable and because of data limitations at the farm level, DRAM aggregates agricultural activities of individual farms to the regional level. DRAM distinguishes between fourteen regions. The selection of regions in DRAM is based on homogeneity of soil and regional concentration of agricultural production. Different soil types have different yields and regions distinguished by DRAM are therefore characterized by different predominant soil types. Besides differences in yields per soil type, environmental impacts can also be soil type specific e.g. intensity of nitrate leaching. Intensive livestock, milk and beef production is mainly concentrated in the sand regions in the south, east and middle of the Netherlands. Arable production is concentrated in clay regions in the north, middle and south-west of the Netherlands. In regions with peat soils, grassland production to feed dairy cows and beef cattle is predominant, while arable production, including fodder maize is almost impossible due to soil characteristics and high groundwater level.

Outputs and inputs

In DRAM agricultural outputs are produced by agricultural activities. Economic importance and possible environmental effects determine the selection of agricultural outputs.

Within each of the fourteen regions, thirteen arable crop activities, two roughage crops activities, one non-food activity, seven intensive livestock activities, including beef cattle and fattening calves and nine dairy cow activities are distinguished. Other sectors like horticulture under glass, nursery trees and products produced by these sectors are left out of the model. In the Netherlands there is limited interaction between these sectors and agricultural activities modelled.

The livestock activities included in the model represent dairy cows, beef cattle, fattening calves, sows, fattening pigs, laying hens, meat poultry and mother animals of meat poultry. DRAM includes nine dairy cow activities. More detail is included here because of the economic importance and impact of dairy farming on land and manure markets. Livestock activities produce more than one output. For example, sows produce meat, piglets and manure. It is assumed that each livestock activity produces a specific type of manure as application cost and transport cost can be different per type of manure. Furthermore, the nutrients content and the workability of nitrogen in animal manure (or mineral fertilizer equivalent) for crop growth, differs per manure type.

The following inputs are distinguished: concentrates, pesticides, mineral fertilizers (nitrogen and phosphorus) and other variable inputs. Other variable inputs consist of services, other fertilizers, seed and planting materials, energy, hired labour and by-products (as a negative input).

Technology

Technical input coefficients concerning the total use of nutrients (nitrogen (N) and phosphorus (P), either from animal manure or mineral fertilizer), young animals and roughage (grass and maize) per activity are exogenous. A realistic representation of technology requires that the same type of output can be produced with different input-output coefficients. This is taken into account by including different input-output coefficients per activity per region. Regional differentiation of technical coefficients is especially important for crop production because of the differences in soil type per region and the important relationship between soil type and yield. Moreover, milk is produced through nine types of dairy cow activities, with type and region specific input-output coefficients. Moreover, the same quality of grass and fodder maize is produced by the dairy cow activities and separate grassland and fodder maize activities.

Remaining variable costs (concentrates, pesticides and other variable inputs) per activity are modelled using a quadratic variable cost function. The approach of Positive Mathematical Programming (PMP) is used to calculate the parameters of the cost functions in such a way that the observed activity level is almost exactly reproduced (Howitt, 1995).

Fertilisation requirements of the crops and can be fulfilled using nutrients from animal manure and mineral fertilizer. Hence, application of animal manure and mineral fertilizer per crop are endogenously determined within the model. Technical restrictions on application of animal manure are included to model manure acceptation of manure. The model allows for regional transport, export abroad and large scale processing of animal manure. The different variables in the model allow to calculate nutrient balances at soil level, including ammonia emission from stable, pasturing and application of manure and nutrient surplus as a resulting variable. To model manure acceptation and policies, more realistically, the mathematical programming approach allows to include restrictions on groups of agricultural activities e.g. restrictions over all arable crops. Note that this specification of the manure markets is much richer than described in section 2 of this paper.

Markets

Prices of most outputs and inputs are treated as exogenous variables, as they are assumed to be determined at the internal EU market or world market. For these inputs and outputs the small country assumption is applied. Regional prices are used to take into account possible regional differences in output and input quality, farm size and transport cost.

Intra-sectorally produced inputs in DRAM are different qualities of roughage, young animals and manure. Intra-sectorally produced inputs are produced and consumed within the agricultural sector. Prices of the intra-sectorally produced inputs are partly endogenous within DRAM and they can be traded between regions and internationally. In case intra-sectorally produced inputs are traded between regions, regional prices are linked and differences can not exceed transportation costs (Takayama and Judge, 1971). The small country assumption is applied to export- and import prices: export- and import prices of intra-sectorally produced inputs are fixed. An upper-limit is included for export of animal manure. Output prices of some arable crops as consumption potatoes are endogenous as well using inverse linear demand equations.

Fixed inputs

Fixed inputs in the model are land and quotas. Agricultural land and quota for sugar beets are assumed fixed at the regional level. Quotas for milk and starch potatoes are assumed fixed at the national level. Capital and labour are assumed not to be restrictive at the sectoral level.

Manure and nutrients policies

MAO can be directly included in DRAM through restrictions on nitrogen (N) from animal manure per hectare. MINAS is defined at the farm level. This means that high nutrient surpluses attached to high nutrient crops can be canceled out by low nutrient surpluses attached to low nutrient crops. If a nutrients surplus still remains this needs to be transported from the farm or the farmer has to pay a levy. Acceptation of manure will be different for different farm types. To reduce aggregation bias and to take into account possible differences in behavior with respect to manure demand and supply, the mathematical programming approach allows to group activities that are related to each other. Doing so DRAM describes regional MINAS balances for 11 group of activities: 9 type of dairy cow activities, 1 group of arable activities and 1 group of grassland and fodder maize activities.

4. Scenarios

MINAS threshold levels and levies on nutrients surpluses above threshold levels until 2004 are presented in Appendix 1 of this paper. Under MAO the maximum application of nitrogen from animal manure in 2004 equals 250 kg N per hectare for grassland and 170 kg N per hectare for arable land including fodder maize. Excretion of nitrogen per animal under MAO equals 85% of nitrogen in manure under MINAS. The base scenario is a simulation of Dutch agriculture in 1996.

To bridge the rather long period between manure utilization standards in 1996 and manure and nutrients policies in 2004, some farm management adjustments taken from farm level studies (de Hoop, 2002; Beldman et al., 2003) are included exogenously in DRAM. It is assumed that these farm management adjustments are directly induced by the changes in manure and nutrients policies. The advantage in this respect is the mathematical programming approach of DRAM. Mathematical programming allows the inclusion of many variables that are part of the generally very detailed farm level studies. It is recognized that in reality it is difficult to distinguish between management adjustments induced by policy changes and autonomous technological changes.

The scenarios are the following:

S1: - MINAS 2004 threshold levels and corresponding levies and MAO are assumed to be introduced in the base, with exogenous variables at base period (1996) levels. The following (farm management) adjustments are taken into account:

- 12% increase in milk production per dairy cow activity;
- 5%, 20% and 40% decrease in minimum workable nitrogen (N) input per hectare grassland for dairy cow activities with low nitrogen input per hectare grassland (LMLN, MMLN, HMLN), medium nitrogen input per hectare grassland (LMMN, MMMN, HMMN) and high nitrogen input per hectare grassland (LMHN, MMHN, HMHN) respectively. This recognizes the fact that more adjustments can be expected for grassland activities with relatively high nitrogen (N) input levels;
- 25% increase in workability of nitrogen in animal manure applied to grassland and fodder maize and linked to dairy cows activities;
- 25% decrease in manure production in the field by grazing dairy cows;
- 15% increase in grassland production per hectare grassland;
- Nutrients excretion per type of animal equal to 2003 standards given by van Staalduinen et al. (2002) and van Staalduinen et al. (2003). This recognizes the fact that from the early nineties, nitrogen (N) and phosphorus (P) excretion of sows and fattening pigs on the one hand and laying hens on the other, have decreased by -5 to -10% and -15 to -30% respectively (Statistics Netherlands, different years). Nutrients excretion of beef cattle and fattening calves is assumed constant;
- 250% increase in the export of manure from laying hens and meat poultry (van Staalduinen et al. 2002; van Staalduinen et al., 2003). Moreover, all the manure from meat calves is processed so that nutrients leave the agricultural sector;
- all other exogenous variables remain unchanged.

S2: See S1, but:

- 6% increase in milk production per dairy cow activity;
- 2,5%, 10% and 20% decrease in minimum workable nitrogen (N) input per hectare grassland for dairy cow activities with low nitrogen input per hectare grassland (LMLN, MMLN, HMLN), medium nitrogen input per hectare grassland (LMMN, MMMN, HMMN) and high nitrogen input per hectare grassland (LMHN, MMHN, HMHN) respectively. This recognizes the fact that more adjustments can be expected for grassland activities with relatively high nitrogen (N) input levels;
- 12.5% increase in workability of nitrogen in animal manure applied to grassland and fodder maize and linked to dairy cows activities;
- 12.5% decrease in manure production in the field by grazing dairy cows;
- 7.5% increase in grassland production per hectare grassland;

5. Results

Under scenario S1 the number of dairy cows decreases with 10% (table 1). This is explained by the partly exogenous increase in milk production per dairy cow. Moreover, the hectare of grassland decreases with 4%. The decrease in the number of dairy cows will ease the pressure on manure markets and this limits the effect of MINAS 2004 and MAO on the numbers of animals in other livestock industries. Nevertheless, under S1 the number of beef cattle decreases by 34%, while the number of fattening pigs and poultry decreases by 8% and 5% respectively (table 1).

Under S1, the area of grassland and fodder maize decreases by 4% and 2% respectively. This is the net result of two effects that work in opposite directions. On the one hand the area of grassland and fodder maize decreases due to a reduction in the number of dairy cows and beef cattle. Moreover, the yield per hectare of grassland increases. On the other hand there is an increase in demand for grassland due to a switch to extensive production methods in dairy farming. The hectare of land allocated to cereals increases with 14% under S1.

Table 1 also shows the effects on profits in a number of selected industries and the economy as a whole. Here profit is defined as revenues minus variable costs. Table 1 shows an increase under S1 in profits from dairy farming and arable farming, including vegetables in the open and flower bulbs, of about 6.1% and 3.0% respectively. However, the effects on profits are very different per region and per type of dairy cow. Under S1, the change in total profits from dairy cow activities ranges from -4% in the sand regions to +19% in the peat regions. These effects are the result of the policy change in combination with farm management adjustments and the resulting changes in regional allocation of milk production. Moreover, changes in profits range from –11% for dairy cow activities with high nitrogen from mineral fertilizer per hectare of grassland (intensive production methods) in the sand regions, to +27% for dairy cow activities with low nitrogen from mineral fertilizer per hectare of grassland (extensive production method) in the peat regions.

The increase in profits in arable farming is the net result of (1) lower prices for especially vegetables in the open and flower bulbs due to a small increase in supply, (2) the increased production of cereals and other arable crops in particular and (3) higher profits from manure acceptation. Under S1, the effect on profits is especially large for pig farming, -8.1% (table 1). This is explained by the increased costs of manure removal from farms. In absolute values the average national producer price of pig manure increases from € 6 per m3 in the base to about € 11 per m3 under S1.

Table 1 shows that the effect on profits in total agriculture of scenario S1 is positive. The total effect of S1 on the Dutch economy is a decrease in profits of € 216 million. This is mainly explained by a decrease in profits in the meat industry (€ 83 million) and input delivering industries (€ 196 million). The effects presented in table 1 show that in absolute terms, the economic effects for the rest of the economy by far exceed the economic effects for agriculture.

Table 1. Changes in some selected variables under S1 and S2 as compared to the base (1996).

	Base	S1	S2
		%	
Dairy cows (1000 head)	1,653	-10	-5
Beef cattle (1000 head)	450	-34	-43
Fattening pigs (1000 head)	6,965	-8	-10
Poultry (1000 head)	90,104	-5	-6
Grassland (1000 ha)	1,030	-4	-2
Fodder maize (1000 ha)	221	-2	-4
Cereals (1000 ha)	199	14	6
Profits dairy farming industry (million €)	2,116	6.1	-4
Profits pig industry (million €)	740	-8.1	-10.4
Profits arable farming, vegetables in the open and flower bulbs (million €)	1,417	3	5.2
		Million €	
Profits total agriculture (million €)	7,916	68	-134
Profits total economy (million €)	226,025	-216	-472
		%	
Emission of ammonia (kg N per ha)	80	-3	-12
Net nitrogen surplus (kg N per ha)	219	-50	-40

Table 1 also shows the effects on net nitrogen surplus at soil level. Compared to the base in 1996, this variable decreases with 50% under scenario S1.

Under scenario S2 with limited farm management adjustments the number of dairy cows decreases by 5%, a change of 10% compared to scenario S1 (table 1). Under S2 the number of beef cattle decreases by 43%, a change of –34%. The number of fattening pigs decreases by 10%, a change of -8%. These differences are explained by higher manure prices under S2 as a result of higher nutrients and manure production from dairy cows as compared to scenario S1. Land allocated to grassland decreases with 2%, this was 4% under S1. This effect is due to the higher number of dairy cows and the lower grassland production under S2. Under S2 profits in the dairy farming industry decrease by 4% compared to the base. Detailed results show that under S2, total profits from dairy cow activities decrease by 13% and 3% in the sand and remaining regions respectively. Profits from dairy cow activities increase by 7% in the peat regions. Due to higher manure prices profits in the pig industry decrease by 10.4% under the new S2 scenario. Due to higher profits from manure acceptation, profits in arable farming increase by +5.2% compared to the base. Table 1 shows that the total profit in agriculture under S2 decreases by €134 million, compared to a change of plus € 68 million in scenario S1. Total profits in the rest of the economy decrease by € 472 million. Under S2, net nitrogen (N) surplus decreases by 40% compared to the base.

Regional effects and technology shifts in dairy farming

With MINAS and MAO and exogenous management adjustments taken into account, the optimal technology in dairy farming moves into the direction of extensive production methods. Table 2 shows that the scenarios favour the re-allocation of milk production in the Netherlands from more intensive type of dairy cow activities to relative extensive type of dairy cow activities. This is especially true under scenario S2, with limited farm management adjustments in dairy farming. Differences in the share of extensive type of dairy cow activities in total regional milk production, also explains the effects of the scenarios on regional milk production (table 3). Table 3 shows that milk production increases in the peat regions, but decreases in the sand and in the remaining regions. A technical explanation is that the farm management adjustments will increase the shadow price of milk quota. As milk quota becomes more expensive, extensive production systems and regions with a relative large share of extensive production methods in regional milk production are now more competitive because of the relative low variable costs per kilogram milk.

Table 2. Percentage change in milk production per type of dairy cow under different scenarios(base in 1000 tonnes)

	Base	S1	S2
Milk production			
(kg per dairy cow)			
LOW	5,024	4.9	2.7
MEDIUM	4,619	-1.7	-1.2
HIGH	1,807	-9.1	-4.3
Total	11,451	0.0	0.0
Nitrogen from mineral fertilizer			
(kg N per hectare grassland)			
LOW	2,759	12.1	16.6
MEDIUM	4,821	-4.4	-1.2
HIGH	3,871	-3.1	-10.3
Total	11,451	0.0	0.0

Milk production (kg per dairy cow): LOW <6500; 6500 < MEDIUM < 7500; HIGH > 7500;

Nitrogen from mineral fertilizer (kg N per hectare grassland): LOW < 250; 250 < MEDIUM < 350; HIGH > 350

Table 3. Percentage change in regional milk supply under different scenarios (base in 1000 tonnes)

	Base	S1	S2
Sand[1]	4,429	-4.3	-3.6
Peat[2]	3,189	9.0	5.7
Remaining regions[3]	3,832	-2.5	-0.6
Total	11,451	0.0	0.0

1.Eastern sand region, Southern sand region, Central sand region; 2.Northern peat region, Western peat region; 3.Northern clay region, Northern sand region, Central clay region, Southern clay region, River area, Loess area, Peat colonies, Rest of Northern Holland, Rest of Southern Holland.

6. Sensitivity analyzes: Common Agricultural Policy of the European Union

Until now it is assumed that exogenous variables are equal to base year levels. In this section we discuss the possible effects of manure policy changes for Dutch agriculture given the changes in the Common Agricultural Policy (CAP) of the European Union (EU) as put forward in Agenda 2000 and CAP Reform 2003.

Analyses of Helming (2005) of direct and indirect effects for Dutch agriculture of Agenda 2000 and CAP Reform 2003 suggest that the hectare of land allocated to cereals decreases and hectare of land allocated to grassland increases. Although milk prices decrease, the milk quota is still fully produced. The share of extensive production methods (specified as dairy cow activities with low nitrogen from mineral fertilizer per hectare of grassland) in total milk production slightly increases. In the animal sector the number of beef cattle decreases strongly, whereas the number of pigs and poultry slightly increases. In total the production of animal manure will decrease. The increase in the number of pigs and poultry is explained by the increase in the manure price due to the decrease in animal manure supply in total.

The above-mentioned effects of CAP changes, will only to a limited extend effect the results of Dutch manure policies as described in this paper. More restrictive manure policies basically increase manure prices. The effects on manure prices will be somewhat smaller after CAP changes. This is explained by the decrease in animal manure production due to a decrease in number of beef cattle after CAP changes. Moreover, manure application room increases because of the increase in the hectare of grassland after CAP changes.

7. Discussion and conclusion

This paper aims to analyze the environmental and economic effects of MINAS 2004 threshold levels for nutrient losses and related nutrients levies combined with manure application standards from MAO.

Results show that MINAS 2004 and MAO mainly affect production in the beef cattle and intensive livestock industries, including intensive dairy farming. The results also show that farm management measures induced by the policy change reduce the net nitrogen (N) surplus in the soil balance by 50%, while profits in agriculture as a whole increase by about 0.9% or € 68 million. However, the effects on agricultural profits are differing between industries and regions. Moreover, due to the uncertainties particularly concerning farm management adjustments induced by the policy change it is concluded that the economic effects for the economy as a whole range between € -216 million and € -472 million. In general, the scenarios presented in this paper show that in absolute terms the effect on profits in the rest of the economy by far exceeds the effect on profits in agriculture.

Other studies that analyze the effects of manure and nutriens policies for the Dutch agricultural sector and economy are presented by De Hoop and Stolwijk eds. (1999) and Komen and Peerlings (1998). De Hoop and Stolwijk use an input-output model. According to experts' opinions the number of beef cattle, meat calves, pigs and poultry decreases by –30 %, -10 %, -15 % and –20 % respectively due to the tightening of manure and nutrients policies. These are short to medium term effects as the assumed adjustment period is from 1998 to 2002 (de Hoop and Stolwijk, 1999). De Hoop and Stolwijk (1999) estimate the profit effect for the economy as a whole to be € - 492 million (1998 prices). Komen and Peerlings (1998) use an Applied General Equilibrium (AGE) model. The national manure surplus resulting from different permitted standards for phosphate loss are translated into a reduction of livestock numbers. Nitrogen loss standards are not taken into account. The effects of a reduction in the numbers of pigs and poultry are compared with a reduction in the number of pigs only. A reduction in beef cattle is not considered. Effects on national profits of a permitted phosphate loss standard of 30 kg per ha, ranges from € - 211 million (1990 prices) as a result of a reduction in the number of pigs and poultry, to € - 328 million (1990 prices) as a result of a reduction in the number of pigs only. Komen and Peerlings (1998) take into account possible changes in output prices of pigs and poultry production due to a decrease in supply in the Netherlands. Results from both studies on economy wide effects exclude the higher transportation costs of animal manure and the increased profits in arable farming. An advantage of the study presented in this paper is the explicit modeling of manure markets.

DRAM can be characterized as a short to medium term model since technology is fixed in agriculture. In the longer term alternative technologies may become available. Investment costs connected to exogenous farm management adjustments are not taken into account in this study. Furthermore, some farmers will not have the capacity (nor the wish) to adopt the required measures and so achieve the assumed management levels in relation to milk production per dairy cow, manure handling and grassland management. Increased investments costs and a lack of management capacity to cope with manure and nutrients policies after 1996, have probably accelerated the decrease in the number of farms and the increase in farm size.

Uncertainties that can be identified are nutrients production, the uptake of nutrients by crops, acceptation of different types of animal manure, manure export to other countries, the costs of mineral fertilizer application, spatial distribution of an environmental impact (DRAM implicitly assumes that crop and livestock production and the related environmental effects are evenly distributed in a region), manure processing costs and changes in farm management.

Moreover, the farm management adjustments that are taken into account are not differentiated per region or technology (type of dairy cow). With more information available, especially by close cooperation with regional experts and the application of DRAM in interdisciplinary research, this could be improved upon.

Notwithstanding the uncertainties, it is believed that the modeling system offers a flexible and consistent tool for policy analysis at the Dutch agricultural industry and economy levels.

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Appendix 1

MINAS nutrients threshold levels and levies

Table 1. MINAS nutrients (nitrogen (N) and phosphorus (P)) threshold levels, in kg per ha per year

	1998-1999	2000	2001	2002	2003	2004
Phosphorus loss standard						
- arable land	17.47	15.28	15.28	13.10	10.92	10.92
- grassland	17.47	15.28	15.28	10.92	8.73	8.73
Nitrogen loss standard						
- arable land clay/peat regions	175	150	150	150	100	100
- arable land dry sand/loess	175	150	125	100	80	60
- grassland	300	275	250	220	180	180
- grassland dry sand/loess	300	275	250	190	160	140

Source: Ministry of Agriculture, Nature Management and Fisheries (2002a; 2002b).

Table 2. Levies on nutrients surplus above threshold level, in € per kg

	1998-1999	2000	2001	2002	2003>
Phosphorus (P)					
0 - 4.37 kg /ha	2.60	5.20	5.20	20.78	20.78
> 4.37 kg/ha	10.39	20.78	20.78	20.78	20.78
Nitrogen (N)					
0-40 kg/ha	0.68	0.68	0.68	1.13	2.27
> 40 kg/ha	0.68	0.68	0.68	2.27	2.27

Source: Ministry of Agriculture, Nature Management and Fisheries (2002a).