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**LINKING FARM AND MARKET MODELS TO ANALYSE THE  
EFFECTS OF THE EU NITRATE DIRECTIVE FOR THE DUTCH  
AGRICULTURAL SECTOR**

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# LINKING FARM AND MARKET MODELS TO ANALYSE THE EFFECTS OF THE EU NITRATE DIRECTIVE FOR THE DUTCH AGRICULTURAL SECTOR

## Abstract

This paper presents a modeling system that can be used to analyze the trade off between economy and environment. It takes into account manure policy, farm structure and manure surpluses at farm level as well as the economic effects of manure surpluses at market level. The modeling system consists of two models that are linked to each other by at the one-hand manure prices and distribution of manure over different destinations and at the other hand changes in agricultural and total manure production. One model is the so-called Manure and Ammonia Model (MAM). This model calculates manure surpluses and deficits at the farm level and distribution of manure to own farm, own region, other regions, export abroad and processing at the regional level. Moreover, MAM also calculates ammonia emissions coming from different sources. The second model is a market model that includes the most important agricultural markets. The models are calibrated for 2002. The modeling system is tested to analyze the effects of sharpened manure policies until 2006.

Key words: farm models, market models, manure, economy, policy

## 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.

Since 1984 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 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. An important aspect of MINAS is that standards have been sharpened over time (Ministry of Agriculture, Nature Management and Fisheries, 2002).

In the Netherlands studies on the socio-economic effects of manure policies are mainly based on farm level models (Nieuwenhuizen (ed.), 1995; Hoop, de and Stolwijk (eds.), 1999; Hoop, de (ed.), 2002; Hoop, de, et al., 2004). These studies concentrate on effects at farm level. Sometimes these effects are aggregated to the regional and national level to reach agricultural sector level and economy wide results. The advantage of this approach is that differences in farm structure, management qualities and objectives can be taken into account when analysing behaviour of farmers and the effects of policy changes. Policy makers are provided with insights in the distribution of the different effects over individual farms. A disadvantage is that the effects of farmers' behaviour on different market prices through changes in aggregated demand and supply and the backward link to farmers behaviour, is not taken into account. As a result aggregation of outcomes from farm models to the regional or national sector level will give biased results.

Another approach to study socio-economic effects is the sector model approach as presented by Helming (2005) and Komen and Peerlings (1998). An advantage of the more aggregated approach is that different markets can be optimised simultaneously, including supply and demand on manure

markets. Another advantage is that agricultural sector models describe the agricultural sector as a whole, while farm models tend to specialise in the most important farm types. A disadvantage is that differences in farm structure are not or only partly taken into account. Also a limited number of management qualities and objectives of farmers can be taken into account.

Looking at the different approaches that are available there is need for a modelling tool that takes into account farm structure and market effects simultaneously. This paper develops such a modelling tool by linking a farm-based model of manure supply and demand with a market model. Next analysing the possible socio-economic effects of sharpened manure and nutrients policies in 2006 as compared to the base situation, tests the modelling system.

Section 2 describes the theoretical background. Section 3 describes the empirical models and the iterative linkage procedure. Section 4 describes the data and discusses some issues concerning the specification of the models. Section 5 presents the scenario and some selected results. We finish this paper with a discussion of the methodology, the application and the specification of the models.

## 2. Theoretical background

### 2.1 Manure demand

Standard economic theory says that producers maximize profits. To start with in this sub-section we describe the behavior of one specific transporter and user of animal manure. Moreover, only one type of animal manure and one region is included. The manure surplus, variable  $m$  in equation (1) is defined as total manure production minus destination own farm, that is the manure that is available on the regional market. The profit function ( $Z$ ) of the transporter and user of the specific type animal manure can be written as follows:

$$\max Z = (-\alpha_1 + 0.5\alpha_2 m)m - \mu * m \quad (1)$$

where:

- $m$  = total manure surplus (kg P).
- $\mu$  = manure purchase price (€ per kg P).

Parameters  $\alpha_1$  and  $\alpha_2$  are parameters of the net revenue function of the transporter and user of animal manure to be calculated. Net revenue consists of the monetary value of the nutrients in animal manure in nutrients from mineral fertilizer equivalents minus application and transport costs. The transporter and user of the manure surplus maximize profits, as marginal revenue equals marginal costs:

$$\frac{\partial Z}{\partial m} = -\alpha_1 + \alpha_2 m - \mu = 0 \quad (2)$$

That is the purchase price of the manure surplus, that takes the form of the standard inverse manure demand function, equals marginal revenue of transporter and user of animal manure:

$$\mu = \alpha_1 - \alpha_2 m \quad (3)$$

### 2.2 Manure supply

To explain the modeling of manure supply, in this sub-section we assume one producer of animal manure. Again, only one type of animal manure, one final agricultural output and one region is included. We also assume that the producer of manure does not own any land and all the manure that is produced is transported and used within the region. So manure surplus  $m$  in equation (1) is also equal to total manure supply. Manure is a by-product of livestock production. As a result we can

assume a fixed relationship between manure supply and agricultural production in the initial situation. In that case the profit maximization problem of the producer of the manure surplus is written as.

$$\max Z1 = p * m + \mu * m - (\beta_1 + 0.5\beta_2 m)m \quad (4)$$

where:

$Z1$  = profit of producer of animal manure (€)  
 $p$  = price of agricultural output (€ per kg P)  
 $m$  = total manure production (kg P)  
 $\mu$  = manure selling price (€ per kg P)

Parameters  $\beta_1$  and  $\beta_2$  are parameters of a quadratic cost function. Profit of the producer is maximized as:

$$\frac{\partial Z1}{\partial m} = p + \mu - (\beta_1 + \beta_2 m) = 0 \quad (5)$$

That is the inverse supply or marginal cost function for manure supply by the producer of animal manure is given by:

$$\mu = \beta_1 + \beta_2 m - p \quad (6)$$

Equation (6) shows that there is a positive relationship between the selling price of animal manure and the supply of manure surplus: if the selling price decreases the supply of manure will decrease.

### 3. The empirical models

#### 3.1 The Manure and Ammonia Model (MAM)

The manure and ammonia model (MAM) as available at LEI, the Hague was developed during the 1980s and has been further developed and used for manure policy analyses ever since (Luesink, et al., 2004, Staalduinen et al., 2001 and 2002; Groenwold et al., 2002; Oudendag and Luesink, 1998).

Analytically the model can be compared with the analytical model presented by Feinerman et al. (2004). The basic ideas in MAM are (a) manure is a by-product of livestock production and manure supply is assumed inelastic in the short run, (b) crops need a minimum amount of nitrogen (N) and phosphate (P) to reach a maximum yield, (c) to fulfill the nutrient requirements both nutrients from animal manure and mineral fertilizer can be used, (d) application of animal manure is restricted by manure regulatory standards and willingness to accept animal manure and (e) distribution of manure to different kind of destinations is based on cost minimization (f) nutrients N and P in manure are not separable. The latter means that in general meeting the crop requirements of one nutrient will require higher manure applications than needed to meet the crop requirement of the other nutrient. A more detailed description of MAM can be found in Appendix I.

#### 3.2 The market model

The market model that is presented below is an adapted version of the Dutch Regionalised Agricultural Model (DRAM). DRAM can be defined as a comparative static, partial equilibrium, regionalized Positive Mathematical Programming (PMP) model of Dutch agriculture with environmental aspects. This model is presented and discussed in Helming (2005). Therefore, the description below concentrates on the new elements.

*The profit function*

In the profit function the sum of producers and consumers surplus is maximized. The profit function is given by:

$$\begin{aligned}
 \max Z = & \overbrace{\sum_y \sum_r (\omega_{yr} - 0.5\epsilon_{yr} Q_{yr}) Q_{yr}}^1 + \overbrace{\sum_a \sum_{d0} \sum_r \mu_{ar} QD_{ad0r}}^2 \\
 & + \overbrace{\sum_a \sum_{d1} \sum_r c_{ad1r} QD_{ad1r}}^3 - \overbrace{\sum_i \sum_r (kk_{ir} + \alpha_{ir} X_{ir} + 0.5\beta_{ir} X_{ir}^2)}^4 \\
 & + \overbrace{\sum_i \sum_r prem_{ir} X_{ir}}^5 + \overbrace{\sum_z \sum_r p_{zr}^e E_{zr}}^6 - \overbrace{\sum_z \sum_r p_{zr}^i M_{zr}}^7 \\
 & - \overbrace{\sum_z \sum_r \sum_{r'} fc_z T_{zrr'}}^8
 \end{aligned} \tag{7}$$

$$Q_{yr}, X_{ir}, E_{zr}, M_{zr}, T_{zrr'}, QD_{adr} \geq 0$$

The indices in objective function (7) are defined as follows,  $r$  regions,  $i$  activities,  $d$  all destinations of animal manure (1= own farm, 2=own region, 3=other regions, 4=export/processing of animal manure),  $d0$  sub-set of all destinations of the animal manure (1=own region, 2=other regions),  $d1$  sub-set of all destinations of the animal manure (1=own farm, 2=export/processing of manure),  $y$  final agricultural outputs,  $l$  inputs not produced within the market model,  $z$  intra-sectorally produced inputs young animals and roughage,  $a$  represents different types of animal manure.  $\omega_{yr}$  And  $\epsilon_{yr}$  are parameters of the consumers utility function and  $kk_{ir}$ ,  $\alpha_{ir}$  and  $\beta_{ir}$  are parameters of the producers costs functions. The latter are based on model calibration following the method of Positive Mathematical Programming (PMP) (Howitt, 1995). The endogenous variables, written with upper case and the exogenous variables, written with lower case are defined as follows:

$Z$  = total surplus (producer surplus plus consumer surplus) (1000 €)

$Q_{yr}$  = total (domestic and export) demand of agricultural product  $y$  in region  $r$  (1000 tonnes)

$X_{ir}$  = agricultural activity  $i$  in region  $r$  (1000 ha; 1000 head)

$M_{zr}$  = import of intra-sectorally produced input  $z$  in region  $r$  (1000 head, 1000 kVEM<sup>1</sup>)

$E_{zr}$  = export of intra-sectorally produced input  $z$  in region  $r$  (1000 head; 1000 kVEM)

$T_{zrr'}$  = transport of intra-sectorally produced input  $z$  from region  $r$  to region  $r'$  (1000 head)

$prem_{ir}$  = EU direct payment for activity  $i$  in region  $r$  (€ per ha; € per head)

$p_{zr}^i$  = import price of intra sectorally produced input  $z$  in region  $r$  (€ per head; € per kVEM)

$p_{zr}^e$  = export price of intra sectorally produced input  $z$  in region  $r$  (€ per head; € per kVEM)

$\mu_{a,r}$  = purchase price of animal manure type  $a$  in region  $r$  (euro per kg P)

$c_{a,d1,r}$  = application costs of manure type  $a$  at destination  $d1$  and region  $r$  (euro per kg P)

$QD_{a,d0,r}$  = transport of animal manure type  $a$  from region  $r$  to destination  $d0$  (1000 kg P)

$QD_{a,d1,r}$  = transport of manure type  $a$  from region  $r$  to destination  $d1$

<sup>1</sup> VEM (Voeder Eenheid Melk, fodder unit milk) is a Dutch measure for the amount of energy in feed products: 1VEM = 6.9 kJ Net Energy for Lactation.

The second element of objective function (7) calculates the revenue from manure production and distribution within the own region and in other regions. The third element gives the revenue from manure production and distribution to the own farm, export and processing. All manure prices in the market model are exogenous, e.g. determined outside the market model.

*Balances of final products, intra-sectorally produced inputs and fixed inputs*

Variables  $X_{ir}$ ,  $Q_{yr}$ ,  $M_{zr}$ ,  $E_{zr}$  and  $T_{zrr}$ , are elements of different balances for final products and intra-sectorally produced inputs as used and produced by agricultural activities (Helming, 2005). Agricultural production is limited by the availability of fixed inputs. Availability of land and sugar quota is modeled at the regional level. Quota for milk and starch potato are modeled at the national level. It is assumed that labor and capital are not restrictive at the agricultural market level.

*Manure balances*

The manure production is distributed over different kind of destinations. Restriction (14) shows that production of animal manure per type must be less than the sum of animal manure over all destinations.

$$\sum_i \sum_{a1} \gamma_{ialr} t_{aal} X_{ir} \leq \sum_d QD_{adr} \quad \forall a,r \quad \left[ \pi_{ar}^7 \right] \quad (8)$$

The new index  $a1$  equals animal manure of individual activities (e.g. different type of dairy cows, fattening pigs, etc.). Variable  $t_{aal}$  is the linkage variable between animal manure produced by individual activities and animal manure produced by activity groups. The shadow price  $\pi_{ar}^7$  gives the marginal costs of animal manure. That is, the shadow price  $\pi_{ar}^7$  equals the regional purchase price of animal manure, given in objective function (7), if manure is transported within the own region or to other regions, but not exported abroad or processed in factories. In case manure is exported or processed in factories, the shadow price equals the costs of manure export and processing. Manure prices and distribution of animal manure over the different destinations are determined outside the market model. The distribution of the manure over the different destinations is controlled by restriction (15).

$$QD_{adr} \leq m_{adr} \quad \forall a,d,r \quad \left[ \pi_{adr}^8 \right] \quad (9)$$

Variable  $m_{adr}$  represents distribution of animal manure type  $a$  from region  $r$  to destination  $d$  (1000 kg P). This variable is directly included from MAM. The shadow price  $\pi_{adr}^8$  gives the price difference between shadow price  $\pi_{ar}^7$  and the given manure price per destination as included in objective function (7).

*3.3 Linking MAM and the market model*

To link MAM to the market model, an iterative procedure is applied. The iterative procedure is presented in figure 1. The first step is the translation of the manure policy in terms of MAM. Next, the model calculates the distribution of the manure over the different types of destinations. Regional manure prices, given manure surpluses from MAM under different kind of manure policies are calculated ex-post using equation (3). Next, the calculated distribution of animal manure and the regional manure prices are used in the market model (see figure 1). The market model calculates the effects of changes in manure distribution and manure prices on livestock activities and allocation of land to crops. In the third step, these results are feed back into MAM. This is done by means of regional indices that are applied at farm level. Given the new farm structure the distribution of manure and manure prices are updated.

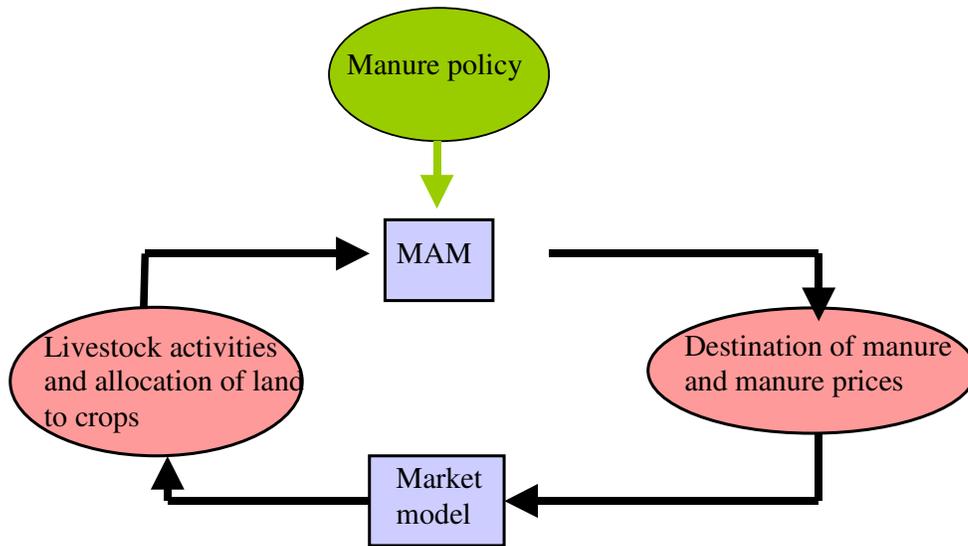


Figure 1. The Manure and Ammonia Model (MAM) iteratively linked to a market model.

#### 4. Data and specification of the models

Within MAM manure surpluses and manure deficit at farm level are aggregated to 31 regions, the so-called manure regions, before it is transported to other destinations. MAM is flexible with respect to the specification of types of animal manure. In this paper 29 types of animal manure are distinguished, differing in nutrients content and dry matter content. Individual crops are aggregated to 9 crop groups. Aggregation of regions, manure types and crops is necessary to limit computation time and because of limited computer capacity.

The manure and ammonia model is calibrated to observed distribution of animal manure in 2002. The data used can be classified as (Oudendag and Luesink, 1998):

1. number of animals and area of several crops;
2. excretion of nutrients and manure;
3. emission factors for ammonia (NH<sub>3</sub>);
4. transport cost from source regions to regions of destination;
5. export abroad and manure processing quantities;
6. willingness to accept manure from other farms.

The first category of data is obtained from the Annual Census (yearly updated), while the second is determined every year by a group called the 'WUM working group' (van Eerdt, 1994a,b,c). The transport cost from source regions to regions of destination is taken from van Horne et al. (1995). The manure export and processing in volume terms is taken from (van Staalduin et al., 2002). Willingness to accept manure from other farms is based on surveys among farmers (van Staalduin et al., 2002). MAM is calibrated for 2002, results and further detailed data description is presented in van der Hoek (2002).

Demand of manure is assumed to be rather in-elastic (Baltussen et al., 1993). Therefore demand elasticities that are necessary to calculate the parameters of the inverse demand functions (equation 3) are assumed equal to  $-0.5$ .

The market model is calibrated to observed activity levels in 2002. The calibration is based on Positive Mathematical Programming (PMP) (Howitt, 1995). Regional economic and technical data are

available from the Dutch Farm Accountancy Data Network (FADN) and the Agricultural census. The market model that is used in this paper includes the 31 manure regions and 7 types of manure (dairy cows, beef cattle fattening calves, sows, fattening pigs, laying hens and meat poultry). The manure types included in the market model are linked to the different types of animal manure that are distinguished in MAM in this paper. The market model includes nine different types of dairy cows for milk production. The dairy cows are classified by milk production per cow and use of nitrogen from mineral fertilizer per hectare grassland and represented different type of dairy farms found in FADN. Further specification of agricultural activities, inputs and outputs in the market model can be found in Helming (2005).

Table 1: Marketing and application costs of animal manure per manure type and region in 2002 (€ per m<sup>3</sup>).

	Own farm	Purchase price own region		Export	Processing
		concentration regions <sup>1</sup>			
		South	East		
Dairy cows	-2.5	-7.5	-6.5	-5.1	-36.3
Beef cattle	-2.5	-7.5	-6.5	-5.1	-36.3
Fattening calves	-2.5	-7.5	-6.5	-5.1	-36.3
Fattening pigs	-2.5	-8.5	-7.5	-6.1	-36.3
Sows	-2.5	-8.5	-7.5	-6.1	-36.3
Laying hens	-3.2	-14	-13	-11.6	-25.0
Mother animals of meat poultry	-3.2	-14	-13	-11.6	-25.0
Meat poultry	-3.2	-14	-13	-11.6	-25.0

1.Regional distribution of 31 manure regions over concentration region South, East and non-concentration region can be found in Appendix II of this paper.

Source: Luesink e.a., 2004; own calculations

The market model uses manure prices (€ per kg P) and distribution of animal manure per type of animal manure in volume terms (see restrictions (7) and (15)). Manure prices (translated in € per m<sup>3</sup>) per manure type per region per destination in the base are presented in table 1. Table 1 shows that the manure purchase price is negative and differs per region and manure type. The negative manure purchase price means that the supplier needs to pay to transport the manure from the farm. Moreover, it is assumed that costs of manure exports abroad equals costs of manure processing. Possible regional differentiation in export and processing costs are not taken into account.

Table 2: Destination per type of manure in 2002 (percentages).

	Own farm	Own region	Other region	Export plus processing	Total
Dairy cows	97.4	2.2	0.4	0.0	100.0
Beef cattle	90.0	7.0	2.4	0.0	100.0
Fattening calves	37.7	41.0	2.9	18.4	100.0
Fattening pigs	23.0	37.3	36.1	3.5	99.9
Sows	31.8	43.4	24.4	0.4	100.0
Laying hens/mother animals of meat poultry	7.3	14.7	37.2	40.8	100.0
Meat poultry	13.6	16.2	6.6	63.6	100.0

Source: own calculations with MAM

The national average distribution of animal manure per type of animal manure in the base, resulting from MAM, is presented in table 2. Table 2 shows that in the base most of the manure from dairy cows and beef cattle is applied to the own farm, while manure application at the own farm is relatively limited for intensive livestock activities. Export of manure in the base is limited to animal

manure from poultry. This is consistent with lower export and processing costs of these types of manure (see table 1).

## 5. Scenario and results

### 5.1 Scenario

Manure policies in the Netherlands have been sharpened over time. However instead of a MINAS system with sharpened threshold levels, a system of maximum nutrients from animal manure and mineral fertilizer application standards will be effective in 2006. As well as MINAS this will also result into sharpened manure policies in the Netherlands as compared to the base. In this paper we take into account<sup>2</sup>:

- maximum standards for nitrogen from animal manure and mineral fertilizer in nitrogen from mineral fertilizer equivalents;
- maximum standards for phosphate from animal manure and mineral fertilizer;
- maximum standards for nitrogen from animal manure;
- Standards for workability of nitrogen in animal manure;
- Normative figures for excretion of nutrients per type of animal.

It is assumed that the sharpened manure policy in 2006 is introduced in the base with exogenous variables at base year levels (2002). As in reality manure policies are sharpened gradually overtime, giving time to farmers to adjust, the results presented below will give maximum effects.

### 5.2 Results

#### *First round*

Translation of the sharpened policy into model terms changes the distribution of the manure over the different destinations in MAM. Results are presented in table 3.

Table 3: Destination per type of manure under sharpened manure policy with manure production equal to base levels (farm structure unchanged) (percentages).

	Own farm	Own region	Other region	Export plus processing	Total
Dairy cows	82,9	12,7	4,4	0	100
Beef cattle	80,7	15,4	3,9	0	100
Fattening calves	32,6	28,7	20,4	18,3	100
Fattening pigs	13,9	17,2	22,6	46,2	99,9
Sows	23,2	22,6	54	0,3	100,1
Laying hens/mother animals of meat poultry	5,8	9,8	3,5	80,9	100
Meat poultry	11,7	3,4	0	84,8	99,9

Source: own calculations with MAM

Table 3 shows that compared to the base (see table 2) the tougher manure policy substantially reduces the scope for using manure in the Netherlands on the own farm. The relatively largest decrease is found for dairy cows, beef cattle, fattening pigs and sows. The increased use of manure from dairy cows and beef cattle within the own region seems to decrease the use of manure from other animals in the own region. The use of manure from dairy cows, beef cattle, fattening calves and sows in other regions than the own region increases. At the same time use of manure from fattening pigs and poultry in other regions than the own region decreases. Especially the amount of manure from fattening pigs that must be exported under the sharpened manure policy increases sharply.

<sup>2</sup> As far as known by the time the calculations were done (June/July 2003).

It is assumed that regional purchase prices of all types of animal manure changes proportional with purchase price changes of manure from fattening pigs in concentration region South. Purchase prices of manure from fattening pigs is a function of manure surpluses of fattening pigs (in kg P) in concentration region South as calculated by MAM (see equation (3)). The result of this procedure is an increase of the purchase price in the own region of about 80% in all regions. For example the purchase price manure from dairy cows in concentration region South increases from € -7.5 per m<sup>3</sup> to € -13.4 per m<sup>3</sup>. It is assumed that regional manure prices can not exceed export and processing costs and export and processing costs under the sharpened manure policy equal export and processing costs in the base.

Tabel 4: Agricultural production in base and under sharpened manure policy (number of animals, hectares) (\*1000)

Activity	Base	Sharpened manure policy	Difference (%)
Dairy cows (1000 head)	1,486	1,477	-0.6
Beef cattle (1000 head)	318	315	-1.1
Fattening calves (1000 head)	713	689	-3.5
Sows (1000 head)	1,007	904	-10.3
Fattening pigs (1000 head)	5,591	4,787	-14.4
Poultry (1000 head)	100,338	99,031	-1.3
Grassland (1000 hectare)	1,007	1,003	-0.4
Fodder maize (1000 hectare)	218	218	0.0
Total fodder crops (1000 hectare)	1,225	1,221	-0.3
Arable crops, vegetables in the open and flower bulbs (1000 hectare)	684	687	0.6
Total agricultural land (1000 hectare)	1,908	1,908	0

Source: own calculations with the market model

Changes in distribution of animal manure and corresponding changes in regional manure prices and marginal costs of animal manure (see variable  $\pi_{ar}^7$  in equation (8)) effects agricultural production. This is presented in table 4. Table 4 shows a small decrease of the number of dairy cows. The technology switch in dairy farming towards relatively high productive dairy cows explains this. High productive dairy cows are more competitive under the sharpened manure policy because marginal costs of animal manure per kilogram milk are relatively low. The milk quota is still fully produced. The effects on number of beef cattle, fattening calves and poultry are relatively limited. The number of fattening pigs at the national level decreases with more than 14%. Connected to the sharp decrease of the number of fattening pigs, the number of sows decreases with 10.3% due to decreased prices of piglets.

Regional effects on agricultural activities can be quite different from the national average. Under the sharpened manure policy the number of dairy cows in concentration region South (see Appendix II) decrease with 4%. In concentration region East the number of fattening pigs decrease with 23%, while in concentration region South and in the remaining regions the number of fattening pigs decreases with 12% and 10% respectively. The decrease in the number of poultry is largest in the remaining regions. Poultry producers in these regions are faced with increased marginal costs of manure, while in the surplus regions a large part of the poultry manure was already exported abroad in the base situation.

#### *Economic effects*

The market model is used to calculate economic effects at the national sector level. Total profits (revenue minus variable costs) in dairy farming decrease with €74.8 million or 4% due to the sharpened manure policy. Total profits in pig farming decrease with €128.7 million or 22.6%. Profits for transporters and users of animal manure increase with €128.7 million. The market model is fully integrated in an agricultural input-output table (Koole and van Leeuwen, 2001). Mixed input-output

modeling is used to calculate the economic effects for the processing and input supply industries of changes in primary agriculture. The procedure is described in Helming (2005). The results are as follows. Due to a decrease in agricultural production, especially in pig farming profits in the meat industry and in the input supply industries decrease with €74.3 million and €182.6 million respectively. For the economy as a whole the profits decrease with €400 million or 0.2% of total profits in the Dutch economy.

### ***Second round***

In the second round MAM calculates the effect of the sharpened manure policy on the distribution of animal manure when adjustments in agricultural production and manure production taken from the market model are taken into account. Results show that the relative application of manure on the own farm does not change much before and after adjustments of agricultural activities and manure production. This was to be expected because application on the own farm is limited by the sharpened manure policy. The main differences are export and processing of manure from fattening pigs before and after adjustments in manure production. As a result the number of fattening pigs decrease with 11.1%, compared to 14.4 % in the first round (see table 5). This also means that the economic effects as presented above (based on first round effects) are slightly overestimated.

### ***Environmental effects***

Calculations with MAM show that emission of ammonia at national level decreases with about 8% under the sharpened manure policy. At regional levels the application of nitrogen from animal manure on grassland in concentration region South, East and remaining region decrease with 25%, 50% and 9% respectively.

## **6. Discussion**

This paper presents a modelling system that can be used for detailed analyses of changes in manure policies. The modelling system is based on farm models and market models that are iteratively linked to each other. Below some strengths of the proposed modelling system are discussed as well as some points for improvement.

The strength of the modelling system are that environmental variables as manure surpluses and deficits and emission of ammonia are calculated at farm level, taking into account differences in farm structure. Moreover, the calculations apply to the whole of the Netherlands, that is all farms that are included in the Dutch agricultural census. The incorporation of the results into the market model allows to calculate regional and national effects on agricultural production, in an economic consistent way. Interactions between agricultural activities are taken into account through the modelling of (a limited number of) final agricultural output markets, markets of intra-sectorally produced inputs (young animals and roughage) and markets of fixed inputs (land and quota). The integration of the market model into an agricultural input-output model allows to calculate back and forward economic effects and economic effects for the economy as a whole as well.

There are also points for improvement. The first point is that there is no feed back between changes in purchase price of animal manure and willingness to accept manure from other farms in MAM. The second point is that the distribution as calculated by MAM is not based on first order conditions of demand and supply (that means manure supply is fixed). The third point is that allocation of land over the crops is now underestimated because changes in manure prices are not translated into changes of marginal fertilization costs per crop. These three points could be improved upon by including manure surpluses (transport of manure within the own region, to other regions and to export and processing of manure) as endogenous variables in the market model. Moreover, it also requires the modelling of fertilization balances. However, if this is done at farm level, this will result in an enormous increase in computation time and demand for computer capacity. Another difficulty is that the model will not automatically calibrate to observed purchase prices of animal manure. Models with endogenous manure prices for different types of animal manure are presented by Helming (2005) and Feinerman et al. (2004).

Another point that can be improved upon is that the specification of MAM and the market model needs to be harmonized further. For example, the market model includes different type of dairy cow activities representing different type of dairy farms. However the manure distribution from MAM is not known at farm level but at the level of manure types. At the moment these manure types do not correspond to the activities in the market models.

With respect to the policy application presented in this paper, we do not take into account the time horizon of the policy change. Because the policy change becomes effective in 2006, autonomous developments might change the reference base and this in turn might effect the economic and environmental effects of the policy change. Autonomous developments and the development of a new reference base are relatively easy to implement in the modelling system. Farm models can be used to deliver input concerning exogenous technical variables in MAM and in the market model. In doing so the results of the detailed farm models can be aggregated to the regional and national sector level in an economic consistent manner.

The modelling system can be defined as a short term model as technology is fixed and own produced manure is applied to the own farm first. In the short term, the changes in production in the intensive livestock industry might affect market prices of final outputs. This is not taken into account in this paper, as it is assumed that prices of final outputs from the intensive livestock industry are fixed. This means that effects on production in the intensive livestock industry, especially pig production is overestimated.

Remaining uncertainties are related to costs of manure export and processing and behavior of users and producers of animal manure (e.g. changes in farm management). Uncertainties can be reduced through close cooperation with regional and farm experts.

Different types of mineral policies can be analyzed with the presented modeling system, among others the possible effects of the European Union (EU) Water Framework Directive (2000/60/EC). Moreover, the proposed modeling system can also be used to analyze economic and environmental effects of changes in the Common Agricultural Policy (CAP) of the EU.

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## Appendix I: The Manure and Ammonia emission Model (MAM)

The manure and ammonia emission model (MAM) is a model with which the manure productions, manure surplus and ammonia emission can be calculated at farm level per kind of manure. Next, transport, export and processing of manure are calculated at area level and soil load of minerals at municipal level per kind of crop.

The distribution of the surplus manure over the different destinations in the model is ruled by the linear programming package GAMS with as goal the minimization of all the costs (such as: distribution, storage, processing, export, application) at national level. The effect of the minimization of the costs is, that manure kinds with high mineral grades are transported over long distance and manure kinds with low mineral grades would be placed at the production farm or transported over short distance.

In the model (figure I.1) are five modules with activities, which are: manure production, placing of manure, excess of manure, transport of manure and amount of soil load with minerals. The mentioned ones of figure I.1 are in the text underlined and italic. The places of the flags of figure I.1 are the places of ammonia emission.

The manure production takes place at agriculture farms on which are kept animals. The animals produce different kinds of manure, whereby ammonia disappears. How much ammonia disappears depends on: kind of animal, food-ration and standing-place (in the pasture and or stable type) of the animals. The production of manure per kind of manure will be placed as much as possible at agriculture land of the own farm. The amount of manure what is placed at the own farm depends on the areas of agriculture land and the amount of manure that could be applied what in the application room.

With the application of own produced manure emission of ammonia takes place. When the application room is not completely used by own manure, than there is the possibility to apply manure from other farms, the so called room for farm-strange manure. How much farm-strange manure really will apply at such farms depends on the acceptance degree. The acceptance degree is the part of the room for farm-strange manure that may be filled up with farm-strange manure.

The excess manure had been transported to other farms inside or outside the own area or exported. Minimizing the cost of distribution, export and manufacturing optimizes transport of excess manure. The excess manure that is used inside or outside the own area, is applied to other farm (manure at strange-farm). With the applying of manure at a strange farm again ammonia disappears. From the amount of fertilizer nitrogen from the Dutch farm accountancy data network and the nitrogen (N) fertilization requirements (advice gifts) the gift of inorganic nitrogen is calculated. The total use of nitrogen per crop is given by the gifts of in- and anorganic manure and the deposition of nitrogen from the air.

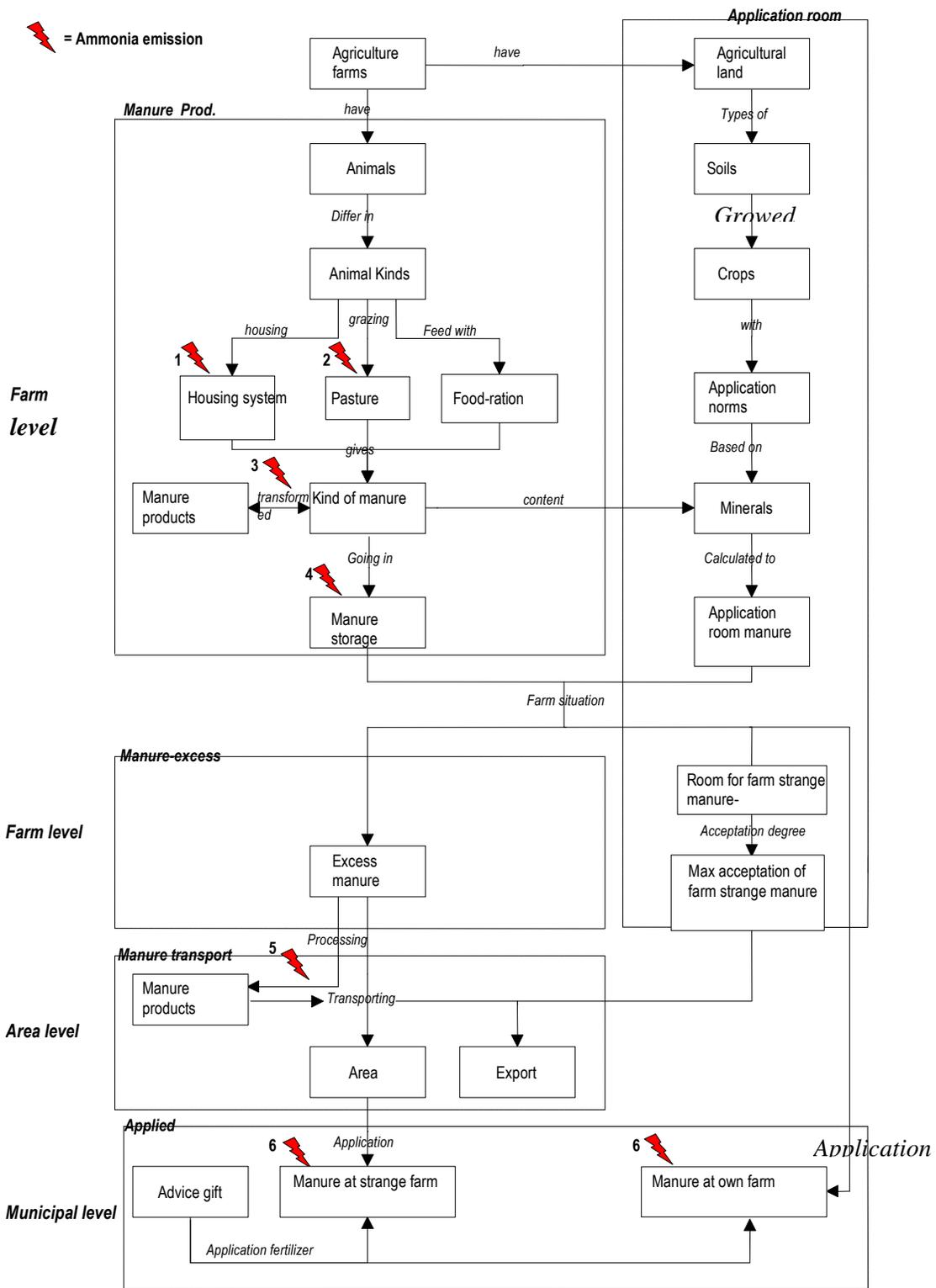


Figure I.1: The manure and ammonia model

Appendix II: Allocation of 31 manure regions to non-concentration region, concentration region East and concentration region South.

