Mineralflow : A model to determine cost efficient strategies to improve pig slurry application under de Dutch MINeral Accounting System

Minéral flux : un modèle destiné à déterminer les stratégies les plus efficaces et les moins onéreuses pour améliorer l'épandage de lisier de porc en regard de la nouvelle réglementation Hollandaise sur le système du bilan des minéraux.

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Abstract

A deterministic model (MINERALFLOW) was developed to determine the maximum economic performance of an individual pig farm. Decision variables were phosphorus (P) and nitrogen (N) content of the food, the feeding strategy, the slurry treatment system, the amount of slurry treated and the slurry application. MINERALFLOW was developed within the framework of the Dutch MINeral Accounting System (MINAS). At farm level the increase in feeding costs, due to a lower P content of the ration, and the decrease in slurry disposal costs have to be weighed. The decrease in slurry disposal costs depends primarily on the number of hectares own land and the intermediair slurry price.

Résumé

Un modèle déterministe MINERAL FLOW a été développé afin de déterminer les performances économiques optimum à l'échelle d'une exploitation porcine individuelle. Les variables étaient le phosphore (P), l'azote (N), contenus dans l'aliment, la stratégie d'alimentation, le système de traitement du lisier, la quantité de lisier traité et l'épandage de lisier. MINERAL FLOW a été développé dans le cadre de la nouvelle réglementation sur le bilan des minéraux (MINAS). A l'échelle de la ferme, l'augmentation du coût de l'aliment due à la diminution de la teneur en P dans la ration, et les diminutions du coût de gestion des lisiers doivent être prises en compte. La diminution du coût de gestion des lisiers dépend principalement du nombre d'hectares appartenant à l'éleveur et des coûts intermédiaires du lisier.

1. Introduction

On January 1th 1998 a new environmental legislation, the MINeral Accounting System (MINAS), was brought into operation in the Netherlands. With MINAS the

Dutch Government tries to ensure a non excessive use of minerals on the land, thus reducing emission of ammonia and reducing wash out of nitrogen and phosphate. MINAS allows only limited losses of phosphate and nitrogen to individual farms. A loss is determined by a mineral account as the difference between the amount of P and N brought onto the farm and the amount of P and N brought of the farm.

As total space for mineral application tightens by MINAS regulations, pressure on the slurry market increases. This leads to increased prices for slurry and higher slurry costs for animal production farms, thus increasing the financial incentive for these farms to take measures. On farms with intensive animal production this will be noted first and most heavily. In the Netherlands pig farming is intensive. Tight regulations for arable farmers will reduce the application space for minerals even more. By improving the slurry quality the acceptation of slurry by arable farmers can be increased, thus reducing the pressure on the slurry market and decreasing slurry costs.

In this paper a model was presented which determined the optimal mineral strategy for individual intensive pig farms. The impact of differences between individual pig farms on the optimal mineral strategy was described. Furthermore the impact of different autonomic developments on the optimal strategy made by individual pig farms was described.

2. Method and materials

Mathematical model

MINERALFLOW was a deterministic mixed integer programming model. The model calculated results on the individual farm level and maximizes over the period of one year. Continuous decision variables (mineral content of the food, slurry application, the amount of slurry treated) as well as binary variables (feeding strategy, slurry treatment system) were used. All restrictions and the goal function were linear. The model was solved using the Branch and Bound method from the LP-procedure in the SAS package (SAS 1990).

Input variables were the number of pigs and performance of the farm, the number of hectares of land on which slurry can be applied, application time, other costs, type of housing (low emission or not) and the intermediair slurry price. The goal function maximized economic performance. The goal function was :

MAX economic performance =

revenues -/- (housing costs + pig costs + labour costs + health costs + heating costs + electricity costs + water costs + remaining costs) -/- feeding costs -/- slurry treatment costs -/- slurry costs

The decision variables had an impact on the feeding costs, slurry treatment costs and slurry costs. Labour costs, electricty costs and water costs concerning the feeding system and slurry treatment system were counted to the feeding and slurry treatment costs respectively. The other costs and revenues were assumed to be fixed.

The mineral composition of the slurry excreted by the animals was determined through simulation as the difference between the amount taken up with the food and the amount which was taken up by the animals. Slurry volume was determined depending on the amount of drinking and cleaning water.

Mineral regulations

The application of minerals had to take place within the regulations of MINAS. In MINAS animal production farms with an animal intensity per hectare higher than a proposed standard had to apply a detailed mineral registration system. On these farms only a maximum loss of phosphate and nitrogen was allowed. On farms which had an actual loss that was higher than a standard loss, a levy was imposed. Farms with an animal intensity lower than the proposed standard (mostly arable farms) applied until 2002 only standards for supply of phosphate. From 2002 on for these farms also standards for phosphate and nitrogen losses were introduced. Until 2008 the regulations in MINAS tightened in phases (table 1) (Manure and fertilizing law 1997).

	1998	2000	2002	2005	2008
declaration on from animal intensity (gve[3]/ha)	2.5	2.5	2.0	2.0	2.0
standard for phosphate loss (kg P_2O_5/ha)[1]					
grasland, arable land and fallow	40	35	30	25	20
natural terrain	10	10	10	10	10
standard for nitrogen loss (kg N/ha)[2]					
grasland	300	275	250	200	180
arable land and fallow	175	150	125	110	100
natural terrain	50	50	50	50	50
standard for the supply of phosphate (kg P_2O_5 /ha)					
grasland	120	85	80	80	80
arable land	100	85	80	80	80
fallow	40	35	30	30	30
natural terrain	20	20	20	20	20

[1] The levy on phosphate loss is 10.00 Dutch Guilders (Dfl) in 1998/1999 per kg phosphate per hectare. For the first 10 kg the levy is 2.50 Dfl. From the year 2000 on these levies are doubled to 20.00 Dfl and 5.00 Dfl respectively. From 2005 on the low levy on phosphate loss is only for the first 5 kg.
[2] The levy on nitrogen losses is 1.50 Dfl per kg nitrogen per hectare.
[3] gve is a standard for the number of animals. For example a fattening pig counts for 0.18 gve and a sow with piglets till 25 kg for 0.495 gve. 1 gve corresponds with 1 cow.

Table 1
Regulations in MINAS

Quality of slurry

In this paper, slurry quality was defined by both the ratio of P / N / potassium / organic matter in the slurry and this ratio compared to the ratio of the crop requirements for these components. The better the slurry composition was adjusted to the requirements, the better the slurry quality and the lower the slurry (disposal) price. The price was determined by the difference between (1) the amount of N, K, and organic matter which maximal could be applied on the land (depending on the regulations) and (2) the amount of effective N, K and organic matter brought onto the land with the slurry by applying as much slurry as the phosphate standard allowed.

Slurry quality could be improved by changing the ratio between P, N, K, and organic matter. A pig farmer could realize this by changing the mineral content of the feed ration or by slurry treatment. Moreover, slurry treatment was used to lower the slurry transporting costs by removing water from the slurry. Most slurry treatments were based on separation of the slurry in a thin watery fraction and a thick fraction. The thin fraction could be used as a N-K fertilizer, the thick fraction as a P-organic matter fertilizer. The qualities of these two fractions were based on their fertilizing values.

Quantitative assumptions within MINERALFLOW

In table 2, the defined situations at onset for farms with fatteners are presented. The farm situations varied with the number of pigs and performance.

		fav.[1] (1)	unfav.(2)	fav.(3)	unfav.(4)
number of fattener places[2]		435	455	2690	2810
occupancy percentage	%	92	88	93	89
daily gain	g/day	750	700	760	710
feed conversion ratio	kg/kg	2.70	2.90	2.50	2.80
water usage	l/kg food	2.10	2.30	2.10	2.30
housing costs[3]	Dfl/place	90	90	71	71
slurry treatment costs (centrifuge)	Dfl/m^3	5.95	5.95	5.95	5.95

[1] fav. = favourable performance, unfav. = unfavourable performance.
[2] The number of places is higher on farms with a lower occupancy percentage to reach an equal number of delivered pigs per year.
[3] Excluding slurry treatment, slurry storage outside the pig house, food storage and feeding system.

Table 2
Main quantitative assumptions within MINERALFLOW

In the situations at onset the farms had 14.4 hectare of land (8 hectare gras, 3.4 hectare maize and 3 hectare sugar beets). The slurry that was not applied on own land, was sold to an intermediair at an intermediair slurry price of 15.00 Dfl per m^3. The farms had a low emission pig barn and slurry was applied in spring. Application in autumn decreased the N effectiveness by 50%.

3. First results and discussion

Tightening regulations

Over time, regulations in MINAS tightened (table 1). It appeared that the phosphate regulations were strict for pig slurry. As a consequence of tightening regulations total application space for P on own land reduced resulting in a higher optimal value of the P content of the ration. In 1998 the calculated optimal P content of the ration was 4.92 g per kg food, in 2000 5.02 g per kg and eventually in 2005 5.12 g per kg. For the larger farm, optimal P content of the ration was the upper value defined, i.e. 5.12 g per kg. The economic performance decreased with 0.04 Dfl on the large farm and 0.30 Dfl on the small farm, each time the regulations tightened. At farm level total decrease in economic performance was almost equal for all four farms.

Due to tightening regulations less slurry could be applied on own land, thus increasing the amount of slurry which had to be sold to an intermediair against a higher price. This increased total slurry costs. A pig farmer had to find the optimal combination of feeding costs and slurry costs. In figure 1 an example is given for the farm with 400 fatteners and favourable performance. In this case the optimal strategy, i.e. the strategy with the minimal sum of feeding and slurry costs, was reached at a P content of the feed ration of 4.92 g per kg.

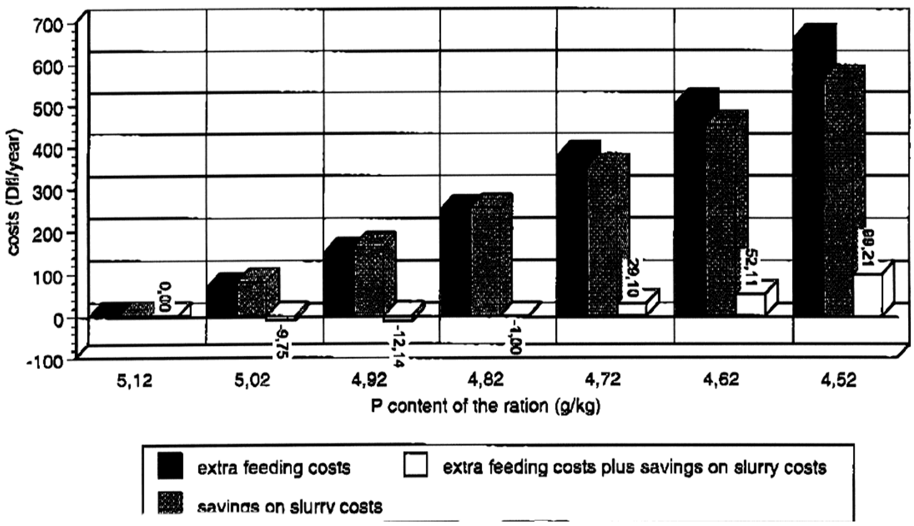

Figure 2
Extra feedings costs, savings on slurry costs and sum of feeding and slurry costs for 400 fatteners in relation to the P content of the ration.

Higher pressure on the slurry market

A higher pressure on the slurry market resulted in higher slurry prices. As slurry prices increased from 15.00 Dfl to 45.00 Dfl, the optimal P content of the feed ration decreased from 4.92 with two phase feeding to 4.05 g/kg with multi phase feeding for the small farms and from 5.12 with two phase feeding to 4.37 g/kg with three phase feeding for the large farms. Three phase feeding was optimal for the large farm, because the additional investment costs could be spread over a large number of pigs. At very high slurry prices, 45.00 Dfl or higher, the optimal strategy for the large farm at onset was reducing the volume of slurry sold to an intermediair by slurry treatment. The thin fraction was applied on own land and the thick fraction was sold to an intermediair. The large farm treated as much slurry, untill the total costs of treating 1 m^3 slurry, i.e. treatment costs, application costs of the thin fraction, including a levy, and the selling costs of the thick fraction, were higher than the slurry price.

Number of hectares

The optimal mineral content of the feed ration depended on the amount of hectares own land (figure 2). Only in a small limited number of farm situations, the optimal P content of the ration was lower than the upper content defined in the model. Too little land implied that savings on the slurry costs were too small. The amount of additional slurry that could be spread on own land as the P content in the slurry was lower, was so small for a farm with little own land, that the savings on the slurry costs did not make up for the additional feeding costs. When a farm had enough own land to apply all the slurry, it was not necessary to reduce the level of P produced, because no savings could be made on slurry costs. The small farm had a lower optimal P content in the ration from around 12 to 22 hectares, depending on the performance. An unfavourable performance implied a high P production in the slurry and more own land needed to apply all slurry produced.

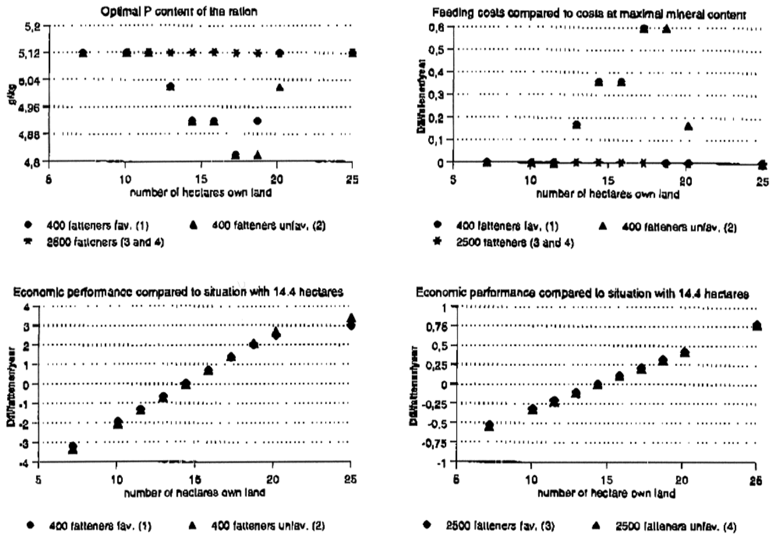

Figure 3
Optimal P content, extra feeding costs and economic performance in relation to the number of hectares own land.

Application on arable land with a quality approach

In table 3 the optimal mineral strategy and the slurry price are given when all slurry was applied on one type of crop in spring and in autumn for the farms in the situation at onset with favourable performance.

	Optimal P content				slurry price			
	400 fatteners		2500 fatteners		400 fatteners		2500 fatteners	
	spring	autumn	spring	autumn	spring	autumn	spring	autumn
intermediair	4.92	4.92	5.12	5.12	15.00	15.00	15.00	15.00
gras	5.12	4.82	5.12	4.77	8.49	11.10	8.36	10.98
maize	4.72	4.62	4.77	4.47	11.63	14.18	11.40	13.74
winter wheat	4.72	4.62	4.77	4.47	11.63	13.93	11.40	13.52
sugar beets	4.72	4.62	4.77	4.67	11.63	12.47	11.40	12.67
consumption potatoes	4.52	4.52	4.37	4.37	11.74	16.94	11.38	16.17
industrial potatoes	4.72	4.62	4.77	4.37	11.63	15.88	11.56	14.92
seed-potatoes	4.72	4.62	4.77	4.37	11.63	15.88	11.56	14.92
summer barley	4.72	4.72	4.77	4.77	11.63	11.63	11.40	11.40
seed-onions	4.62	4.52	4.77	4.37	12.86	14.06	12.93	13.28

Table 3
Optimal P content of the ration (g/kg) and slurry price (Dfl/m^3) by applying all slurry in spring or autumn on one type of crop for farms with a favourable performance

When slurry quality was taken into account, it appeared that only measures to reduce the P content of the ration were cost effective and measures to reduce the N content of the ration were not. Table 3 shows that the optimal P content of the ration when applying pig slurry to arable land, depending on the type of crop, application time and number of pigs, laid between 4.37 and 4.77 g/kg which was lower than the optimal P content when selling to an intermediair (4.92 to 5.12 g/kg). With application on grasland the optimal P content of the ration laid between these values. For the large farm three phase feeding was optimal with application on arable land, for the small farm two phase feeding on all possible applications.

The intermediair slurry price was fixed at 15.00 Dfl and assumed to be not depending of the slurry quality. The slurry price at application on arable land depended on the type of crop and laid in spring between 11.63 Dfl and 12.86 Dfl for the small farm and between 11.40 Dfl and 12.93 Dfl for the large farm. Application on arable land in autumn raised slurry prices due to the lower N effectiveness. Slurry prices varied in autumn between 11.63 Dfl and 16.94 Dfl for the small farm and between 11.40 Dfl and 16.17 Dfl for the large farm. The slurry price for grasland was about 3.00 Dfl lower than for arable land because application costs were about 3.00 Dfl lower. In general, exept for application on seed-onions, the slurry price for the large farm was lower than for the small farm.

The optimal values of the small and large farm with unfavourable performance (situations 2 and 4) were comparable to those of the farms with favourable performance (situations 1 and 3 respectively). In general the optimal P content of the ration was lower and the optimal slurry price higher.

4. Conclusions

4.1. With the above presented model of the slurry market and the MINAS legislation, it generally could be said that measures to reduce slurry costs were based on the P excretion. This meaned in the first place that measures to reduce the P content of the ration were taken and measures to reduce the N content of the ration were not cost effective.

4.2. The amount of reduction of the P content of the ration primarily depended on the ratio of application space for P on own land and the amount of food used. A farm reduced the P content in the ration when the additional feeding costs were smaller than the reduction in slurry (disposal) costs. Slurry costs reduced as the P content of the slurry decreased and a larger volume could be spread on own land, at lower costs than selling to an intermediair. In general a lower P content in the ration was optimal when the total P production in the slurry was just lower than the total application space for P on own land.

4.3. A high pressure on the slurry market resulted in a high intermediair slurry price, which leaded to more incentives to take measures to reduce the amount of P excreted in the slurry by reducing the P content of the feed used or changing to three or multi phase feeding. A higher level of the intermediair slurry price resulted in a lower optimal P content of the ration.

4.4. When slurry quality was taken into account, the optimal P content of the ration when applying pig slurry to arable land was lower than when selling to an intermediair, without slurry quality. Application on grass land implied an optimal P content of the ration in between these values. As the N effectiveness decreased the slurry price increased. Also the optimal P content of the feed was lower when the N effectiveness was lower.

5. Literature

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