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Grazing animal husbandry based on sustainable nutrient management

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Abstract

Sustainable husbandry systems for grazing animals (cattle and sheep) can be achieved by sustainable nutrient management (SNM). This implies the tuning of inputs to outputs of nutrients, to achieve and maintain optimum ranges of agronomically wanted and ecologically acceptable reserves of single nutrients in the soil. P is presented as the 'boss cow of the nutrient herd' and its optimum range of available reserves, in the Netherlands expressed as P-AL count, is quantified as a P-AL count of 30–55. SNM is elaborated into two scenarios. In both, output of milk and meat is compensated for by a P-equivalent input from concentrates. However, in the scenario 'off-take manure', on soils with a P-AL count greater than 55, all manure produced indoors is to be removed from the farm until the P-AL count is 55 or less. If large-scale manure processing is not a realistic option, the scenario 'own concentrates' can be followed. In this case, on soils with a P-AL count of 55–100, output of milk and meat can no longer be compensated for by a P-equivalent input from concentrates, so concentrates are to be produced on the farm. Furthermore, soils with a P-AL count greater than 100 need maximum sanitation by off-take of all plant produce, so grazing and manure application are no longer allowed. At the farm level, SNM is elaborated into a quota system for stocking rate (livestock units ha^{-1}) and milk production (kg milk 4% fat ha^{-1}). If applied on a national level in the Netherlands, SNM will extensify grazing animal husbandry through a reduction in stocking rate by 27–41% and in milk production by 16–34% in the scenarios 'off-take manure' and 'own concentrates', respectively. At the same time, livestock and milk quotas will be redistributed across regions and farms. Consequently, current surpluses on the annual P balance-sheet of the national grazing animal husbandry will turn into 'shortages', implying a gradual decline in excessive soil P reserves. In the scenario 'off-take manure', this is achieved by a more than 50% reduction in the import of concentrates and by the export of stable manure. In the scenario 'own concentrates', it is achieved by a complete replacement of import of concentrates by concentrates produced on-farm. In a similar way, SNM reduces the surpluses on the N balance-sheet of the national grazing animal husbandry.

Keywords: Input–output nutrient balance-sheets; Sustainable stocking rates; Milk quota; Manure surpluses; P-saturated areas; Extensification

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1. Lack of sustainability

Intensive animal husbandry, as practised in the European Union (EU) and the USA, is not economically nor ecologically sustainable, because there is insufficient control of production and of nutrient flows. Surplus production causes a fall in prices, and eventually loss of income and unemployment. Excessive inputs of nutrients cause accumulations in the soil and eventually losses into groundwater and surface waters. In 1985–1986 in the Netherlands, grazing animal husbandry including calf rearing and bull fattening, was responsible for about 65% of the N surpluses (650 000 000 kg) of the 'national farm' and more than 25% of the P surpluses (80 000 000 kg) (Van der Meer and Meeuwissen, 1989). Facing such problems, policy-makers have developed various instruments, but these are inadequate. The present EU milk quota does not assure a stable, soil-borne milk production and encourages a shift from milk to meat production.

The application of manure is increasingly restricted by law. For example, the Netherlands has adopted norms for P input in manure and fertilizer related to P output in feed at the field level. However, these P input norms are several times the P output in animal products (meat and milk) at the farm level, as most of the P taken off by grass and fodder crops is returned as manure. Consequently, accumulation and loss of P and other nutrients continues. The ultimate goal of manure legislation in the Netherlands is the realization of the so-called 'final norm' for P: input equal to output. At the farm level this amounts to 25–30 kg ha^{-1} $year^{-1}$ P on arable farms and only 10–15 kg ha^{-1} $year^{-1}$ P on grazing farms. (In principle, grass and fodder crops also withdraw 25–30 kg ha^{-1} $year^{-1}$ P, but after their conversion into milk and meat, the greater part of the nutrients remains on the farm as farmyard manure.) Meanwhile, besides the area of forage maize, large areas of grassland are becoming saturated with P in the Netherlands (Breeuwsma and Reijerink, 1992). In the case of grassland, 27% has achieved a P-AL count far above the agronomically wanted reserves (Fig. 1). (P-AL count is the common indicator in the Netherlands for available P reserves in grassland (mg P_2O_5 per 100 g of soil extracted in a solution with a shaking ratio of 1:20 of 0.1 N ammonium lactate and 0.4 N acetic acid).) Delay in introducing legislation to achieve P input equal to P output will increase the area of grassland with excessive P reserves and associated accumulation of cadmium and other heavy metals. It will also increase losses into groundwater and surface waters, affecting the quality of life of future generations. At present, only the short-term consequences of manure surpluses, namely eutrophication and acidification of forest and nature areas by ammonia and pollution of groundwater by nitrate, are taken seriously by politicians. As a result, control of N emissions from buildings, manure silos and spreaders is at present receiving more attention than control at the source by reducing total input of nutrients. Moreover, the initial results from this curative approach are disappointing.

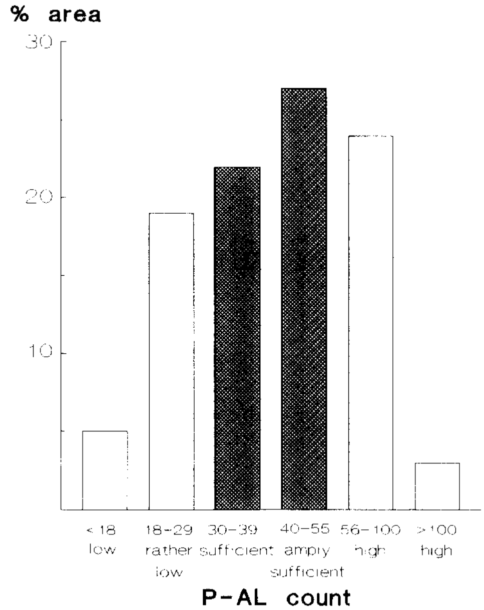

Fig. 1. Available P reserves of the Netherlands' grasslands 1991–1992 (1.1×10^6 ha) and the agronomic appreciation.

To prevent a further intensification of grazing animal husbandry, reduction in stocking rates is becoming increasingly urgent. The EU is still investigating the possibilities of introducing a maximum stocking rate. Such a measure would be simpler and more fraud resistant than present manure and mineral accounting. In a recent policy paper, the Netherlands' Ministry of Agriculture, Nature Management and Fisheries (LNV) suggested a maximum stocking rate of three livestock units per hectare (LNV, 1989). However, this limit is too high to reduce effectively the existing surplus production of milk and meat, and surpluses of plant nutrients, caused by an ever-diminishing relationship between animal production and roughage production on the farm owing to increasing purchases of concentrates. Thus, in terms of energy and nutrients, current stocking rates are not tuned to the variable production potentials of soil for roughage and livestock for milk and meat. Neither is the current manure application level tuned to the agronomically wanted level of soil reserves, which in many places is being greatly exceeded. This paper explains how ecologically and economically more sustainable systems of grazing animal husbandry can be devised by sustainable nutrient management, implying the tuning of stocking rates and manure application to production potentials of soil and livestock. Because it leads to stabilization of animal production, it also provides the basis for economical sustainability of grazing animal husbandry.

2. Sustainable nutrient management as a solution

At present, lack of ecological sustainability of agricultural activities is often deduced from the surplus on annual input and output balance-sheets of various nutrients at farm or regional level. However, such a criterion ignores the available soil reserves of nutrients. Therefore, annual balance-sheets offer no clear insight into actual accumulations or losses and offer little prospect of a sustainable management of nutrient flows and reserves. Fig. 2 shows that a balance-sheet surplus is not necessarily the same as losses. A larger or smaller portion of the surplus is added to the soil reserves. It depends, amongst other factors, on the nutrient in question, the absorption capacity of the soil and the saturation level of this capacity. These factors determine the

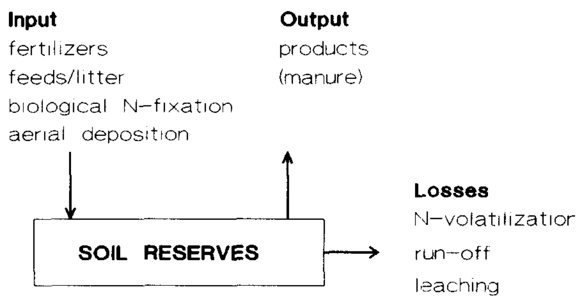

Fig. 2. Nutrient flows in agro-ecosystems (field, farm, region).

available fractions of soil nutrient reserves, which in their turn determine plant production to a large extent, in agriculture as well as in natural areas.

Against this background, the level of available soil reserves is the best criterion to determine whether the input on a balance-sheet should be larger than, equal to, or smaller than the output. There are some complications, however. Nutrients can be put into a farming system singly as fertilizers or combined as farmyard manure and concentrates. They behave very differently (compare P, K and N) and the agronomically wanted level of their reserves varies with the condition of the soil and the requirements of the crop. Nevertheless, is it possible to identify one or more nutrients to represent and control the total flow of macro-, meso- and micro-nutrients and their effects? From an agricultural as well as ecological point of view, P and N seem the most appropriate, considering their dominant role as macro-nutrients. Unlike N, P is not prone to loss in gaseous components, is little soluble in soil water, and is easily immobilized in the soil. Therefore, P is the most stable and easily quantified macro-nutrient and may be called 'the boss cow of the nutrient herd'.

The Netherlands' government has chosen to base its manure legislation on P. However, a policy based on mineral accounting and norms for P input which ignores soil P reserves cannot solve the problem. Therefore, a more preventive approach is called for: sustainable nutrient management (SNM), aimed at agronomically wanted and ecologically acceptable soil P reserves. Additionally, inputs and losses of the other nutrients are adjusted, especially N, the least controllable and therefore particularly polluting nutrient (Vereijken, 1992; Aarts et al., 1992).

3. SNM in two scenarios

SNM aims at the restoration and conservation of agronomically wanted and ecologically acceptable soil nutrient reserves, by tuning the nutrient flows into and from farms to minimize losses of nutrients. For grazing animal husbandry, it implies the tuning of inputs of P in feed or fertilizer to soil P reserves and P outputs in milk and meat (and possibly farmyard manure). The P input in concentrates may equal P output in milk and meat (Table 1) as long as the level of the available soil P reserves, indicated by the P-AL count, is within the agronomically wanted range (i.e. a P-AL count of 30–55, Fig. 1). This assumes no P input by fertilizer and no P output by farmyard manure, nor any other inputs and outputs of P exceeding 1 kg ha^{-1} $year^{-1}$. For the few farms with an average P-AL count less than 30, the same approach is proposed, which implies that they are preferably managed as natural grassland. If required, soil P reserves are increased with farmyard manure.

If the mean available P reserves of a farm are higher than agronomically wanted (i.e. a P-AL count of more than 55; Fig. 1), sanitation of the soil is required. All farmyard manure should be removed from the farm until the agronomically optimum range of P-AL count has been regained (Table 1). A net P output of 20–25 kg ha^{-1} $year^{-1}$ can be achieved if farmyard manure can be processed and exported on a large scale (scenario 'off-take manure'). This scenario assumes that surplus manure cannot be applied on arable land in the Netherlands, as its P need is already covered two to three times by pig and poultry manure. If manure export is not feasible, at a P-AL count of more than 55 surplus soil P reserves can be gradually reduced by no longer compensating P output as milk and meat by P input as concentrates. This implies that concentrates should be produced on-farm, leading to a net P output as milk and meat of only 8–10 kg ha^{-1} $year^{-1}$ (Table 1) (scenario 'own concentrates'). Because the soil will be sanitized at only half the rate, pollution will continue twice as long. Therefore, on soils with P reserves with a P-AL count of more than 100, it is desirable to termi-

Table 1
SNM scenarios 'off-take manure' and 'own concentrates' in grazing animal husbandry, elaborated for increasing levels of available soil P reserves

Scenarios	Level of available soil P reserves (P-AL count)	Agronomical appraisal	Ecological appraisal	P output	P input	Net P output[1] (kg P ha^{-1})
Both	< 30	Unwanted	Wanted	Milk/meat	Equivalent to output milk/meat	0
Both	30–55	Wanted	Acceptable	Milk/meat	Equivalent to output milk/meat	0
Off-take manure	> 55	Unneeded	Unwanted	Milk/meat/ farmyard manure	Equivalent to output milk/meat	20–25
Own concentrates	55–100	Unneeded	Unwanted	Milk/meat	Nil	8–10
Own concentrates	> 100	Unneeded	Unacceptable	All crop produce (no more animal production)	Nil	30–35

[1]A dry matter production of 10–12 tons ha^{-1} from grassland is assumed and animal production according to Table 2.

nate animal husbandry and remove all crop produce (Table 1). Then, net P output will be at a maximum (30–35 kg ha^{-1} $year^{-1}$) (scenario 'own concentrates').

Sanitation by removing all crop produce is not only faster but also technically more appropriate than manure off-take. As sanitation is time consuming (to reduce P-AL count by 1 unit $year^{-1}$, a net P output of 10–25 kg ha^{-1} $year^{-1}$ is required) and very expensive, government and industry should rapidly adopt SNM.

4. SNM elaborated into a farm structure

At the farm level, SNM can be elaborated into a sustainable farm structure by use of a quota system for livestock and milk production. The number of livestock units (lu, where 1 lu is equivalent to the annual energy need of a 600 kg cow producing 4000 kg of milk (4% fat) (standard cow); based on their annual energy needs, all farm animals, irrespective of species, age or productivity, can be expressed in livestock units) which can be fed on 1 ha of grass or fodder crops, possibly supplemented by an amount of purchased feed P equivalent to the output of milk and meat, is called the sustainable stocking rate (SSR, in lu ha^{-1}) (to be supported by norms for N losses). The SSR varies with the production potential of the soil for fodder crops. Also, in the scenario 'own concentrates', SSR varies with the level of the soil reserves, reaching maximum values at a P-AL count of 55 or less, when the P output in milk and meat may be balanced by the P input in concentrates, and minimum values at a P-AL count of 55–100, when concentrates are to be produced on the farm (Table 2).

A larger or smaller proportion of SSR may consist of dairy cattle. Therefore, a second criterion is added, the quota for sustainable milk production (SQmilk, in kg ha^{-1}). This is the amount of milk (4% fat) to be produced at the SSR and varies between zero (pure meat production) and a maximum (maximum dairy production with a minimum of youngstock, and thus a minimum production of meat) (Table 2, variants *a–z*).

Milk production per hectare increases with the production potential of soil and livestock, so large differences arise. On a hectare basis, almost twice as much milk can be produced on grassland producing 14 tons of dry matter compared with that producing 10 tons of dry matter. In the first case, livestock is kept at 2.9 lu ha^{-1} with a potential milk production of 7500 kg and a minimum of youngstock. In the second case, livestock is kept at 2.0 lu ha^{-1} with a potential milk production of 5500 kg and all youngstock (Table 2, Part (a)). This difference is mainly caused by purchase of concentrates based on P output (2.5 vs. 1.9 tons ha^{-1}), but in addition roughage from more productive grassland is utilized more efficiently because of its higher quality.

Despite large differences in milk production, differences in farmyard manure production are minor. At the two extremes mentioned above, 26 kg ha^{-1} P and 20 kg ha^{-1} P, respectively, are produced as farmyard manure during the indoor period. The farmyard manure production based on the SSR can be called the sustainable quota for manure application (SQmanure, in kg P ha^{-1}). SQmanure is the amount of farmyard manure (in kg P ha^{-1}) produced during the indoor period (cows are also indoors overnight during the grazing period) and to be applied on the farm. SSR, with SQmilk and possibly SQmanure, are clear and manageable criteria for cattle and sheep farmers which can be used to achieve and maintain agronomically wanted and ecologically acceptable reserves of nutrients, first of all P.

5. Restructuring farms

To introduce SNM at farm level, a procedure of restructuring has to be followed. Initially, the actual mean P reserves (soil analysis) and the potential roughage production (regional experimental field data extrapolated by a geographical information system) per hectare have to be determined on each farm. Also, the mean potential milk and meat production per animal (from herdbook data) are determined to calculate SSR. Subsequently, the farmer chooses SQmilk, varying between zero and the calculated maximum,

Table 2
Sustainable stocking rate (SSR)[1] and sustainable quota for milk production (SQmilk)[2] at various production levels of roughage and milk per cow with maximum (*a*) and minimum (*z*) side production of meat

Potential grass production[3] (tons ha^{-1} dry matter)	% Area fodder beet (b) or grass pellets (c)	SSR (lu ha^{-1})	SQmilk (t ha^{-1} milk 4% fat) related to potential milk production[4] (kg per cow per lactation)							
			5500		6500		7500		8500	
			a	*z*	*a*	*z*	*a*	*z*	*a*	*z*
(a) Rations of roughage and purchased concentrates P equivalent to the output of milk and meat (scenario 'own concentrates' on farms with P-AL count ⩽ 55 and scenario 'off-take manure')										
14		2.9	9.2	11.6	10.3	12.8	11.3	13.9		
12		2.5	8.1	10.2	9.0	11.3	9.9	*	*[5]	
10		2.0	6.7	8.5	7.5	*	*	*		
(b) Rations of roughage and farm-grown fodder beet (12 t ha^{-1} dry matter, 1025 VEM[6] kg^{-1} dry matter) (scenario 'own concentrates' on well-drained farms with P-AL count 55–100)										
14	16	2.4	7.7	9.8	8.6	10.8	9.4	11.7		
12	14	2.1	6.9	8.7	7.7	9.7	8.5	*		*[5]
10	12	1.8	5.9	7.5	6.6	*	*	*		
(c) Rations of roughage and farm-grown grass pellets (12 t ha^{-1} dry matter, 850 VEM kg^{-1} dry matter (scenario 'own concentrates' on farms with wet soils with P-AL count 55–100)										
14	20	2.3	7.3	9.3	8.2	10.2	9.0	11.1		
12	19	2.1	6.6	8.3	7.4	9.2	8.1	*	*[5]	
10	15	1.6	5.7	7.2	6.4	*	*	*		

[1]Sustainable stocking rate is number of livestock units (lu ha^{-1}) which can be fed on 1 ha of fodder crops. SSR is maximum if output of milk and meat can be compensated by a P equivalent input from concentrates. It is minimum if all concentrates have to be produced on farm.
[2]Sustainable quota for milk production is the amount of milk (4% fat) which can be produced at an SSR. At any SSR, SQmilk has a range. It is maximum if only youngstock for replacement are kept (variant *z*) and minimum if all youngstock are reared or fattened on the farm (variant *a*). Only these two extremes of SQmilk have been calculated.
[3]Potential roughage production is the sum of daily grass growth during the growing season at standard usage, depending on climate, soil type and hydrological regime, at optimal fertilizer status and with strict standards for emission of ammonia and nitrate.
[4]Potential milk production is the mean amount of milk (4% fat) per cow per lactation based on data from herdbook registration.
[5]Ration below norms.
[6]VEM, feed unit lactation, the net energy for milk production (1 VEM = 1.65 kcal = 6.9 kJ NE). The net energy (Netherlands system) is about 60% of the metabolic energy (English system) (1 VEM = 11.5 kJ ME).

and the farm structure can be adjusted accordingly. SSR and SQmilk fix the permitted meat production. There are two variants for the introduction of SNM on the farm (Fig. 3).

Variant I applies to the majority of the Netherlands' farms and implies an obligatory extensification of the present farm structure. It relates especially to the smaller farms, which until now have maintained their income and employment by intensification. Stocking rate and quota for milk production can be reduced by sale or lease in the case of farmers without a successor, or those with health problems or a separate income (Variant Ia). Alternatively, systems can be made more extensive by purchase or lease of land in the case of farmers wishing to maintain a full income from the farm (Variant Ib).

Variant II applies to the minority of the Netherlands' farms and implies a voluntary intensification. It relates especially to the larger farms, which until now did not need intensification to maintain their income. Stocking rate and quota for milk production can be increased by purchase or lease (Variant IIa). Farmers with good-quality grazing land for dairy cattle may increase the quota for milk production. Farmers with lit-

Does
present stocking rate/quota for milk production
exceed
sustainable stocking rate/quota for milk production?

YES (I)	NO (II)
obligatory decrease stocking rate/quotum for milk production by sale or lease of stock and quotum in excess (Ia) or purchase or lease of land in shortage (Ib)	voluntary increase stocking rate/quotum for milk production by purchase or lease of stock and quotum (IIa) or sale or lease of land (IIb)

Fig. 3. Restructuring of grazing animal husbandry farms according to sustainable stocking rate (SSR) and subsequently to sustainable quota for milk production (SQmilk).

tle free labour capacity or with grazing land too poor for dairy cattle may increase the stocking rate for beef cattle or sheep. Alternatively, intensification can be achieved by sale or lease of surplus land (Variant IIb). These restructuring variants based on SNM can result in a reallocation of land, livestock and milk quota with the needed flexibility, despite their strict character.

6. Consequences for farm management

SNM implies the restoration of traditional self-supporting grassland management during both summer and winter. It has important consequences for both quantity and quality of the roughage. At present, dairy husbandry relies on high-quality roughage requiring relatively young swards. As a result, total grass production remains far below potential production. Moreover, high protein contents in young swards are nutritionally excessive and lead to high N losses (Van Vuuren et al., 1990). In SNM, more emphasis is given to the quantity of the roughage although maintaining a minimum quality to be specified. It requires a restricted number of relatively full-grown swards near the potential production (1700 or 3500 kg dry matter ha^{-1} for grazed or mown swards).

Farm management based on SNM requires maximum possible efficiency in conversion of roughage into milk and meat. From Table 2, Part (a), it appears that, at a certain potential roughage production, the SQmilk increases with the potential milk production per cow up to a maximum. At this maximum, the allowed purchase of concentrates according to a P balance is just enough for dairy cattle to realize their potential milk production ('standard feeding'). Dairy cattle with a higher potential ('concentrate cows') are restricted to such an extent by the quality of the roughage that actual milk production per hectare will probably increase no further (the entries marked with an asterisk in Table 2). A particular problem is the heterogeneity of soil nutrient reserves within farms. This requires a further elaboration of SNM into a consistent strategy of grassland use and manure application.

7. Consequences for the Netherlands' grazing animal husbandry

Table 3 gives an outline of the national grazing animal husbandry in terms of the SNM scenarios 'off-take manure' and 'own concentrates'. It is assumed that the area of forage maize is destined for cattle and sheep only. As a consequence, manure from intensively housed livestock such as pigs and poultry can no longer be spread over maize land and should be recycled in an agronomically appropriate and ecologically acceptable way by arable farmers and vegetables growers (Vereijken, 1990), by export of (processed) manure abroad and, where required, by reducing stocking rates.

Table 3
Livestock and milk production in the Netherlands' grazing animal husbandry[1] for SNM scenarios 'off-take manure' and 'own concentrates'

Level of available soil P reserves (P-AL count)	Acreage (10^3 ha)		SNM scenario 'off-take manure'			SNM scenario 'own concentrates'		
	Maize land	Grass land	Livestock (10^3 lu)	Milk production (10^3 tons year^{-1})	Manure off-take (10^3 tons P year^{-1})	Livestock (10^3 lu)	Milk production (10^3 tons year^{-1})	Manure off-take (10^3 tons P year^{-1})
≤55	0	788	1770	5760	0	1770	5760	0
55–100	24	259	640	2460	6	540	2100	0
>100	178	33	470	1830	5	0	0	0
Total	202	1080	2880	10050	11	2310	7860	0
Reduction compared with 1991[2] (%)			27	16		41	34	

[1]Grazing animals comprise cattle and sheep, including calves for rearing and bulls for fattening. Grass and maize production amounts to 11 tons dry matter ha^{-1} on average, all youngstock is raised (variant *z*) and SQmilk is maximum according to Table 2.
[2]In 1991, 3920×10^3 lu and 11930×10^3 tons of milk (4% fat) were produced.

Table 4
P and N balance sheet of the Netherlands' grazing animal husbandry in SNM scenarios 'off-take manure' and 'own concentrates' (10^6 kg year^{-1})

	Input		Output			Total balance
	Fertilizers	Concentrates	Milk/meat	Manure	Concentrates	
P balance sheet						
1985–1986	11	29	20			20
'Off-take manure'	0	14	14	11	0	–11
'Own concentrates'[1]	0	0	11	0	2	–13
N balance-sheet						
1985–1986	355	144	85			414
'Off-take manure'[2]	277	66	65	62	0	216
'Own concentrates'[2]	277	0	51	0	9	217

[1]Production of concentrates on land with P-AL count greater than 100 is more than enough to cover the need of farms with P-AL count of 55 or less. On land wit P-AL count greater than 100 a crop rotation 1/6 fodder beet, 2/6 maize and 3/6 grass for production of concentrates is assumed.
[2]Organic manure is assumed to be applied with minimum loss of NH_3 (55% crop recovery) and supplementary N fertilizer according to crop requirements.

The area used to produce feed for grazing animals is subdivided into maize land and grassland with three levels of P-AL count. The feasible yield of maize land and grassland is assumed to be 11 tons dry matter ha^{-1}, this being the average of soils that are well drained or well supplied with moisture (12 tons ha^{-1}) and waterlogged or excessively dry soils (10 tons ha^{-1}). Raising of all youngstock is included. This implies that fodder production and manure application in the husbandry of redundant female and male calves (calf rearing and bull fattening) also takes place at the dairy farms, considering the high nutrient status of the Netherlands and the limited export facilities for farmyard manure. At the current maize and grassland production, the SSR with the highest possible milk production per hectare is used in the calculations. Because of a reduction in total stock, we expect the average amount of milk (4% fat) per cow per lactation to increase (Table 2). Compared with the situation in 1991, the national number of grazing animals and milk production will decrease respectively by about 27% and 16% in the scenario 'off-take manure', and by 41% and 34% in the scenario 'own concentrates'. If the Netherlands still had land to allocate, the current number of grazing animals and level of milk production could be maintained by enlarging the area by 460×10^3 ha if the scenario 'off-take manure' is followed or by 720×10^3 ha with the scenario 'own concentrates'.

In the scenario 'off-take manure', with farmyard manure produced during the indoor period on soils with a P-AL count of more than 55, an amount of 11 million kg P is to be removed. Adoption of the P-based SNM results in half of the current input level of concentrates (Table 4). This is the main reason for reducing the contribution of grazing animal husbandry to the national P balance from +20 million kg $year^{-1}$ P to −11 million kg $year^{-1}$ P. In the scenario 'own concentrates', roughage and concentrates are produced on farms with a P-AL count of 55–100, and only concentrates are produced on farms with a P-AL count greater than 100. This results in a complete replacement of imported concentrates by farm-produced concentrates and a reduction in the contribution of grazing animal husbandry to the national P balance from +20 million kg $year^{-1}$ P to about −13 million kg $year^{-1}$ P (Table 4).

In both scenarios, it is assumed that farmers can be convinced that P fertilizers are agronomically not needed and environmentally unacceptable under the present circumstances. The latter may be supported by environmental taxes on P fertilizers and levies or penalties on excessive soil P reserves. Choice of P as the basic instrument for regulation of nutrient input also improves the N balance-sheet. The N surplus of 414×10^6 kg in 1985–1986 for the Netherlands' grazing animal husbandry is reduced by about 120×10^6 kg in both scenarios, assuming an unchanged fertilizer utilization. If N fertilizer use on grassland and maize land is restricted to the level of crop requirement (Aarts et al., 1992), N surpluses are reduced by a further 78×10^6 kg (Table 4).

8. SNM and policy

SNM can be introduced on the basis of maximum self-regulation by the industry and minimum control by the government. It implies that the industry manages SSR and SQmilk whereas the government confines itself to monitoring P reserves of farms by sampling every 5–10 years (on arable and vegetable as well as livestock farms), as much as possible combined with monitoring of N reserves in the autumn. The data from these samples can be used by farmers to apply farmyard manure on a field-by-field basis and to tune the frequency of mowing (maximum nutrient output) and grazing (minimum nutrient output) in each field, to bring grassland use in line with SNM.

If on the national level a step-wise approach is chosen, SNM should at first be implemented in vulnerable regions with P saturation and groundwater or nature reserves, preferably within the framework of land redevelopment (Hermans and Vereijken, 1992). Implementation of SNM at the national or EU level will not only lead to an ecologically sustainable production; by limiting production to agronomic potential and ecological carrying capacity, SNM breaks the vicious circle of surplus production and price or income fall, and thereby also provides for the base of economic sustainability. Thus, SNM offers a fair basis for production control, unlike the administrative contingency in 1984 which favoured intensive farms and placed extensive farms at a disadvantage.

In intensive areas of production, such as the Netherlands, introduction of SNM will reduce production per hectare. It can be compensated for by increasing farm size and/or premiums per hectare or per unit of produce (Hermans and Vereijken, 1992). In the short term, a sustainability premium per hectare can be realized within the Common Agricultural Policy of the EU countries. In the long term, premiums per unit of produce should be paid by consumers based on production under an ecological label (Vereijken, 1992). To mobilize consumer interest, the help of environmental organizations is essential. If the home market is gained by sustainable pro-

duction methods, farmers do not have to fear losing it as a result of the liberalization of world trade.

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