Anim. Prod. Aust. 2002 Vol. 24: 241-244

NITROGEN BALANCES AS A TOOL TO DECREASE NITROGEN SURPLUSES ON DAIRY FARMS

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SUMMARY
138 nitrogen (N) balances from dairy farms in southern Sweden were analysed. The balances were calculated using the farm gate method. N balances of the whole farm are a comparison of the farm's inputs and outputs. Amounts of purchased mineral fertilizer, purchased fodder and purchased concentrate are recorded in the accounts as well as data on milk sold, live animals sold or animals slaughtered and vegetable products sold. The investigation included N balances from three consecutive years, 1997,1998 and 1999.The N efficiency was improved and the N surplus per hectare was decreased in the second and third years of the study relative to the first year. The main reason for this was a lower fertiliser rate of N. However, there was a tendency on farms with a low N surplus in the first year to increase the fertiliser rate of N in subsequent years. The input of N from purchased feed did not change during the study period.

Key words: nitrogen balances, dairy farms, nitrogen efficiency

INTRODUCTION
Mineral balances as a concept were introduced over 100 years ago in research to analyse the nutrient flows in arable land (van Noordwijk 1999). Later they have been widely used both in fields and at farm, regional or national level to analyse nutrient flows (Parris, 1998; Sveinsson *et al.*, 1998). Elements for which balances have been calculated include N, P and K (Sandgren *et al.* 1999).

The overall basic concept for a N-budget is simply a conservation of mass; N in minus N out = N stored within, or lost from the agro ecosystem. N stored within or lost from the system has been called various names; for example: N-surplus (Halberg *et al.* 1995), long term potentially leachable-N, positive or negative balances (Fagerberg *et al.* 1996).

Different types of farm gate balances are used in N-balances. Watson & Atkinson (1999) differentiate between the following three types of balances; economic input/output (EIO) budget accounts for purchased and sales of N over the farm gate, biological input: output (BIO) budget, includes estimates of biological N fixation and attempts to partition losses into leaching and gaseous forms and transfer: recycle: input: output (TRIO) budget, which also accounts for key soil processes.

MATERIALS AND METHODS
Information on the mineral balance sheet of dairy farmers shipping milk to the dairy plant Dairy Skåne was used as an input. The mineral balance sheet N, P and K was constructed using the farm gate model and balances were calculated for the whole farm.

Amounts of purchased mineral fertilizer, purchased fodder and purchased concentrate are recorded in the budgets as well as data on sold milk, sold live animals or slaughtered animals and sold vegetable products. The N fixation from legumes was calculated using a subjective evaluation of the content of clover in the leys. This is an approximate figure and may distort the result if the farm grows a large area of leys (Högh-Jensen *et al.* 1998). The N deposition from the atmosphere is also an approximation, but it is of minor importance for the whole inflow of N. Advisors collected data from the regional society for artificial insemination. The farmers were interviewed about input values and output values, for example how much mineral fertiliser was bought per year or how much concentrate was fed to the animals per year, doubtful data were double-checked with the farmer to exclude incorrect data from the analysis.

The balances were calculated for each calendar year of the study. All data were collected, processed and stored in a database. The protocols from the mineral balances were sent to the farmers in the following spring. Atmospheric N deposition was estimated to be 12 kg /ha according in accordance with estimates made by the Regional Agricultural Society. The N fixation from legumes was calculated according to the method used in STANK (Swedish Board of Agriculture 1999), with the result dependant on a subjective evaluation of the clover content of the leys.

The whole farm's N balance was defined as the difference between N inputs to the farm and the recovery of N in agricultural products. The N surplus per hectare was defined as the difference between input and output of N divided by the size of the farm in hectares. The farm size was defined as land on which it was possible to spread manure , including all arable land at the farm but not natural pasture. The N efficiency was defined as the ratio between N output and N input (van der Hoek 1998).

All farms shipping milk to Dairy Skåne were defined as dairy farms. Most of the dairy farms were, as stated before, mixed farms, hence, could produce arable crop products or other animal products, for example pig meat. In the analysis dairy farms, which produced other animal products for example pigs were excluded. Dairy farms that exported or imported manure were excluded from the statistical analyses due to the uncertain analytical values of nitrogen in manure (Oenema *et al.* 1998; Steineck *et al.* 1999). The number of remaining dairy farms with mineral balances for all three years was 138.

RESULTS

The average area of arable land was approximately 65 hectares and milk delivery per hectare was about 6800 kg. The size of farms varied during the study due to changes in renting of land or the inclusion of newly purchased land. The delivered milk yield per hectare was similar throughout the years. Input of N from mineral fertiliser and fixation of legumes decreased significantly from the first year (Table 1). The N surplus per hectare decreased by approximately 25 kg between 1997 and 1998. This improvement did not continue into the next year, 1999. The N efficiency followed the same trend. The changes between 1997 and 1998 in N surplus per hectare and N efficiency were statistically significant, but there was a great variation in both parameters (Table 1).

Table1. Means values and standard deviation of N efficiency and N surplus per hectare. Farms that export manure are excluded from the analysis (n = 138)

Factor	1997		1998		1999		
	Mean	SD*	Mean	SD	Mean	SD	*P* for year
Arable land (ha)	58 a	51	66 a	61	66 a	62	ns
Total milk delivery per year (kg)	371347 a	254152	394027 a	268864	420021 a	290740	ns
Delivered milk yield (kg/ha)	6917 a	2319	6622 a	2513	6865 a	2219	ns
N from mineral fertiliser (kg N/ha)	101 a	39	88 b	35	91 b	33	0.0101
N from purchased feed, kg (N/ha)	86 a	40	80 a	41	86 a	44	ns
N from fixation by legumes (N/ha)	33 a	21	26 b	20	26 b	18	0.0020
N efficiency, %	24 a	8	27 b	8	29 b	8	0.0025
N surplus (kg N/ha)	187 a	57	161 b	57	167 b	57	0.0002

SD = standard deviation, ns= non significant
a,b Values within a row without a common letter differ significantly

In Figure 2 the dairy farms were classified in four groups according to the surplus of N per hectare 1997. Figure 2 shows a difference in the rate of N from mineral fertiliser between dairy farms with a low surplus of nitrogen per hectare in 1997 and a high surplus per hectare in 1997. The dairy farms with a high surplus in 1997 decreased the inflow of N from mineral fertiliser, while those with a low surplus increased the inflow of N from mineral fertiliser.

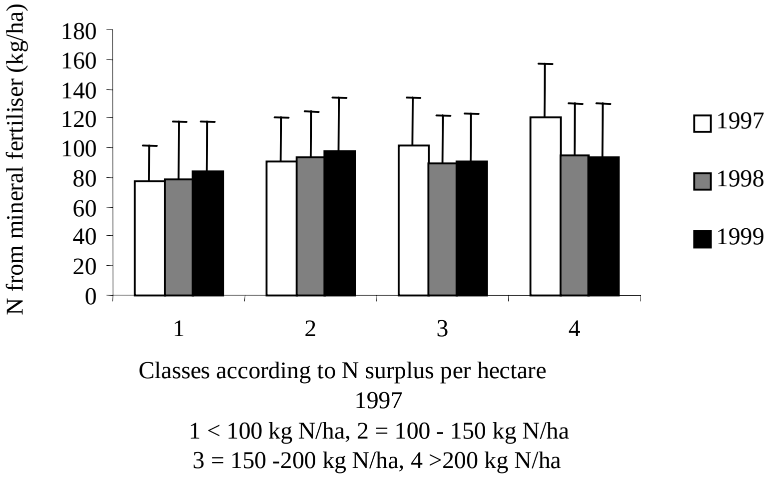

Figure 2. Change of N from mineral fertiliserduring the years 1997, 1998, 1999

DISCUSSION

Farm gate balances of minerals have both advantages and limitations. Advantages are that they are easy to calculate and produce key-figures, which are easy to compare with other farms from the same region or with other countries. According to Oenema (2001), farm gate balances are more reliable than soil surface budget or soil system budgets. An uncertain source of N is the N fixation from leys (Högh-Jensen *et al.* 1998). This N source can be of great importance, especially with a low input of N from purchased mineral fertiliser. It is also difficult to compare N balances from conventional and organic farming where the latter is often based on N fixation from legumes which is probably underestimated in organic farming systems.

The Netherlands has the highest nitrogen surplus in the whole of Europe, estimated to be approximately 300 kg N per hectare (Neeteson 2000). N-surplus was defined as ammonia volatilization + leaching + denitrification + change in mineral N and organic N in soil. Also Denmark has an average above that of our investigation (Halberg *et al.* 1995). Two factors can explain the difference between the Netherlands, Denmark and our results. First, both the Netherlands and Denmark have a higher inflow of N from mineral fertiliser, secondly they also have a more intensive milk production, expressed as kg milk ha^{-1}. In our investigation, the inflow of N from mineral fertiliser was 100 kg and milk delivered to the dairy industry was on average, slightly more than 6800 kg ha^{-1}. Our investigation was carried out in one of the most intensive animal production regions in Sweden, which means that the N surplus should be smaller for other parts of Sweden. When comparing the three years, the N surplus per hectare decreased and the N efficiency improved. The explanation of this is probably a lower input of N from purchased mineral fertiliser and N fixation from legumes, calculated per hectare. The input of N from purchased feed per hectare was on the same level, on the other hand, during the three years (Table 1).

Choosing between good N efficiency and a low N surplus per hectare it is probably more important with a low N surplus. Small surpluses mean a reduced pressure on the environment per hectare, land is a limiting factor in most countries land (Halberg 1999).

Conclusions

- N surplus per hectare among dairy farms in the south of Sweden is lower than corresponding levels found in other intensive milk production countries in western Europe, for example the Netherlands and Denmark.
- The N surplus per hectare among the investigated dairy farms decreased from 1997 to 1999.
- The decrease of N surplus per hectare was probably due to a change of strategy in the use of mineral fertilizer.

REFERENCES

FAGERBERG,B., SALOMON, E. & JONSSON,S. (1996). *Swedish J. Agric, Res.* 26: 169–80.

HALBERG, N. STEEN KRISTENSEN, E. & SILLEBAK KRISTENSEN. (1995). *J. Agric. Environ. Ethics* **8**, 30-51.

HALBERG, N. (1999). *Agr. Ecosyst. Environ*. **76**, 17–30.
HÖGH- JENSEN, H., LOGES, R., JENSEN, E.S., JÖRGENSEN, F.V. & VINTHER, F.P. (1998). *In* ‘Kvaelsofudvaskning og - balancer i konventionelle og ökolgiske produktionssystemer’ (Ed. Kristensen, E.S Olesen). Föjörapport 2, Forskningscenter for Ökologisk Jordbrug.
NEETESON, J.(2000). *Biol. Fertil. Soils*. **30**, 566-72.
OENEMA, O., BOERS, P.C.M., van EERDT, M.M., FRATERS, B., van der MEER,H.G., ROEST,C.W.J., SCHRÖDER, J.J. & WILLEMS, W.J. (1998). *Environ. Pollut*. **102 (S1)**, 471–8.
OENEMA, O. (2001). *In* ‘Proceedings of the Workshop on Element Balances as a Sustainability Tool’ March 16 – 17, SLU, Uppsala.
PARRIS, K. (1998). *Environ. Pollut.***102 (S1)**, 219-25.
SANDGREN, P., SWENSSON, C. & SÄLLVIK, K. (1999). Växtnäringsbalans på mjölkgårdar i södra Sverige. *SSJ - Info* 17. Sydsvensk Jordbruksforskning. *In Swedish.*
STEINECK, S., GUSTAFSON, G., ANDERSSSON, A., TERSMEDEN, M. & BERGSTRÖM, J. (1999). *In* ‘Swedish Environmental Protection Agency, Report 4974’. *In Swedish.*
SVEINSON, T., HALBERG, N. & KRISTENSEN, I.S. (1998). *In* ‘International Workshop on Mixed Farming Systems in Europe’. Dronten, The Netherlands, 25 - 28th May.
THE SWEDISH BOARD OF AGRICULTURE. (1999). Manual till kalkylprogrammet STANK 3.1. *In Swedish.*
VAN DER HOEK, K.W. (1998). *Environ. Pollut.* **102 (S1)**, 127–32.
VAN NORDWIJK, M. (1999) *In* ‘Nutrient Disequilibria in Agroecosystems Concepts and Case Studies’ (Eds E.MA. Smaling, O.Oenema and L.O. Fresco).pp 1 – 26. (CAB International, Oxon).
WATKINSON, C.A, & ATKINSON, D. (1999). *Nutr. Cycl. Agroecosys.* **53**, 259-67.

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