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Element balances as a sustainability tool

Workshop in Uppsala March 16 – 17, 2001

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Contents

Introduction

The workshop ”Element balances as a sustainability tool” originated in the project ”Sustainable nutrient flows”, which is a part of the synthesis work carried out within the Swedish research programme Food 21 – Sustainable Food Production. On the basis of a preliminary study of methods for monitoring nutrient flows and budgets on farm and field scale, we decided to invite people from Sweden and other countries to a workshop on the subject for mutual sharing of experiences and methods. There are many people working with nutrient and trace element flows, balances and budgets, and one aim was also to establish a network of people working with research and applications within this field. The workshop is arranged as a satellite meeting to the European Conference FoodChain2001 held in Uppsala March 14-16.

We decided to focus on element balances as a sustainability tool. Without further elaborating on the concept of sustainability, our aim was to illuminate the dual purpose of element balances, to increase nutrient efficiency and to decrease negative environmental impact. A fundamental question is how useful the element balances are for these purposes.

An organising committee was established, consisting of Associate professor Ingrid Öborn from the Swedish University of Agricultural Sciences (SLU), Research Coordination Manager Kjell Ivarsson Swedish Farmers’ Supply and Crop Marketing Association and Research Manager Anna Richert Stintzing from the Swedish Institute for Agricultural and Environmental Research. The planning of the workshop has been carried out in a group consisting of the above mentioned, plus Drs Karin Blombäck, Minh Ha Fagerström, Professor Ingvar Nilsson and Drs Håkan Marstorp and Ernst Witter from the Department of Soil Sciences, SLU.

We are aiming at an international publication of selected full papers and review papers from the workshop after peer review in a special issue of European Journal of Agronomy. Guest editors will be Professor Ingvar Nilsson, SLU, and Dr Anthony Edwards, Macaulay Land Use Research Institute, Scotland.

The results so far are promising, we are happy to say that we have received 46 abstracts for presentation during the workshop and that 70 participants have registered for what promises to be two very interesting and fruitful days. Welcome to Uppsala!

Programme

Friday March 16

14-15	**Registration and coffee** at Hotel Linné (posters are mounted for display)
15.00	**Welcome address**, **Rune Andersson**, Program director of Food 21
	Introduction by the organising committee
15.15-18.30	**Key-note presentations (30 min) and discussions (15 min)**
15.15	**Meine van Nordwijk,** ICRAF Southeast Asia, Indonesia. Element balances at different scales as a tool to understand and improve sustainability of agricultural production systems.
16.00	**Steve Jarvis**, IGER, UK. Improving N use efficiency from balance sheets – will it result in reduced losses to the environment?
16.45	Break
17.00	**Paul Withers**, ADAS, UK. Field nutrient budgeting as a tool for nutrient management and environmental risk assessment. Phosphorous as an example.
17.45	**Oene Oenema**, Wageningen University and Research Centre, NL. Uncertainties in nutrient budgets due to biases and errors; implications for policies and measures and decision support systems.
19.00	**Dinner**
20-23	**Evening session. Posters, refreshments and entertainment** (posters will be on display during the entire workshop)

Saturday, March 17: Workshop sessions

7.30-8.45 **Breakfast**

9.00-15.00 **Workshop sessions** in groups.

Group 1: N balance sheets as a measure of N use efficiency and N losses. How do we include the soil N processes?

Group 2: Interpretation and uncertainties of element balances at different spatial and temporal scales- from field to regional levels.

Group 3: Selecting the tools: Element balances versus other agricultural and environmental management tools such as soil testing, critical limits, stocking rates etc.

10 Coffee

12-13 Lunch

15.00-15.30 Coffee break

15.30-17 **Final discussion and conclusions:**

15.30 **Reports from the workshop groups** (group 1 Steve Jarvis; group 2 Oene Oenema, group 3 Paul Withers)

16.00 **Discussion** about the outcomes of the workshops

16.45-17 **Summing up and concluding remarks** (M van Nordwijk)

18.00 **Dinner, Cultural Event and/or Music Pub**

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Workshop sessions Saturday March 17 at 9-15

During the morning and early afternoon sessions the participants will be working in three groups to discuss different aspects of element budgets and balances. The maximum number of participants in each group is set to 25 persons. Aspects of element budgets and balances that are common to all groups are:

1. How useful are element budgets and balances as a tool to increase nutrient use efficiency and reduce losses to the environment? What is your experience?

2. How can element budgets and balances be applied in agricultural and environmental management plans? How can existing accounting systems be improved/ or how should they ideally be constructed? Which complementary tools do we need?

The three groups will have different focuses when dealing with these questions. Each workshop will start with short (10 or 20 min) oral presentations of selected papers followed by group work and discussions in which everybody will participate on basis of their ideas, knowledge and experiences.

Group 1: N balance sheets as a measure of N use efficiency and N losses. How do we include the soil N processes?

Moderators: Håkan Marstorp, Ernst Witter, Kjell Ivarsson and Steve Jarvis

Speakers:

Marjoleine Hanegraaf: ”Perspectives and limitations of nitrogen balances”

Viesturs Jansons: ”Catchment and field nutrient balance and trends in nutrient run-off in Latvia”

Anders H Nielsen: ”Element budgets as a management tool on dairy farms in Denmark”

Janne Linder: ”STANK- the official model for input/output accounting on farm level in Sweden”

Søren K Hvid: ”Use of farm-specific reference figures for nitrogen surplus in nutrient balances”

Thord Karlsson: ”ICBM-N, a simple model for including internal soil N fluxes in field-scale balances”

Group 2: Interpretation and uncertainties of element balances at different spatial and temporal scales – from field to regional levels.

Moderators: Ingvar Nilsson, Karin Blombäck, Tony Edwards, Minh Ha Fagerström, Meine van Nordwijk and Oene Onema

Speakers: Avo Toomsoo and Tomas Törra: ”Nutrient balance of the Rägina River Watershed in Matsalu”

Tony Edwards: “Identification, designation and formulation of an action plan for a Nitrate Vulnerable Zone: A case study the Ythan Catchment, NE Scotland.”

Carlo Grignani: “Developing a Regional Agronomic Information System (RAIS) for large scale estimates of nutrient losses.”

Lennart Mattsson: “Nutrient balances in a long-term perspective based on 40-year field experiments.”

Karin Blombäck: “Is it possible to aggregate complex information at field scale into a few model parameter values valid for a whole catchment?”

Group 3: Selecting the tools: Element balances versus other agricultural and environmental management tools such as soil testing, critical limits, stocking rates etc.

Moderators: Anna Richert Stintzing, Ingrid Öborn and Paul Withers

Speakers: Gillian Goodlass: ”Input Ouput Accounting Systems in the European Community - an appraisal of their usefulness in raising awareness of environmental problems”

Christine Watson: ”Fate of N and P in outdoor pig production systems”

Ingrid Rydberg: ”Phosphorous as a limiting factor for livestock density”

Armin Keller: ”The influence of changes in P fertilization plans on Cd and Zn balances for farming systems”

Anne Falk Øgaard: ”K balances versus soil testing as a tool for optimal K fertilisation of grass”

J. J Schröder: ”Potential and limitations of whole-farm nutrient balances”

Abstracts

Keynote speakers

Element balances at different scales as tool to understand and improve sustainability of agricultural production systems

Meine van Noordwijk[1] and Jacques Neeteson[2]
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There is hardly any problem with element balances at a truely global scale, as input to and output from planet earth are negligibly small for all nutrients. Within the terrestrial agro-ecosystems, however, substantial transfers from fossil deposits (P, S, cations and metals) and atmospheric stocks (N_2) into agricultural soils occur, as well as into the sites where urban and industrial processing wastes end up. As the enrichment of agricultual soils leads to lateral flows into surface and ground-water, and the return flow of N to the atmosphere is partly in NH_3 (redeposited as part of the 'acid rain' complex) and N_2O (with global warming implications), valid concerns exist on the environmental impacts of current agricultural practices. Globally, part of the agro-ecosystems in the tropics continues to be depleted, while many systems in the temperate zone have been enriched beyond what is desirable. An increase in nutrient use efficiency has generally been advocated as a way to reduce the production -- environment conflict. Nutrient use efficiency (NUE: output per unit input), however, depends on the system boundaries where inputs and outputs are measured. Increasing NUE at plot scale does not necessarily increase NUE at farm scale, or at the sub-regional scale where many environmental problems are perceived. Regulation of allowable agricultural practices, by imposing a nutrient balance book keeping at farm and plot level, has been introduced in the Netherlands over the past decade as a way of reducing lateral flows of nutrients to other environmental compartments. These measures have increased awareness of options for increasing farm level nutrient use efficiency, but have hardly lead to the desirable reintegration of animal and crop production systems at farm level. The impacts of these measures on nutrient use efficiency and sustainability of farming in a wider sense remains to be assessed. The presentation will highlight issues of scales and the relations between them, and on the interpretation of total versus available fractions of element pools in soils as a basis for reducing the environment -- production conflict.

Uncertainties in nutrient budgets due to biases and errors;

Implications for policies and measures and decision support systems

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Abstract

Nutrient budgets are constructed either (i) to increase the understanding of nutrient cycling, (ii) as tool in nutrient management planning, (iii) as indicator (awareness raiser) for monitoring changes over time, (iv) and as regulating policy instrument to enforce a certain nutrient management strategy in practice. Nutrient budgeting involves the estimation of nutrient pools and of the flows between these pools. The accuracy and precision of these estimates depend on many factors, including the agro-ecosystem under consideration, budgeting approach and data acquisition strategy. There is often a considerable amount of uncertainty in budgets, due to biases and errors in the estimates of inputs and especially outputs. This paper firstly reviews the various possible sources of biases and errors in nutrient budgets, and secondly analyzes the implications of uncertainties for governmental policies and measures and for decision support systems.

Bias is defined as systematic deviation, error as random variation. There are five possible sources of biases and two sources of errors. Sources of biases are personal bias, sampling bias, measurement bias, data manipulation bias and fraud. Sources of errors are sampling and measurement errors. Both biases and errors in nutrient budget estimates may lead to wrong conclusions. Bias can be avoided by system analyses, testing of assumptions and by proper planning and application of well-adopted techniques and procedures. Errors can be minimized via appropriate sampling and analytical procedures.

Uncertainties in nutrient budgets usually increase in the order “farm-gate budget” < “soil surface budget” < “soil system budget”. A *farm-gate budget* is easy to construct and requires little data. A *soil surface budget* is most appropriate for estimating the net loading of the soil with nutrients, and is an appropriate indicator for potential (long-term) total nutrient losses from the soil. A *soil system budget* accounts for nutrient inputs, recycling of nutrients within the system, nutrient loss pathways and changes in soil nutrient pools; it is the most detailed budget and provides detailed information for nutrient management planning. Uncertainties are relatively large for internal nutrient flows (recycling), leaching losses, and gaseous emissions.

Quantifying uncertainties requires a combination of (a) systems analyses, considering all possible nutrient pools, inputs and outputs, (b) classification of uncertainties, (c) specification of distributions of probabilities of the various sources and of the correlation between sources, and (d) monitoring of the nutrient pools, inputs and outputs over time, and evaluation of monitoring results. Because of uncertainties, the “pre-cautionary principle” seems relevant when nutrient budgets are used as regulatory policy instrument. Decision support systems should present nutrient budget results as probabilities, and predictions need to be evaluated by monitoring data.

Field nutrient budgeting versus soil testing as a tool for nutrient management and environmental risk assessment

P. J.A. Withers[1] and A.C. Edwards[2]

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Abstract

Since phosphorus (P) is largely conserved in soil, it is often assumed that a series of relationships exist between the cumulative surplus of P inputs, build-up of soil P fractions and increased risk of P loss in land run-off and drainage from agricultural land to water. These assumptions are currently being exploited in a number of countries as a means of reducing background P loss through the development of critical soil test P (STP) concentrations above which P loss is greatly accelerated. The usefulness of STP as an indicator of P loss is reliant on the principle that P release is more dependent on the surplus applied to a soil than it is on the soil characteristics governing P dynamics, and that collective nutrient budgeting on individual fields will help reduce P loads to the watercourse. However, there are a number of shortfalls associated with these assumptions. STP methods were introduced to develop fertiliser recommendations on the basis of correlations with yield response to fresh inputs. As a nutrient budgeting tool they are less reliable due to errors associated with representing a whole field with a single sample, lack of sensitivity over short time scales and the temporal changes in P availability in solution associated with biological and chemical processes. The relative impact (?) of accumulated surplus P on soil P fractions will vary spatially depending on the initial soil P status, soil type, the amount of the surplus and the soil depth over which it has been redistributed. Relationships between STP and P loss in run-off are also not linear. This temporal and spatial variation across the landscape complicates the prediction of catchment P loss based simply on soil P status. The vulnerability of a site to P loss maybe largely independent of soil P status and reducing the surplus may have little impact on P loss. The paper will review the nature of the linkage between P surplus, soil P status and soil P release on different soil types and dicsuss the implications for assessing P loss at the catchment scale and the role of nutrient budgeting in reducing the environmental impact of nutrient additions. It will evaluate the usefulness of the current emphasis being placed upon soil analysis with the wider catchment scale context of P loss and its potential impacts.

Improving nitrogen use efficiency from balance sheets: opportunities to reduce losses?

S. C. JARVIS

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Nitrogen (N) cycling in agricultural systems is complex, especially when animal production is involved. Inevitably, there will be losses of N away from the farm. There is movement of N away from all ecosystems because of the nature of this element and its characteristic ability to be cycled within a much larger context than just the farm or local system scale. Balances of one sort or another provide one relatively simple means of providing a description or diagnostic from the system under consideration which can be used to define and then to refine the management. Balance sheets can be used at different operational scales, usually the field or the farm scale, and with different levels of complexity to provide either an input/output balance or a complete system balance which details all the internal flows and transfers. Both field and farm scales are used with similar aims, but that for the soil/field is generally employed by practitioners to determine inputs in relation to immediate production needs whilst the farm scale has a much wider suite of potential roles which include regulation, manipulation, investigation and comparison.

Most tillage systems operate with a closer ‘farm gate’ balance than do livestock farms. The presence of livestock immediately creates a substantial N surplus because of the imbalance in the amounts of N needed to produce sufficient dry matter to sustain animal production and that eventually converted into live-stock products. There is a clear linear relationship between, for example, surplus for dairy farms and the extent of the losses when data for simple farm gate balances are examined. Considerable proportions of the N entering livestock farms are still poorly accounted for: rates of incorporation into soil organic matter, losses in organic forms and denitrification are poorly quantified. This information is essential for complete systems balances which allow opportunities to identify leaky components of the management and the means of being able to more effectively use the N that is being cycled.

Simple farm gate balances can be used to provide indicators of current staus and opportunities for improvement with information that is relatively easily obtained. Surplus itself is one such indicator and when this and other details of inputs and outputs of N are expressed in terms of units of production, these can be used to as guides to the needs for improvement, comparisons and knowledge transfer. Farm gate balances are also being used as regulatory tools. The opportunities for the employment of balances to improve N use efficiency and reduced losses are therefore considerable especially within livestock and mixed farming enterprises.

Abstracts

Group 1

N balance sheets as a measure of N use efficiency and N losses. How do we include the sol N processes?

Perspectives and limitations of nitrogen balances

Abstract for the workshop "Element balances as a sustainability tool", March 16-17, 2001, Uppsala.

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Nitrogen balances are in widespread use in the Netherlands. They were first introduced in the 1980s as a voluntary management instrument for dairy farmers. This proved so successful that the technique was developed and formalised in the MINAS policy instrument (MINerals Accounting System), which is designed to reduce the manure surpluses by minimising nutrient inputs and increasing the efficiency of their use. MINAS has now become the key element in the implementation of the Nitrates Directive in the Netherlands. From January 2001 its use is compulsory for livestock farmers, arable farmers and other open-air producers, both conventional and organic. Observations on the use of MINAS in these diverse situations allow discussion of the prospects and limitations of the system. The discussion focuses on the following points:

- *Legislation* The Dutch government claims that MINAS ensures a maximum nitrate concentration in groundwater of 50 mg/l, but 'Brussels' is not yet convinced that this is justified. Any effects of using MINAS should be reflected in data on the nitrate concentration in the groundwater. Nutrient management has been conducted since 1990 on the experimental dairy farm 'De Marke', which has dry sandy soils. An effect of nutrient management on the nitrogen surplus and the nitrate concentration in the uppermost meter of the groundwater is demonstrated by RIVM (National Institute of Public Health and Environmental Protection).

- *Arable farming and horticulture* What is the effect of using a nutrient balance on individual arable farms? NMI carried out a demonstration project from 1996 to 1998, and the results from the participating farms give cause for optimism. However, open-air vegetable growers are currently protesting against the use of MINAS. One of the reasons for their protest is that MINAS gives poor results when double cropping systems are used.

- *Organic farming* Is a nitrogen balance an equally suitable tool for use on organic farms? If animal manure is applied the calculated nitrogen surpluses are high compared with conventional farming, where slurries combined with mineral fertilisers are used. This problem is partly caused by the use of fixed data for manure. Accompanying measures used with MINAS pose problems as well.

- *Future use of nitrogen systems* Issues discussed are unavoidable losses v zero balance, fixed data v on-farm measurements, and the development of indicators for nitrate leaching other than the nitrogen surplus.

Catchment and field nutrient balance and trends in nutrient run-off in Latvia

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Abstract

Agriculture is one of the major sources of nutrients contributing eutrophication of the inland water bodies and Baltic Sea. Monitoring programme specifically aimed at assessing point and non-point source agricultural pollution started in Latvia in 1994 -1995. Results from a 6-year study in Latvian small catchments and drainage fields indicated that most important factors of agricultural pollution are acreage of arable land, farming practices and nutrient management. In particular, we focused our attention on the factors that control the temporal variability and trends in the load of nutrients in the drainage basin and field level, as well as the effects of agricultural soil nutrient balance.

The highest observed nutrient run-off was measured in Berze catchment characterized with high share of arable land and high nutrient inputs for grain farming. In Berze catchment losses ranged from 10-17 kg ha $^{-1}$ year^{-1} of nitrogen and 0.13-0.52 kg ha $^{-1}$ year^{-1} of phosphorus (NPK input 20-120 kg/ha). Nitrogen run-off was very low in Vienziemite site, ranging from only 4-8 kg ha $^{-1}$ year^{-1} (NPK input 5-6 kg/ha).. The measurements demonstrate large variations in losses. It is obvious that the losses of nutrients from soil depend on a complex of factors and vary with soil type, drainage, climate, agricultural practice, and interactions of these factors. Although the tendencies in nutrient losses are difficult to evaluate, measurements in Latvian small catchments and drainage fields showed relatively small losses (N_{tot} 2-27 kg ha $^{-1}$ year^{-1}) compared with results under similar cropping systems and soils in Nordic countries, where the measured losses varies 20-50 kg ha $^{-1}$ year^{-1}. Study of nitrogen concentration changes in run-off reveals upward trends both in small catchments and field drainage. The upward trend in field drainage concentrations was greater than in small catchments. The most significant increase was associated with the large share of arable land and increase of fertilizer application in Berze small catchment and drainage field during last years. The negligible increase of nitrogen in Vienziemite catchment had resulted from the relatively low intensity (fertilization) of agriculture with negative nutrient balance. The results indicate that the nutrient balance plays an important role in the leakage of the nutrients from the drainage and small catchments. It was also found that natural variability in water discharge was the main factor controlling the temporal variability in the load of nutrients (*i.e.* differences in load between seasons and years).

Element budgets as a management tool on dairy farms in Denmark

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The use of element budgets at farm level as a management tool meets different barriers when practised. A better conceptual understanding is needed among farmers, advisers and decision-makers.

In several research projects, mass balances at farm level have been calculated and analysed. A number of factors influencing the nitrogen (N) balance on a dairy farm have been identified and their impact on the N surplus has been estimated (Kristensen & Kristensen, 1992; Halberg et al., 1995; Kristensen, 1997; Nielsen, 1999). Recently, the Danish Advisory Centre has launched software that facilitates the calculation of farm balances (Hvid, 2000). However, experience with the use of element budgets as a management tool on private farms is still limited in Denmark.

An ongoing project at The Danish Institute of Agricultural Sciences (DIAS) is focusing on the management possibilities at farm level for reducing the N surplus. The N balance at farm level has been calculated on a number of conventional and organic private dairy farms. Although there is a correlation between stocking rate and N surplus on the dairy farms (Figure 1), there is also a considerable variation in surplus per hectare for a given amount of manure per hectare. Nielsen (1999) showed that crop yield and economic return was not positively correlated to N surplus per ha - on the contrary. All together, this indicates that it is possible to reduce the N surplus through better management on many farms without damaging the production efficiency.

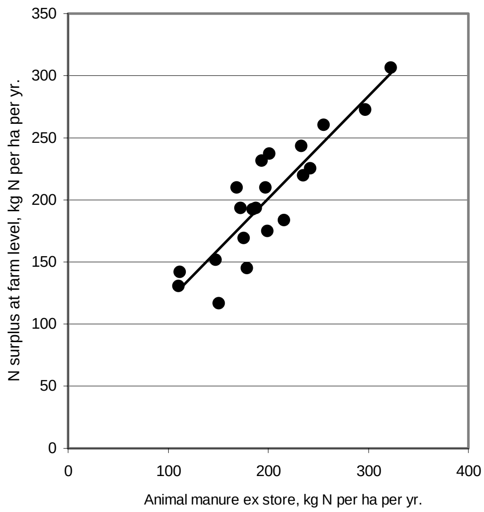

Figure 1. Kg N surplus at farm level per hectare per year as a function of stocking rate expressed as animal manure-N ex store per hectare per year, 21 conventional dairy farms; data from study farms in 1999, the line is the best linear fit to all points; modified after Nielsen (2000)

A system approach has been used to develop and perform a systematic analysis of the N-turnover on the farms. By using a farm model (SAMSPIL; Hansen & Kristensen, 1997), changes in N-surplus following different production strategies are predicted. The different strategies are discussed with farmers and farm advisers to uncover barriers for implementation.

The management strategies evaluated through this project include manipulation of N input such as feed and fertiliser, alteration of crop rotation and allocation of manure, and reduction of stocking rate per hectare. Results from the project will be presented and discussed.

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Abstract for the Food 21workshop on ‘Element balances as a sustainability tool’
March 16-17, 2001 Uppsala, Sweden

STANK – the official model for input/output accounting on farm level in Sweden

Linder, Janne

STANK was introduced as a tool for extension staff in order to facilitate the calculation of nutrient balances on farm level. From that a comprehensive tool for calculations on quantity, nutrient content and ammonia losses from animal manure was developed. Later a farm plan was added for planning of crops and application of animal manure and chemical fertiliser. Connected to the farm plan there is a model for calculating the leaching nitrate.

In addition to the above mentioned parts there is also a possibility to make calculations for individual farm machines and building equipment. These calculations can be summarised in a machine cost analysis. The main purpose is to use the calculations for a system analysis to see the effect on both the utilisation of nutrients and the economy for different alternatives.

The program is built in the Microsoft database program Access and contains a large number of accessible background data. Nutrient balance can be made on an individual crop as well as on a complete crop rotation. There are good possibilities for simulating different management and all data can rapidly be copied to a new alternative where new assumptions can be tested. At the moment a lot of efforts are put on the description of the program and on calculating values to facilitate the interpretation of the nutrient balances.

STANK is currently evaluated in a study launched by The European Commission.

Content of STANK

Part	Parameters	Comment
Nutrient balance	Surplus or deficit of N, P, K. Utilisation of N, P, K.	Database products. Nitrogen fixation is calculated.
Manure quantity	Storing capacity. Spreading area.	Considerations of milk yield, dishwater, calving age, etc.
Nutrient content in manure	Content of N, P and K. Plant available nitrogen.	Specification of ammonia losses in stable, during storing and spreading.
Machinery and buildings	Investment costs for machinery and buildings	Database with the most common buildings and machinery
System analysis	Economic comparisons for different alternatives containing, machinery costs, storing costs, labour, ammonia losses, harmful soil compaction etc.	Uses the data from together with some other important factors to give a total picture of different alternatives.
Farm Plan and leaching of nitrate	Crops and use of fertiliser. Cultivation practice etc.	Explains important factors affecting the leaching of nitrate.

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Use of farm-specific reference figures for nitrogen surplus in nutrient balances

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Over the past decade Danish advisers have carried out several projects in which nutrient balances have been prepared for a considerable number of farms. These balances are made at farm level and in some cases barn and field balances have been prepared as well. The nutrient balances show how nitrogen surplus deviates in practice on Danish farms. The balances also show the normal levels of nitrogen surplus on different types of farms and the importance of stocking density (number of livestock units (LU) per ha) on nitrogen surplus.

However, it has been difficult to utilize the nutrient balances for targeted guidance of the individual farmer with a view to reducing nitrogen surplus because the nutrient balances are difficult to interpret in relation to the individual farm. On the basis of a nutrient balance alone it is not possible to assess the potential reduction of the nitrogen surplus via farm management measures.

To increase the value of the nutrient balance for guidance purposes The Danish Agricultural Advisory Centre has developed a farm-specific reference figure for nitrogen surplus. The calculation of this reference figure is an integrated part of a computer program called Green Account (in Danish: Grønt Regnskab) which the Danish agricultural advisory service and the Danish farmers use to prepare nutrient balances. The reference figures are calculated automatically and require no extra input of data.

In short, the reference figure shows the nitrogen surplus of a farm if the production of this farm observe all standards concerning feeding, fertilisation, crop yields and contents of animal manure etc. This figure eliminates the variation in nitrogen surplus caused by farm type (cattle, pigs, arable, etc.), soil type, livestock housing system, type of animal manure, choice of crops, stocking density (number of LU per ha) as well as import and export of animal manure. This may eliminate the causes of deviations in the current nitrogen surplus of the farm relative to the reference figure to only a few factors which are characterized in that they can be influenced by the farm manager in the short term.

The most important factors which may lead to deviations in the current nitrogen surplus of the farm relative to the reference figure are feed consumption, protein content in feed, crop yields, protein content in crops and the amount of nitrogen fertiliser applied. Based on a common knowledge of the production and efficiency of the farm it is normally possible to assess which of these factors cause(s) a given deviation. On the basis of an analysis of the farm conditions it is possible by using the reference figure of the farm to define realistic goals for reducing the nitrogen surplus.

ICBM-N, a simple model for including internal soil N fluxes in field-scale balances

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The annual input and output of nitrogen to and from agricultural land is relatively small compared to the total stock of N in soil. However, N mineralisation is often not explicitly considered in fertilisation planning and N surpluses in budgets are often regarded as more or less equal to losses, without considering immobilization in soil organic matter.

We show how the internal N cycling can easily be introduced into field-scale N-balances, using the simple carbon and nitrogen model ICBM-N, which is available in e.g. MS-Excel-format. This model is regarded as a minimum approach for calculating soil N balances. Parameter estimation may be based on 'best guesses', parameter optimisation to available data, or independent front-end models.

We give examples of model applications and show how the results can be used to improve in- output balances at the field and farm level.

Nitrogen balances for three crops, kg N ha^{-1}, including mineralisation/immobilisation

	Barley, 4 500 kg/ha	Grass seed, 1 000 kg/ha, year 1	Winter rape, 2 600 kg/ha, year 1
Inputs			
Fertilization[1]	80	105	133
Deposition[2]	4	4	4
Seed[2]	3	0	0
Mineralization[5]	50	33	41
Total input	137	142	178
Outputs			
Harvested crop[2]	74	20	91
Crop residues (incl. roots)[5]	46	137	90
Ammonia from crop and soil[3]	1	1	1
Denitrification[3]	5	5	5
Leaching[4]	14	7	7
Total output	140	170	194
Unaccounted	-3	-28	-16

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Abstracts

Group 2

Interpretation and uncertainties of element balances at different spatial and temporal scales – from field to regional levels

Nutrient Balance of the Rägina River Watershed in Matsalu

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The Rägina River watershed is located in western part of Estonia in Martna parish on the territory of Matsalu Nature Reserve.

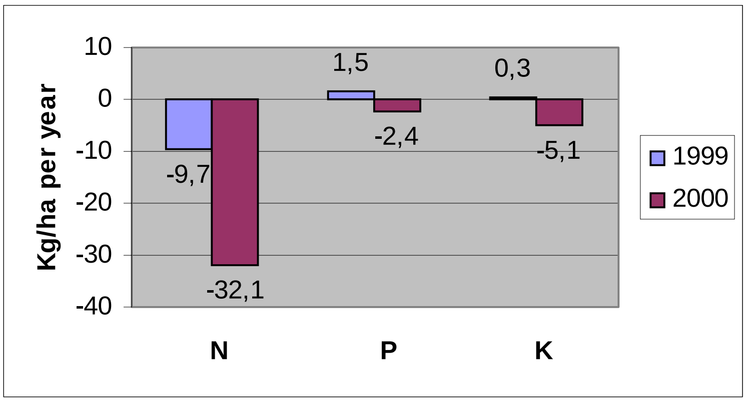
Within the Baltic Environmental Agricultural Run-off Project (BEAROP) the nutrient balance in the Rägina river watershed was calculated in the years 1999 and in 2000 on different levels:

1. Field level (against different fertilizer backgrounds of field experiment)
2. Farm level (on the basis of the demonstration farm and the Agricultural Company Lähtru)
3. Watershed level

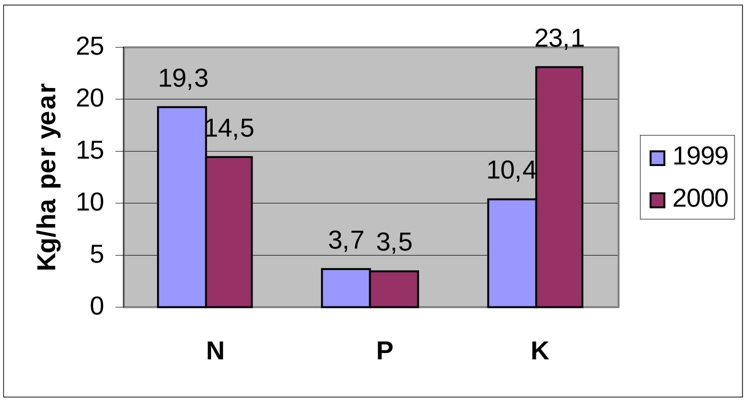
A detailed inventory of total nutrient input and output showed that in the field experiment the balance of main plant nutrients (N, P, and K) was strongly dependent on fertilization level. In many cases the balance was negative: removal of plant nutrients from soil was higher than their addition with fertilizers.

In the demonstration farm the balance of all plant nutrients was negative in 2000 due to low fertilization rate. In the Agricultural Company Lähtru the application of fertilizers was higher and hence the balance of all three main nutrients (N, P, K) was positive.

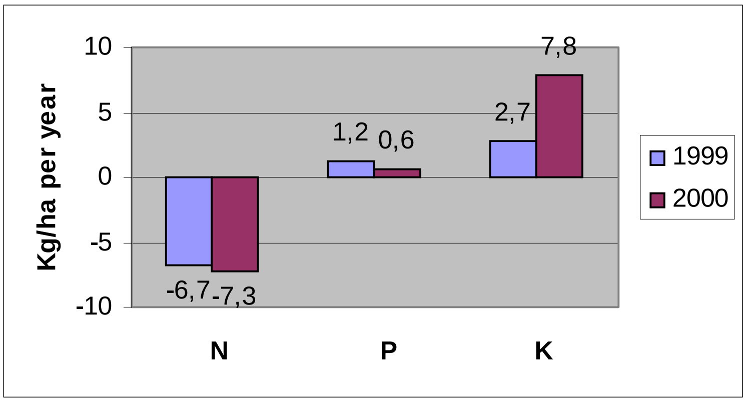
In the whole watershed area the average balance of nitrogen was negative in both years; while the balance of phosphorus and potassium was positive.



Nutrient balance in the demonstration farm of Rägina River Watershed



Nutrient balance in the Lähtru Agricultural Company



Nutrient balance in the Rägina River Watershed

Identification, designation and formulating an action plan for a Nitrate Vulnerable Zone: A case study the Ythan Catchment, NE Scotland

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Abstract

The EC Nitrates Directive (91/676), agreed by the EC Environment Council in 1991, is an environmental measure designed to protect water against pollution caused by nitrate from agriculture. In 1999 the River Ythan catchment, a 68 000 ha area of predominantly agricultural land in NE Scotland, was designated a Nitrogen Vulnerable Zone (NVZ) by the Scottish Executive. A combination of reasons for designation was suggested, including evidence of elevated nitrate concentrations in the surface waters of the catchment together with the criteria set out at Annex IA(3) of the EC Nitrates Directive i.e. that the estuary is eutrophic or in the near future may become eutrophic. Evidence from Scottish Environment Protection Agency surface water monitoring sites has revealed several tributaries of the Ythan with nitrate concentration exceeding the maximum permitted level of 50 mg/lt (11.3 mg/lt NO_3-N). Nitrate concentrations from other sites are also high, while waters in the main spine of the river demonstrate a rising trend of nitrates over a considerable period of time. There has been an approximate 3-fold increase in nitrate concentrations since the early 1960's to a current value of ~ 35 mg/lt (8 mg/lt NO_3-N). The amounts of fertiliser N applied annually has also increased substantially which in 1994 accounted for ~ 60 % of the total annual N budget equivalent to 194 kg/ha when averaged over the whole catchment scale (Domburg et al., 2000).

Various stages were involved in reaching a decision to designate the Ythan catchment area and these will be outlined. Various documents have been put out for public consultation and these will also be discussed. The wider implications arising from this NVZ designation, particularly with respect to the need to develop an Action Programme, will be discussed. Some of immediate and longer-term consequences for the local agricultural community arising from this designation will be examined.

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Developing a regional agronomic information system for large scale estimates of nutrient losses

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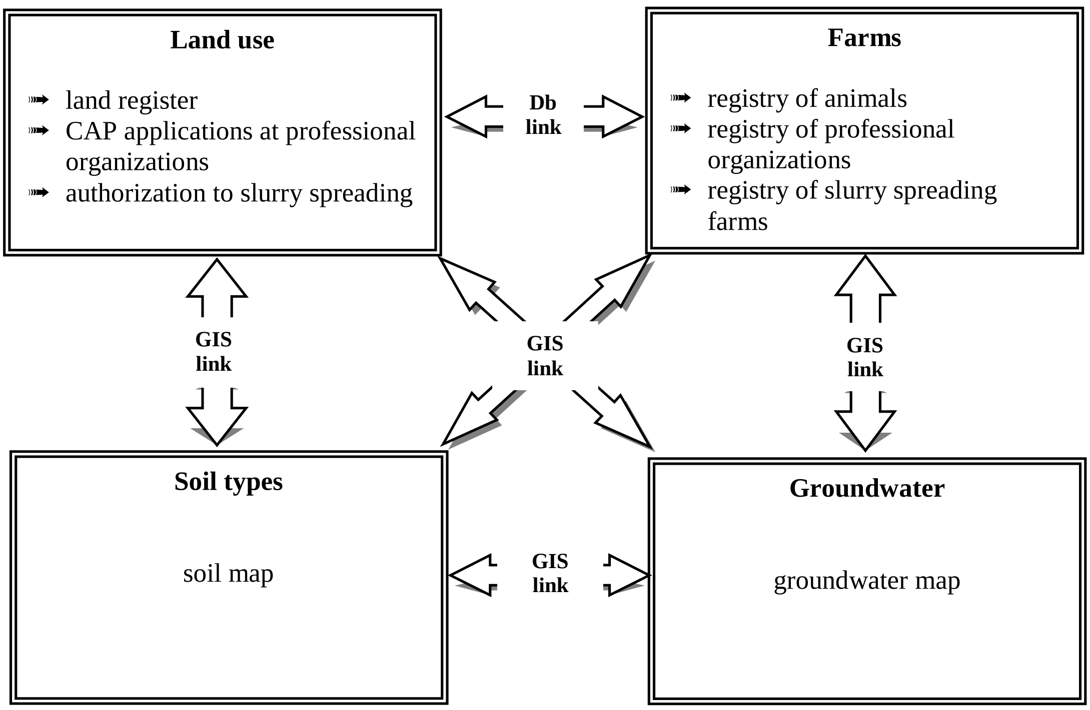
There is a need of semi-automatic procedures to assess the impact of agricultural practices on soil and water at the scale at which legislation can be applied: municipality or region. The mass-balance method is probably the most easy to apply at large scales and is not necessarily less reliable than more complex methods, such as models.
A lot of data are normally collected by professional organizations to provide farmers with technical support and management tools. The most useful information they can provide is the land use, coming from the application of the European Policy and the list of farms present in the region.
Authorities also collect data such as information about the number of animal present in each farm and about the surface on which the slurry is spreaded.

Anyway, collecting and linking information is very difficult, because
- databases are built ignoring that they can be useful for other purposes
- professional organizations have no interest in showing what their associates do
- there is a law which protects personal data, so data are supplied without information about the name and address of the farmer, or fiscal code or VAT number (which serve as a code to join different databases)
- a few municipalities have a digital land register, and it is not progressively updated, so a lot of georeferenced information cannot be used
- the Government Agency for Intervention on Agricultural Market, which holds the only public database on CAP supports, does not publish or release any data.

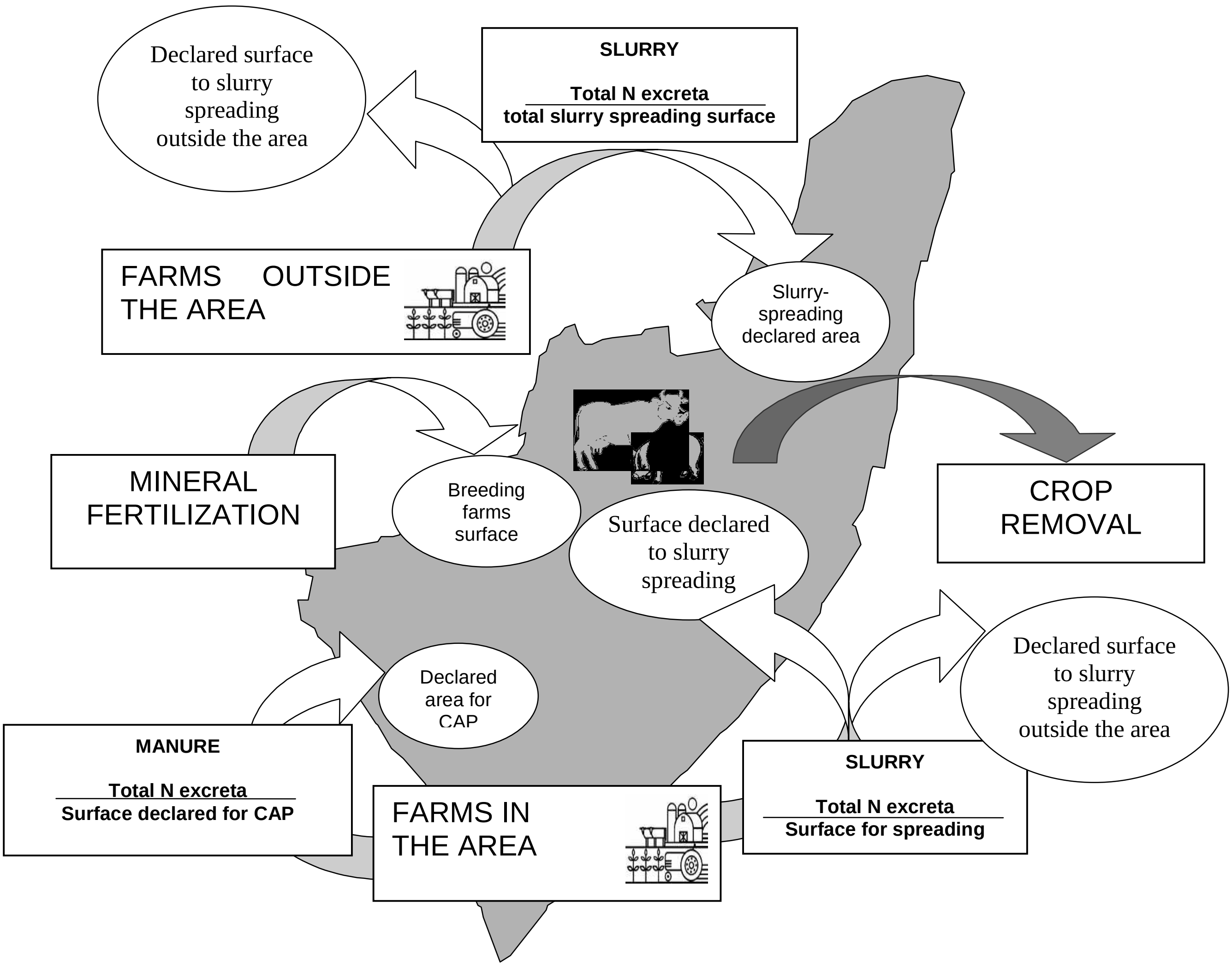
The available databases and information are reported in the following figure, which also reports the type of join between information:



A second problem derives from converting information about the farms in nutrient fluxes in the area. For this, estimates are needed about the amount of nutrient excreted by animals in relations to the farm and breeding type, estimates of mineral fertilization and losses. All of these approximations increase the final uncertainty in terms of nutrient balance.

Possible outcomes of this work are:
- nutrient balance at the regional scale
- amount of fertilizer supply
- relation between land-use and soil characteristics (eg. stones, groundwater depth)
- relation between land use and farm characteristics
- relation between land use and type of breeding
- relation between slurry spreading and soil type
- relation between land use and slurry spreading

A better cooperation in collecting data and more precise tools in converting information will make this approach more powerful to define the nutrient balance at large scale.



Group No. 2: Interpretation and uncertainties of element balances at different spatial and temporal scales - from field to regional levels

Nutrient balances in a long-term perspective based on 40-year-old field experiments

by Lennart Mattsson
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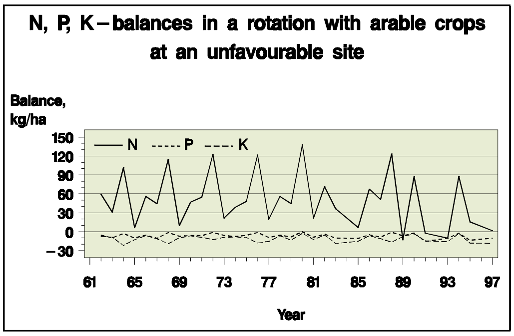
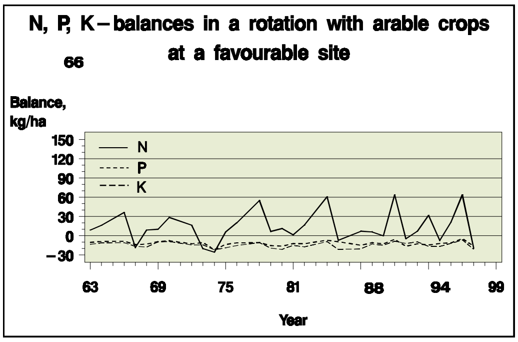
Nitrogen, phosphorus and potassium balances studied for some decades in long-term field experiments show a very large variation between years. No definite temporal trends can be observed. Crop, fertilization and yield level determine the balance for individual years.

The left figure below shows the time course of the balances in a 4-year rotation with barley, oil seeds, winter wheat and sugar beets in south Sweden, while the right one shows the same for a 6-year rotation in central Sweden with barley, oats, oil seeds, winter wheat, oats and winter wheat. The sites chosen represent less favourable and favourable edaphic conditions in south and central Sweden, respectively. The first crop in each rotation cycle is indicated on the horisontal axis.

Applied N minus N export with harvested products gives the annual balance. All the harvest residues are left and incorporated into the soil and are not included in the balance. The N application averaged 100 and 82 kg ha^{-1} yr^{-1} in south Sweden and central Sweden, respectively. P and K were not applied. Their annual balances are in the range –10 to -20 kg ha^{-1} with only minor deviations.

A very regular pattern for the N balance can be seen. This is a consequence of the crop sequence in the rotation. A specific crop appears at regular intervals. Some crops are effective, while others are less effective to take up and use applied N and the chosen fertilizer level might be more or less optimal for a specific crop. A peak in the N balance curve means that too much N was applied. The peaks coincide with sugar beets and oil seeds, while the troughs refer to barley or winter wheat.





Is it possible to aggregate complex information at field scale into a few model parameter values valid for a whole catchment?

by K Blombäck[a], R. van den Bosch[b], J. Thompson[c], Xuezheng Shi[d], Chen Yibing[e], S. Ledin[a] and C. Ritsema[b].

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The Hilly Purple area of the Sichuan Basin is one of the most important agricultural areas in Western China. This area has for long been degraded by constant soil erosion, which has direct negative effects on the productivity of the land by loss of nutrients and soil. The use of chemical fertilisers in China is expected to increase and substitute the amount of organic fertilisers. Together with a strong emphasis to increase grain production, this can lead to further deterioration of the physical soil properties with risk for increased erosion, runoff and nutrient losses during the coming years. The EroChiNut project aims to develop a participatory conservation planning method by combining modelling of soil erosion and nutrient losses at catchment scale and land evaluation techniques, to find conservation strategies acceptable to both farming families under the present socio-economic conditions and policy-makers.

A catchment of about 3.6 km^2 in the Purple Hill area is studied. More than 400 farmers live and work in the area. 15-20 crops are grown in an intercropping system and the choice of crop and fertilisation management is very dependent on the actual market prices and on available labour. Information concerning land use, cropping management and socio-economic conditions is achieved by participatory methods. Soil nutirent status, crop properties as well as soil physical properties are continuously monitored in different fields. Monitoring has been performed during two years and ended up in a lot of data. But how do we treat all this information?

The GLEAMS model is used to simulate N and P balances at field level. The simulated results will be used as input values for the catchment model LISEM, which is used to simulate water runoff, soil erosion and N and P losses at the catchment scale. Measured data is used both for model parameterisation and testing of model performance. Parameterisation of the models forces us to categorise and aggregate the diverse information at field and farm level into a few representative values at the catchment scale. The 15-20 major crops that are used in the intercropping system will be categorised in approximately 3 crop types – grain crops, N-fixing crops and trees – representing different nutrient input classes. The different fertilisation strategies have to be generalised into only a few strategies – low and high input with and without manure. But we also have to disaggregate the simulated results at catchment scale to feasible information at field/farm level to be used in the participatory work on effects of changed land use on soil and nutrient losses.

Abstracts

Group 3

Selecting the tools: Element balances versus other agricultural and environmental management tools such as soil testing, critical limits, stocking rates etc.

Input Ouput Accounting Systems in the European Community – an appraisal of their usefulness in raising awareness of environmental problems

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Abstract

Input Output Accounting systems (IOAs) can be used to help identify farming practices which are not 'environmentally neutral' and thus unlikely to be sustainable in the long term. In an EU sponsored project, European countries have been surveyed and over 50 farm level IOAs identified. The topics covered by the IOAs included nutrients, pesticides, energy, soil/habitat conservation, wastes (eg packaging and tyres) and other items such as veterinary products. Nearly half the IOAs covered more than one topic and nutrient budgets were the most commonly included (91% of the IOAs studied). Looking at the 30 single subject systems most (26) were nutrients with only 3 pesticide and 1 energy based system. In total 50 systems covered nutrients.

Overall, where specified, nutrient budgets covered Nitrogen (N), Phosphorus (P) and Potassium (K) in 13 cases, N and P in 12 cases, N only in 9 and P only in 4 cases. Two systems also covered heavy metals, both of these were Danish. The most common indicators for nutrient budgets were calculation of a balance followed by nitrate leached. Farming sectors were not equally represented and a breakdown is shown in Table 1.

Table 1. Number of Nutrient IOAs by Farming Sector

arable	horticulture	beef/veal	dairy	pigs	poultry	organic farming	other[1]
38	26	25	32	30	24	25	16

[1]including protected crops

Farmers received a detailed interpretation of their results in two thirds of the systems, most commonly related to official limits or targets. Most of the systems were developed to reduce adverse environmental impacts and 65% of the systems were considered by the respondents to have had a positive environmental impact by reducing surpluses or improving waste disposal. Use of five of the systems could lead to a marketing advantage via certified produce with a recognised quality label.

A representative sub set of IOAs covering nutrients, pesticides and energy are being studied in more detail. In due course guidelines for a framework IOA system for EU agricultural holdings will be developed based on the findings from the study.

Fate of N and P in outdoor pig production systems

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Outdoor pig production is an important sector of the UK pig farming industry. It is popular with consumers as it is perceived to be both animal welfare and environmentally friendly. The combination of stocking rate and livestock diet can however result in application rates in excess of 500 kg N/ha and 200 kg P/ha. Unlike well-managed fertiliser and manure applications, the return of nutrients in outdoor pig systems is spatially specific due to excretory behaviour patterns. We examined the effects of feeding low and high nutrient diets, and of nose-ringing pigs to preserve vegetation cover, on the quantity and fate of N and P in an outdoor pig system on a sandy soil in NE Scotland. For P, the influence of nose-ringing on soil P status was minimal. Soil N levels throughout the soil profile were greatest where pigs did not have nose rings. Pigs showed a clear preference for excreting in the areas around the plot boundaries. Available P levels in the top 5 cm of soil were over 5 times greater in areas preferred for excretion.

The results will be discussed in the context of potential adverse environmental impacts, and nutrient availability for the following crop.

Phosphorus as limiting factor for livestock density

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In 1988 the Swedish Parliament decided to launch a programme to reduce plant nutrient losses from agriculture. One part of this programme is legislation on livestock density.

It is important that there is balance between the amount of animals on the farm (and thus the amount of manure) and the amount of land available for spreading manure. The maximum livestock density has been decided with consideration taken to the amount of phosphorus and nitrogen in manure and a crops normal requirements and removal of plant nutrients. The limiting factor for the Swedish legislation on livestock density is phosphorus, with a maximum amount of approximately 22 kg P/ha (50 kg P_2O_5).

One advantage with using phosphorus instead of nitrogen as limiting factor, is that the figures on phosphorus content in manure are more reliable, as phosphorus losses in the stable and during storage are almost non-existing. P is also easy to check by doing nutrient balances and there will be surplus of P long before there is a surplus of N.

The number of animals per hectare may not be larger than:

Type of animal	**Animals/ha**
Dairy cows	1,6
Cows for breeding calves	2,3
Heifers, bulls, steers > 1 years age	4,6
Sows in production	2,2
Fattening pigs, places	10,5
Laying hens, places	100
Broilers, places	470

Accessible land for spreading manure can consist of:

- suitable arable land used for crop production on the farm
- arable land elsewhere if there is a contract on manure spreading for at least a 5 year period
- grazing land, pastures on farms with grazing livestock

Due to intensified production, pig-units usually exceed this limit of 22 kg P/ha. There are two different solutions to get back to the intended limit. Either the amount of animals permitted are lowered. In this case it would mean 7 places/ha instead of 10,5. Or the phosphorus-content of the manure is lowered. To decrease both nitrogen and phosphorus contents in manure by better feeding strategies is an interesting challenge and this will hopefully reduce the influence on the environment from manure.

The influence of changes in P fertilization plans on Cd and Zn balances for farming systems

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Using the mass flux balance model PROTERRA-S (Keller et al., 2000a) we analysed the role of P fertilization strategy on Cd and Zn accumulation in agricultural soils for different farm types and cropping systems at a regional scale. For this purpose, the Sundgau region of northwestern Switzerland was used as a case study area. Estimated net Cd fluxes ranged between 1.0 - 2.3 g ha^{-1} yr^{-1}, for arable farming systems, to 0.6 - 2.0 g ha^{-1} yr^{-1} for dairy and mixed farming systems, and 9.1 - 17.8 g ha^{-1} yr^{-1} for animal husbandry farms. Largest net Zn fluxes of 17.9 - 39.8 kg ha^{-1} yr^{-1} were estimated for animal husbandry farms, whereas for arable farming systems net Zn fluxes of 100 - 260 g ha^{-1} yr^{-1} and for dairy and mixed farming systems of 348 - 3360 g ha^{-1} yr^{-1} were found.

Propagation of uncertainty in model input parameters led to large variations of the calculated net element fluxes. Variation of net Cd fluxes resulted mainly from uncertainty of crop concentrations, atmospheric deposition, leaching parameters and uncertainty of Cd/P concentration ratio of commercial fertilizers. The former two uncertainty sources and the Zn/P concentration ratio in animal manure contributed in general the most to the total uncertainty of the net Zn fluxes of the land use systems. The pattern of the uncertainty sources varied between the farming systems, in particular for the Zn balances.

Analysing scenarios of changes in P fertilization on the metal inputs, the model showed that the effects may be more complex than expected at a first glance. For example, decreasing P surpluses by reducing commercial fertilizer use was estimated to result in decreasing Cd and Zn accumulation rates on dairy and mixed farms, while for arable farms either Cd or Zn inputs increased.

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K balances versus soil testing as a tool for optimal K fertilisation of grass

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The mineral composition of Norwegian grass crops is often not optimal with regard to animal health, because of a too heavy K fertilisation and consequently luxury consumption of K. Often this is caused by underestimation of the K supply from the soil. Therefore, a project has been started aiming at getting more knowledge about K dynamics and the ability of some Norwegian soils to supply plants with K.

In different parts of Norway 17 field trials were established on grass in 1997 or 1998 with a K fertilisation of 0, 60, 120 and 180 kg K/ha. Soil samples are taken each spring and autumn and analysed for ammonium-acetate-lactate extractable K (K-AL). At start of the experiment the soil samples were also analysed for acid soluble K (extracted with 1 M HNO_3). Yields are determined and plant samples analysed for K, Ca and Mg. Based on these analyses the K balances and the amount of K taken up by the plants from AL-extractable K and reserve K (total K uptake minus K uptake from K-AL and fertiliser K) were calculated. In this presentation, results from the ten field trials started in 1997 are shown.

The K supply from the soil to the grass, both from AL-extractable K and reserve K, was considerable even at the highest level of K fertilisation. As a result the K balance was negative at all levels of K fertilisation (Table 1).

Table 1. Mean values (10 fields) of K balances at different levels of K fertilisation

Experimental year	0 kg K/ha	60 kg K/ha	120 kg K/ha	180 kg K/ha
1.	-302	-249	-204	-159
2.	-224	-189	-157	-119
3.	-171	-148	-122	-86

In many of the fields K fertilisation did not increase dry matter yields significantly, not even in the third experimental year. The K content in the grass was, however, significantly increased by K fertilisation. In some fields luxury consumption of K (>2% K in the dry matter) was observed also in the treatment without K fertilisation, despite that a considerable part of the K uptake originated from reserve K. This shows that grass has a good ability to exploit the K resources in soil, and aiming at a zero or positive K balance in grass production will often reduce the fodder quality with regard to mineral composition.

K analyses of soil samples taken after the previous season gave useful information about the need for K fertiliser. The yields did not increase with K fertilisation if the K-AL value in spring was above 100 mg K/kg. With K-AL values lower than 100, the effect of K fertilisation was dependent of the value of acid soluble K. If acid soluble K was larger than 1000 mg K/kg, there were no significant yield effects of K fertilisation the first three experimental years even at small K-AL values.

The results indicated that the soil has a certain “equilibrium level” for K-AL that varies between different soil types. The grass easily took up the content of AL-extractable K that was in excess of this ”equilibrium level”. If the K-AL value is far above the “equilibrium level”, the soil has a pool of easily available K that ought to be evaluated as a K source for the following crop to avoid luxury consumption of K and with that risk of grass tetani and lacteal fever.

Potential and limitations of whole-farm nutrient balances

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Nutrient balances at a whole-farm level are a powerfull tool to evaluate the environmental impact of nutrient use by agriculture (e.g. Schröder et al., 1996). Therefore, balances play a central role in present Dutch legislation on nutrient management. Balances provide stronger warrants for environmental protection than regulations on the maximum application rate of manure (Neeteson, 2000). However, the usefulness and reliability of balances strongly depends on their completeness. The informative value of whole-farm balances may increase, when used in combination with other indicators (Aarts et al., 2000).

The present paper discusses the strengths and weaknesses of using whole-farm balances for the assessment of the environmental impact. Nutrient balances have proven to raise awareness among farmers and have made them reconsider questionable routines.

A whole-farm balance and an output input ratio provide incorrect estimates of the management skills of a farmer (Schröder et al., 1998), as the surplus (kg ha^{-1}) and the ratio (kg kg^{-1}) do not only depend on skill-related internal conversion coefficients A, B, C and D, but also on the feed import fraction (I = imported feed/feeds available to animals) and the crop export fraction (E = exported crops/crops) (Figure 1):

surplus = input – ouput = input x (1- p/q) with:

p = (C + (E x (1 - I)/(B x (1 - E)))) and

q = (I + (p - C)/(E x A) - ((1 - C) x (1 - D)))

and output/input = p/q

Whole-farm balances may obscure the nature, location and magnitude of losses, in particular when balance terms or balances underlying the whole-farm level are lacking. An example will be given to show how legislation based on balance sheet calculations, has to manoeuvre in between the desire to keep rules simple and equal to all on the one hand, and to make these rules robust and goal-oriented on the other.

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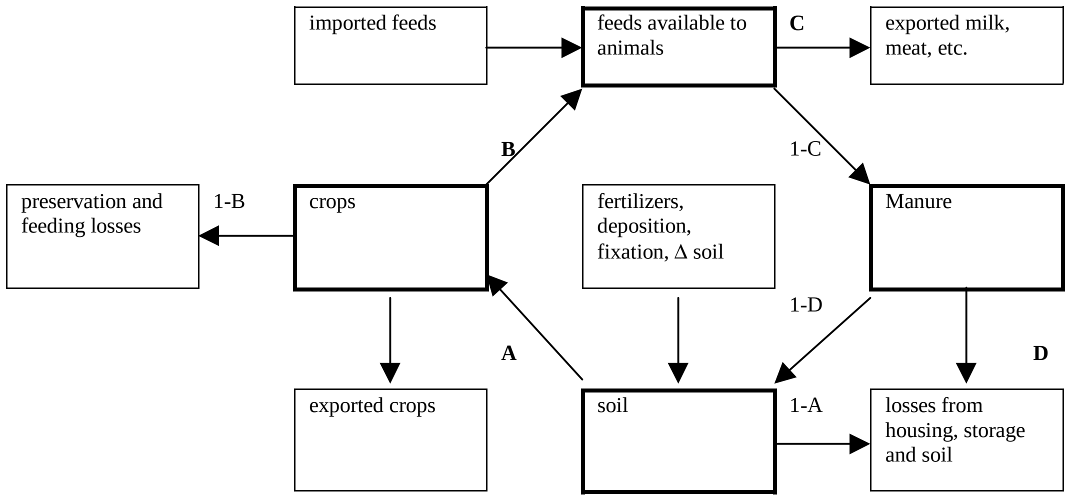
Figure 1. Flow diagram for a mixed farming system



Abstracts

Posters

Cadmium and zinc field balances in organic and conventional dairy farming – variation in manure application and crop removal

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The knowledge obtained from element budgets depends to a large extent on the scale considered. Field balances can be calculated for individual fields but are more often calculated as an average for the whole farm. Within the FOOD21 research program fluxes and balances of nutrient and trace element are studied at field and farm level in organic and conventional dairy farming. The field balances are calculated as the differences between input of elements via organic- and mineral fertilizers and atmospheric deposition, and output via harvest and water run-off. The different flows within the balance are estimated from measurements at various scales. Deposition and water run-off are quantified as an average for the farm. Deposition is estimated from the national environmental monitoring program based on metal analyses of mosses. Water run-off is based on average concentrations (in main soil types) and estimates of the water balance. The input via fertilisers has been quantified (volume and element content) for each field, while the harvested crop has been quantified with grid sampling over the farm (one sampling site for every two hectares). In this abstract we present the variations in manure application and harvest for each crop in the crop rotation. Thereby including information that may have been lost in the scaling up to average field balances. The average field balances established for the farm show an accumulation of Cd and Zn in the soil in both farming systems, but with a higher rate for Zn (Tab. 1). However, the balances for a single crop indicate a major variation between crops. There are high accumulations of Cd and Zn in the soil where oats/pea, barley and potatoes are cultivated. This is mostly due to the manure application not being evenly spread over the crop rotation. Differences in volume of, and element content in harvested crop also effects the imbalance. To evaluate the field balances this variation in element flows within the farm and the uncertainties in the flows will be studied further in this project.

Table 1. Input via manure and urine and output via harvest of Cd and Zn (g $ha^{-1}year^{-1}$) for the different crops in a cropping season (1998) for organic and conventional farming. *The balance also includes input via mineral fertilisers (Cd: 0-0.02 kg ha^{-1} and Zn: 0-18 kg ha^{-1}) and atmospheric deposition (Cd: 0.34 kg ha^{-1} and Zn: 82 kg ha^{-1}) and output via water run-off (Cd: 0.44 kg ha^{-1} and Zn: 65 kg ha^{-1})

	Cd			**Zn**		
Organic	Fertilisers	Harvest	Balance*	Fertilisers	Harvest	Balance*
Oats/pea	0.41	0.13	+0.18	292	140	+169
Ley I	0	0.15	-0.25	0	230	-213
Ley II	0.01	0.14	-0.23	18	209	-174
Ley III	0.01	0.08	-0.17	69	108	-22
Barley	1.19	0.01	+1.08	721	25	+713
Potatoes	0.79	0.17	+0.52	1219	48	+1188
Mean	*0.41*	*0.11*	*+0.19*	*387*	*127*	*+277*
Conventional						
Oats/pea	0.78	0.18	+0.50	1140	161	+996
Ley I	0.02	0.21	-0.29	3	232	-212
Ley II	0.03	0.14	-0.21	27	170	-126
Ley III	0.05	0.19	-0.24	153	135	+37
Barley	1.11	0.13	+0.88	906	137	+786
Potatoes	0.97	0.05	+0.82	951	24	+962
Mean	*0.48*	*0.15*	*+0.24*	*529*	*143*	*+407*

Crop yield and NPK flow on the field and farm level in Lithuania

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Abstracts

Since 1994 Lithuania is engaged in BEAROP - the international project on agricultural runoff study in the countries round the Baltic Sea, proposed by Swedish scientists. One of demonstration watersheds of this project is river Graisupis watershed, located in the plain agricultural region of Lithuania. Crop yield and nutrient balance data obtained at V.Liutkevièius Demonstration farm on the farm and field level and reasons for such a results are discussed in this paper. It was evident after calculations of NPK flow and balance to observe the discrepancy between the real and estimated yield amount. This is a common problem: such an unbalanced fertilisation system exists in many farms of Lithuania. In order to make fertilisation system more rational, the balanced fertilisation computer model was created at Lithuanian Institute of Agriculture (prof.A. Ðvedas) and used for this purpose in V.Liutkevièius Demonstration farm.

The soils in Demonstration farm are rather productive and fertile, they could produce high yields, however at farm they were low not only in 1997, but also in 1995 and 1996 (BEAROP in Lithuania 1996 and 1997). The main reason for that - wrong management of soil potential and non-rational fertilisation: surplus of phosphorus and shortage of potassium.

There is no established constant crop rotation in the Demonstration farm still, that is why fertilisation plans were built in many variants for each field starting in 1997 (table 1).

Table 1. Data on estimated productivity of V.Liutkevièius farm fields

Crop	Yield, t/ha			
	real (without fertiliser)	optimal (with fertiliser)	limited (without fertiliser)	limited (with fertiliser)
1 field, 6 ha				
Winter rye	3.49	4.36	3.52	4.75
Winter wheat	4.39	5.27	4.42	5.75
Barley	3.58	4.11	3.61	4.51
Oat	3.2	3.84	3.23	4.2
Potatoes	23.07	32.29	23.15	34.73
Sugar beets	31.93	41.51	32.01	44.81
2 field, 0.8 ha				
Winter rye	3.37	4.21	3.44	4.65
Winter wheat	4.25	5.1	4.34	5.65
Barley	3.43	3.95	3.51	4.39
Oat	3.09	3.71	3.16	4.11
Potatoes	22.04	30.86	22.37	33.55
Sugar beets	30.76	39.98	31.08	43.51

3 field, 10 ha				
Winter rye	3.61	4.51	3.61	4.88
Winter wheat	4.49	5.39	4.5	5.85
Barley	3.74	4.3	3.75	4.68
Oat	3.31	3.97	3.32	4.31
Potatoes	23.86	33.41	23.96	35.94
Sugar beets	32.65	42.44	32.79	45.9

These data were used to make rational fertilisation model promising the competitive yield and minimal negative impact to environment in each field. There were suggested 3 variants of crop rotation for the field No. 1 (6 ha): farmer could select the most suitable rotation and fertilisation type in respect of his resources. Variant 1 includes only mineral fertilisers, variants 2 and 3 - mixed fertilisation system consisting of FYM and additional nitrogen and potassium fertilisers, since the crops require lots of nitrogen (potatoes, sugar beets) and potassium in this field.

Phosphorus fertilisers for 2-3 years are not needed to use since the soil is still rich in available phosphorus.

The same calculations were done for another two fields.

The next step is to test agrochemically the rest land of Demonstration farm and to plan the crops, yields and appropriate fertilisation in those fields.

In order to obtain higher yields, necessary to use not only balanced fertilisation, but also integrated cultivation and plant protection measures. There was too little attention paid for the application of integrated plant protection measures in this farm since now.

The drainage system 7.4 ha as a separate field, growing mixture of ley at V.Liutkevièius demonstration farm was chosen for the nutrient balance calculation in 1997 and 1998.

Field was not fertilised with manure nor with urine. The ammonium nitrate was used three times by rate 50 kg/ha of N from early spring till the last cut. Amophos and potassium chloride were used early in the spring: for 50 kg/ha P_2O_5 and 57 kg/ha K_20.

Leaching was measured by drainage runoff recorder and water was sampled once a month for analysis. Denitrification value was assumed 30 kg/ha per year for sandy-loamy soil and biological fixation of nitrogen was calculated by computer program NPK-FLO (Fagerberg B., Salomon E., Steineck S., 1993). Analysis for composition of deposits from atmosphere was done from samples at the farm. The ammonia losses with plant material were assumed as 5 kg/ha, because the grass after cutting was left in the field only for 1 day and night, ammonia losses from animal excrements - as 50 % of all ammonium nitrogen content in the faeces and urine.

Data of NPK flow calculation on field level have shown that nitrogen balance in this field was positive, phosphorus - almost neutral, however potassium balance was much more negative. It is needed to pay more attention to the utilisation of such an organic fertiliser as urine in this field and to establish more white clover in the sward.

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Phosphorus sorption/desorption and soil phosphorus tests in some different soil types in Sweden

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It was a general consensus for a long time that the bulk of phosphorus (P) applied to agricultural land is tightly bound in the soil. However, in the last two decades it has been evident that P from agricultural land is contributing to the eutrophication in surface waters. P is transported to surface waters through surface runoff and subsurface leaching.

Soil P tests are often used to assess the risk of P leaching, but these methods are usually developed for agricultural purposes and are not always suitable for environmental purposes. Nevertheless, it is interesting to study the relation between soil P tests and P leaching risks since data from soil P tests are available for many agricultural soils.

In this project, two common soil P tests (P-AL and Olsen-P) were studied and related to potentially leachable P. Since desorption through extraction with $CaCl_2$ has shown good relationship with P in drainage water, this extractant was used for estimating potentially leachable P. Furthermore, P sorption in some different Swedish soil types were studied to determine soil properties related to sorption.

Soils from 10 long-term fertility field experiments with four P levels were collected. The soils represent different common soil types in Sweden with varying pH, organic matter and clay content. The soils were studied in laboratory for sorption/desorption, soil P test values and general properties. From five of the experiments, soils have been collected for investigations in lysimeters.

Results showed that P sorption capacity was related to the content of iron and aluminium extractable in ammonium oxalate. In contrast, it was not related to clay content. For potentially leachable P, total P and molybdate reactive P were determined in the $CaCl_2$-extracts. Both fractions markedly increased in response to increasing P-AL and Olsen-P values in the soils. However, the increases were accentuated in low P sorbing soils compared with high P sorbing soils. The results indicate that if both soil P test values and P sorption capacity are considered, a better estimation of potentially leachable P could be obtained.

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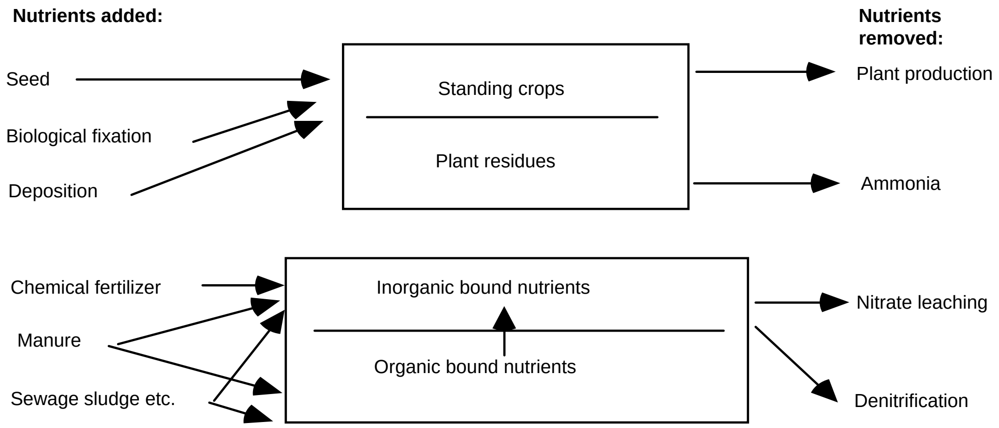
Nitrogen and phosphorus balances in arable land and agricultural sector in Sweden

Solveig Danell, Statistics Sweden (SCB)

Abstract

Nitrogen and phosphorus balances in Swedish agriculture have been calculated by Statistics Sweden. The balances have been calculated for arable land in different regions for 1991, 1995 and 1997 according to the *soil surface* method. At national level balances have been calculated according to the *farm gate* method for 1951, 1985, 1991, 1995 and 1997. The results have been published in Na 40 SM 9701 and Mi 40 SM 9901 from SCB.

The following variables are included in the *soil surface* method:



Nutrients added (input) :	***Source:***
Chemical fertilizer and manure (after losses of ammonia from ventilation, storage and application)	Applied amounts according to a field investigation
Biological fixation	Nitrogen fixation calculated from areas of leguminous plants
Deposition	Regional figures from measuring and and estimations by research institutes
Seed	Recommended amounts
Sludge	Delivered amounts to arable land from waste water treatment plants
Nutrients removed (output):	
Nutrients in plant production and harvested plant residues	Yield figures on district level. Standard content of nutrients in different crops

The difference between "Input" and " Output" gives a surplus containing ammonia from the fields, leaching, denitrification and built-up of nutrients in the soil. Separately calculations and estimations have been made for leaching of nitrogen. The balances have been calculated for counties, production districts, drainage regions as well as for the whole country. Balances have also been calculated according to animal density per hectare and for different crops.

The losses of ammonia from ventilation, storage and application of manure and fertilizer have been calculated and published in Mi 37 SM 0001 by SCB.

The soil surface balances gives for 1997 a total input of 132 kg nitrogen and 17 kg phosphorus per hectare arable land and a removal by harvest with 89 kg nitrogen and 14 kg phosphorus. The differences between input and output gives a surplus of 44 kg nitrogen and 3 kg phosphorus per hectare. The nitrogen surplus contains leaching (27 kg/ha) and denitrification as well as built up in the soil. The ammonia losses from ventilation, storage and application on the fields have been calculated to 16 kg N per hectare.

The *farm gate* method quantifies the total supply of nutrients to the agriculture enterprises and the delivery of products from the agriculture sector. Products circulating in the agriculture enterprises are not quantified. The nutrients added include fertilizer, deposition (excluding ammonia originated from Swedish agriculture), sludge, biological fixation, oil meal, mineral fodder and industrial by-products. The removal includes vegetables and animal products for sale. The surplus includes all nutrient losses in the agriculture sector, not only from arable land, that is ammonia to the air, leaching, denitrification, but also storage losses in feed-stuff handling.

The calculations according to the farm gate method give a total surplus of about 70 kg N per hectare for 1997, that is a little lower than 1995. The surplus of P is about 6 kg per hectare in 1997. Compared with 1985 the surplus is halved.

Some practical and theoretical aspects of soil sampling, analysis and interpretation

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Abstract

Results from soil analysis are increasingly used as a part of the overall assessment of the potential environmental impacts arising from agricultural nutrient surpluses and increasing nutrient availability in soils. However, insufficient attention is given to the act of soil sampling and the likely errors that may be introduced and propagated through subsequent sample preparation, analysis, interpretation and extrapolation stages. A major source of error can be attributed to the equilibration of reactive species (such as phosphorus (P)) that occurs upon mixing soil samples having different physico-chemical properties. Using the topical example of extractable P, it is demonstrated how the act of soil mixing, either during the collection of a composited soil sample or through cultivation can introduce serious bias. Mixing soil, sampled from two depths resulted in a reduction of 20 % in extractable P compared to that predicted as the arithmetic mean calculated from the analysis of individual soil samples. Scenarios are used to illustrate the error that could arise from compositing soil samples with a range of sorption capacities and P status. In all cases the observed value of extractable P for composited samples was less, and in some cases up to 100% smaller, than the predicted arithmetic mean. The example of a gradually increased depth of ploughing when combined with a constant soil sampling depth is used to demonstrate how sensitive data describing long-term trends are to external influences. It is possible to demonstrate that despite an annual agricultural surplus of P over the last 40 years the effect of deeper ploughing was sufficient to totally obscure any expected upward trend in extractable P. The wider implications of this work will be explored within the context of developing environmental indices for P.

Simulation of nitrogen flows in the environmental systems analysis model SALSA

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Environmental Systems Analysis including computer simulation is a useful tool to describe and analyse the complex system of a farm with its large inflows and outflows of substances. Simplifying and summarising the most important flows can create a comprehensive picture of the system. The amount of fertiliser used and management practice play central roles in farming because they not only affect yields but can also lead to pollution of the environment. These emissions arise during the production step as well as during the growing season and also after harvest.

A simulation model SALSA (Systems AnaLysis for Sustainable Agriculture), has been constructed with the aim of studying environmental impacts and the use of natural resources connected to farm production. Materials, important elements and energy used in the production, from "cradle to gate" (from the time resources were manufactured, until the products left the farm), were recorded and categorised according to their environmental impacts (the greenhouse effect, eutrophication, etc). Processes that give rise to large environmental impacts or large use of natural resources, ("hot spots"), indicate where in the system improvements are needed.

The modelling of what happens during the growing period is the most difficult part, because of uncertainty surrounding input-parameters,, processes and variability in conditions from field to field.

The purpose is to describe the most important flows, so detailed modelling is not included in this perspective. The more complex a model is, the easier it is to get lost in parameters and spend too many hours programming. Therefore, the SALSA model used yearly values of nitrogen leakage and uptake into plants obtained separately from the SoilN-model.

The purpose of this paper is to discuss some of the problems relating to finding the right focus in environmental systems analysis modelling. Specifically, problems associated with selecting accurate nitrogen models and uncertainty of experimental data will be discussed.

P balance and soil P availability at field level of some land use systems in the highlands of northern Vietnam

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Nutrient budgets and nutrient balances are being used world-wide as useful tools for evaluating the sustainability of different managed ecosystems. Since negative nutrient balances are “paid” by the soil pool of nutrients, sustainability of different land use systems should be evaluated based on nutrient budgets in combination with quantification of soil nutrient pools and their lability (Smalling et al., 1999).

P-pools of different lability, analysed according to Hedley et al. (1982), and P balances were used as criteria for evaluation of the P sustainability of three innovative systems with *Tephrosia candida* as (1) an improved fallow species (TepFa), (2) in hedgerows (TepAl) and (3) in a mulch transfer system (TepMu), with rice (*Oryza sativa* L.*)* cultivation on sloping land in northern Vietnam during 1996-1999. The systems tested were compared to the existing systems, including natural fallow (NaFa) and monocropping of rice (Mono; Table 1).

The *Tephrosia* systems (TepFa, TepAl, TepMu) were shown to effectively prevent P losses by erosion (Table 1). This, together with increased P inputs through the mulching practice (in TepMu and TepAl) and increased recycling of P (in TepFa and TepAl), improved P balances under the *Tephrosia* systems. In both TepFa and TepMu, the moderately labile NaOH-extractable organic P seemed to be depleted in the topsoil due to high P uptake. Thus, soil P seemed to be “mined” in TepFa and TepMu. These findings show the importance of the combined use of both P balances and availability in evaluation of P sustainability under different land use systems. Hypotheses concerning the mechanism of the P pool reallocation in connection with N are discussed.

Table 1. P balance and soil P-pools of the systems tested during April 1996-April 1998, prior to burning. (Means in the same row differ significantly by contrast tests (p<0.1) if they are marked with different letters)

Parameter	Fallow period		Continuous cropping		
	NaFa	TepFa	Mono	TepAl	TepMu
<u>Soil and nutrient losses through erosion</u>					
Soil mass loss (Mg ha^{-1})	23^{a}	2^{a}	76^{b}	37^{b}	66^{b}
Eroded P (kg ha^{-1})	13^{a}	1.5^{a}	50^{b}	22^{c}	37^{c}
<u>P balance</u> (kg ha^{-1}, except the ratios)					
P input + recycled P	7.8^{a}	6.1^{a}	1.7^{b}	6.7^{c}	6.8^{c}
Removed (harvested) P	0.1^{a}	1^{b}	4.9^{c}	3.3$^{c\,d}$	6.3$^{c\,e}$
Ratio 1[1]	78^{a}	6^{b}	0.3^{c}	2^{d}	1^{e}
Ratio 2[2]	0.6^{a}	4^{b}	0.03^{c}	0.3^{c}	0.2^{c}
<u>Soil P-pools</u> (Figures within brackets were obtained in April 1996, while the other figures were obtained in April 1998; kg ha^{-1})					
Bicarb-Pi	4.0^{a}	2.8^{b}	1.0^{c} (27^{d})	1.7^{c}	2.0^{c}
Bicarb-Po	50^{a}	71^{a}	22^{b} (11^{b})	14^{b}	12^{b}
Bicarb- Po + NaOH-Po	123^{a}	123^{a}	98^{b} (103^{b})	98^{b}	76^{b}
NaOH-Po	73^{a}	52^{b}	76^{c} (92^{c})	84^{cd}	64^{ce}

[1]Ratio 1 = P input + cycled P / removed P; [2]Ratio 2 = P input + cycled P / eroded P.

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Decision support system MACROBIL for sustainable nutrient management at the farm level

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Objective

System MACROBIL working under EXCEL sheet is aimed at providing farmers with a tool for analysing the correctness of fertilizer management practices already applied at the farm. This is therefore a decision support system DSS and not fertilizer recommendation system FRS. The important prerequisite was to limit the input data to those commonly collected or accessible to the farmer. Another prerequisite was the transparency of the system and the possibility to substitute all the default values by the own values if available. The system is based on the nutrient balance at the soil surface supplemented by the concept of nutrient equivalent for nitrogen and balance coefficients for phosphorus and potassium. MACROBIL has been already tested for two years on the example of 25 tenant's farms covering the area 400 – 2000 ha.

System description

Input date

Yield and area of arable crops, meadows and pastures, utilisation of crop's by-products (straw, leaves), disposition of manure for several crops.

Average stock of animals in kinds (cattle, pigs, sheep ...) and groups (milking cow, heifers ...) and ways of keeping (deep bed, slurry ...).

Percentage of soils in valuation groups and fertility classes (pH, content of available phosphorus and potassium), fertilizers consumption.

Balance of nutrients

Surplus (deficit) = fertilizers + manure (faeces + urine + straw – losses) + crop by– products (ploughed down) + N fixation (area and yield of leguminous crops) + N deposits (default values for region) – crop uptake (area * yield * nutrient unit uptake).

Analysis of surplus (deficit)

To bring the amount of nitrogen from all sources to the common denominator – so called acting nitrogen i.e. nitrogen showing the same efficiency as the nitrogen from fertilizers. For this purpose the amount of nitrogen from the particular source is multiplied by nitrogen equivalent N_e (N_e for fertilizers = 1, N_e for FYM applied for the crop = 0.3, N_e for rape straw = - 0.7 – as few examples only). In MACROBIL it is assumed (according to our experience and experts opinions) that the total amount of acting nitrogen should be equal to nitrogen uptake by crops. Other elements of "true" nitrogen balance (losses, mineralization, fertilizer utilisation coefficient) are included into "black box".

Combining the crops and soil demands for phosphorus and potassium. For this purpose the uptake of phosphorus and potassium by crops is multiplied by so called balance coefficients for these elements. Balance coefficients calculated from the results of long-term field experiments have the values from 0 (very high content of available P and K) to 2.0 (very low content of available P and K). In MACROBIL it is assumed that the total amount of phosphorus and potassium supplied in fertilizers, manure and crop residues equals the amount of nutrient uptake corrected by balance coefficients.

Farm indexes to evaluate the fertilization management at farm level

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Several agronomic and environmental reasons stress the need of defining and using technical tools to optimise the fertilization management (Schepers and Mosier, 1991). A rational fertilizer use on herbaceous crops should not only satisfy crop requirements, but should also permit: a) a saving of money spent on mineral fertilizers; b) a promotion of technical enhancement for farmers; c) an adaption of farm management to the laws that rule the use of animal wastes; d) a reduction of the losses of nutrients in the environment (Snijders *et al*., 1999).
A nutrient balance sheet that is particularly suitable for animal breeding farms in the Po plain (North Italy) has here been formulated and developed. This balance sheet is aimed at optimise the fertilization management. It compares nutrient outputs (crop uptakes, nutrient losses by leaching, volatilisation and immobilization in the soil) and nutrient inputs (organic and mineral fertilizers, soil nutrient availability due to the organic matter mineralization, dry and wet depositions, N fixation).
All nutrient balance sheets require a local calibration in order to be applied. The purpose of this work is to use the proposed balance sheet to calculate a P efficiency index and, through this, to show how this tool can be used to evaluate different scenarios in manure management of breeding farms.

Materials and methods

The balance sheet was applied to 12 breeding farms located in the Po plain (Fossano, NW Italy) where a high stock density is frequent. Four farms were dairy (DC), three were beef breeding farms (BB), and four raised pigs (PB).
The efficiency index was calculated as total P output : total P input ratio.
Two scenarios were studied: a) the optimization of the actual fertilization technique without any structural change in the farm; b) the reduction of the farm stocking rate to the threshold imposed by environmental legislation limits (stocking rate equivalent to 340 kg of excreted N ha^{-1} and to 170 kg N ha^{-1} in vulnerable areas). The excreted amount of N produced in manure is calculated from the live weight of farm animals. This reduction may be reached by reducing the animal stock in the farm, or increasing the land where manure is spread.

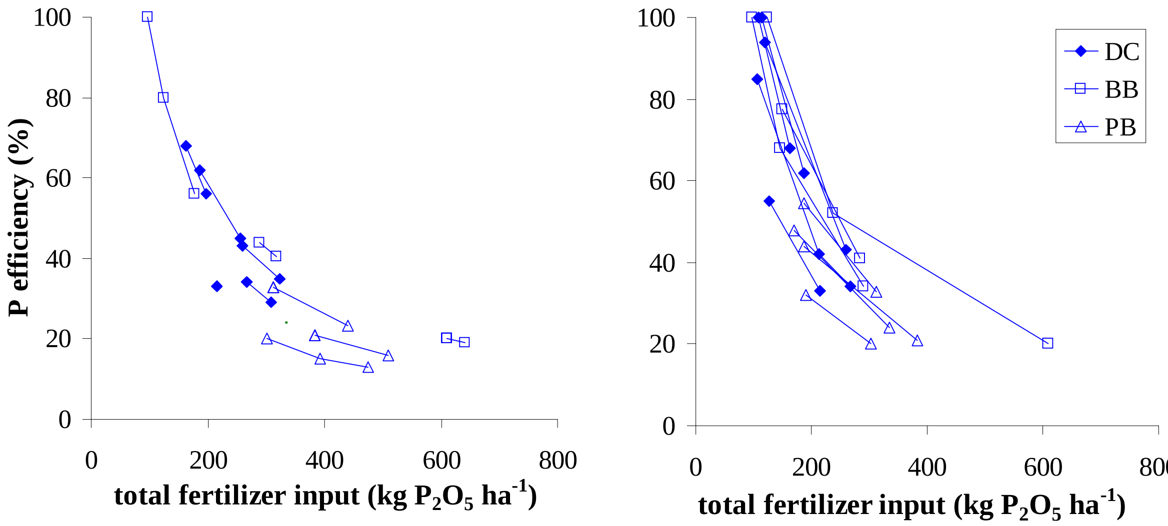
Results and discussion

Crop uptakes have been compared to total and organic P inputs in the actually adopted fertilization management . In most cases, the P organic input exceeds the crop uptake, and the excess is two to three fold the crop uptake. When used, the mineral P fertilizer enhances the P surplus. An optimization of the actual fertilization technique does not require any structural change in the farm, or in the breeding management. Therefore, it is the easiest and most immediate solution to propose. The optimization of the P fertilization can be obtained mainly through a reduction of the mineral P input, and this results in an increase of the total efficiency index, especially in DC and BB farms (Tab. 1 and Fig. 1). In most of the farms tested in the present work the live weight was already under the 340 kg excreted N ha^{-1} limit; only one DC farm (418 kg excreted N ha^{-1}) and one BB farm (873 kg excreted N ha^{-1}) were above this limit. Reducing the stocking rate to 170 kg N ha^{-1} appears to be the only way to provide an organic P spreading that is similar to the crop uptake, a substantial increase of P efficiency index and an important reduction of the P surplus (Tab. 2 and Fig. 1).

Tab. 1. Average P efficiency index obtained through an optimization of fertilization management

Farm type	Total P efficiency index actual %	Total P efficiency index optimized %	Increase in efficiency %	Mineral P fertilizers saved by optimization kg P_2O_5 ha^{-1}	Farms where mineral P saving is possible %
DC	40	48	8	42	80
BB	38	55	17	47	100
PB	19	24	5	84	75

Fig. 1. Increase in total P efficiency indexes due to a reduction of P total input obtained through: the optimisazion of P fertilization management (left) and the reduction of the stocking rate to 170 kg organic N ha^{-1} (right).



Tab. 2. Average P efficiency index obtained through a reduction of the stocking rate

Farm type	Average production of N in manure *kg N ha^{-1}*	Total P efficiency index optimized %	Total P efficiency index reduced to 170 kg N ha^{-1} %	Increase in efficiency %
DC	318	48	87	+39
BB	438	55	93	+38
PB	328	24	45	+21

Conclusions

The main results of the present work are: a) the actual P efficiency index ranges between 19 and 40%: crops are heavily over-fertilized; b) pig breeding farms have the lowest P efficiency (19%), owing to the low crop uptake and the very high amount of mineral fertilizer supply; c) optimizing the actual fertilization technique determines an increase in the P efficiency to a range of between 24 and 55%; d) if the animal stocking rate is reduced, a substantial increase in the P efficiency can be reached (up to 45% in pig farms, 87% in dairy cow farms, 93% in beef breeding farms).

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Preliminary results from a study of fluxes and balances of P, K and Zn in a conventional and ecological dairy farm system through feeds, animals and manure during one year

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In a three year research project at the Swedish University of Agricultural Sciences (SLU) the focus is put on the flows and stores of nutrient elements on and within the farm level. Beside the interest for the fluxes of each of various elements with different properties in a farming system, the aim in this project is to assess what kind of questions that can be answered by counting on balances at farm level, barn level and field level from time perspectives between the annual cropping season to three years. The project is facilitated at the Öjebyn Research Farm, SLU. For twelve years this farm is partitioned into two farming systems for milk production, one is ecological the other conventional according to Swedish standards.

In this abstract of preliminary results the flows and balances over one year on barn level are in focus. Barn level in this case includes feeds-cows-manure.

The elements assessed are potassium (K), phosphorus (P) and zinc (Zn). Potassium (K) represents an element highly soluble in water with high risks for leaching and with a high secretion into urine. P in the forms it appears in soil is usually not very soluble in water, but can be lost from a farm in particles by surface run off and preferential flows through the soil column. For cows, most P is excreted in the faeces. Zn represents elements that are purchased in mineral feeds to animals in quantities that could threaten the future soil quality.

The flows of K, P and Zn from feeds and bedding material through milk, urine and solid manure, and the balance between input and output on barn level during one year are shown in table 1.

Table 1. Flows of K, P and Zn from harvested feed crops and purchased feeds (F) and bedding (B) through milk (M), calves (C), urine (U) and solid manure including discarded feed and feed refusals (MA), kg year^{-1}. Balance between input and output on barn level (F +B)-(C+M+U+MA). Import of nutrients in heifers is approximately the same as the export in cows for slaughter. *Note:* A negative sign in the last column means that more of the element was found in the output than in the input

Element	In harvested feed crops and purchased feeds F	In bedding material B	In milk M	In calves C	On manure pad and in urine tank U+MA	Balance
Ecological						
K	8914	23	615	5	5688	2629
P	1399	3	411	23	965	3
Zn	18.1	0.2	1.6	0.1	22.8	-6.2
Conventional						
K	9365	21	682	5	5278	3421
P	1391	3	443	23	904	24
Zn	20.9	0.2	1.8	0.1	21.0	-1.8

Who needs a nutrient balance in Vietnam?
A case study in An Son, southern Vietnam

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In Europe nutrient balances are used as a tool in nutrient management, often with an aim to meet environmental goals. In Sweden, for example, a farm nutrient balance is required in order to receive REKO-support (an environment-related farm subsidy), and to obtain planning permission to keep more than 200 livestock units. Also the area-related limit for the number of livestock units on a farm has also been derived from nutrient balances. It translates to 2.2 sows or 10.5 fattening places pigs per year and ha. And this ensures that P input does not exceed 22 kg per year and ha, which corresponds to an average removal of P by a cereal grain crop.

In the village An Son in southern Vietnam the number of pig units per area of land is much higher than the maximum permitted in Sweden. In An Son pig raising is very popular especially in areas where the farms are small and the farmers are forced to make a living out of a small piece of land. It is not unusual that a farmer with 0.1 ha land available has two fattening pigs in two cycles per year, i.e. 20 fattening pigs places per ha. The solid manure is used for the crop (except for jackfruit and durian), but the liquid slurry is not utilized. Crop removal of P in this area is about 25 kg P/ha removed by rice (3 crops per year) provided that the straw is left on the field. In a fruitgarden, which is often combined with pig production, the P output is substantially lower. For example in a farm with mature trees of durian *(Durio zibethinus)*, jackfruit *(Artocarpus integrifolia)*, bon bon *(Lansium domesticum)*, rambai *(Baccaurea sapida)* and mangosteen *(Garcinia mangostana)* the P output per hectare and year is only 9 kg. Most of the P in the manure is derived from bought-in fodder and as the farmers moreover often also fertilize with mineral fertilizers the examples from above indicate a large P surplus. The environmental impact of such seemingly excessive fertilization will depend on the risk of P losses, which is related to the nutrient status of the soil. It is possible that high P fixation of the soils necessitates such seemingly excessive P fertilization, and it may be compared to the situation in many European countries at the time of introduction of mineral fertilizers where the fertilization strategy often included a building up of the soils' nutrient status.

In this paper I present nutrient balances of 14 farms in the village of An Son and discuss the findings in relation to the famers' perception of nutrient management and the risk to the environment of existing farming practices.

Swedish Seal of Quality and its key indicators

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Both environmental and quality assured crop production

Swedish Seal of Quality is a concept for environmental and quality assured crop production. In 2000 Swedish Seal consisted of around 35 000 ha of a total arable area of over 85 000 ha on 620 farms. They produced 240 000 tonnes of their total production for Swedish Seal. Crop production according to this concept consists of the following plant nutrition rules:

Nitrogen: A yearly field balance for input/output of nitrogen and goals depending on production of the individual farms.

Phosphorus and Potassium: A farm gate balance every third year according to STANK, the official input/output model by the Swedish Board of Agriculture, and goals depending on soil map values.

Cadmium: Treshold values for soil and plant content of cadmium

Key indicators for plant nutrition

Nitrogen

On field level the goal is a nitrogen efficiency of 80 % of input on cereal farms and 60 % of input on the most efficient livestock farms. Farms with milk production usually have a farm gate balance around 30 % of input.

The field efficiency is calculated in the following way (showed as a winter wheat example):

	Source of nitrogen	Nitrogen, kg/ha
Input	Deposition	8
	Mineralisation	
	Effect of previous crop	30
	Effect of previous slurry/manure	0
	Mineralisation of soil organic matter (3,75 kg N per % SOM when the SOM content is above 4 %)	0
	Fixation of N by leguminous plants	0
	Seed	4
	Slurry/manure plant available N first year	0
	Fertilizer N	140
Total input		182
Output	Yield with present protein content	136
	Crop litter taken away from the field	0
Total output		136
Surplus		46
N efficiency	75 % of input	136/182

The nitrogen efficiencies on field level 1998 and 1999 for different crops were as follows:

Crop	1998, % of N input	Number of fields	1999, % of N input	Number of fields
Winter wheat	69	465	69	764
Spring wheat	-	-	66	168
Spring malting barley	77	195	74	502
Oats	69	93	72	269
Rye	67	68	72	80

Phosphorus and potassium

The goal for phosphorus is an optimum use of the finite resource and balance with consideration of soil map values and environmental risks. The use of potassium is also a resource problem, especially on sandy soils with high precipitation.

The recent farm gate values for the efficiency of P and K in % of input are:

	Effiency, % of input	Standarddeviation	Minimum value	Maximum value
Phosphorus	103	31	21	278
Potassium	101	41	30	377

Do Organic Farming Practices Reduce Leaching of N?

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Introduction

The use of organic farming principles brings about a range of secondary effects. One important feature of organic farming is that, on average, the supply of nitrogen to field crops is lower compared to conventional farming practices. However, large inputs of N-rich crop residues (legumes) in organic farming systems can lead to high amounts of nitrate in soil during periods when no crops are grown. We attempt to summarize the current literature on this topic and compare N leaching when using animal manure and inorganic fertilizer.

Summary of literature review

- Any leaching study in which organic and conventional farming has been compared differs in crop rotation (i.e. crop longevity, crop residues and number of winters covered by crops) and/or the input of N. This limits the possibility to compare results.
- Average long-term leaching estimates from a range of organic (n=6) and conventional farming studies (n=11) do not differ in terms of amounts of N leached.
- Leachable inorganic nitrogen tend to be higher in organic farming systems presumably due to the frequent input of N-rich legume residues.
- The type of crop grown has a greater influence on N leaching than the amount and type of fertilizer used, i.e. perennial crops always reduce N leaching independent of the type of fertilization. In other words, both organic and conventional farming systems can have low or high leaching losses.

Results of a lysimeter study with organic manure and inorganic fertilizer

- Of the N applied, N leaching from organic manures was ten times higher than from ammonium nitrate (Table 1). This was mainly due to poor synchrony between N demand by the crop and N mineralization from manures.
- From aerobically treated manure, similar amouts of N were leached as taken up by the crop (Table 1).
- If leaching of added N is expressed in relation to plant N uptake, instead of per areal unit, much less N is leached if inorganic fertilizer is used.

Table 1. Leaching of total-N and recovery of ^{15}N-labeled fertilizer and ^{15}N-labeled manure in plants and leachate during the period 1992-1995

Treatment	Total N leaching	Fertilizer N uptake	Fertilizer N leaching
		kg N/ha	
No N	38.7(±12.5) b	–	–
NH_4NO_3	128 (±25.7) a	57.0 a	3.5 b
Fresh manure	139 (±45.4) a	54.4 ab	24.6 a
Anaerobic manure	170 (±31.0) a	49.9 b	31.8 a
Aerobic manure	148 (±8.4) a	32.6 c	27.4 a

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Use of nutrient balance for environmental impact calculations on experimental field scale

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First nutrient balance on the country level in Lithuania was made in 1968-1970 year [1]. Plant fertilization and yield increase was the main objective of balance calculations. Nutrient balance as a measure for evaluation of agriculture environmental impact was started to use in international projects supported by the Swedish Government beginning from 1993.

Leaching of nutrients is the most important factor concerning water pollution. In average, agriculture is estimated to account for 30-35 % of the nitrogen load [2]. Elaboration of the proper procedures in agriculture protecting water and environment quality that would allow avoiding errors, which were committed in developed countries, is nowadays the main task for countries in transition such as Lithuania [3]. Crop structure and rotations oriented to environmentally sound agriculture development will help to reach this task.

In this presentation we demonstrate five years field experiment seeking to reveal influence of different crop rotations on nutrient leaching and relationship with plant nutrient use, accumulation in soil and balance.

A network of representative experimental fields was established in the Experimental Department of LIWM in village Lipliunai, Kedainiai region. In every field (treatment) crop rotation is different. Crop rotation for all five fields in 1996-2000 is presented in table 1.

On the fields the following parameters were measured: drainage water discharge, soil moisture, soil, water and plants nutrient content, main and supplementary production, residues yield and nutrient content.

Results and discussion

Cereal rotations carried-out in the third field resulted in highest average nitrogen leaching (113.3 kg/ha), but fertilization rate in this field was 2.5 times lower than in second field. Sugar beets dominating in second field rotation (three years out of five) and higher fertilization resulted in highest nitrogen concentration (16.4 mg/l), from first and fourth fields, where grasses were included in crop rotation and fertilization rate was lower, nitrogen concentration and leaching was lowest (table 2).

Leaching of phosphorus in experimental fields was very low (table 2). Potassium concentration and leaching was lowest in second treatment (0.52 mg/l and 3.4 kg/ha). Sugar beets took more potassium from the soil in this treatment.

Nitrogen balance of every year for every experimental field included input with fertilizers and precipitation, output with production and leaching (table 3). Difference of input and output was positive (+) or negative (-). The highest result of nitrogen negative balance was revealed in IV field (five year sum -370 kgN/ha) where clover and barley was in rotation. Fourth field was not fertilized and decrease of nitrogen content in the soil was observed in autumn of 1998 and spring 1998 and 1999 years when cereals grasses remained on the field. In summer IV field under grasses was ploughed and nitrogen content in soil increased.

The highest positive balance was for field with sugar beets in rotation (83 kgN/ha). In III field where cereals dominated, surplus of nitrogen was 65 kg/ha. We suppose that low cereals yield and nitrogen immobilization determined such result. There is quite good relationship between nitrogen leaching and nitrogen balance on experimental fields (fig. 1). Coefficient of determination R^2=0.897.

Conclusions

1. Nitrogen leaching in fields under different crop rotations differs from 49.5 to 113.3 kgN/ha in 1996-2000 year. The highest leaching was in the fields under sugar beets and repeatedly planted cereals - 101.2 and 113.3 kgN/ha.
2. Calculation of nitrogen balance in the experimental fields revealed that the highest surplus of nitrogen (+83 and +65 kgN/ha) was in fields where nitrogen leaching was highest. Relationship between nitrogen leaching results and nutrient balance is positive (R^2=0.897).

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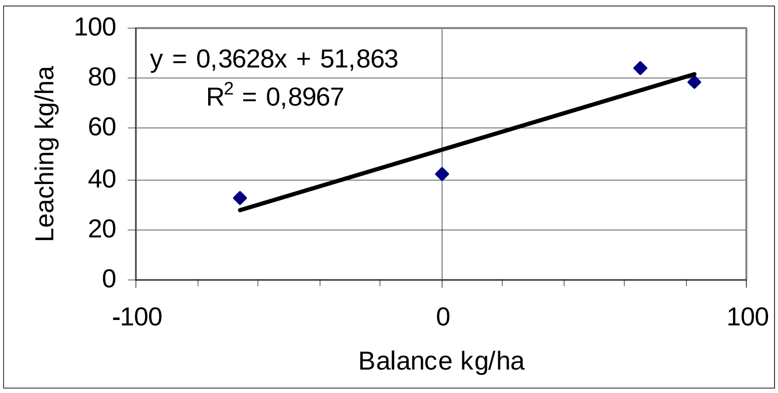

Fig. 1. Relationship between nitrogen leaching and balance in the experimental fields.

Table 1. Crop rotation in every field in 1996 – 1999

Year	Crop rotation fields				
	I	II	III	IV	V
1996	Sugar beet	Sugar beet	Winter wheat	Barley under sown grass	Fodder bean
1997	Barley under sown grass	Fodder bean	Barley	First year use perennial grass	Winter wheat
1998	Perennial grass and winter wheat in autumn	Sugar beet	Barley and winter wheat in autumn	Second year use perennial grasses	Triticale
1999	Winter wheat	Barley	Winter wheat	Third year use perennial grass and winter wheat in autumn	Summer rape
2000	Sugar beet	Sugar beet	Barley	Winter wheat	Winter wheat

Table 2. Concentration of NPK in drainage water (mg/l) and leaching (kg/ha) in experimental fields

Fields	Nitrogen leaching					N concentration	N leaching
	1996	1997	1998	1999	2000	For 1996-2000	
I	5.4	7.8	10.4	8.9	18.2	10.5	50.7
II	7.3	17.7	39.0	13.9	25.4	16.4	103.3
III	3.6	23.8	37.2	19.6	32.5	13.5	116.7
IV	2.0	16.3	10.2	8.7	24.9	11.2	62.1
V	0.8	14.8	17.5	8.8	13.5	11.5	55.4
Fields	Phosphorus leaching					P concentration µg/l	P leaching kg/ha
	1996	1997	1998	1999	2000	For 1996-2000	
I	0.03	0.02	0.04	0.05	0.02	38.2	0.16
II	0.04	0.01	0.07	0.04	0.03	34.6	0.19
III	0.03	0.05	0.06	0.05	0.05	40.2	0.24
IV	0.008	0.02	0.06	0.11	0.04	47.0	0.24
V	0.006	0.02	0.06	0.08	0.04	52.4	0.21
Fields	Potassium leaching					K concentration mg/l	K leaching kg/ha
	1996	1997	1998	1999	2000	For 1996-2000	
I	0.41	0.62	1.14	0.93	0.81	0.83	3.9
II	0.39	0.40	0.94	0.92	074	0.52	3.4
III	0.27	1.59	1.40	1.64	1.23	0.80	6.1
IV	0,14	1.56	1.74	1.77	1.66	1.22	6.9
V	0.01	0.90	1.45	1.55	1.24	1.00	5.2

Table 3. NPK balance in the experimental fields (total for 1996–2000)

Field	Nitrogen kgN/ha			Phosphorus kgP_2O_5/ha			Potassium kgK_2O/ha		
	input	output	balance	input	output	balance	input	output	balance
I	391	450	-59	167	117	+50	200	352	-152
II	621	447	+174	257	119	+138	480	358	+122
III	377	303	+74	18	82	-64	100	64	+36
IV	90	516	-426	10	130	-120	13	372	-359
V	326	411	-85	40	126	-86	90	141	-51

Optimisation of Soil Organic Matter (SOM)

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From 26 long-term trials in Western Europe the following results are abtained:

1. All considerations in respect to organic substances of the soil makes it necessary to differentiate between at least two fractions, one of them being more or less inert (which means that this kind of permanent humus to a high degree does not participate in mineralisation processes and does not depend the conditions on site) while the other is decomposable (mineralisable) and mainly determined by the conditions of the agricultural cultivation (nutritional humus).

2. Any change to the C_{org} level in the soil concerns more or less exclusively its decomposable part and happens very slowly. Depending on the original level more than 50 years may pass till a new equilibrium of flow has been reached.

3. The soil improving effects of the SOM on the yield may reach 10% in case of sandy soil and up to 5% in case clayey soil, whereby the percentage of the yield is the result of a comparison between an exclusively (and in respect to kind, quantity and timing optimal) mineral fertilisation and an optimum combination of organic and mineral fertilisation.

4. Analytically the SOM_{dec} can be determined by hot water extraction (Körschens and Schulz 1997, Schulz 2000), while the N_{dec} and C_{dec} may be determined by Near Infrared Spectroscopy (NIRS) (Wenzl 1999). The hot water extract will always be a relatively undefined fraction of the SOM. This fraction contains partly microbial soil matter as well as single organic compounds and (under extraction conditions) by water hydrolyzable / depolymeryzable compounds (i.e. parts of the SOM which decompose most easily), which means that these parts of the microbial soil masses may be viewed as part of the active SOM (Franko, 1997).

5. Carbon and nitrogen in the soil show an ecological range that has a relatively narrow optimum. In the common agricultural production systems under conditions found in Central Germany and comparable sites this range amounts to a percentage of 0.2 to 0.6 for decomposable C and 0.02 and 0.06 for decomposable N. Below this range the fertility of the soil, its yield and the binding of CO_2 by plant biomasses proof to be insufficient, above this range environment polluting losses (emissions) occur.

6. In case of changes to the agricultural cultivation system the direction of the changes of the C_{org} content depends on the original level. Equal measures may result in an increase in case of a low initial level, whereas a reduction may be caused in case of a high initial level.

7. Compared to organic fertilisation the input of fertiliser nitrogen results in a more favourable (environmentally more friendly) carbon and nitrogen balance (if

the current scientific knowledge is consequently taken into account); this kind of input yields higher output and therefore achieves higher CO_2 bonding, which contributes to a relief of the atmosphere if the organic substances (e.g. straw) are utilised energetically without any net CO_2 emission into the atmosphere (which is possible e.g. if CO_2 sources like fossil energy carriers are substituted).

8. Atmogenic N input amounts to > 50 kg/ha.a; they must be taken into account in the determination of the balance and the fertiliser quantity.

9. The optimum humus thickness (and other tillage depth) ranges from < 35 (e.g. black soil) to > 20cm (e.g. sandy soil).

10. Quality parameters like C_{org}/S_{org} (100/l) and C_{org}/P_{org} (150/l) are homogeneous to a high degree.

11. In long-term agricultural cultivation of arable soils the resulting type of humus is therefore always mull.

12. In order to uphold the optimum SOM conditions mentioned before it is necessary to add about 2 tonnes of reproduction-efficient organic substance (ROS) $\cdot$ $ha^{-1} \cdot a^{-1}$ in order to achieve an SOM balancing (in case of normal production intensity). This addition equals the addition of 2 tonnes of dry matter (stable manure / solid matter from liquid manure) or 10 tonnes of raw matter, equivalent to the yearly amount 1 gross weight or life weight unit of 500 kg of life weight produces each year. That way the optimum input of phosphorus, potassium and magnesium is also achieved (Körschens and Pfefferkorn 1999). If land conservation is considered in cultivation processes combined with a reduction of farming intensity the addition of organic substances can be reduced.

13. So far there is no comparable knowledge for the optimisation of the SOM of grassland soils and forest soils, but these can be obtained to a later point of time by way of the same procedure introduced here.

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NPK balances in two Swedish cropping systems with leys

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In two Swedish long-term experiments applied and removed amounts of N, P and K were measured. One experiment in south Sweden, Kronoberg, was located on a glacial till with pH 6.3 and 7 % clay and the other, Offer in north Sweden, on a silty soil with 27 % clay and pH 6.4. Rotations were barley, ley I-II, winter rye, spring turnip rape and oats at Kronoberg and barley, ley I-III, green rape, oats and potatoes at Offer. Two complete rotations were studied.

There were 3 P-levels, 2 K-levels and 5 N-levels in all combinations arranged in a split-plot design with PK-kombinations on main plots and N-levels on sub plots in two completely randomized blocks. The P-levels were replacement (R), R+20 and R+40 kg $ha^{-1}yr^{-1}$, K-levels R and R+80 K and N-levels varied with the crop from 0 to 217 kg ha^{-1}. At Offer manure was applied twice in the rotation. At Kronoberg no manure was used. P and K in the manure was accounted for in PK fertilizer levels but N was not.

The N balance without inorganic N fertilization was negative with 60 to 90 kg ha^{-1} yr^{-1} (Table 1). The highest N-level resulted in an annual surplus of N with 40 to 60 kg ha^{-1}. Replacement plus 40 kg P or 80 kg K annually gave only slightly increased P off-takes, at Kronoberg none. For K the off-take increased with some 60 to 200 kg ha^{-1} over the period at Kronoberg and Offer, respectively. Some of the surplus P was recovered in the AL-soluble fraction (Table 2) and one can expect that more P is transformed to less soluble compounds which can be recovered later. For K nothing was recovered in the AL-soluble form and large losses must be expected. The surplus N could not be detected in increased soil C contents. In fact, no reasonable differences in the soil C content after different N levels could be observed.

Table 1. NPK-balances, kg ha^{-1}, for low and high treatment levels in two Swedish experiments

	Offer, 14 years				Kronoberg, 12 years			
Treatment	Applied	Removed	Balance	$Year^{-1}$	Applied	Removed	Balance	$Year^{-1}$
N1	408	1292	-884	-63	0	1121	-1121	-93
N5	3448	2596	852	61	1840	1340	500	42
P1	198	198	0	0	302	302	0	0
P3	790	230	560	40	776	296	480	40
K1	1737	1737	0	0	1412	1412	0	0
K2	3053	1933	1120	80	2432	1472	960	80

Table 2. Top soil C % and easily (AL-) soluble P and K, mg 100^{-1} g soil

	Offer, 14 years						Kronoberg, 12 years					
	C, %		P-AL		K-AL		C, %		P-AL		K-AL	
	N1	N5	P1	P3	K1	K2	N1	N5	P1	P3	K1	K2
Start	2.5		7.9		10.0		2.6		15.9		29.5	
End	2.9	2.6	6.6	15.1	9.0	9.5	2.7	2.7	12.6	19.7	11.0	17.8

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Investigation of ways to introduce mineral balances on farm level for different Flemish farms

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Since the early nineties, Flemish agriculture has been confronted with serious nutrient problems. Today, Flanders has to deal with an annual N surplus of 66 $*10^6$ kg and a P surplus of 15.7 $*10^6$ kg. To solve these problems, the Flemish government outlined a policy based on three important pillars: problem solving at source (mineral content in concentrates), stimulate the farmers to fertilize more judiciously and manure processing. The government also tries to make farmers feel more responsible, by giving them the choice between a manure administration system based on fixed standards or a nutrient balance system. In this nutrient balance system three subsystems can be distinguished: a manure excretion balance (level of animal production), a soil balance (level of plant production) or a mineral balance on farm level.

In this project possibilities for the introduction of mineral balances on Flemish farms were investigated. These balances should be scientifically reliable, practically performable and verifiable. Nutrient streams were followed during one year on 40 Flemish farms in different sectors (cattle, pigs and poultry) and a mineral balance was calculated for each of them. This allowed farmers to immediately assess the theoretical guidelines on their practical consequences. Based on the balance results of the different farms (Table 1), four important bottlenecks for its composition could be identified:

- the legal bias permitted on the mentioned mineral content of imported concentrates on the invoice
- the determination of the amount and the mineral content of imported or exported manure
- the assessment of differences in stock on farm at the beginning and the end of a year
- the accuracy of the data collected by the farmers.

Further research is needed to deal with these problems.

Table 1: Examples of mineral balances on four different Flemish farms

Type of farm	**Dairy cattle**		**Beef Cattle /arable farming**		**Swine**		**Poultry: broilers**	
Mineral	**N (kg)**	**P (kg)**	**N (kg)**	**P (kg)**	**N (kg)**	**P (kg)**	**N (kg)**	**P (kg)**
Total import	7761	1525	32564	5556	101260	18933	3749	571
Total export	1812	348	7181	1559	83502	16425	2974	562
Nutrient surplus	**5949**	**1177**	**25383**	**3997**	**17758**	**2508**	**775**	**9**
Surplus per ha	**259**	**51**	**363**	**57**				
Surplus per animal					**3.4**	**0.5**	**0.025**	**0.0003**
Efficiency* (%)	**21**	**20**	**20**	**24**	**41**	**40**	**47**	**73**

* Efficiency= [(export via animals, animal products and plant products) / total import]*100

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Nutrient flows and balances in different farming systems – A study of 1 300 Swedish farms

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Abstract

In Sweden plant nutrient balances are used for monitoring the nutrient situation at farm level, and a large number of balances have been established within the Swedish environmental agricultural Advisory Service. In a master thesis, balances for the macronutrients nitrogen, phosphorous and potassium have been studied with special emphasis on livestock production systems at different stocking rate of animals and different techniques for manure handling. The results indicate evident differences in nutrient surplus and nutrient utilisation efficiency between different production systems, but also a great variety within one production system. The median values for nitrogen surpluses vary from 46 kg/ha (arable farming) to 119 kg/ha (milk production). Median values for nutrient use efficiency (the ratio of the amounts of nutrients exported to that imported) of nitrogen vary from 27% (milk production) to 68% (arable farming). For phosphorous and potassium the differences between different production systems show the same tendencies but are less obvious.

The results also show that the surplus of nitrogen, phosphorous and potassium is positively correlated to stocking rate of animals with the clearest correlation for nitrogen within milk production. There is a tendency against the opposite correlation for nutrient use efficiency. Nitrogen use efficiency, expressed as surplus of nitrogen per ton milk, differ between dairy farms with high stocking rates and dairy farms with low stocking rates, 27 kg N/ton milk and 22 kg N/ton milk respectively. In pig production, farms with slurry were shown to have a better nitrogen use efficiency than farms with solid manure. On farms with milk production there seems to be no such differences between different handling systems for manure.

To use nutrient surplus and nutrient use efficiency, defined as above, as parameters for the nutrient handling on a single farm one has to consider a great number of facts true for that specific farm. To be able to compare single farms they have to be grouped due to these facts. This work has shown that stocking rate is of major importance for the output of a farm balance. Also, on farms with livestock production, any sale of crop products should be taken into account. Facts as techniques for manure handling and stock production system are of lower priority.

Phosphorus accumulation in soils derived from volcanic ashes in the southern of Chile

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Introduction

Chilean soils in the southern region are mainly derived form volcanic ashes. These soils are chemically characterised by a strong P retention capacity and a low pH value (5.0–6.0) associated with low amount of exchangeable basis. A model to predict the available P (Olsen-P) after P application to soils in basis of P balance in the agricultural system has been developed.

$$Pd = \frac{(Padded - Poff) * 0.4t^{0.9}}{FCO} + Pi$$

Where *Padded* is the average of P applied, *Poff* is the average of P exported from the agricultural system, *t* is time in years, *Pi* is the initial available P and *FCO* is a factor to convert P added to available P (P-Olsen). This model works with only soluble P added and it has not included rock phosphate as a source to P added, so research it is needed to known the P accumulation in soils when rock phosphate has been applied.

Materials and Methods

Three soils (two Andisols and one Ultisol) derived from volcanic ashes were incubated for 365 days at 25 ºC after a rate of 700 mg P kg^{-1} was applied. The sources used were monocalcium phosphate (MCP) and rock phosphate (Rock P). Also a control with no P application was included. After this period a P fractionation method (Tiessen and Moir) was used to extract the different fractions were P applied was accumulated. A pattern of P distribution was determined by type of soil and type of fertiliser used. These patterns were compared with those found from samples taken form farmers fields were only MCP, only Rock P or mixed of MCP and Rock P has been applied during for at least the last 10 years.

Results and Discussion

This research showed that there is differences in the P fractions between the different kind of soils and it is influenced by the P source utilised for fertilisation. It was also observed that in soils with an addition of MCP there was a marked affect in the NaOH fraction, and in soil with an addition of Rock P this effect was shown in the HCl 1M fraction (Figure 1).

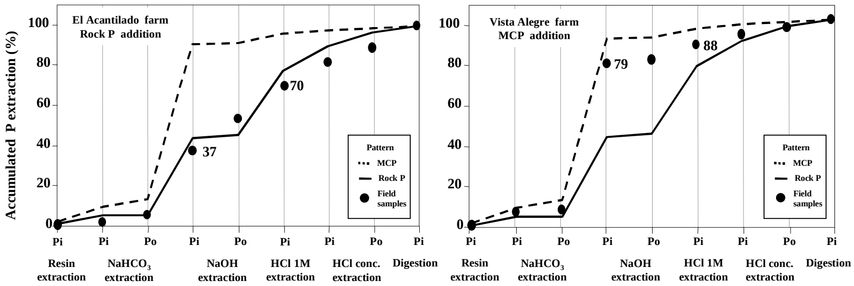

Figure 1. Pattern of accumulated P extracted by the sequential extraction method (Tiessen and Moir) for an Andisol derived from incubation experiment compared with the P extraction from field samples where different P sources has been applied.

A close adjustment was observed between samples from incubation test and the field samples (Figure 1). The differences between them were a more presence of P applied in the organic P and the more occluded P fraction in the field samples that those form the incubation technique.

A simple model to describe the available phosphorus accumulation in soils

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Introduction

The soils in Chile are still deficient in available P (Olsen-P) to crops and pastures. To increase its content to a sufficient level for crops and pastures a simple model is been developed on the base of a balance between P added, P offtake and the reaction in soils which decrease the availability of P with time.

Experimental basis of the model

For a laboratory experiment twelve soils were chosen to represent a wide range of properties which might affect the P dynamics in soils. As extractant it was used sodium bicarbonate (Olsen method). Two experiments were carried out (a) to study the initial reaction between soil and phosphate and (b) an incubation study of added P with soil under controlled conditions (temperature and moisture content) to evaluate the change in extractability of P over time.

Model

The model has two main components: a parameter ***FCO*** which describes the immediately availability of P applied after an initial reaction to the soil (1 day) and ***KP*** which represents the lost of extractability of P applied with time. It is considered that immediately after P was applied a measurement of P available content **(*FCO*)** represents the P which is similar to P labile assuming that after a day the slow reaction which made P unavailable has not occur or occur to a very low degree, so all P applied as a soluble source is available. After that with time the initial available P (Olsen-P) is loosing its availability because of slow reactions of soil with phosphate and P accessibility to plants. ***FCO*** parameter is well correlated with the P fixation capacity of soils but ***KP*** seems to be independent of it. ***KP*** can be described by a general function which depends on temperature and P ageing $(KP = (1 + at)^{-0.15})$. To predict the residual effect of added P on the extractability by the Olsen method a balance is established between the inputs of P (*Pin*) and the offtake of P (*Poff*) considering the reactions of P in soil with ageing. The following relationship applies

$$Olsen-P = \frac{\left[\sum_{t=1}^{t=n}(Pin_t * KP_t) - \sum_{t=1}^{t=n} Poff_t\right]}{FCO}$$

Model evaluation

The model was evaluated by comparing the values of Olsen-P estimated by the model with measured values from four field experiments from England and Chile. The model describes well the residual effect measured by the Olsen method and highly correlation were obtained between estimated and measured values.

Fertiliser recommendation on the basis of potassium and phosphorus farm-gate balance in livestock farms

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Abstract

The „farm gate” phosphorus (P) and potassium (K) balance was made in 12 livestock farms being the demonstration farms in Baltic Agriculture Runoff Action Program. The calculated mean surplus amounted to about 25 kg ha^{-1} P (max. 66 kg ha^{-1} P) and 60 kg ha^{-1} K (max. 147 kg ha^{-1} K). Most soils in these demonstration farms have very high soil P and K test. An important source of P surplus is purchased fodder. The surplus of K resulted from over-fertilisation with this nutrient. The high P and K surplus is not only a risk to the environment, but also an economic loss for farmers, that may be rather acute in the case of overuse of P fertilisers. The „farm gate” balance method is a good tool to improve fertiliser recommendation system in the direction to protect environment and increase the farmer’s benefit.

The nutrient inputs to animal farms comprise not solely fertilisers and but also purchased fodder including concentrates usually enriched in P up to the content of 0.5% P or more. The purchased fodder could be the dominant nutrient sources in some farms, where the field area is to small to produce enough foodstuffs. However, this fact is seldom considered in fertiliser strategy in Poland. The calculated P balances shown that the highest found P surpluses resulted from P inputs with purchased fodder. This regularity is not obvious in the case of K, which relative inputs with fodder are evidently less than with fertilisers.

The nutrient efficiency in animal farms depends mostly on the system of manure management. The bulk amount of nutrient comprised in crops or pasture herbage is used there as foodstuff or bedding in livestock production and is returned to fields or grassland in the form of manure. Each fertiliser recommendation system is based on some average nutrient content in different kind of manure. That may create some unwanted effects to farm economy and/or to environment quality.

The decrease of P and K surplus has not only an environmental meaning, but also economic one. The surplus of P and K in farm with soil rich in available forms of these nutrients means that farmers are losing a genuine quantity of money for buying P or K fertilisers. In the case of P the price of 1 kg P in fertilisers is about 1.5 USD in Poland. Thus some demonstration farmers are missing up to 90 USD per hectare each year.

Calcium balance in field scale on unlimed and limed grassland on the background of nitrogen rate

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The nutrients balance in different scale is efficient method for the mitigation of nutrient dispersion in to environment. Calcium (Ca) is one of the nutrients indispensable to plants growth as well as responsible for pH status and fertility of soil.

The Ca balance in field scale on the background of different grassland soil pH (as a post-effect of liming) and two nitrogen fertilization levels was presented. The goal of investigations, conducted on 3 long-term grassland experiments in Mazowieckie voivodship started in 1981/82, was to estimate a deficiency or surplus of Ca in unlimed and limed (at the start of experiments) soil, fertilized with 120 and 240 N ha^{-1}. It is important to recognise the Ca behaviour in the soil-plant system, because the Ca deficiency causes soil acidification but it surplus is a source of excessive Ca leaching to ground and surface waters.

Three fazes of Ca balance have been given out in the period 1981-1995 (I faze, 1981/82-1985, II faze, 1986-1990, III faze, 199101995). The Ca efficiency was about 60-80% in the case of unlimed soils, where the Ca source is only deposition and fertilizers used (superphosphate), but it was about 30% in limed soils. In unlimed soils the Ca surplus was about 10-140 kg $.ha^{-1}.year^{-1}$, in relation to soil properties, N dose and balance faze. In limed soils a great Ca surplus has arisen (from about 60 up to about 1100 kg $.ha^{-1}.year^{--1}$) depend on a lime dose and balance faze. In spite of successive pH decreasing the Ca presence in these soils counteract the soil acidification process. Taking in to consideration the time of new equilibrium state that establish on grassland after liming as well as the cost of this operation, the higher lime dose used once for longer time (about 6 years) is more reasonable in comparison to frequently grassland liming with small lime dose.

Experiences from using farm gate balances as an extension tool in dairy production in the south of Sweden

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Introduction

Mineral balances are one tool of many which try to reshape the conventional dairy farming in Europe. The mineral balances as a concept were introduced decades ago in research to analyse the nutrient flows in arable land, in fields or at farm level, regional level or national level (Parris, 1998; Sveinsson et al., 1998). Since 1997 mineral balances of dairy herds, using the farm gate model, have been calculated in the south of Sweden ((Slak et al., 1998; van Eerdt & Fong, 1998). The dairy plant, Dairy Skane, wants the dairy farmers to be aware of the dairy herds environmental impact and uses the mineral balances as a tool to show the dairy farmers environmental effects (Sandgren et al. 1999; Swensson, 2000)

Objectives

The main objective of this paper is to describe and analyse mineral balances from dairy herds. The special objectives of this paper are to analyse the results from three consecutive years, 1997, 1998 and 1999.

Preliminary results

A comparison has been made between 1997 and 1998 and these results indicate a change in strategy of fertilization between the years (Fig. 1).

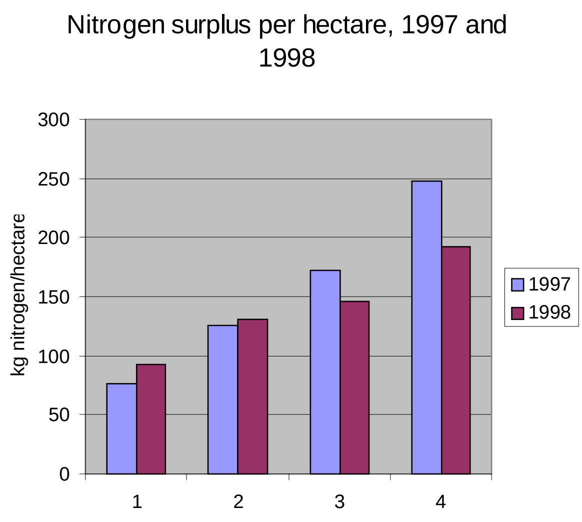

Figure 2. Classes according to nitrogen surplus per hectare 1997

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Nutrient Balance and Management in the Kabala Räpu river Demonstration Watershed

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In Estonia is the 4,5 milj. ha land, about 1,4 milj. ha agricultural land. In the central part of Estonia situated the Kabala, Räpu river watershed. Whole watershed largeness is 1500 ha what a 0,1% of whole Estonian agricultural land.

Major part of arable land (1142 ha) belongs the Kabala agricultural company. The company is specialised in large-scale cattle husbandry. Only 430 ha of all arable land of the watershed belongs today to private farmers. At present, ther are 34 private farms and about 40 households in the demonstration watershed.

Soil at the demonstration watershed are very fertile and among the best Estonian soil. The average humus content of arable land is 3,9%. The baseroc is limestone, therefore only 30% of soils need slight liming.

The content of plant nutrients in the Räpu river watershed soils is predominantly characterized by medium to high phosphorus content and by low to medium potassium content, medium to high magnesium and manganese content and by the low to high level of microelements (Cu, B and Co).

The main part of the arable land in the watershed area is under the grassland and field grass. The area of grassland and field grass has increased in recent years and is sufficiently large, making up 66,9% of arable land. The area of winter cereals has degreased in recent years from 8,5% to 2,3%, but the total area of green grops (grassland + winter cereals) is also sufficiently large at the present time (69,2% of arable land). This is very impotant in the aspect of environmental protection: the danger of leaching N and P has decreased. At the same time, the area of spring cereals, potato and crops has slightly decreased.

The data collected during the last six years by interviewing all farmers living in the catchment area showed that in the demonstration watershed in Kabala, nutrient balance in private farms is negative after a dramatic reduction of fertilizer input during the last six years. However, thanks to the application of mineral nitrogen fertilizer and an extremely low yield of field crops at the Kabala agricultural company, nitrogen balance on the farm level is still positive.

In most farms, natural economy and very low production level are dominating. The main part on the whole watershed area is under grassland and field grass. The area of field grass and winter cereals has decreased in recent years. The area of green crops decreased recent years from 74,7% to 69,2%, but the area of green crops is sufficiently large at the present time. From the viewpoint of agricultural production, the species composition of grassland is aged, their productivity is low, and most of them need to be recultivated.

In private farms manure was used mainly for potato and root crops as well as for vegetables small gardens. At the Kabala agricultural company manure was applied mainly for winter cereals and grasslands. Manure was applied mainly in autumn, while it was always ploughed in as early as possible. Today all farms have enough arable land where spreading of manure is necessary, and there is no environmental risk, because the number of livestoc is not yet very large.

Application of mineral fertilizers in the demonstration watershed area has been very low in recent years. Extremely low was the use of nitrogen fertilizer in private farms, 62% did not use nitrogen fertilizers, and only five farms used combined (NPK) fertilizers.

Environmental impact of Zn and Cu as feed additives to pigs – using the field balance approach to assess the long-term soil accumulation

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The risks of high Zn and Cu concentrations in pig manure have been reported and discussed in several European countries, for example, Sweden (Steineck et al, 1999), Denmark (Poulsen, 1998) and the Netherlands (Jongbloed et al, 1998). The metal (Zn and Cu) load from pig production to arable soils is depending on metal concentration in the feeding stuffs, animal density (permitted animals per hectare) and the area on which the manure is spread. Soil budget calculations on different Zn and Cu levels in feeding stuffs were performed within the EEC-working group on 'Revision of the maximum authorized levels of trace elements as additives in feedingstuffs' (Working group, 1999) in order to predict the soil accumulation and the potential risks on long term sustainability of the soil fertility. The Cu and Zn intake per animal were calculated for the present (dir 70/540) and proposed maximum authorized levels in feeding stuffs and the potential soil input per hectare was calculated based on Swedish animal density regulations (Table 1). Input-output field balances and soil accumulation rates were calculated using data on deposition, crop removal and leaching from Andersson (1992). Years to reach the maximum allowable concentrations (MAC) for sludge application to arable soils, 40 mg Cu and 100/150 mg Zn kg soil^{-1}, were calculated for arable soils in Southern (S Sw) and Eastern Sweden (E Sw) having median metal concentrations on 9 and 28 mg Cu Zn kg soil^{-1}, and 49 and 97 mg Zn kg soil^{-1} (Eriksson et al, 1997) Applying the present EEC feed allowances gave a soil accumulation rate of Cu (sows and piglets) on 320 g ha^{-1} yr^{-1} reaching the MAC within 280 (S Sw) and 90 (E Sw) years, while with the proposed level the MAC would be reached within 1500 and 490 years, respectively (assuming the same crop removal and leaching). The present maximum feed level for Zn gives the highest accumulation rate (1 150 g ha^{-1} yr^{-1}) for fattening pigs reaching MAC within 250 (S Sw) or 310 (E Sw) years. The proposed Zn feed level would decrease the accumulation rate and MAC would be reached within 500 years. The calculations will be related to monitored pig manure/slurry concentrations and the animal densities in the intensive pig areas to get an estimate of the potential environmental hazard. The Zn and Cu contribution from manure application will also be discussed in relation to the Swedish and EEC sewage sludge application regulations.

Table 1. Intake of Cu and Zn (g per animal and year) calculated for the present (dir. 70/524) and proposed EEC (Working group, 1999) maximum levels in feeding stuff, and annual input to the soil applying the Swedish animal density regulations[1]. For Cu and Zn, 99 and 85%, respectively, of the content in feeding stuffs was assumed to be excreted

Scenario	Feeding stuff, kg^{-1} yr^{-1}	Feed mg Cu kg^{-1}	Intake per animal g Cu	**Cu** Input to soil g ha^{-1}	Feed mg Zn kg^{-1} yr^{-}	Intake per animal g Zn	**Zn** Input to soil g ha^{-1}
Sow + 20 piglets (up to 25 kg)							
Present Swedish limit	2 040	35	71	156	250	510	954
Present EEC allowances	1400/640	35/175[2]	161	351	250	510	954
Proposed level	2 040	20	41	89	120	245	458
Fattening pigs (25-100 kg)							
Present Swedish limit	235	35	8	214	250	59	1 311
Present EEC allowances	78/157	175[2]/35	19	498	250	59	1 311
Proposed level	235	20	4	122	120	28	629

1. 2.2 sows per ha (incl 20 piglets) and 10.5 stalls (‘places’) for fattening pigs per ha (Jordbruksverket, 1996). For fattening pigs 2.5 batches per year was assumed giving 26.3 pigs ha^{-1} yr^{1-}.
2. 175 ppm for piglets up to 17 weeks

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Farm gate and farm balances of P, K and Zn in organic and conventional dairy farming at the Öjebyn Farm in Northern Sweden

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Nutrient and trace element fluxes and balances (Ca, Cd, Cr, Cu, K, Mg, Mn, total-N, Ni, P, Pb, S and Zn) will be quantified in organic (org.) and conventional (conv.) dairy farming at the Öjebyn Farm in Northern Sweden (Food21, 2000). In a first approach, we have evaluated three chemically different mineral elements, K, P and Zn, on barn (Gustafson et al, 2001) and field (Bengtsson et al, 1999; 2001) level and *farm gate* and *farm* balances have been established for a 12-month period. In the *farm gate* balance, fluxes in and out of the farm gate were included, i.e. purchased (feedstuffs, bedding material, heifers etc) and sold (milk, potatoes, calves, cows etc) products, which made it fairly easy to obtain good quantitative data. In the *farm gate* balance the farming system is handled as a closed system, which is not true. Therefore *farm* balances were established including 'diffuse fluxes' such as nutrient losses through leaching and inputs through atmospheric deposition and weathering (K). Although some measurements were performed within the actual systems, regional data and qualified estimates had to be used in order to establish these farm balances.

In the *farm gate* balances purchased feedstuffs accounted for the main inputs of Zn, K and P. For Zn, feedstuff accounted for 94 and 96% in the organic and conventional farming system. For K the figures were 98 (org.) and 83% (conv.), and for P 82 (org.) and 86% (conv.). Purchased heifers constituted 17 (org.) and 12% (conv.) of the P input. In the conventional system K and P fertilisers were purchased but they accounted for not more than 16 and 2% of the input. P fertiliser was only applied to the potato field. The main element export from both farming systems was through sold milk, 76 (org.) and 82% (conv.) of the Zn, 71 (org.) and 75% (conv.) of the P and 55 (org.) and 68% (conv.) of the K. For the K export sold potatoes were also of importance and accounted for 40 (org.) and 30% (conv.), respectively. For all elements, except P in the organic system, the inputs exceeded the outputs. This tendency was most pronounced for Zn, of which only 23 (org.) or 16% (conv.) of the purchased amount left the farm by the sold products. The excess K was less in the organic system than in the conventional one, and for P there was a surplus in the conventional system but a small deficit in the organic one. In the organic system, 90 and 109% of the purchased K and P, respectively, were sold as animal and crop products. Corresponding figures for the conventional dairy farming was 42% for K and 76% for P.

In the *farm* balances atmospheric deposition was an important input for Zn, but not for K and P. Surface run-off and leaching were the main outputs of Zn, but they also influenced the K balance. The figures on surface run-off and leaching are, so far, based on only a few measurements of soil water chemistry and have to be seen as first estimates. At this stage only dissolved fractions of elements, i.e. PO_4-P, were accounted (0.2 kg PO_4-P $ha^{-1}yr^{-1}$), but during spring a loss of particulate-P can be expected as well. Compared to the *farm gate* balances the outputs have increased more than the inputs. In the organic system the P and K balances are negative indicating a depletion of K and P on the farm, i.e. in the soils.

Within the Food21-project we will estimate the contribution from mineral weathering by a simulation model. At this stage the potential release of K has been estimated to 15 ± 5 kg K ha^{-1} and year by using the PROFILE model (Sverdrup & Warfvinge, 1988; 1993). When the potential weathering release of K is included in the balances also the organic system ends up with a positive balance. This shows that a reliable estimate of the element release by weathering is of major importance for obtaining a correct farm balance and for the overall judgement of the sustainability of the two farming systems.

Data collections for the fluxes and balances on farm, field and barn level have been going on since the summer 1997. The evaluation of these data will form a good basis for recommending an optimal sampling/monitoring strategy for farm specific input data to field, barn and farm balances.

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