International Workshop From yield-based to society-based fertilizer recommendations

Program, minutes, abstracts and presentations
16-18 April | Lelystad, the Netherlands

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International Workshop
From yield-based to society-based fertilizer recommendations

Program, minutes, abstracts and presentations

16-18 April, Lelystad, the Netherlands

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Wageningen University & Research

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This report contains the program, minutes, abstracts and presentations from the International Workshop From yield-based to society-based fertilizer recommendations which was held from 16-18 April 2024 in Lelystad, the Netherlands.

Keywords: fertilization recommendation, nutrient management, arable farming, nitrogen, phosphorus, organic matter

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1 Introduction

This report contains the program, minutes, abstracts and all presentations from the International Workshop "From yield-based to society-based fertilizer recommendations" which was held from 16-18 April 2024 in Lelystad, the Netherlands.

Background of the workshop
Fertilization is not only affecting crop yield and financial return but also many other societal aspects as water quality, greenhouse gas emissions and biodiversity. However, current fertilizer recommendations are generally focused on maximizing (financial) yield for the farmer only. Besides, many recommendations were developed a few decades back. Recent knowledge and needs, for instance on site specific fertilization, is included to a limited extent in the recommendations. Finally, fertilizer recommendations have been developed nationally or even regionally with different methodologies resulting in different recommendations in similar situations.

New Dutch research program on fertilization recommendations
We have started a research program in the Netherlands to develop new methodologies for fertilization recommendations because of the need to incorporate the latest knowledge in the recommendations and to adapt the recommendations to future cropping systems and societal needs. We have organized this international workshop to be able to explore the knowledge from surrounding countries and to explore possible cooperations in fertilizer recommendation development.

International applied sciences workshop
The workshop was held from 16 to 18 April 2024 in Lelystad, The Netherlands with about 45 participants. This applied sciences workshop was aimed at developing concrete solutions to improve fertilizer recommendations. The workshop was focused on the following themes:

1. Current state of fertilizer recommendations in Europe and need for new recommendations
2. Options to improve fertilizer recommendations:
    a. Integrating organic matter, nitrogen and phosphorus recommendations
    b. Integrating fertilizer choice in the recommendations
    c. Guided fertilization systems
    d. Fertilizer recommendations for Ca, S, Mg and micronutrients
3. Integrating fertilizer recommendations to a fertilizer plan on field and farm level

Next to oral and poster sessions there were discussion sessions on the themes. Besides, an excursion to the Farm of the Future in Lelystad was organized.
The workshop was mainly aimed at (applied) researchers in the field of fertilizer recommendation development in Northwest Europe. However, the workshop was open for researchers from other parts of the world and for staff from companies and organizations involved in fertilizer recommendations.

2 Program of the workshop

2.1 Afternoon Tuesday 16 April, Van der Valk Hotel Lelystad

12:00-13:30 Registration and Lunch

13:30-13:45 Opening of workshop: Janjo de Haan, WUR: Background, aims & expected results of the workshop

13:45-18:00 Session 1. Setting the Scene: Current state of fertilizer recommendations in Europe and need for new recommendations
Chair: Wim van Dijk, WUR

13:45 Keynotes and presentations: 15 min per presentation +5 min discussion

1. Janjo de Haan, WUR: Fertilizer recommendations renewal in the Netherlands (why PPS BAAT)
2. Suzanne Higgins, AFBI: EJP SOIL Stocktake on harmonizing methodologies for fertilization guidelines across regions
3. Stefaan De Neve, Ghent University: Evaluating the performance of current N and P fertilizer advice systems in Belgium
4. Poster pitches, 2 minutes
    a. Milan Franssen, Delphy: Nutri-Check Net, current and new fertilizer recommendation systems in Europe
    b. Renske Hijbeek, WUR: Nitrogen fertilizer replacement values of organic amendments: determination and prediction

15:00 Break
15:30 Introduction of the case study during the workshop
16:00 Discussion in groups on main challenges, objectives and possible solutions for new fertilizer recommendation systems
17:00 Plenary recap and closing of session

18:00-20:00 Diner buffet

2.2 Morning Wednesday 17 April, WUR Field Crops

9:00-12:00 Session 2. Integrating organic matter, nitrogen and phosphorus recommendations and Guided fertilization systems
Chair: Janjo de Haan, WUR

9:00 Keynotes and presentations: 15 min per presentation +5 min discussion

1. Christine Watson, SRUC: Growing our future: routes to sustainable soil and nutrient management
2. Bart Timmermans, LBI: Integrated carbon, nitrogen and phosphorus management: lessons learned from Dutch long-term experiments.
3. Karoline D'Haene, ILVO: The calculation of the nitrogen mineralisation amount in fertilisation advices
4. Cathy Thomas, Rothamsted: Nitrogen recovery and losses with different types and rates of organic fertiliser in a long-term wheat rotation field trial
5. Poster pitches, 2 minutes
    a. Bart G.H. Timmermans, Louis Bolk Institute: NDICEA - calculating carbon and nitrogen dynamics in agricultural fields

b. Geert-Jan van der Burgt, Louis Bolk Institute: Integrating time related processes in nitrogen fertilization recommendation
c. Annemie Elsen, Bodemkundige Dienst Belgie: N-INDEX expert system: A powerful tool in nitrogen recommendation
d. Koen Willekens, ILVO: Crops nutrient supply from different sources in soil
e. Goovaerts Ellen, Proefstation voor de Groenteteelt: Nitrogen advice in Flanders
f. Evelin Loit-Harro, Estonian University of Life Sciences: Comparison of Organic and Conventional Crop Management in Estonia since 2008
g. Dr. Susanne Klages ,agri.kultur: Update of Critical Values for plant analysis under present conditions in Saxony-Anhalt
h. Stefan Geyer, Francisco Josephinum Wieselburg: TerraZo - free application map creation and deployment based on field trials
i. Lex Slootweg, ICL: Controlled Release Fertilizers, a way to improve farmers nutrient use efficiency

10:45 Poster session on topics of session including coffee break
11:15 Discussion in groups on topics of session using the case study
12:15 Plenary recap and closing of session

12:30-13:30 Lunch

2.3 Afternoon Wednesday 17 April, WUR Field Crops

13:30-15:00 Excursion Farm of the Future

15:00-17:30 Session 3. Fertilizer recommendations for Ca, S, Mg and micronutrients and Fertilizer choice recommendations
Chair: Romke Postma, NMI

15:00 Keynotes and presentations: 15 min per presentation +5 min discussion
1. Sven Verweij, NMI: Fertilizer selection tool
2. Arjen Reijneveld, Eurofins: Advances in fertilization recommendations: A three-step approach incorporating new insights
3. Poster pitches, 2 minutes
   a. Hans-Werner Olfs, Osnabrück University of Applied Sciences: Measurements of plant-available P, K and Mg contents and pH of soils with the soil sensor system Stenon “FarmLab” as a basis for fertilizer recommendations for arable crops
   b. Karolina Barcauskaite, Lithuanian Research Centre for Agriculture and Forestry: Do composts meet organic fertilizers quality requirements: Lithuanian case study?
   c. Wieke Vervuurt, WUR: Long-term effects of phosphate fertilization
   d. Wieke Vervuurt, WUR: Evaluation framework to predict the fate of organic materials
   e. Hendrik Holwerda, WUR: Potential for reducing P fertilization without affecting crop yield

16:00 Poster session on topics of session and session 1 including coffee break
16:30 Discussion in groups on topics of session using the case study
17:30 Plenary recap and closing of session

18:00-20:00 Drinks and dinner

2.4 Morning Thursday 18 April, Van der Valk Hotel Lelystad

8:30-12:00 Session 4. Integrating fertilizer recommendations to a fertilizer plan on field and farm level
Chair: Janjo de Haan, WUR

- 8:30 Keynotes and presentations 15 min per presentation +5 min discussion
  1. Frank Liebisch, Agroscope: The Swiss fertilizer recommendation - historic development, current status and integration in legislation and ways forward to sustainable nutrient management (on the example of arable crops)
  2. Janjo de Haan, WUR: Integration of fertilizer recommendations to farm level
- 9:15 Panel discussion led by André Hoogendijk, panel: Gert Jan van Dongen (farmer), Harm Brinks (Delphy), Arjan Reijneveld (Eurofins) en Geert-Jan van Roessel (LambWeston)
- 10:15 Break
- 10:30 Discussion session on integrating fertilizer recommendations at farm level
- 11:30 Plenary recap of discussion session

11:50-12:30 Closing of the workshop

- 11:50 Pitches WP-leaders PPS BAAT what they take with them from the workshop
- 12:10 Formulation of needed actions and possible follow ups

12:30 Lunch and farewell

3 Minutes of the workshop

3.1 Opening of the workshop

Afternoon Tuesday 16 April, Van der Valk Lelystad

Janjo de Haan opens the meeting and welcomes the 40 participants. Marjoleine Hanegraaf, co-organizer is still ill and therefore some items in the program are changed. Janjo gives a short background on the objective and program of the workshop.

3.2 Session 1. Setting the Scene: Current state of fertilizer recommendations in Europe and need for new recommendations

Afternoon Tuesday 16 April, Van der Valk Lelystad
Chair: Wim van Dijk, WUR

Keynotes, presentations and poster pitches
Session 1 contained three presentations and two poster pitches. Suzanne Higgins presented online due to travel problems. Sheets of the presentations and poster pitches are in the appendix.
A question about the presentation of Janjo de Haan was how to convince farmers to use the new recommendations? The new recommendations must have an added value for the farmers, they must have the tools to apply them and they need to have trust in the new recommendations without fear of losing yield. We have to provide that. A second question was about the relation of the new recommendations to legislation. We have no objective to change legislation or to have recommendations for new legislation. We just want to show with new recommendations how to comply to societal goals. However it can be an outcome later that the recommendations are also used in legislation. Legislation is changing, see for instance the current evaluation of the Nitrated Directive.
Another question was to what extent harmonization of methodologies for fertilization guidelines across regions in Europe is really needed. Indeed, some are difficult to harmonize due too different climatical conditions, soil types and farming systems in Europe.
A question about the presentation of Stefaan de Neeve was if the labs were informed about the large differences in recommendations. Yes, the labs are informed and they are discussing this together. One of the participants is of one of the labs and she indicated that the recommendations were changed because of this study.

Introduction of the case study
David de Wit introduces the case study (Gert-Jan van Dongen, arable farmer on heavy clay soil in Flevoland) we will use during the workshop to illustrate first results and which we have used in the PPS BAAT for a first integration study of the fertilizer recommendation system. He shows also nutrient balances of nitrogen, phosphate and potassium of the farm. Nitrogen fixation is not included in the balance presented and expected to be of limited size for this farm. The potassium surplus is high, mainly because of the high potassium levels in the digestate.

Discussion session
Three questions were discussed during the discussion session

1. *How do you rate the fertilizer recommendations in your country in terms of 1) Up to date to actual knowledge and technology; 2) taking in to account societal requirements and 3) practical applicability by farmers?*

Current recommendations are mainly economic and yield based and different systems are used in every country. The quality of the systems is judged differently by the researchers. Some researchers indicate that knowledge is up to date but technology needs improvement. Other researchers have the impression that fundamental knowledge is missing for a good recommendation. And there are also researchers who state that the use/implementation of recommendations can be improved. Situation varies a lot between countries in e.g. percentage of organic farms, who is responsible for the recommendations, the investment in development and innovation of fertilizer recommendations, how the information supply to the farmers is organised and how much attention is paid to environmental issues. Social requirement are not really taken into account, except for the legislation and measures for which subsidies are received.

2. *What are the most urgently needed improvements in fertilizer recommendations?*

Old fertilizer recommendations are often at the safe side to prevent the risks of yield reduction. This leads to larger environmental risks. Also education of farmers to improve their knowledge about fertilization is needed. It is needed to give farmers more insight in nitrogen flows and effects of reduced fertilization and other factors involving nutrient efficiency and nutrient losses. Besides a good prediction of the nitrogen mineralization of the soil is needed. Finally, a good tool is needed to evaluate the fertilization.

3. *Is harmonization of fertilizer recommendations within Europe necessary? Why?*

The question is what is the value of harmonization? The participants are unanimous about the need to harmonize methodologies and the basic principles to make fertilization advices. Uniform criteria for how a good advice does look like, where it comes from and guarantees of independence are desired. About harmonization of recommendations itself there is debate. There are now many differences which make harmonization difficult, e.g. different extraction systems for nutrients in soil and recommendations should be integrated into other cultivation aspects of the crop. More cooperation is however needed if we want to modernize recommendations, especially for crops with small acreage. It is too expensive and also inefficient if in every country new recommendations are developed. Besides there is a need for tools to help farmers make the right decisions.

General conclusions of session

- Large differences in fertilizer recommendations within Europe, as well in methodology as in organization
- Focus of current systems is mainly on optimal economic yield, limited incorporation of societal aspects
- The application of fertilizer recommendations by farmers can be improved, better independent recommendation needed
- Improvements of fertilizer recommendations are needed, especially on estimation of soil nitrogen mineralisation
- Societal aspects mainly forced by legislation and subsidies
- More cooperation on modernizing recommendations needed, but the need for harmonization is discussed

3.3 Session 2. Integrating organic matter, nitrogen and phosphorus recommendations and guided fertilization systems

Morning Wednesday 17 April, WUR Field Crops
Chair Janjo de Haan

Keynotes, presentations and poster pitches

Session 2 contained four presentations and nine poster pitches. Sheets of the presentations and poster pitches are in the appendix.

Discussion Integrating organic matter, nitrogen and phosphorus recommendations

In Belgium and the UK an index-system is used which is more or less based on a balance. In the Netherlands, the Nmin-system is used currently in which the recommended N rate is based on the measured soil mineral N in spring. This system leaves less room for taking into account specific crop and soil characteristics (e.g. crop yield level and soil N delivery).
In order to modernize/improve current systems a system approach is necessary, a balance system fits in that and is already used in different countries. It will also increase the transparency compared to e.g. Nmin-systems. However, the balance system needs estimations for different inputs and outputs, a couple of them were discussed:

- The soil N mineralisation could be based on model calculations taking into account soil characteristics (e.g. OM content, C/N-ration OM), fertilisation history, crop rotation and length of the growing season of the crop. In NL the Eurofins lab also provides such a calculation to clients bur the calculation method is not public. The calculation could be fine-tuned during the growing season taking into account actual weather data or by soil and crop measurement of the N status of the crop-soil system (guided systems, see also below).
- For the crop N demand the N recovery of available N is an important parameter. However, this parameter when derived from experiments is also affected by the soil N mineralisation level. Therefore, in Belgium the crop N demand is estimated by the sum of total crop N uptake and the residual soil mineral N after harvest. The latter is an indicator for unrecovered N.

It is important that farmers get confidence in the system. Therefore a testing on farms is necessary and helpful.

For organic matter (OM) currently in Belgium and the Netherlands, the system of the effective OM supply via crop residues and organic manure is used and as threshold level a minimum amount of EOM-supply is used (fixed level or by assuming an annual 2% mineralisation of soil OM). This system may be improved by using models (e.g. NDICEA) to calculate the annual C mineralisation based on soil characteristics, crop rotation and fertilisation history. This could be coupled to the calculation of the soil N mineralisation which is necessary for the N balance system. For the C as well as the N mineralisation the same calculation can be used.

Discussion guided fertilization systems
There are several systems available for estimating the N-rate. The systems are all known in the different countries, but not all countries use them. Most used are the nitrogen guidelines based on soil mineral N (N-min guideline) and the N-balance method. Decision support systems that can be used for adjusting the N-rate during the growing season are the KNS-method, petiole sap or leaf analyses, chlorophyll measurements, systems based on remote sensing or nearby sensing, crop growth models and a combination of sensing and crop growth models. The different types of systems which are already available have each their own pro’s and con’s.
In Belgium and Germany especially vegetable growers use the KNS-method, forced by law. In the Netherlands this system is available but it is rarely used. The system is developed in Germany and is for a number of crops adapted to the Belgium or Dutch growing conditions. The system calculates the required N fertilisation (top up N-rate) at different stages during crop growing season based on measurement of soil mineral N and expected crop N uptake. An improvement of the method would be to adjust the recommended supplemental N application rate to the expected N mineralisation.
In Germany decision support systems based on nearby sensing or measuring the chlorophyll content of the leaves are commonly used in cereals. By comparing the measured values to target values, the top up N-rate is determined. The systems are developed by Yara and provided to the farmers for free. The farmers only have to share their farm data, amongst others yield, with Yara. With this information Yara can improve the system. The target values differ per variety and are established by Yara through research.
For all systems it is important to take the expected yield into account, that can be based for example on the average yield of five years on the same field.
The decision support systems and N balance method are difficult for farmers to understand and they need support for this. Farmers need to get confident that lower fertilization levels at start don’t give yield risks when monitored well. Legislation can stimulate uptake/use by farmers.
A point of discussion was whether farmers should legally be obliged to use decision support systems or should be convinced and be supported to use it. Use a system perspective by designing new fertilizer recommendations.

General conclusions from the session
Integrating organic matter, nitrogen and phosphorus recommendations

- Different current systems in countries to look at organic matter nitrogen and phosphorus
- In the discussion groups two main paths to assess the needed N rate were discussed: 1) assessing the needed N rate in advance and 2) assessing the N rate by guided systems during the growing season. Both pathways can also be combined. For both systems a balance method seems to be the best option taking into account specific crop and soil characteristics.
- The organic matter recommendation can also be based on a balance and calculation that were done for soil N mineralisation could also be used for annual OM mineralisation.
- Confidence by farmers is an important aspect, therefore testing in practice is necessary.

Guided fertilization systems

- Interest in guided fertilization systems by farmers but these systems are not frequently used
- For using guided fertilization systems, farmers need support and constant improvement or adaptation to e.g. new varieties of the systems is needed
- Different types of systems already available with each their own pro's and con's
- Legislation can stimulate uptake/use by farmers of guided fertilization systems

3.4 Session 3. Fertilizer recommendations for K, Ca, S, Mg and micronutrients and Fertilizer choice recommendations

Afternoon Wednesday 17 April
Chair: Romke Postma, NMI

Excursion to the Farm of the Future
We made an excursion to the field lab of the Farm of the Future in Lelystad with explanation by David de Wit. More information see https://farmofthefuture.nl/en/.

Keynotes, presentations and poster pitches
Session 3 contained two presentations and 5 poster pitches. Sheets of the presentations and poster pitches are in the appendix.

Discussion on potassium recommendations
In the Netherlands the K-fertilization recommendation is split up into a recommendation for the soil and a recommendation for the crop. The soil recommendation comprises target values for the available soil stock, the calculation of a K-rate to repair a too low soil stock and the calculation of the necessary K-rate on rotation level to maintain the desired soil stock. The latter is based on a balance method (K-supply by fertilization and K-disposal by the harvested products and K-losses). The crop recommendation depends on the available soil stock and the effect of K on crop yield and quality aspects. Both recommendations must be complied with.

In other countries the K-recommendation is less complex than in the Netherlands. They do not have a soil recommendation like in the Netherlands, but only a crop recommendation or the crop and soil recommendation are integrated. The type of soil test that is used to determine the available K soil stock differs per country and in some countries there are even more soil tests used, dependent on the laboratory. In all countries the K-recommendation is based on the crop type and the K soil level. With respect to the crop, the K-uptake is taken into account and/or the disposal of the field. Quality aspects are not really taken into account. It was also noted that the need for very accurate systems is not that high as for N as the response of K and other nutrients as Mg, Ca and micronutrients is quite weak.

It was also discussed whether fertilisation with Ca en micronutrients is really necessary. Often manure is used that also contains nutrients. It's better to wait if lack symptoms become visible and to act (by e.g. foliar applications). Is interaction of nutrients important (see Albrecht method), in NL research on that topic did not show that is was very relevant.

The Dutch system is regarded as complex and too difficult for farmers. The formula for calculating a K-rate to repair a too low soil stock, is regarded as mock-accuracy. Integration of the soil and crop recommendation is recommended.

Discussion on fertilizer choice recommendations

There are no fertilizer selection systems in use in European countries as far as known by participants, while fertilizer choice may strongly affect nutrient availability and dynamics, nitrate leaching, ammonia volatilization and/or greenhouse gas emissions. Fertilizer choice in Belgium and the Netherlands is often financially driven in the current situation, not on agronomic or sustainability needs. Because of the negative price, pig and/or cattle slurry is often applied at the maximum rate that is allowed within legal limits. Fertilizer choice is one of the aspects in fertilization, that is of importance in addition to the amount of nutrients applied. Because of the effects on agronomic and environmental performance, it would be useful to include them in fertilizer recommendations. In addition, other aspects like placement (e.g. via row application) and timing (e.g. split N application) may be incorporated. The tool for fertilizer choice is context dependent, based on soil type, crops and cropping systems. E.g. mixed farms will use own manure first.
A proper evaluation of all aspects affected by the fertilizer choice will be difficult, but could be done via pricing of all effects. For some aspects this is difficult, e.g. for nutrient losses and/or the overall value of organic matter. Weighing of various agronomic and environmental aspects is possible if a common unit (e.g. euros) is used, but remains difficult as this involves policy decisions.
Farmers have no overview on available fertilizers and their pro's and con's, while the amount of different fertilizer types is growing. For that reason, giving insight in agronomic, financial and environmental aspects via a tool for fertilizer choice, can be helpful. However, the system is quite complex and farmers want a very simple advice, so many of the choices have to be made for them: e.g. crop requirements and what environmental objectives they need to fulfil. Another reason for drawing up recommendations for fertilizer choice could be to comply with ecoschemes (CAP) or CO_2-footprints for retailers.

General conclusions from the session

- The Dutch potassium recommendations are for a large part comparable to other countries but rated as too complex with separate soil and crop recommendations.
- A fertilizer selection tool could be a valuable addition to fertilizer recommendations and it may be of use for farmers, but it should be very simple to use. It should include effects on nutrient availability and dynamics, nitrate leaching, ammonia volatilization and/or greenhouse gas emissions, so that it can be used to quantify effects on GHG-emissions and/or for implementation in ecoschemes.

3.5 Session 4. Integrating fertilizer recommendations to a fertilizer plan on field and farm level

Morning Thursday 18 April, Van der Valk Hotel
Chair Wim van Dijk

Presentations

Session 4 started with two presentations. Sheets of the presentations and poster pitches are in the appendix.

Panel discussion

A panel discussion was held, led by André Hoogendijk, director of BO Akkerbouw, the branch organization for Dutch arable farming and with the following members representing important stakeholders in Dutch arable farming: Gert-Jan van Dongen, farmer; Harm Brinks, consultancy organization Delphy; Arjan Reijneveld, soil testing lab Eurofins and Geert-Jan van Roessel, LambWeston, processor of potato products.
First question was whether the panel members gained new insights during the workshop? Arjan indicated that everyone is struggling with the same issues. Main challenge is to let farmers use the fertilizer recommendations and that they also take societal goals into account. Gert-Jan said that there is a large difference between growers. The challenge is to show growers that attention to soil health and following recommendations pays off. Harm Brinks pointed that advising on fertilization is challenging as the legal norms are lower than the advice. How to help farmers to reduce losses and keep a good crop yield. However

nitrogen fertilization is not the most important thing and does not have to be used as correction if all other factors of the cropping system are well managed, but this is different for every farmer, soil and rotation. Gert-Jan points at the importance of organic matter management. He has been very much focused on increasing organic matter content and have been able to get it about 2% higher compared to his neighbours. Besides it is important to look to the whole rotation and not to individual crops only. Estimating nitrogen mineralization is difficult. We need to give the tools to farmers to help them optimize their fertilization, however the trust in models and calculations is low. We have to show that they are of help.

Discussion session

4 questions were discussed in the last discussion session:

1. *Is integration of fertilizer recommendations to farm level really needed?*

Nitrogen fertilization recommendations must be determined on field level scale, taking into account the N supply by mineralization of the soil and residues of previous crops and green manures. Other nutrients, such as P and K can be determined on filed level scale (dependent on the soil level and the crop) but also on rotation or farm level scale, to maintain soil fertility. Due to legal restrictions allowed N-rates may be lower than the recommended rates. This can only be assessed on a farm level. For those situations the allowable amount of nitrogen must be divided between crops and fields must be optimized in order to prevent yield reductions as far as possible. Also, other assessments of societal goals have to be made on farm level.

2. *How can farmers goals and societal goals best be combined in the fertilizer recommendations?*

A higher yield merges a higher disposal of the field, a lower soil surplus and lower losses to the environment. Therefore farmers must pay (more) attention to other cultivation factors that affect yield and take care for or improve amongst others soil quality. Education is important. N-fertilization recommendations must be more accurate, taking account the potential yield of the field and the N-mineralization. N-fertilization recommendations have to be integrated in the total crop management. A clever crop rotation including nitrogen catch crops can reduce the nitrogen losses. Farmers must be made more aware of the consequences of environmental pollution due to fertilization.

3. *How to deal with the scale issue: translate national and regional goals to goals at farm level?*

It depends on the land use and soil type per region. The composition of type of agricultural companies in a region can differ, for example whether there are mainly dairy farmers or arable farmers or vegetable farmers. How to achieve the goals differs per region and must be translated to the farms in that region. The goals on farm level scale must be checked and monitored, amongst others by measuring the mineral N-content in the soil before winter.

4. *How do we keep fertilizer recommendations transparent and practical applicable for farmers?*

The balance method approach for fertilization recommendations is transparent and gives a clear insight in how the recommended rate is built up. When the necessary background information is accompanied, it must be well understandable for farmers. It can also give famers a better idea of how much nitrogen the soil supplies, of which they are often not aware.

An adviser or advisory services should not only give the farmer the recommended fertilization rates but also supply the balance and back ground information. Open source tools for fertilization planning are important to understand but also to be not dependent on a single organization.

General conclusions of the session

- Fertilizer recommendations at farm level are necessary for legislation and societal goals.
- Setting goals at farm level will be difficult.
- Educate farmers and advisors better on the backgrounds of fertilizer recommendations.

3.6 Closing of the workshop

Morning Thursday 18 April, Van der Valk Hotel

- Pitches WP-leaders PPS BAAT what they take with them from the workshop
- WP1 Integrating organic matter, nitrogen and phosphorus recommendations, Wim van Dijk: recommendations about N. In the Netherlands, we want to move towards a balance system. For this system we need good estimations for inputs and outputs from which soil N mineralisation and crop N demand are most important. For soil N mineralisation a model calculation could be a good basis giving at the same time also an estimation of the soil OM balance. For crop N demand the crop N recovery could be an indicator but the recovery (as measured in trials) is also affected by soil N mineralisation. Therefore look also at other systems (e.g. using residual soil mineral N as done in Belgium).
- WP2 Guided fertilization systems, Wieke Vervuurt: dynamic split application. Struggling with this part. There is a societal aspect, trust in the system. Predict N-min still difficult.
- WP3 Fertilizer recommendations for K, Ca, S, Mg and micronutrients, Wieke Vervuurt: K-recommendation. From crop response to balance system. It looks now complex for other countries, good to take this into account.
- WP4 Fertilizer choice recommendations, Sven Verweij: giving farmers insight and take the environmental aspects there with. Give the consequences.

Formulation of needed actions and possible follow ups

- Accurate estimation of soil nitrogen mineralization and connected measurements and models is a big gap to be solved. Geert-Jan van Burgt recommend the researchers in the PPS BAAT to use existing scenario's in NDICEA to analyse current situations.
- We have to better use the available knowledge from each other's. This workshop was mainly organized by the Dutch research program PPS BAAT and a follow up is not foreseen. It is however important to exchange research results in future.
- Currently there are no calls for EU-wide research on this topic. It is encouraged to exchange ideas, data and results in the meantime and look for new opportunities.
- The workshop was well received by the participants.

4 Abstracts oral presentations

4.1 Session 1. Setting the Scene: Current state of fertilizer recommendations in Europe and need for new recommendations

4.1.1 Fertilizer recommendations renewal in the Netherlands

Janjo de Haan, WUR

How fertilization of arable crops is carried out in agriculture influences many current social challenges. Reduction of emissions through fertilization is necessary because of the needed reduction of: a) nitrogen and phosphate to ground and surface water (Nitrate Directive, Water Framework Directive), b) ammonia emissions to the air (the ‘nitrogen crisis’) and c) nitrous oxide and methane emissions from organic manure to the air (reduction of greenhouse gas emissions). In addition, farmers have to: a) sequester more carbon in the soil (Climate Agreement) through, among other things, the right choice of manure; b) use organic residues as fertilizers (circularity) and c) limit the use of finite raw materials (phosphate, potash, gas for the production of nitrogen fertilizer). Together with this all, fertilization for the farmer has to contribute to optimal and profitable crop production and maintenance of soil fertility.
Practically applicable fertilization recommendations that addresses both these social and production aspects are necessary. Current fertilization recommendations as included in the Dutch Soil and Fertilization Manual are not tailored to this. These fertilization recommendations are focused on economic efficient production with limited attention to the societal aspects. Besides, current fertilizer recommendations are mainly based on old concepts and do not make sufficient use of recent knowledge and do not respond sufficiently to the local situation of the field and farm and the options of new precision fertilization techniques. This makes that maximum efficiency and effectiveness in fertilization are not achieved.
Therefore, we developed in 2022 a 4 year research project with public private partners and financing to develop new methodologies for fertilizer recommendations in arable farming. Researchers are working with partners from trade organizations, suppliers, retail, fertilizer producers, laboratories and with the Ministry of Agriculture, Nature and Food Quality to develop new fertilizer recommendations. These new recommendations have to balance the needs of the crop, the soil and the supply of nutrients better and also contribute to the above social challenges.
The project consists of the following work packages; WP1) the development of plot- and location-specific fertilization recommendations integrally for nitrogen, phosphate and organic matter; WP2) the development of dynamic seasonal fertilization recommendation by combining modelling with soil and crop measurements; WP3) the development of fertilizer recommendations based on the intensity and capacity of the soil for potassium, sulphur, calcium and a number of trace elements; WP4) a fertilizer selection tool to provide insight into suitable (circular) fertilizers and WP5) integration of fertilization recommendations at farm level and testing of the integrated recommendations in practice. After approval by the Arable Farming Field Vegetable Fertilization Committee (CBAV), the new fertilizer recommendations will be included in the Dutch Soil and Fertilization Manual for arable farming.

4.1.2 EJP SOIL Stocktake on harmonizing methodologies for fertilization guidelines across regions

Suzanne Higgins, AFBI

The European Commission has set targets for a reduction in nutrient losses by at least 50% and a reduction in fertiliser use by at least 20% by 2030 while ensuring no deterioration in soil fertility. Within the mandate of the European Joint Programme EJP Soil 'Towards climate-smart sustainable management of agricultural soils', the objective of this study was to assess current fertilisation practices across Europe and discuss the potential for harmonisation of fertilisation methodologies as a strategy to reduce nutrient loss and overall fertiliser use. A stocktake study of current methods of delivering fertilisation advice took place across 23 European countries. The stocktake was in the form of a questionnaire, comprising 46 questions. Information was gathered on a large range of factors, including soil analysis methods, along with soil, crop and climatic factors taken into consideration within fertilisation calculations. The questionnaire was completed by experts, who are involved in compiling fertilisation recommendations within their country. Substantial differences exist in the content, format and delivery of fertilisation guidelines across Europe. The barriers, constraints and potential benefits of a harmonised approach to fertilisation across Europe are discussed. The general consensus from all participating countries was that harmonisation of fertilisation guidelines should be increased, but it was unclear in what format this could be achieved. Shared learning in the delivery and format of fertilisation guidelines and mechanisms to adhere to environmental legislation were viewed as being beneficial. However, it would be very difficult, if not impossible, to harmonise all soil test data and fertilisation methodologies at EU level due to diverse soil types and agro-ecosystem influences. Nevertheless, increased future collaboration, especially between neighbouring countries within the same environmental zone, was seen as potentially very beneficial. This study is unique in providing current detail on fertilisation practices across European countries in a side-by-side comparison. The gathered data can provide a baseline for the development of scientifically based EU policy targets for nutrient loss and soil fertility evaluation.

4.1.3 Evaluating the performance of current N and P fertilizer advice systems in Belgium

Stefaan De Neve & Steven Sleutel, Research group Soil fertility and nutrien management, Department Environment, Ghent University, Coupure Links 653, 9000 Gent, Belgium – stefaan.deneve@ugent.be

We have made a systematic comparison of the performance of N and P fertilizer recommendation systems in Belgium, based on advices that were given for a number of typical arable and vegetable crops. There were often large differences in formulated N fertilizer advice for one and the same field and based on the same available data. In general N fertilizer advices were (much) larger than advices calculated on the basis of a systematic and full N balance, and would lead to increased risks of N losses. Despite the high P status of all of the soils in this study, P fertilizer was still recommended by all of the investigated systems, and will lead to a further and unnecessary build-up of P. There is an urgent need for further streamlining the existing fertilizer recommendation systems, by e.g. setting up agreed tables of parameter values that need to be used when calculating a N fertilizer advice. Clearly accelerated P mining is hampered by the large availability of animal manures.

4.2 Session 2. Integrating organic matter, nitrogen and phosphorus recommendations and Guided fertilization systems

4.2.1 Growing our future: routes to sustainable soil and nutrient management

Christine Watson, SRUC and SLU

For decades, the default position for arable agriculture has been to rely to a large extent on the use of fossil fuel derived fertilisers. Recently, issues with supply disruption caused by events such as Ukraine and the Covid pandemic, combined with climate change and the diminishing amount of phosphorus reserves are forcing us to rethink this paradigm. Nitrogen fertilisers derived from non-fossil fuel sources are on the drawing board but still a long way from being mainstream. Targets for sustainable crop nutrition have also shifted beyond individual crops to a more systems-based approach related to the entire cropping or farming system and taking into account impacts on soil health, carbon, biodiversity, water quality etc.

Going forward we need to reduce our dependence on energy expensive fertilisers and find innovative solutions from a systems perspective. There are no easy answers, and this will require a range of innovative solutions including agroecological and technology-based interventions in agriculture as well as consideration of structural changes in farming and society to make better use of co-products. This opens up a dialogue on regional solutions and how we can make the most of existing resources to meet future crop nutrition and soil health needs. This presentation will explore some alternative approaches to sustainable nutrient management with a view to exploring this further through the workshop.

4.2.2 Integrated carbon, nitrogen and phosphorus management: lessons learned from Dutch long-term experiments.

Bart Timmermans[1], M. Hanegraaf[2], Geert-Jan van der Burgt[1]
[1]Louis Bolk Instituut, Bunnik, NL; [2]WUR

Agriculture in Western-Europe is under growing pressure to change in order to become more sustainable. Also so in The Netherlands, where highly intensive agricultural systems are widely spread. But changes are difficult, as the current systems are tangible, and the exact aims for future agricultural systems are vaguer and more insecure. Knowledge and insights can help. Within the project "PPS Beter Bodem Beheer" a study was made of >40 crop rotations in 4 Dutch long-term experiments towards their carbon balances, nitrogen efficiencies and losses, and phosphorus dynamics. The aim was to quantify performance of current agricultural systems and of alternative management treatments tested to see how they perform and what can be achieved. Quantification of the processes was made using the NDICEA model, that was validated at first using field-specific mineral nitrogen measurements and a maximum average deviation of 20 kg N/ha (RMSE). Results of carbon balances and of nitrogen efficiencies and losses are presented. The classical way of calculating NUE is discussed, with an alternative that takes changes in organic matter and organic nitrogen in the top-soil into account. Phosphorus balances are presented, and an effort is made to integrate carbon, nitrogen and phosphorus balances into the management of crop rotations.

4.2.3 The calculation of the nitrogen mineralization amount in fertilization advices

Karoline D'Haene, ILVO
Georges Hofman, Ghent University

The calculation of the nitrogen (N) mineralization amount in fertilization advice is a big challenge due to the large variation between fields. An overestimation of the N mineralization amount can result in reduced yield or quality. An underestimation of the N mineralization amount can lead to high soil contents of nitrate nitrogen at harvest. Especially for late harvested crops, when it is too late to sow an effective catch crop, a high nitrate nitrogen residue should be avoided reducing the risk of nitrate leaching during the winter period. Soil organic matter (SOM) is a key parameter of soil quality because it exerts a strong beneficial influence on physical, chemical and biological soil parameters. Nitrogen mineralization from SOM alone typically provides between 25 and 50% of the N requirement of a crop and on highly fertile soils this can even be more than 100%. The potential N mineralization rate globally depends on the SOM and total N (TN) percentage. However, the N mineralization amount calculated based on a SOM or TN (fraction) measurements needs to be adapted considering the SOM quality and the field history e.g. the frequent application of manure results in a higher N mineralization amount than expected based on a SOM or TN measurement. Also management during the cropping season -e.g. mechanical weed control- can affect the N mineralization rate. For the calculation of the N mineralization amount from crop residues and catch crops and the long term effect from manure application farmers need to give extra information. Due to the impact of management of the previous years the calculation of the N available by mineralization is above all difficult for hired fields.

4.2.4 Nitrogen recovery and losses with different types and rates of organic fertiliser in a long-term wheat rotation field trial

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Appropriate management of fertiliser is essential to ensure long-term soil health and to prevent pollution. This study assessed nitrogen (N) recovery from different types and rates of organic fertiliser, in combination with inorganic N fertiliser at 190 kg/ha-1. A field trial at Rothamsted applied FYM, compost, anaerobic digestate (AD) and straw, at rates of: 3.5 <2.5 <1.75 <1 t carbon/ha-1 for 8 seasons. The total organic plus inorganic N applied with the organic amendments was e.g., with maximum rate 4: 448 < 425 < 329 < 226 kg N/ha-1 with FYM, compost, AD, and straw respectively. The trial was also simulated in the DNDC (DeNitrification-DeComposition) model.
After 8 seasons, the greatest increase of SOC was with rate 4 of both compost and FYM at 33%, and the smallest increase was with no treatment at 2%. Soil N accumulation was greatest with compost at all rates at ~20%, with other treatments it was between 5-15%, but with mid rates of straw and with no treatment there was a decrease in soil N. Crop N uptake (yield * N concentration) was roughly equal across all treatments at ~200 kg/ha-1. Total N recovery (soil accumulation + crop uptake) was greatest with straw rates 1 and 4 at ~100%, and with compost rate 1 and AD rate 2 there was recovery greater than 90%. Otherwise, recovery was between 70-80%, and with no treatment recovery was 68%.
Therefore, with no treatment and high rates of amendment there was around 30% N loss. However, with low rates of compost and AD and rates 1 and 4 of straw there was recovery of 90-100%. Therefore, organic amendments can be applied for soil improvement without excessive pollution. The predicted data from the DNDC model correlated well to the observed data e.g., R2 = 0.78 in soil N accumulation. This model will therefore be used for assessment of the modes of N loss e.g., gaseous or leachate, and for further simulations of optimal organic and inorganic N fertiliser combinations.

4.3 Session 3. Fertilizer recommendations for Ca, S, Mg and micronutrients and Fertilizer choice recommendations

4.3.1 How to Choose the Best Fertilizer Plan for Your Farm: A Multi-Criteria Optimization Framework

Sven Verweij, NMI

One of the key factors that affect the profitability and sustainability of a farm is the selection and application of organic and mineral fertilizers, including products from animal manure. However, most of the existing studies on fertilizer management focus only on the optimal nutrient rates for crop production, ignoring the effects of different fertilizer types and combinations on the farm economics and environment. To address this gap, we propose a novel modelling framework that integrates the monetary aspects of fertilizer management into the decision-making process. The framework consists of six modules that each evaluate the economic outcome of a fertilizer plan based on the costs and benefits of: (1) purchasing fertilizers, (2) disposing farm manure, (3) storing fertilizers, (4) applying fertilizers, (5) harvesting crops, and (6) complying with legal regulations. Optionally, a seventh module can be added to account for the compensation of greenhouse gas emissions from fertilizer use. The framework is designed to operate with matrix operations, which enables fast computation on GPU's and advanced optimization techniques to assist farmers in finding the optimal fertilizer plan. This framework has several benefits, such as:

- It can help farmers to maximize their profits and minimize their costs by choosing the most suitable fertilizer type and amount for their crops and soil conditions.
- It can help farmers to reduce their environmental footprint by avoiding over-fertilization and excess nutrient losses that can cause water pollution and greenhouse gas emissions.
- It can help farmers to comply with the legal regulations on fertilizer use and manure disposal, avoiding fines and penalties.

- It can help farmers to adapt to changing market conditions and climate scenarios by providing them with flexible and robust fertilizer plans."

4.3.2 Advances in fertilization recommendations: A three-step approach incorporating new insights

Arjan Reijneveld, Eurofins

Most current fertilization recommendations are based on soil fertility testing, and have been developed a few decades ago. Since then, the socio-economic environment and scientific insights have altered. Food quality and environmental sustainability are high on the political agendas now. This shows up among others in the approval of 17 sustainable development goals (SDGs), the European Green Deal, the EU Directive on Soil Monitoring and Resilience, and the insight that both healthy food and healthy food production systems are needed. Accurate broad-spectrum soil tests and related fertilization recommendations are essential for achieving these goals.

Commonly, many different tests are needed for a full soil health assessment, which is laborious, expensive, and many tests have a high environmental footprint. New broad-spectrum soil tests offer the potential to assess many soil characteristics rapidly, but often face challenges with calibration and validation.

We created a three-step approach for introducing new broad-spectrum soil tests and new scientific insights in fertilization recommendations, as follows: (1) establishing new broad-spectrum soil tests and new scientific insights, (2) creating translation models bridging old and new soil tests and insights, and (3) validation and implementation of new recommendations in practice. We selected and extensively tested two broad-spectrum techniques, i.e., Near Infrared Spectroscopy (NIRS) and 0.01 M CaCl2 extractions combined with mass spectrometry and ICP.

Comprehensive assessments indicate the accuracy of NIRS determinations for a wide range of soil physical, chemical and biological indices ($R2 \geq 0.90$). Comparisons of results obtained with conventional methods and 0.01 M CaCl2 extractions for essential and beneficial nutrients and nine (heavy) metals provide new insights in sorption characteristics. Translational models were subsequently developed to establish correlation between the results of the broad-spectrum soil tests and conventional methods, enhancing user confidence. In addition, we developed and tested a range of additional indicators, to meet the demands of society and policy as related to food quality and environmental sustainability. This approach allowed us to introduce new fertilization recommendations and concepts, including the soil nutrient intensity-buffering-quantity concept, an assessment of all essential nutrients, as well as soil biological indices.

Validation and implementation of our three-step approach has been successfully conducted across various geographical regions, including European countries, China, New Zealand and Vietnam. The accompanying advice reports (including fertilization recommendations; Soil Carbon Check, Soil Life Monitor and Soil Health Indicator) provide guidance for land users to attain healthier crops and soils, and thereby contributing to the realization of the SDGs.

4.4 Session 4. Integrating fertilizer recommendations to a fertilizer plan on field and farm level

4.4.1 The Swiss fertilizer recommendation - historic development, current status and integration in legislation and ways forward to sustainable nutrient management (on the example of arable crops)

Frank Liebisch, Agroscope

"The official fertilizer recommendation dates back to 1938 in Switzerland. Since then, methods, resources, justification and environmental impact of nutrient use in agriculture changed largely. Today we foster two site and use specific methods: a soil sampling and a model-based estimation of crop fertilizer demand for N and P. However, those methods are not an integral part of the Swiss legislation (law enforcement) allowing

for significant losses to the environment causing significant environmental and resource problems such as surface water eutrophication and nitrate pollution of drinking water reserves.
Consequently, a better integration of good and best fertilizer practices in legislation is one of several challenges for a sustainable nutrient management in Switzerland. Others are the 1. digital transformation closing the gab of information use between field and farm, extension, legislation and environmental and national monitoring, 2. Improvement of fertilizer recommendation, by better calibration to pedo-climatic conditions, estimation of nutrient release from fertilizers and soils using multi-factorial statistics and models and 3. a better integration of spatial and temporal variability by means of precision fertilization methods and technology.
The presentation will be closed by a regional example of an intensive agricultural region having exceeded nitrate levels in their ground water reserves since decades. The example shows, how a multi-stakeholder consortium addresses the above-mentioned challenges in a co-creation process. In particular, the combination of the critical load concept and good fertilization practices, a robust documentation of nutrient application practices and nutrient balancing of all inputs is seen as the regional solution towards a drinking water resource fulfilling national quality standards combined with a productive agriculture in a region with fertile soils."

4.4.2 Integration of fertilizer recommendations to farm level

Janjo de Haan, WUR

Current fertilizer recommendations are mainly on crop and field level and per nutrient. To assess if the fertilization strategy of a farmer is complying to society goals integration to farm level is needed. Societal goals are mainly set at national or regional level and are translation to farm level by e.g. legislation & rewarding. The farm is the main decision unit. In the integrated fertilizer recommendations farmers goals on continuity of the farm operations have to be combined with societal goals and legislation. They are dependent on the available knowledge and technology.
Important societal goals are on water quality of groundwater and surface water (Nitrate Directive and Water Framework Directive), climate mitigation with reduction of greenhouse gas emissions and carbon sequestration (Climate law), climate adaptation and water regulation and nutrient recycling (reduction use of ending sources as energy and fertilizers). Indicators with target values have to be defined to assess the fertilization strategy on these goals. Question is how to translate targets on national or regional level to the farm level.
The first step in integration of fertilizer recommendations is to make optimized fertilizer recommendations for farmers goals which complies to legislation at farm level. Societal impact is calculated but no optimization is done on these goals. Besides reduced fertilization schemes are assessed to give insight in possible effects. The ultimate ambition is to have an optimized fertilizer recommendation within constraints of farmer, legislation and societal goals with insight in trade-offs between goals. The process to make this possible is in development in the PPS BAAT.

5 Abstracts poster presentations

5.1 Session 1. Setting the Scene: Current state of fertilizer recommendations in Europe and need for new recommendations

5.1.1 Nutri-Check Net, current and new fertilizer recommendation systems in Europe

Milan Franssen, Delphy

Nutri-Check Net (NCN) is a Horizon Europe thematic network. In this project we make an inventory of 1) current recommendation systems in 9 European countries, 2) screening of scientific and grey literature for new recommendation systems, tools and services for nutrient management, 3) inventory of commercial tools & services. Existing recommendation systems are compared, new systems, tools and services are assessed (several aspects, also cos-benefit) and discussed with national experts and farmer groups in the partner countries. The project specifically aims for identification of knowledge and tools which improve efficiency of N/P use in target crops potato, wheat and maize across Europe.
The most relevant systems will be tested in practice with the farmers. The inventory so far assessed 12 national recommendation system, 815 research projects of which 225 were deemed relevant to the project, and 217 commercial tools & services of which 155 relevant.
The preliminary results of the inventory show differences between countries, and between the level of adoption of different technologies and methodologies throughout Europe.
The most promising/interesting systems, tools and services will be published on the NCN platform, which is aimed at farmers, researchers, advisors, other supply chain actors, and legal bodies. The NCN platform targets use as central hub for EU-wide information on advisory tools and systems for N/P fertilization.

5.1.2 Nitrogen fertilizer replacement values of organic amendments: determination and prediction

Renske Hijbeek, WUR

"The nitrogen fertilizer replacement value (NFRV) quantifies the value of organic amendments as a nitrogen fertilizer, and is commonly defined as the extent to which organic fertilizer N can replace mineral fertilizer nitrogen (N). NFRVs can be calculated by comparing the crop N uptake from equal N application rates of mineral and organic fertilizer, or by comparing the N rates of both fertilizers needed to obtain equal crop N uptake.
Currently, NFRVs are mainly known for animal manure, whereas other organic waste products may become available as fertilizer products in the future. In this study, a pot experiment with spring wheat was performed to (1) assess NFRVs of a range of organic amendments; (2) compare NFRVs based on equal N application with NFRVs based on equal N uptake; and (3) assess which product characteristics explain observed variation.
Observed NFRVs varied between 6.2 and 78.8%, with the lowest value for raw food waste and the highest for fishmeal. NFRVs were overestimated when calculated based on equal N application rate (with on average 6.9% point), and more so at high N application rate (9.0% point). NFRVs should therefore be calculated based on equal N uptake from organic and mineral fertilizers. Nitrogen concentration of the organic fertilizer provided the best explanation of variation observed in NFRVs ($R2 = 0.86$).
These findings give valuable insights into the large variation in value of organic waste streams as organic fertilizer and can support decisions on sustainable N application rates, to increase crop N uptake and reduce N losses to the environment.

Based on: Westerik et al. (2023) Nutrient Cycling in Agroecosystems (https://link.springer.com/article/10.1007/s10705-023-10316-7)"

5.2 Session 2. Integrating organic matter, nitrogen and phosphorus recommendations and Guided fertilization systems

5.2.1 NDICEA - calculating carbon and nitrogen dynamics in agricultural fields

Bart Timmermans en Geert-Jan van der Burgt, Louis Bolk Instituut

In order to become more sustainable, agricultural systems should optimize between multiple aims: carbon balances should be maintained in order to warrant soil quality, or even increased to help and decrease atmospheric CO_2. Nitrogen efficiency should be high and losses towards the environment minimal. The NIDCEA model is a field-scale agricultural model, that can provide insights into the management of agricultural systems for farmers, extension workers and scientists. It is one of the few models that combines carbon and nitrogen dynamics in its calculations. Containing a large and still increasing number of fertilizers and manures, tillage effects, and characteristics of many crops, short and long-term dynamics of an actual field can be analyzed. Inefficiencies can be identified, and alternatives scenarios can be evaluated.

5.2.2 Integrating time related processes in nitrogen fertilization recommendation

Geert-Jan van der Burgt, Louis Bolk Institute
Philipp Schad, Landwirtschaftskammer Nordrhein-Westfalen

Considering nitrogen availability for crop growth, several complex processes play a role such as mineralization, leaching, denitrification. A society-based nitrogen fertilization recommendation has the targets

- to supply enough nitrogen in a fitting availability pattern for adequate crop growth
- to prevent nitrogen surpluses during and after crop growth.

This requires further elaboration of the 'time' factor in the recommendation strategy in two aspects: time within the season, and time over the years, since a substantial part of the nitrogen mineralization within the crop growth season is related to last year's management practices. This second time aspect implies that a fertilization recommendation cannot be seen independent from crop sequence. The calculation of nitrogen use efficiency has to be reconsidered, calculating this at crop sequence level instead of single crop level, and taking into account changes in soil nitrogen stock.
The required accuracy cannot be covered by using fixed table values for (extra) nitrogen mineralization out of pre crop, cover crop and applied organic manures in the actual year or the past year(s). A future nitrogen recommendation system should instead be based on calculated mineralization in a dynamic soil-crop nitrogen model.
Using the NDICEA model, being such an integrated nitrogen model, examples are given of field experiences in Germany and the Netherlands, showing the importance of taking into account the nitrogen dynamics. This will quantitatively be compared with the actual nitrogen recommendation practice on crops in Germany and the Netherlands. Using the model prediction, nitrogen supply could, under circumstances, be reduced, resulting in reduced nitrogen losses to air and water. If time is taken into account, crop sequence becomes an important factor in nitrogen fertilizer recommendations.

5.2.3 N-INDEX expert system: A powerful tool in nitrogen recommendation

Annemie Elsen, Bodemkundige Dienst van België

The expert system N-INDEX calculates field-specific nitrogen fertilization recommendations for arable crops, vegetables, fruit cultivation and pasture in temperate regions, based on mineral nitrogen analyzes. The N-INDEX indicates how much nitrogen becomes available for the crop during the growing season. Not only the

amount of mineral nitrogen in the soil at the time of sampling is taking into account, also the expected nitrogen mineralization in the coming months.
The N-index system is based on 18 factors that can be divided in three large groups.

I. Factors influencing the amount of available mineral nitrogen in the soil at the time of sampling, and the amount of nitrogen uptake by the crop at the time of the sampling: available mineral nitrogen in the soil is measured by the mineral nitrogen analysis. The nitrogen already taken up by the crop at the time of sampling is determined primarily by the cultivation technique and by the crop development.
II. Factors that determine how many mineral nitrogen the soil will deliver during the growing season: the nitrogen released by mineralization of soil humus, crop residues, cover crops and already applied organic fertilizers.
III. Factors that result in a reduced availability of mineral nitrogen during the growing season: low pH, leaching, volatilization, denitrification and leaching.

To calculate all these factors, both the field history and the field characteristics should be well known. Therefore, at time of sampling, an extensive questionnaire is filled out by the farmer and the sampling staff. Based on the gathered information and the results of the minerals nitrogen content of the soil (based on analysis of the soil sample) the N-INDEX is calculated.
The calculation of the nitrogen fertilization advice (Y) based on the N-INDEX is formulated as follows: Y = A-b*N-INDEX, with A the total nitrogen demand of the crop.

5.2.4 Crops nutrients supply from different sources in soil

Koen Willekens, Flanders Research Institute for Agriculture, Fisheries and Food, Merelbeke, Belgium
Jasper Vanbesien, Inagro research & advice in agriculture and horticulture, Belgium
Peter Vanhoof, Organic Forest Polska, Poland

Crops nutrients supply origins from different sources, (i) nutrients in mineral form present in the soil, (ii) nutrients released from decomposition of freshly amended organic material and (iii) nutrients that become available by symbiosis between plants and micro-organisms in the rhizosphere. We used an analytical method (bio-electronic measurements according to Peter Vanhoof) that distinguishes for these different sources of nutrients in a farmers fields' monitoring in organically managed vegetable cropping systems. In parallel, the amount of plant available N, i.e., the sum of the amount of mineral N in the soil profile plus the N uptake in aboveground plant biomass, was assessed at different time points during the growing season, (i) before fertilization and tillage in spring, (ii) under a young crop at an intermediate sampling moment, (iii) at crop harvest and (iv) at the end of the growing season in autumn.
The partial balance of plant available N in the time span between the first and the second sampling moment reflects the N-release from soil organic matter and organic amendments. The apparent N mineralization rates (kg N per ha per day) are highly different between fields and are likely related to soil characteristics, and partially to the amount and nature of the organic amendments. The field related part can be considered for advice on fertilization and other soil management aspects in the subsequent growing seasons.
Secondly, soil management history and base fertilization clearly affects the ratio between the amounts of nutrients from different sources, as assessed with the bio-electronic measurements at the second sampling moment. Besides stock of mineral nutrients, which includes the mineral N amount at that time point, the measured potential amount from the two other sources can help growers to decide on top dressing for the standing crop.

5.2.5 Nitrogen advice in Flanders based on the KNS-System

Goovaerts Ellen, Proefstation voor de Groenteteelt

The quality of surface and groundwater in Flanders must improve. Therefore there is a strict legislation on nitrogen use. One of these restrictions is the obligated "advisory system" for vegetables. A method research centres use for these recommendations is the former KNS-advice system. The main principle of the system is based on target values for nitrogen and the N-content in the soil, according to rooting depth. The system takes in to account how much a vegetable crop needs at a certain moment of growing. For cultivations with a longer growing period the system advices a fractioned fertilization. A lower dose at planting can be adjust on the moment the N-uptake of the plant increase. This fractional technique gives opportunities for responding on unpredicted climate conditions (eg rain), soil mineralisation, nitrogen release from catch crops or harvest residues. The result is a lower risk of nitrogen leaching for outdoor crops. Good N-advices demands more than an up to date KNS-system. A maximum of input from the field (crop residues, catch crops, the use of manure, compost) must reach the adviser. These elements pose in real life sometimes difficulties to integrate. This can lead to a potential higher nitrate residue in the soil than predicted.

5.2.6 Comparison of Organic and Conventional Crop Management in Estonia since 2008

Evelin Loit-Harro, Estonian University of Life Sciences

"The aim of this study was to compare and analyse the impact of organic and conventional growing systems within the same rotation to the yield and quality of barley, clover, winter wheat, field pea and potato, as well as to assess the soil nutrient content and microbiological diversity in time.
The field experiment was established on 2008 on the experimental fields of the Estonian University of Life Sciences (58o 22´ N, 26o40´E) and the data has been collected since (three full rotations to date). Soil type is Stagnic Luvisol (sandy loam surface texture, C 1,38% and N 0,13%, pHKCL 6,0). The field was divided by nitrogen treatments: three different treatments in organic plots (Org0, OrgI with winter cover crops, and OrgII with cover crops and manure) and four different treatments in conventional plots receiving mineral nitrogen (N0, Nlow, Naverage, and Nhigh). The five-field crop rotation was based on following order: spring barley with undersown red clover, red clover, winter wheat, field pea, potato.
The average yield in organic system was generally lower compared to conventional system. Protein content was in positive correlation with mineral nitrogen rate. However, dietary fiber content (beta-glucan and arabinoxylan) was only impacted by yearly temperature and precipitation and it did not depend on fertilization. The content of all studied macronutrients in the soil has decreased over the years. The soil nitrogen content was the least affected by the treatment with cattle manure in organic system. The greatest nitrogen loss was from the soil of conventional treatment with the highest nitrogen rate. The potassium content of the soil decreased the most. The most sustainable in terms of soil fertility was the manure treatment in the organic system, while the conventional system with the highest nitrogen rate was the most vulnerable.

5.2.7 Update/Validation of Critical Values for plant analysis under present conditions in Saxony-Anhalt

Susanne Klages, agri.kultur

Plant analysis is one method to adjust fertilization (later) during the plant production period. Introduced in the 60ies and updated in the 80ies and 90ies of last century, Critical Values are target concentrations in plant tissue linked to target yields.
There are different methods for the deduction of Critical Values and the evaluation of individual nutrient concentrations in plant tissue in order to tailor fertilization to expected yields and/or qualities.
Aim of ANAPLANT, an EIP-Agri financed project running for 3 years since spring 2023, is to validate the Critical Values used at present in one German Federal State. The first project year was determined by droughts, the second by moderate conditions. We will present first project results and give possible explanations accordingly. Further, we will explain necessary frame conditions for the application of the methods cited above to deduce Critical Values and evaluate plant concentrations as means to predict yield and/or crop qualities.

5.2.8 TerraZo - free application map creation and deployment based on field trials

Stefan Geyer, Francisco Josephinum Wieselburg

"TerraZo, developed by Josephinum Research, is a web application designed to facilitate site-specific fertilization for farmers without requiring high acquisition costs for new equipment or expensive software. Based on Sentinel 2 satellite data and field trials, vegetation indices are calculated, and fertilizer recommendations for each subarea are generated using models. The application maps that are generated can be easily exported and imported into compatible tractor terminals, enabling seamless utilization in the field. Alternatively, smartphones or tablets can be used for site-specific fertilizer application. Result is that variable and site-specific N-fertilization leads to savings in inputs and tailored plant nutrition. In addition, site-specific fertilization ensures a balanced N-budget, higher N-efficiency, and lower greenhouse gas emissions. Nevertheless, the creation of application maps requires not only technical expertise but also the incorporation of agronomic and location-specific characteristics of the fields. Both aspects are considered to simplify the technical barriers for the user and support them in site-specific fertilization through proposed fertilizer quantities. It is important that the user can customize all suggestions to accommodate their personal preferences and experiences. Another important point is that when we able to established such a system on a wide scale, new knowledge is transferred directly to the point of application. This can lead to widespread adoption and implementation of site-specific fertilization practices. By incorporating advanced technologies and data-driven approaches, practice and science can benefit from each other and more informed nutrient management decisions can be made. In order to put this into practice, seminars, training courses and practical events as well as several projects with farmers are carried out as part of the Innovation Farm."

5.2.9 Controlled Release Fertilizers, a way to improve farmers nutrient use efficiency

Lex Slootweg & Ronald Clemens, ICL

The use of Controlled Release Fertilizers (CRF) is standard practice for decades in the horticultural industry in Europe. Nursery stock plants grown in pots or containers are grown with CRF because of its high efficiency and known low losses of nutrients to the environment.
In agricultural field crops this fertilizer technology has been introduced later but in the last 10 years many developments occurred to fit CRFs for field crops as well. Due to its programmed availability for crops, it can improve nutrient use efficiency strongly. So far main reason for farmers to use CRF has been yield increase and labour reduction (reduced applications).
Knowing that within the European Green Deal nutrient losses need to be reduced with 50% and application rates with 20%, an enormous challenge is ahead of the agricultural sector. Following a F2F strategy without substantial improvements in nutrient use efficiency can however lead to yield reductions with negative effects on land use and CO2 Footprints (source: WUR, Jan 2022). Enhanced Efficiency Fertilizers, like CRFs which can be used at lower rates and maintaining yields could be a way to reach Green Deal objectives.
Recent global meta analyses show that CRFs can reduce all pathways of Nitrogen losses like leaching, Ammonia volatilization and N2O emissions substantially while the nitrogen use efficiency can be increased. Other Enhanced Efficiency Fertilizers like Nitrogen stabilizers (urease- and nitrification inhibitors) only effect one of the pathways.
Due to its higher efficiency, higher yields or reduction of nitrogen inputs at similar yields can be achieved. This has a positive effect on carbon footprint reductions of a produced crop.
Also, long term studies show that CRFs can have a positive effect on soil microbial community composition and function.
ICL recently developed a new coating technology eqo.x for coating of Nitrogen and use in agricultural crops. This coating is fully biodegradable and therefor will meet new standards in the FPR from 2026 onwards.

References:

1. Measuring N losses of different fertilizers (NMI Wageningen 2021)
2. The effect of long-term controlled-release urea application on the relative abundances of plant growth-promoting microorganisms (Shangdong Agricultural University China 2023)
3. Next-generation enhanced-efficiency fertilizers for sustained food security (Shu Kee Lam et al 2022)

4. Innovative Controlled-Release Polyurethane-Coated Urea Could Reduce N Leaching in Tomato Crop in Comparison to Conventional and Stabilized Fertilizers (Pisa University 2020)

5.3 Session 3. Fertilizer recommendations for Ca, S, Mg and micronutrients and Fertilizer choice recommendations

5.3.1 Measurements of plant-available P, K and Mg contents and pH of soils with the soil sensor system Stenon “FarmLab” as a basis for fertilizer recommendations for arable crops

Hans-Werner Olfs, Osnabrück University of Applied Sciences

In recent years, sensor devices for so-called ""in-situ"" soil analysis have been increasingly used by farmers as a substitute for classical soil tests (with soil samples and subsequent laboratory analysis) as a basis for deriving suitable fertilizer application rates for arable crops. For this purpose, the German startup Stenon has developed the ""FarmLab"" soil sensor, which is equipped with sensors for measuring the impedance as well as the absorption spectra (NIR to UV spectral range) of soils, GPS position, some weather data, and soil temperature and moisture. Such real-time, laboratory-independent soil analysis would provide rapid and cost-effective access to soil data. However, before these soil sensors can be recommended for use on farm, an independent scientific evaluation is needed to ensure that farmers receive reliable soil data.
To evaluate the performance of the ""FarmLab"" soil sensor, 2 studies were conducted. In spring 2021, a ""FarmLab"" soil sensor was used in a survey study in western Lower Saxony on 64 farmers' fields. In a second study measurements were carried out on P and K long-term field experiments (2 sandy and 1 loamy site for each nutrient; 4 treatments: control without P/K, 0.5, 1, and 1.5 (or 2) times the P/K plant uptake) in eastern Lower Saxony.
In the farm survey, the laboratory data for each of the 4 tested parameters (pH, available soil P, K and Mg) did not agree well with the measured values obtained with the ""FarmLab"". No correlations were found between the laboratory data and the corresponding ""FarmLab"" data for P or K in the 3 long-term P/K fertilization trials. Further evaluations are necessary before reliable statements on the practical suitability for farmers as well as the comparability of the Stenon ""FarmLab"" results to lab data can be made."

5.3.2 Do composts meet organic fertilizers quality requirements: Lithuanian case study?

Karolina Barcauskaite, Lithuanian Research Centre for Agriculture and Forestry

It was investigated the quality of composts produced in Lithuania. Physical characteristics, nutrients, heavy metals and organic pollutants contents were determined in various kinds of composts including green waste, sewage sludge, food waste, cattle manure etc. Moreover, potential risks of the environment have been simulated. Performed Monte Carlo simulations showed that the shortest period in which zinc background concentration in soil could increase twice in 2 years, Cu background level in some cases increase double in 3 years. All the investigations performed in Lithuania and future perspectives will be presented in the workshop. The newest results of Lithuanian farmers and other stakeholders' interests in using processed and unprocessed organic materials in agriculture survey results will be demonstrated as a part of the internal EJP SOIL program BioCASH project activity.

5.3.3 Long-term effects of phosphate fertilisation

Vervuurt, W., van Geel, W.C.A. en Regelink, I.

Excessive supply of phosphate is undesirable due to the negative impact on the water quality, and its efficient use should be pursued since phosphate is a finite resource. Legislation in the Netherlands restricted the maximum supply of phosphate on agricultural soils to minimise losses to the environment. Concerns about soil fertility and yield losses arose. A long-term phosphate trial was initiated and preserved to quantify the effects of P-fertilisation levels on crop growth as well as on soil phosphate levels and phosphate losses. The experiment on a marine light clay soil started in 1990 with four levels of phosphate fertilisation: 0, 70, 140 and 280 kg P2O5 ha-1 yr-1. In 2005, each treatment was split, and fertilisation was continued in one part and discontinued in the other. The 0-treatment was split in a part that remained unfertilised and a part that received 70 kg P2O5 ha-1 yr-1 since then. Crop yields were monitored, and phosphate fractions (P-CaCl2, Pw, P-Al and total P) were determined in the soil and groundwater. Different levels of fertilisation led to divergent soil phosphate levels. An optimum yield was obtained by 70 kg P2O5 ha-1 yr-1 at a soil phosphate level that is considered as optimal (25-45 mg P2O5/litre water soluble-P). Yield losses occurred at fertilised and unfertilised plots with lower soil phosphate levels. Higher soil phosphate levels in combination with and without fertilisation did not affect yields. The crop P-uptake was larger with a higher soil phosphate level and fertilisation, indicating overconsumption of P. Still, high surpluses were found for the treatments with 140 and 280 kg P2O5 ha-1 yr-1. Surpluses became only for a small part visible in plant available phosphate. The other part turned into more stable phosphate fractions in the upper soil, moved to deeper soil layers and to the groundwater.

5.3.4 Evaluation framework to predict the fate of organic materials

Veenemans, L.[a], Vervuurt, W[b], Middelkoop, J.C.[c], Verhoeven, J.T.W.[b], Schoumans, O.F.[a]*
Wageningen Environmental Research, the Netherlands[a]; Wageningen Plant Research, the Netherlands[b]; Wageningen Livestock Research, the Netherlands[c]; [*]Presenter

Introduction
With the transition towards a circular economy, new organic fertilisation products will be introduced to the market. The nitrogen and carbon dynamics of these products is not yet evaluated and suitable tools are not available. To fill this gap, Wageningen Research developed a toolbox that can be used by various stakeholders to easily assess the carbon decomposition and nitrogen mineralisation of these products. The framework is currently being validated and tested.

Methodology
The model RothC has been used to assess C mineralisation and sequestration from farm management. The C/N ratio of the individual organic pools of RothC was used to assess the N-mineralisation and immobilisation. The model was calibrated based on incubation studies in which C and N mineralisation of 16 different organic materials was measured, both in a sandy soil and a clay soil. The measured C-mineralisation was used to determine in each fertilising product the fraction of easily decomposable plant material (f_{DPM}) and the complementary fraction of recalcitrant plant material ($f_{RPM} = 1 - f_{DPM}$). Furthermore, the influence of soil type on mineralisation/immobilisation was quantified. With regression analysis, a connection was made between the fraction of easily decomposable plant material and a large palette of laboratory analyses performed on the organic materials in order to derive a simplified method the estimate C- en N mineralisation of organic products in soils. Five additional organic materials were used to validate the model.

Results and discussion
A new simplified innovative methodology has been developed to predict the fate of an organic product in terms of C- and N-mineralisation and immobilisation. Simple laboratory analyses (total nitrogen content, a pyrolysis parameter and a MicroResp. parameter) could predict the size of the RothC parameter for the easily decomposable fraction of carbon (f_{DPM}) of an organic fertilising product, enabling the prediction of carbon dynamics. The model results were quite similar to what was measured with incubation experiments. However, the MicroResp. parameter is not considered reliable during the validation phase. The use of other parameters, such as COD, BOD or HWC, will now be explored. For N mineralisation, an overestimation was found, meaning that just using a fixed C/N-ratio of each of organic pools in RothC is a too simple approach. However, this approach is a first step from the conventional long-term and costly incubation experiments or field studies that are typically required to assess the impact of organic materials, at least for carbon turnover. The model assessment of N mineralisation will be further investigated.

Conclusion

The tool is a simplified method, and can help to predict the effects of an organic material on carbon storage in soils and in the future possibly nitrogen mineralisation as well.

Acknowledgements
This project was funded by the Dutch KB programme Circular & Climate Neutral Society of Wageningen University and Research.

References

Coleman, K., & Jenkinson, D. S. 1996. RothC-26.3 - A Model for the turnover of carbon in soil. In: Evaluation of soil organic matter models: using existing long-term datasets. Springer Berlin Heidelberg, pp. 237-246.

Schoumans, O.F., et al. in prep. Conceptual framework to evaluate organic fertilisers on C and N mineralisation and economic aspects. Wageningen Research, Wageningen.

Schoumans, O.F., et al. in prep. Description of the Evaluation Framework Tool for Organic Fertilisers (EFTOF). Wageningen Research, Wageningen.

5.3.5 Potential for reducing P fertilization without affecting crop yield

Hendrik Holwerda[ab], Regelink, I.C.[a], Koopmans G.F.[b]*
Wageningen Environmental Research[a], Wageningen University[b], presenter[*]

"Two long-term phosphate fertilization trials initiated in 1972 on a calcareous loam soil near Marknesse and a cover sand soil near Wijster were studied. The loamy soil is a reclaimed clay soil which is rich in phosphate minerals by nature; this soil can sustain crop growth for decades without P fertilization despite the low typical low SPT values. In contrast, the sandy soil is poorly fertile by nature and its P content is the result of human activities.
After 50 years, cumulative P surpluses range between -2500 kg P2O5/ha and +9000 kg P2O5/ha. A comparison between total P and the oxalate-extractable P revealed that more than 70% of the cumulative P surplus accumulated in the oxalate extractable pool linked to Fe/Al oxides. We found that the P-loading of the Fe/Al oxides controls concentrations of PO4 in CaCl2 (P-CaCl2) and water (Pw) and that these relations were similar for both soils despite the large difference in pH and soil texture. The oxide content of the soil is thus a valuable indicator serving as a guidance to determine how much P should be supplied or withdrawn to change P-CaCl2 or Pw to the optimal range.
Critical SPT values for optimal crop yield varied strongly between the loamy and sandy location. Optimal crop yield was defined as >90% of the max attainable yield. For potatoes, the loamy soil requires a critical Pw-value of 14 while the sandy location requires a critical Pw-value of 34. We hypothesized that the lower critical STP in the loamy soil is due to the difference in soil physical properties resulting in higher P diffusion to plant roots. This implies that the widely used SPTs poorly predicts differences in P availability between different soil types.
The far higher critical SPT value on the sandy soil also implies a greater challenge in managing trade-offs between high crop yields versus risk for P losses to ground- or surface water. However, at both locations the high P-surplus application only marginally enhanced P concentrations in soil moisture at 35 and 75 cm compared to the unfertilized fields. For these soils, surface runoff losses are expected to form a larger environmental risk than P leaching losses due the high P sorption capacity of both the topsoil and subsoil.
In conclusion, soil type greatly influences critical SPT values and a soil-specific approach is needed to balance environmental losses versus crop yields.

Appendix 1. Participant list

Name	Organisation	Country
Arjan Reijneveld	Eurofins	Netherlands
Andreas Ettlinger	HBLFA Francisco Josephinum	Austria
Stefan Geyer	HBLFA Francisco Josephinum	Austria
Ellen Goovaerts	PSKW	Belgium
Tommaso Barbagli	WUR	Netherlands
Karolina Barčauskaitė	Lithuanian Research Centre for Agriculture and Forestry	Lithuania
Karoline D'Haene	ILVO-Plant	Belgium
Oane de Hoop	OANEvents	Netherlands
Stefaan De Neve	Ghent University	Belgium
David de Wit	WUR	Netherlands
Annemie Elsen	Bodemkundige Dienst van België	Belgium
Milan Franssen	Delphy	Netherlands
Georges Hofman	Onderzoeksplatform	Belgium
Hendrik Holwerda	WUR	Netherlands
Marianne Hoogmoed	Louis Bolk Instituut	Netherlands
Daniel Kindred	Anglo American Woodsmith Ltd	United Kingdom
Susanne Klages	agri.kultur	Germany
Eline Klompe	CropSolutions	Netherlands
Frank Liebisch	Agroscope	Switzerland
Evelin Loit-Harro	Estonian University of Life Sciences	Estonia
Hans-Werner Olfs	Osnabrück University of Applied Sciences	Germany
Romke Postma	Nutriënten Management Instituut NMI bv	Netherlands
Geert-Jan van Roessel	LambWeston	Netherlands
Philipp Schad	Landwirtschaftskammer Nordrhein-Westfalen	Netherlands
Daniel Simonse	WUR	Netherlands
Lex Slootweg	ICL	Netherlands
Cathy Thomas	Rothamsted Research	United Kingdom
Bart Timmermans	Louis Bolk Institute	Netherlands
Geert-Jan van der Burgt	SPNA	Netherlands
Wim van Dijk	WUR	Netherlands
Willem van Geel	WUR	Netherlands
André van Valen	Stichting IRS	Netherlands
Patrick Verstegen	VLM	Belgium
Wieke Vervuurt	WUR	Netherlands
Sven Verweij	Nutriënten Management Instituut	Netherlands
Koen Willekens	EV-ILVO Plant	Belgium
Janjo de Haan	WUR	Netherlands
Suzanne Higgins	AFBI	United Kingdom
Christine Watson	SRUC and SLU	United Kingdom
Renkse Hijbeek	WUR	Netherlands
Janus den Toonder	Louis Bolk Instituut	Netherlands
Andre Hoogendijk	BO Akkerbouw	Netherlands
Gert-Jan van Dongen	Farmer	Netherlands

Appendix 2. Sheets of keynotes, presentations and poster pitches and all posters

International Workshop

From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

EJP SOIL

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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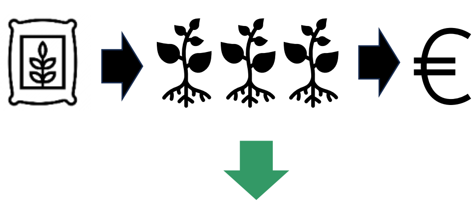
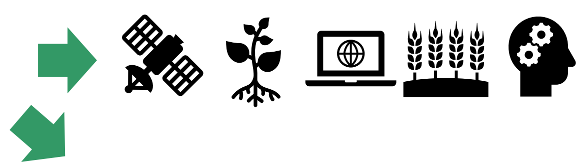
1

Background of the workshop

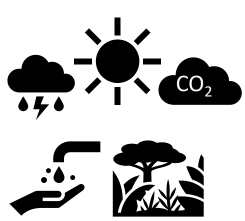
From focus on maximizing financial return to



Taking new developments into account



Incorporating societal aspects



More harmonized in Europe

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Objective and expected results of the workshop

Objectives

1. Share new developments
2. Discuss new approaches and methodologies
3. Discuss the draft methodologies as designed in the PPS BAAT

Expected results

1. Specific recommendations for methodologies in development in the PPS BAAT
2. General recommendations for more harmonized fertilizer recommendations in Europe
3. Input for a paper on the various blueprints for new integrated fertilizer recommendations

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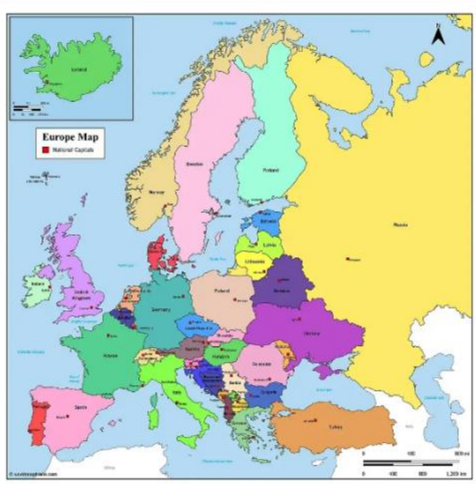
3

Harmonize fertilization advices over Europe



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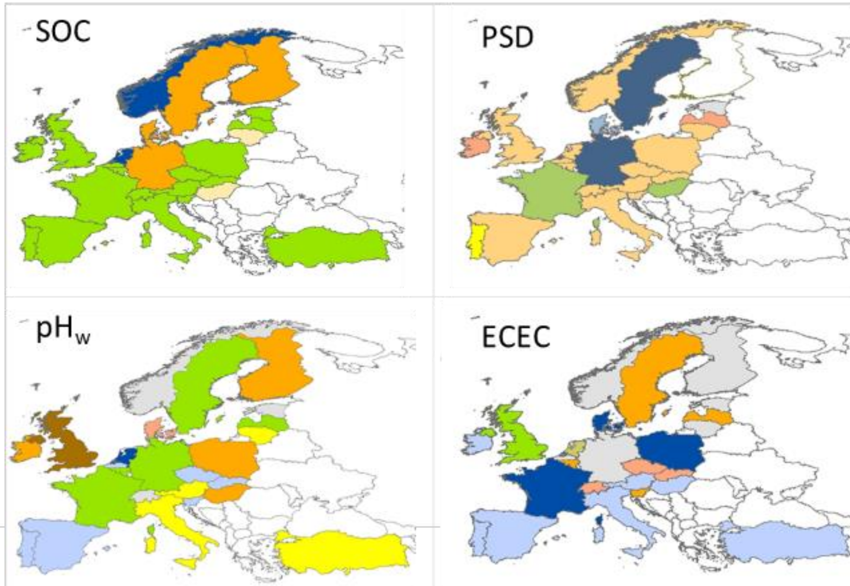
Fertilization recommendations are very different in Europe

Lab methods used per country

The same colour within a map indicates the same applied methodology:

- *SOC – soil organic carbon content;*
  PSD – particle size distribution;
- *pH_w – pH-value in water;*
- *ECEC – effective cation exchange capacity*



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European Joint Programme

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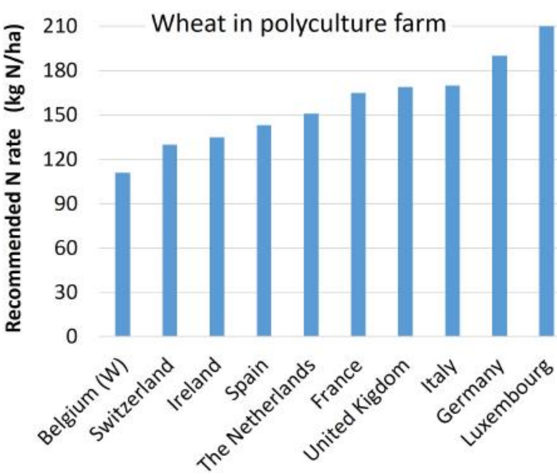
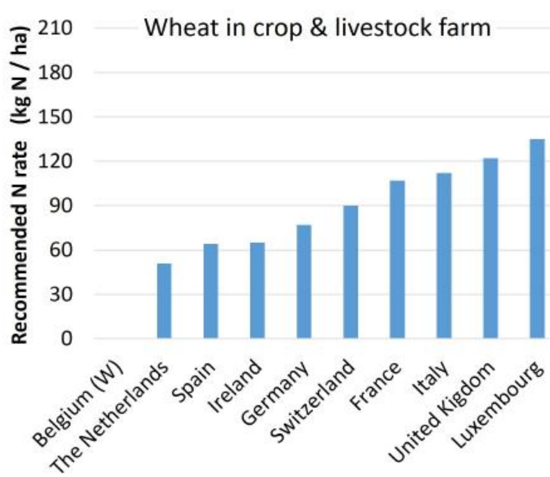
Recommended N-fertilization rates in wheat for two case studies





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based on methods of ten West European countries
Jordan-Meille et al., 2023

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Program workshop

Tuesday 16 April afternoon
Van der Valk hotel

Session 1. Setting the Scene: Current state of fertilizer recommendations in Europe and need for new recommendations

Wednesday 17 April morning
WUR Field Crops

Session 2. Integrating organic matter, nitrogen and phosphorus recommendations and Guided fertilization systems

Wednesday 17 April afternoon
WUR Field Crops

Excursion Farm of the Future
Session 3. Fertilizer recommendations for Ca, S, Mg and micronutrients and Fertilizer choice recommendations

Thursday 18 April morning
Van der Valk hotel

Session 4 Integrating fertilizer recommendations to a fertilizer plan on field and farm level

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Session set up

1. Presentations
2. Poster Pitches
3. Break/poster presentations
4. Discussion
5. Plenary wrap up

4. Discussion in 5 groups of 7-8 people
   - Facilitator & rapporteur per group
   - Discussion questions
   - Use of casestudy
5. Plenary wrap up
   - Identify key points
   - Follow up in closing session

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Practical things

- Transport Wednesday
- Transport Wednesday
- PowerPoint slides presentations and poster pitches
- Posters
- Badges

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Session 1. Setting the Scene: Current state of fertilizer recommendations in Europe and need for new recommendations

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Program session 1

Keynotes and presentations

Janjo de Haan, WUR
Fertilizer recommendations renewal in the Netherlands

Suzanne Higgins, AFBI
EJP SOIL Stocktake on harmonizing methodologies for fertilization guidelines across regions

Stefaan De Neve, Ghent University
Evaluating the performance of current N and P fertilizer advice systems in Belgium

Poster pitches

Milan Franssen, Delphy
Nutri-Check Net, current and new fertilizer recommendation systems in Europe

Renske Hijbeek, WUR
Nitrogen fertilizer replacement values of organic amendments: determination and prediction

Discussion

Introduction of the case study

Discussion

Plenary recap

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Fertilizer recommendations renewal in the Netherlands

Why PPS BAAT

Janjo de Haan

International Workshop From yield-based to society-based fertilizer recommendations

16 April 2024

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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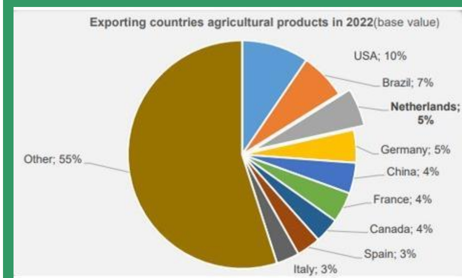
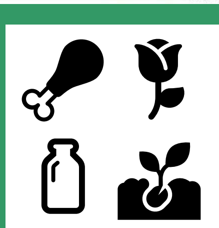
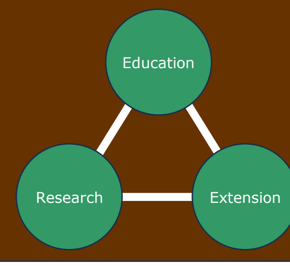
Agriculture in the Netherlands

3th largest exporter in the world

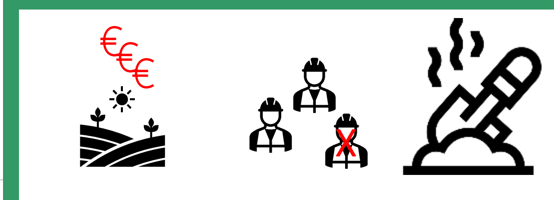




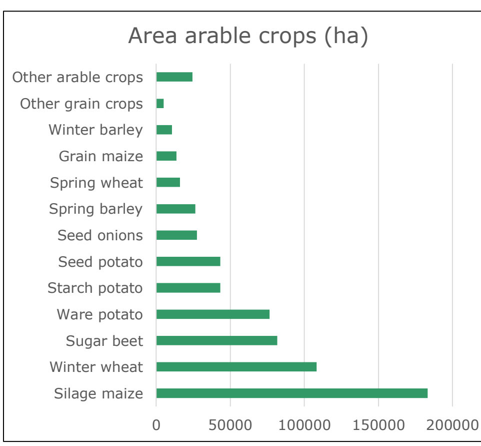
Optimal growing conditions



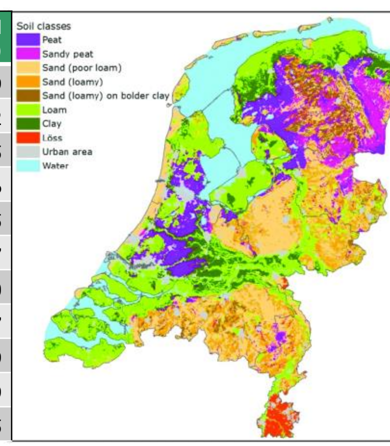
Challenges



Arable farming in the Netherlands



Crops	Gross yield (ton/ha)
Winter barley	8.9
Grain maize	12
Spring wheat	7.5
Spring barley	7.6
Seed onions	45
Seed potato	37
Starch potato	40
Ware potato	47
Sugar beet	89
Winter wheat	9.9
Silage maize	45



Total area arable crops: 660 000 ha

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The nitrogen crises

"water quality crisis much bigger than nitrogen"

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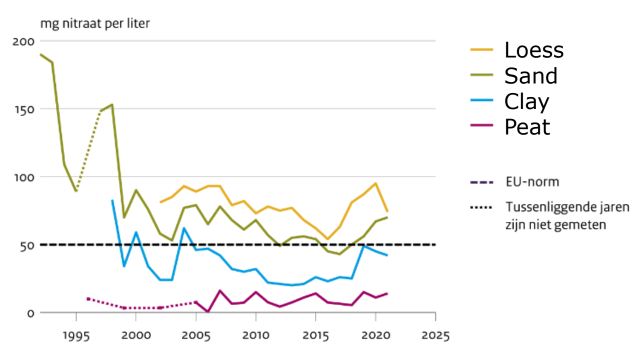
Nitrate concentrations groundwater in the Netherlands

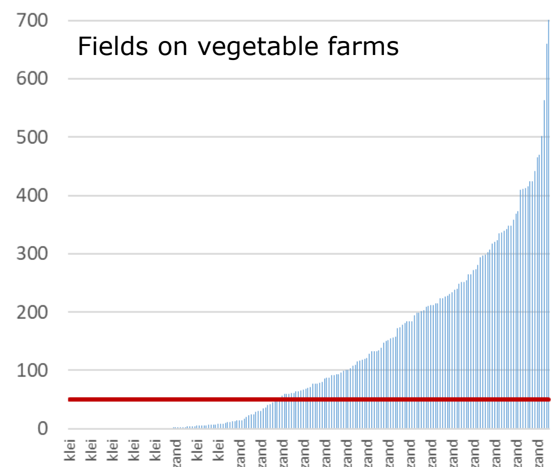
All agricultural farms



Bron: RIVM, Landelijk Meetnet effecten Mestbeleid (LMM)

www.clo.nl

Fields on vegetable farms



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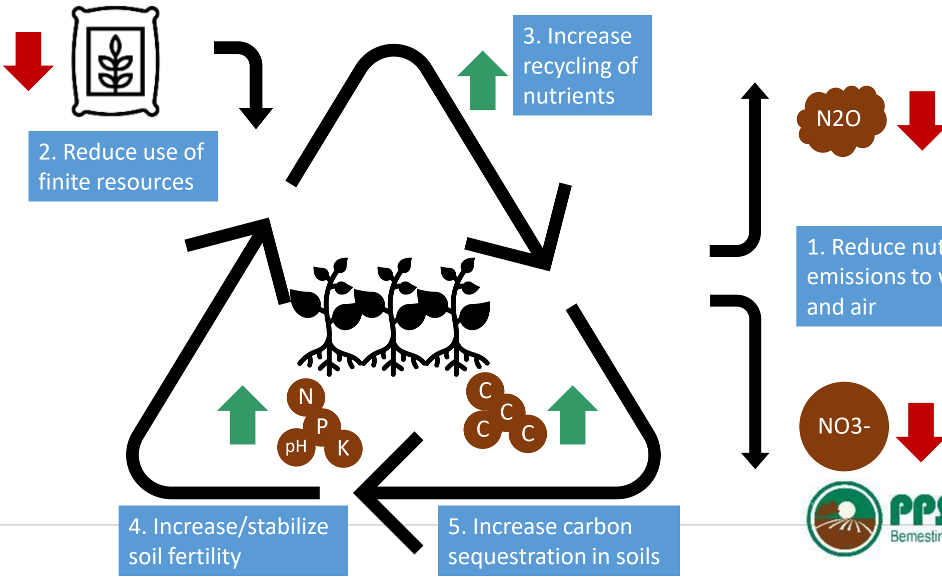
Challenges around fertilization



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Fertilization recommendations in the Netherlands

Two (active) standing committees

- Arable farming & vegetables

www.handboekbodemenbemesting.nl

- Grassland and fodder crops

www.bemestingsadvies.nl

- Independent
- Scientific based
- Researchers, advisors and farmers
- Privately financed by branch organizations
- Regular adaptations of current advices

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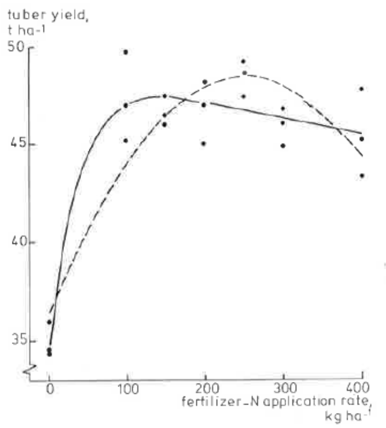
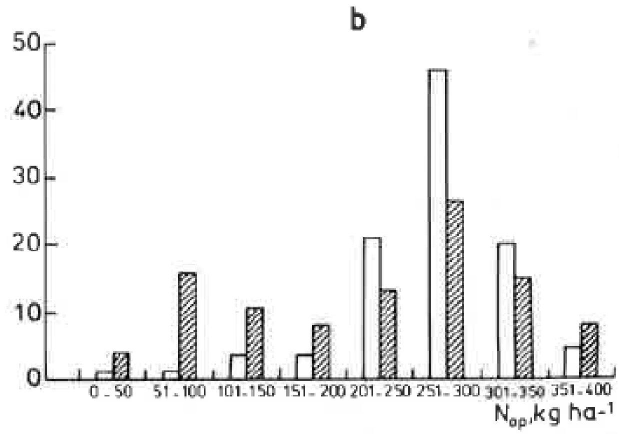
Current fertilization advice in the Netherlands is outdated





Current fertilization advice: agronomic advice per nutrient and crop

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Fertilization advice based on outdated methods

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PPS BAAT New Dutch public-private cooperation project

- 4-year project
- Consortium of 3 research organizations & 13 private parties
  - Branche organizations arable farming, compost & fertilizers
  - Fertilizer producers and retail
  - Laboratories, arable industry
- Focus on arable crops
- Budget 1.5 Meuro
  - 50-50 financed by government and private parties

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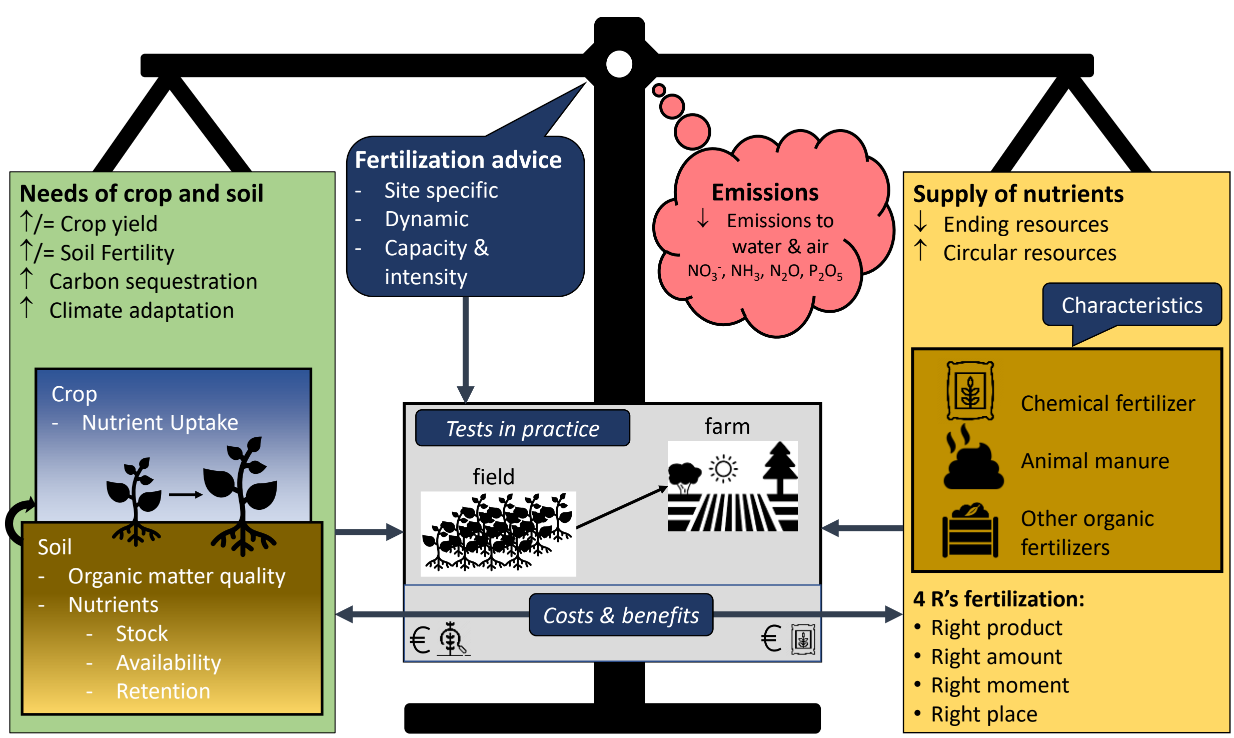

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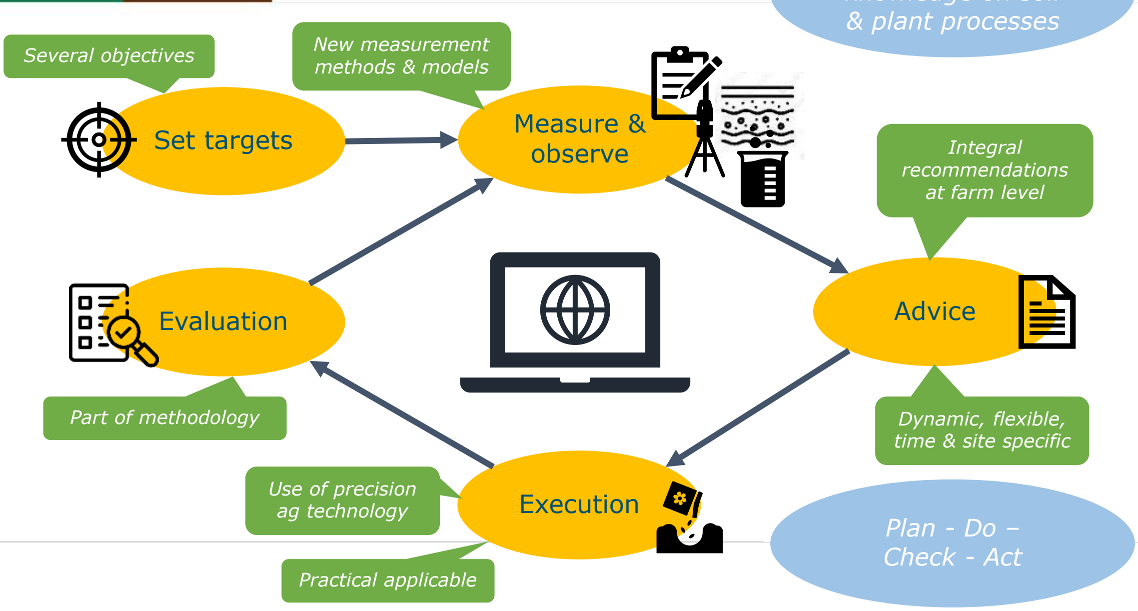
What we are developing



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Expected Results

1. Tested methodology for site specific integrated fertilization recommendations for N, P and organic matter

2. Tested methodology for dynamic (nitrogen) fertilization application within the growing season

3. New fertilization recommendations based on intensity & capacity (P, K, etc.)

4. Tested methodology for fertilizer choice based on objectives and field conditions

5. Integration of advices on field and farm level and publication of advices in the Dutch fertilization manual

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To conclude

- Big need for adapted fertilization advice with societal issues
- Fertilization advices methods differ a lot over Europe
- New knowledge and technology available but not used
- Developing new fertilization advice is needed, we started this in PPS BAAT

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From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

EJP SOIL European Joint Programme

Ministerie van Landbouw, Natuur en Voedselkwaliteit

PPS BAAT BemestingsAdviezen Akkerbouw Toekomstgericht

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International Fertiliser Workshop, 16-18 April, Lelystad, the Netherlands

EJP Soil Stocktake on harmonising methodologies for fertilisation guidelines across regions

Dr Suzanne Higgins

16 April 2024

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EJP Soil Stocktake Studies

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SURVEY ARTICLE

Stocktake study of current fertilisation recommendations across Europe and discussion towards a more harmonised approach

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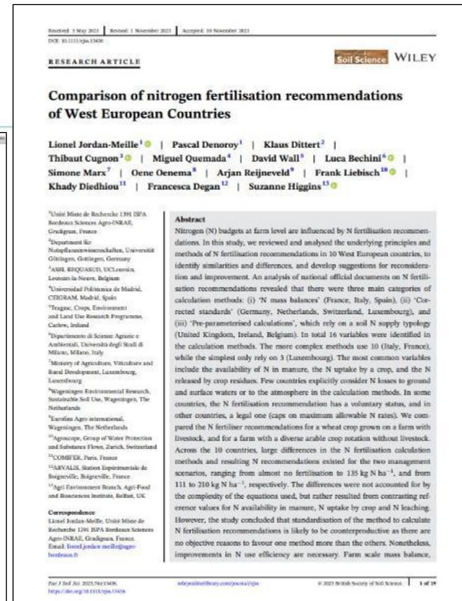
Abstract
The European Commission has set targets for a reduction in nutrient losses by at least 50% and a reduction in fertiliser use by at least 20% by 2030 while ensuring no deterioration in soil fertility. Within the mandate of the European Joint Programme EJP Soil 'Towards climate-smart sustainable management of agricultural soils', the objective of this study was to assess current fertilisation practices across Europe and discuss the potential for harmonisation of fertilisation methodologies as a strategy to reduce nutrient loss and overall fertiliser use. A stocktake study of current methods of delivering fertilisation advice took place across 23 European countries. The stocktake was in the form of a questionnaire, comprising 46 questions. Information was gathered on a large range of factors, including soil analysis methods, along with soil, crop and climatic factors taken into consideration within fertilisation calculations.

For affiliations refer to page 23


RESEARCH ARTICLE

Comparison of nitrogen fertilisation recommendations of West European Countries

Lionel Jordan-Meille[1] | Pascal Denoroy[1] | Klaus Dittert[2] | Thibaut Cugnon[3] | Miguel Quemada[4] | David Wall[5] | Luca Bechini[6] | Simone Marx[7] | Oene Oenema[8] | Arjan Reijneveld[9] | Frank Liebisch[10] | Khady Diedhiou[11] | Francesca Degan[12] | Suzanne Higgins[13]

Abstract
Nitrogen (N) budgets at farm level are influenced by N fertilisation recommendations. In this study, we reviewed and analysed the underlying principles and methods of N fertilisation recommendations in 10 West European countries, to identify similarities and differences, and develop suggestions for reconsideration and improvement. An analysis of national official documents on N fertilisation recommendations revealed that there were three main categories of calculation methods: (i) 'N mass balances' (France, Italy, Spain), (ii) 'Corrected standards' (Germany, Netherlands, Switzerland, Luxembourg), and (iii) 'Pre-parameterised calculations', which rely on a soil N supply typology (United Kingdom, Ireland, Belgium). In total 16 variables were identified in the calculation methods. The more complex methods use 10 (Italy, France), while the simplest only rely on 3 (Luxembourg). The most common variables include the availability of N in manure, the N uptake by a crop, and the N released by crop residues. Few countries explicitly consider N losses to ground and surface waters or to the atmosphere in the calculation methods. In some countries, the N fertilisation recommendation has a voluntary status, and in other countries, a legal one (caps on maximum allowable N rates). We compared the N fertiliser recommendations for a wheat crop grown on a farm with livestock, and for a farm with a diverse arable crop rotation without livestock. Across the 10 countries, large differences in the N fertilisation calculation methods and resulting N recommendations existed for the two management scenarios, ranging from almost no fertilisation to 135 kg N ha^{-1}, and from 111 to 210 kg N ha^{-1}, respectively. The differences were not accounted for by the complexity of the equations used, but rather resulted from contrasting reference values for N availability in manure, N uptake by crop and N leaching. However, the study concluded that standardisation of the method to calculate N fertilisation recommendations is likely to be counterproductive as there are no objective reasons to favour one method more than the others. Nonetheless, improvements in N use efficiency are necessary. Farm scale mass balance,

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EJP Soil Project

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European Joint Programme

- 24 countries, 26 partners
- 2020 – 2025
- To foster climate-smart sustainable agricultural soil management
- Creation to a roadmap to meet key SDGs
- Wide range of sub-projects and tasks

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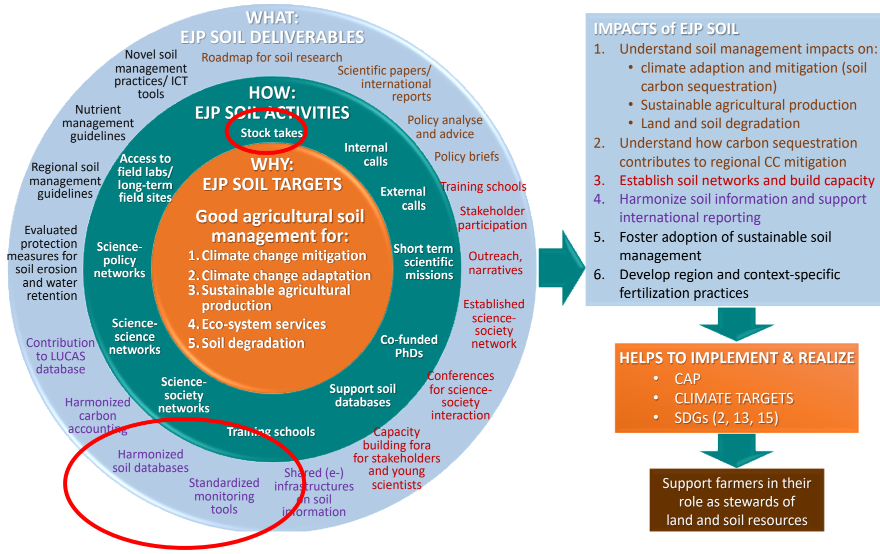
EJP Soil overview and impact

Stocktakes of key soil management practices

Harmonised soil databases
Standardised soil monitoring tools



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Fertiliser Recommendations

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- Based on agronomic requirements, specific to soil and crop type, generated individually within each country.
- To reach or maintain target ranges of plant-available nutrients in soil, to achieve target yields
- The basis of good practice should be to make the best economic use of nutrients while at the same time meeting environmental legislation

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Do we need to harmonise fertilisation guidelines?

- Harmonisation and standardisation of soil monitoring allows comparative baseline data to be collected and allows monitoring of change over time.

Is this the same for fertilisation practices?

- Need to increase nutrient use efficiency on farms
- Need to be accountable for the management of land
- Apply only the nutrients we need and where needed
- Requires data collection
- Can't manage what we don't know

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Differences in Fertiliser Recommendations

- Recognised for many years that differences in fertiliser recommendations exist between countries
- Also differences in methods for tackling nutrient loss
- Improving fertilisation techniques to better match nutrient supply with crop demand would improve overall nutrient use efficiency
- Differences in soil tests and fertilisation guidelines can operate within close proximity e.g. neighbouring countries or regions separated by a land border. Issues for farmers living in border areas
- Management of nutrients where there are shared water bodies or trans-boundary air pollution

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Objectives of Study

- To gather information on how fertilisation guidelines are currently formulated and managed and assess potential for harmonising methods between neighbouring countries and across regions.
- **Objective 1:** To complete a stocktake of current fertiliser guidelines across European countries
- **Objective 2:** To identify the key variables influencing fertiliser guidelines e.g. climate, soil, cropping systems, nutrient loss
- **Objective 3:** To identify synergies, similarities and differences in fertilisation guidelines between neighbouring countries

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Objectives of Study

- **Objective 4:** To assess the potential for harmonisation of methodologies and barriers to harmonisation
- **Objective 5:** To identify the stakeholders involved in formulating fertilisation guidelines within individual countries
- **Objective 6:** To evaluate the importance of knowledge transfer and community engagement.

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Participant Number	EJP Partner	Country	Q1. What environmental zone is your country in?	Q2. What are the main crops grown in your country?	Q3. cou
Sub-Objective 2: Identify key variables in directing these guidelines e.g. climatic, soil, cropping system, nutrient loss					
1	Institut National de la recherche Agronomique (INRA)	FR			
2	Wageningen Research (WR)	NL			
3	BIOS Science Austria	AT			
4	Flanders Research Institute for Agriculture, Fisheries and Food (EV-IL VO)	BE			
5	Centre Wallon de Recherches Agronomiques (CRAW)	BE			

Participant Number	EJP Partner	Country	Q1. Do you feel that fertilization guidelines should be harmonized between neighbouring countries? This implies discussions between countries on common practice and sharing of knowledge	Q2. Should there be a central fertilization management?
Sub-Objective 4: Assess the potential for harmonization of methodologies and barriers to harmonization				
1	Institut National de la recherche Agronomique (INRA)	FR		
2	Wageningen Research (WR)	NL		
3	BIOS Science Austria	AT		
4	Flanders Research Institute for Agriculture, Fisheries and Food (EV-IL VO)	BE		
5	Centre Wallon de Recherches Agronomiques (CRAW)	BE		
6	Czech University of Life Sciences (CULS)	CZ		
7	Aarhus University, Danish Centre for Food and Agriculture (AU)	DK		
8	Estonian University of Life Sciences (EMU)	EE		
9	National Resources Institute of Finland (LUKE)	FI		
10	Johann Heinrich von Thunen-Institut (Thuenen)	DE		
11	Forschungszentrum Julich (Julich)	DE		
12	Centre for Agricultural Research of the Hungarian Academy of Sciences (MTA ATK)	HU		
13	Teagasc (Teagasc)	IE		
14	Council for Agricultural Research and Economics (CREA)	IT		
15	University of Latvia (UL)	LV		
16	Lithuanian Research Centre for Agriculture and Forestry (LAMMC)	LT		
17	Norwegian Institute of Bioeconomy Research (NIBIO)	NO		
18	Institute of Soil Science and Plant Cultivation - State Research Institute (IUNG)	PL		
19	National Institute for Agrarian and Veterinarian Research I.P. (INIAV)	PT		
20	National Agricultural and Food Centre (NPPC)	SK		
21	University of Ljubljana, Biotechnical Faculty, Centre for Soil and Environmental Science (ULBF)	SI		
22	National Institute for Agriculture and Food Research and Technology (INIA)	SP		
23	Swedish University of Agricultural Sciences (SLU)	SE		

Sub-Objective 1 | Sub-Objective 2 | Sub-Objective 3 | Sub-Objective 4 | Sub-Objective 5

Ready | Accessibility: Good to go | 100%

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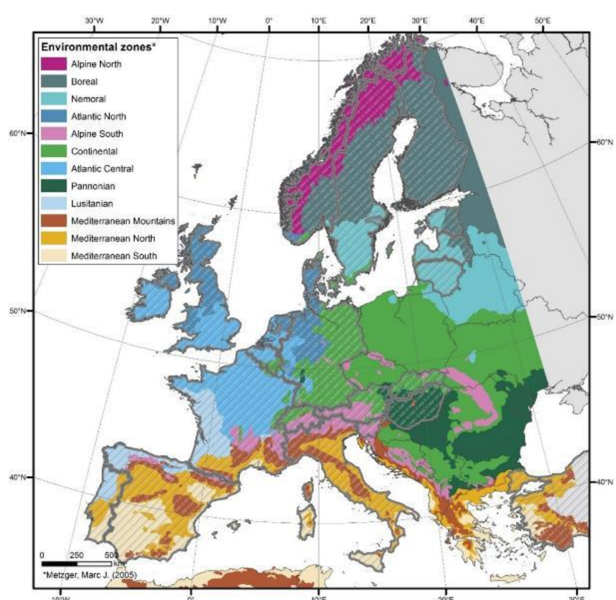
Participating Countries

- Austria
- Belgium (Flanders)
- Belgium (Wallonia)
- Denmark
- Estonia
- Finland
- France
- Germany
- Hungary
- Ireland
- Italy
- Latvia
- Lithuania
- Netherlands
- Norway
- Poland
- Portugal
- Slovakia
- Slovenia
- Spain
- Sweden
- Switzerland
- Turkey
- United Kingdom



Environmental zones according to Metzger et al. 2005

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Results

- Results presented reflect the questionnaire responses, and as such are dependent, in part, on the knowledge and experience of the individual who completed the questionnaire.
- Description of main organisations involved in formulating fertilisation guidelines per participating country
- 83% of countries have a designated committee responsible for fertilisation guidelines e.g. government, research organisations, public authorities, universities, farmer organisations. Small number of countries – government advisory services, universities or research organisations

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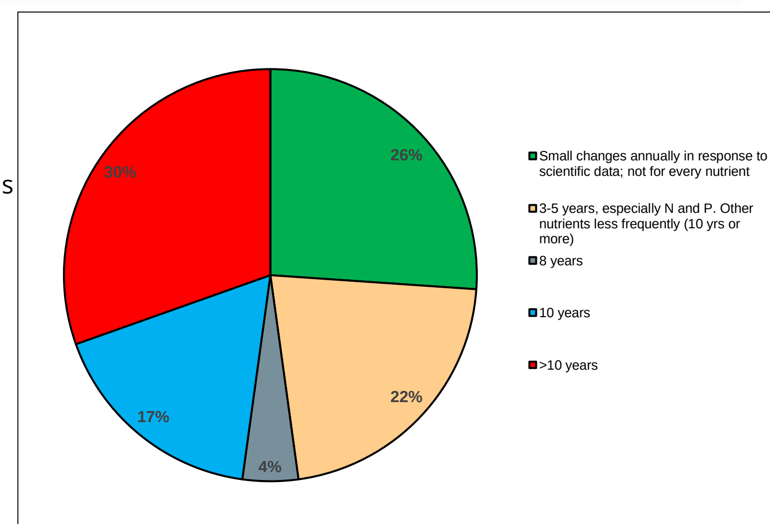
Frequency of updates to fertilisation guidelines

- 1/3 of countries had over 10 years between updates
- Small, regular updates to some nutrients, in response to new scientific data or agronomic trials (France, Netherlands, UK, Austria, Italy, Poland, Sweden)
- > 10 years Estonia, Hungary, Latvia, Lithuania



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Soil P Tests

16 soil P tests identified

In some countries, more than one test for P is used within the same country

Most frequently used is Olsen P (sodium bicarbonate) and Egner-Riehm method (ammonium lactate).

Table 3: *List of plant available soil phosphorus chemical extractant methods recorded by participating countries.*

	Austria	BE (Flanders)	Denmark	Estonia	Finland	France	Germany	Hungary	Ireland	Italy	Latvia	Lithuania	Netherlands	Norway	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	Turkey	UK
0.5 M sodium bicarbonate pH 8.5 (Olsen et *al.*, 1954)			X		X	X				X						X			X			X	X
0.1 M ammonium lactate 0.4 N acetic acid, pH 3.75 (Egner et *al.*, 1960)		X						X			X	X	X	X	X	X		X		X			
Remoisture of soil 1-2 mL soil + 2 mL water (Sissingh, 1971)													X										
0.05 M calcium acetate + calcium lactate +0.05 M + 0.3 M acetic acid pH 4.1 (Schüller, 1969)	X						X						X										
0.015 M ammonium fluoride + 0.2 M acetic acid + 0.025 M ammonium nitrate + 0.013 M niric acid, pH 2.5 (Mehlich, 1984)				X						X							X						
Sodium acetate acetic acid, pH 4.8 (Morgan's 1941) *									X														
0.03 M ammonium fluoride + 0.025 M hydrochloric acid (Bray and Kurtz, 1945										X												X	
1:5 citric acid 2% (Dyer, 1894)						X															X		
0.2 M ammonium oxalate (Joret and Hebert, 1955						X																	
1:2.5, water saturated in CO_2 (Dirks and Scheffer, 1930)													X								X		
0.5 M ammonium acetate + EDTA 0.02 M pH 4.65 (Van den Hende and Cottenie, 1960)																					X		

* Modified Morgan's method used in parts of Scotland (0.5 M ammonium acetate/acetic acid adjusted to pH 4.5) (*MISR/SAC. 1985*).

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K, Mg, Ca

Ammonium acetate
&
Ammonium lactate

Variations in methodology & method descriptions

Table 5: *Methods of measuring plant available K, Mg, Ca in soil across participating countries.*

	Austria	BE (Flanders)	Denmark	Estonia	Finland	France	Germany	Hungary	Ireland	Italy	Latvia	Lithuania	Netherlands	Norway	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland *	Turkey	UK
Ammonium acetate	X		X		X	X				X	X					X		X	X		X	X	X
Ammonium lactate (Egner-Riehm)		X						X			X	X		X		X		X	X	X			
Sodium acetate						X																	
Hydrochloric acid and oxalic acid)													X										
0.01M $CaCl_2$							X						X								X		
Cobalt-hexamine combined with NIRS													X										
Mehlich-3				X						X							X						
Morgan's									X														
Calcium acetate lactate (Schüller)	X																						

* K: CO_2-saturated water; 1:10 water, Ammonium acetate – EDTA.
Mg: $CaCl_2$; 1:10 water; Ammonium acetate – EDTA.
Ca: Ammonium acetate – EDTA.

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Nitrogen

Not usually measured in routine soil analysis in many countries but often classified via soil type, previous crop, management & rainfall, target yields & source of N (mineral or organic) (UK)

Table 6: *Methods of measuring soil nitrogen in participating countries.*

	Austria	BE (Flanders)	Denmark	Estonia	Finland	France	Germany	Hungary	Ireland	Italy	Latvia	Lithuania	Netherlands	Norway	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	Turkey	UK
Total N by Dry combustion (NF ISO 13878)			X			X			X	X	X		X						X				X
Total N by Kjeldahl (NF ISO 112261)						X				X	X	X				X	X		X			X	X
Potentially mineralisable N by ÖNORM L 1204	X																						
Mineral N (N_{min}) by 1M or 2M KCl extraction		X	X					X	X	X		X				X			X			X	X
Mineral N (Nmin) by $CaCl_2$ extraction							X											X			X		
Not measured in routine analysis				X					X				X	X						X			X
No information provided					X																		

Sweden: Plant available N frequently estimated via handheld optical sensors. Yara N sensor is widely used to quantify real-time crop N availability

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Nitrogen

- Underlying principles and methods of N fertilisation recommendations across 10 West European countries
- Three main categories of calculation methods:
- '**N mass balance**' (France, Italy, Spain)
- ' **Corrected standards**' (Germany, Netherlands, Switzerland, Luxembourg)
- '**Pre-parameterised calculations**', which rely on a soil N supply typology (UK, Ireland, Belgium)

- The most complex calculations included 10 variables (Italy, France)
- The simplest relies on 3 variables (Luxembourg).
- Most common variables – N in manure, N uptake by a crop, N released by crop residues.

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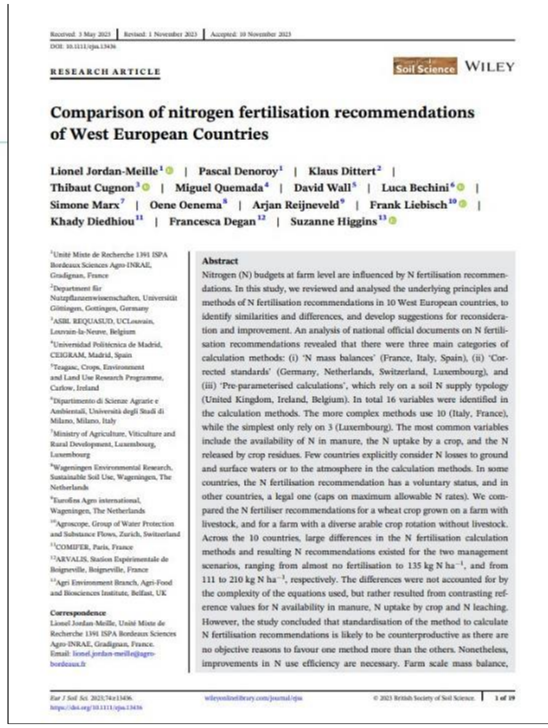
Nitrogen

- Few countries consider N loss to water and atmosphere in calculations
- Some countries but not all, are bound by legal status i.e. NVZs
- Comparison of N recommendations for:
  - Wheat crop on a farm with livestock
    0 to 135 kg N ha-1
  - Arable rotation without livestock
    111 to 210 kg N ha-1

Differences not accounted for by complexity of calculation but by contrasting reference values for N availability in manure, N uptake by crop, and N leaching.

No objective reason to prefer one method over another.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Synergies, Similarities & Differences

- **Common across all countries:**
  - Soil analysis
  - Identification of nutritional needs of crops
  - Interpretation of soil test results
  - Formation of fertilisation plan

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Synergies, Similarities & Differences

- **Differences between countries:**
  - ➢ Methods of communication with stakeholders (farm advisors)
  - ➢ Detail included in fertilisation guidelines (complex to simplified)
  - ➢ Most European countries allocate soil analyses to 4 – 6 classes (low to high)
  - ➢ Presentation to farmers (booklet, manual, app, calculator)

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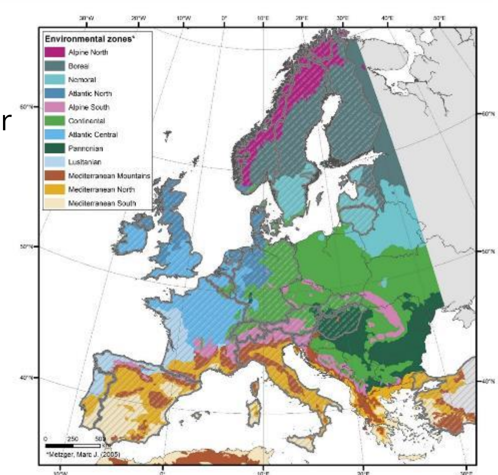
Synergies, Similarities & Differences

- **Awareness of Differences:**
  - ➢ Some countries are familiar with how neighbouring countries formulate their fertiliser guidelines
  - ➢ Many are unaware
  - ➢ Lack of shared information available?
  - ➢ No common European approach
  - ➢ Or unknown to the person completing the questionnaire?



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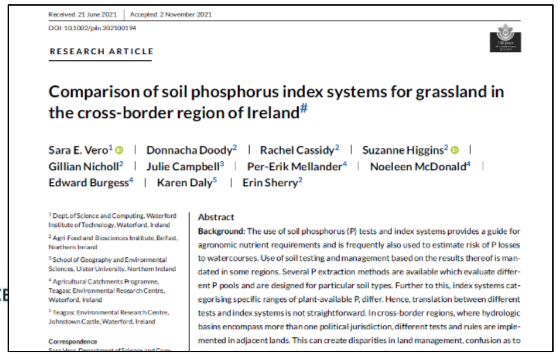
Differences across land borders

- **Examples:**
- **Ireland:** Olsen P test used in Northern Ireland & Morgan's P in Republic of Ireland
- Implications for farmers in cross border regions and implications for shared water bodies in border areas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RESEARCH ARTICLE

Comparison of soil phosphorus index systems for grassland in the cross-border region of Ireland#

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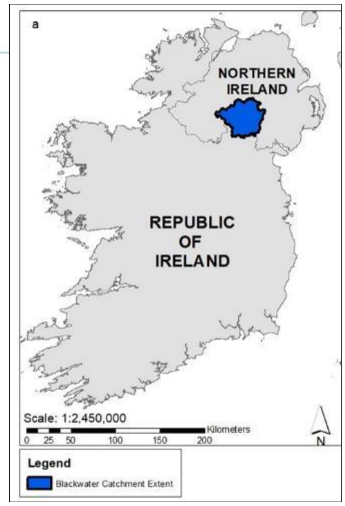
Correspondence

Abstract
Background: The use of soil phosphorus (P) tests and index systems provides a guide for agronomic nutrient requirements and is frequently also used to estimate risk of P losses to watercourses. Use of soil testing and management based on the results thereof is mandated in some regions. Several P extraction methods are available which evaluate different P pools and are designed for particular soil types. Further to this, index systems categorising specific ranges of plant-available P, differ. Hence, translation between different tests and index systems is not straightforward. In cross-border regions, where hydrologic basins encompass more than one political jurisdiction, different tests and rules are implemented in adjacent lands. This can create disparities in land management, confusion as to

Vero et al. 2021



Hayes et al. 2022

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Harmonisation

- Overall support for some kind of harmonisation or standardisation of fertilisation guidelines between neighbouring countries
- Should only be where soil type, growing conditions, crop rotations and yields are comparable
- Climate has huge influence on nutrient cycling and nutrient availability .... Influence on fertilisation requirements

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Harmonisation and Standardisation

- **Standardisation**: Describing data in the same way - agreed definitions, structure and format. Should there be a standardised approach across Europe?

- **Harmonisation**: Translating data to the same units, lab methods, definitions etc. Example of carbon

- Shared indicators of N & P surplus and legacy fertilisation
- Shared indicators of impact of fertilisation
- Harmonisation and alignment of fertilisation guidelines between neighbouring countries and regions will be difficult, if not impossible. Evaluation on case-by-case basis
- Sharing of knowledge may be more important

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Precision Fertilisation

- According to the questionnaire responses, the % of farmers implementing precision technology is quite low, and varies between technologies.
- However, uptake of variable rate fertilisation is increasing, and more decision support tools are now available.
- France & Germany report some of the highest uptake rates
- In the Netherlands approx. 15% of farmers now use satellite imagery, soil scans and variable rate fertiliser applications, and 17% in Switzerland
- In Sweden and Denmark a free of charge platform 'CropSAT' is being widely used.

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Precision Fertilisation

- All of the countries surveyed considered that precision fertilisation using soil and crop sensors is important in future farming

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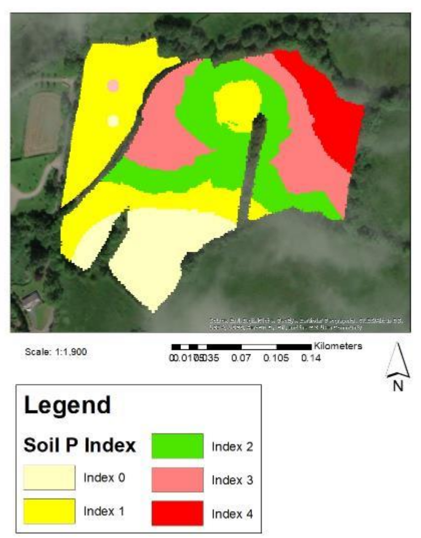
Precision Fertilisation

- Hotspots of nutrients within fields can result in increased GHG emissions or P loss to waterways
- Only apply the nutrients required, and in the correct amounts
- Cowan *et al.* (2021) Up to 20% savings can be made by not applying N where unnecessary to do so



Hayes et al. 2021

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Considerations for harmonisation

- Methods used to formulate fertilisation recommendations
- The way we sample soils
- Laboratory extraction methods
- Factors accounted for e.g. previous crop, management history, manure inputs
- Carbon – set method to measure

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Stocktake of current fertilisation methodologies across Europe

CONTEXT
The European Commission has set targets to:

- Reduce nutrient losses by at least 50% and
- Reduce fertiliser use by at least 20% **by 2030**
- While ensuring no deterioration in soil fertility

OBJECTIVE

- To assess fertilisation practices across Europe and discuss harmonisation of methodologies

METHODS

- A stocktake study of current fertilisation guidelines across 23 European countries took place

RESULTS

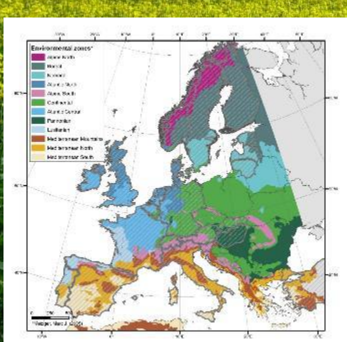
- There are differences in fertilisation guidelines operating between neighbouring countries, even within the same environmental zone

BARRIERS TO HARMONISATION

- Guidelines need to be specific to soil and climatic variables and there are significant agro-ecosystem differences across Europe

POTENTIAL BENEFITS OF HARMONISATION

- Shared learning in best practice
- Collective approach to tackling environmental concerns



SIGNIFICANCE: This data analysis across 23 European countries provides a baseline from which scientific solutions can be developed to deliver EU policy targets for fertiliser use, nutrient loss and soil fertility

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Conclusions

- Careful consideration is required in terms of what can be harmonised / standardised and the limits of this
- Will take time
- A centralised European approach will have advantages and disadvantages and may be impossible
- Discussions in how we measure, map and monitor soil nutrients and crop growth is advancing all the time. Precision farming, AI, high powered computing will all facilitate improved monitoring of soil and crop in future

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International Workshop

From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

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International Workshop: From yield-based to society-based fertilizer recommendations
16-18 April Lelystad the Netherlands

Evaluating the performance of current N and P fertilizer advice systems in Belgium

Stefaan De Neve, Steven Sleutel, Nick Krekelbergh, Orly Mendoza

Department Environment, Ghent University, Belgium

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1. Nutrients and water quality in the North of Belgium

2. Results of in-depth analysis of N and P fertilizer recommendations

3. Lessons learned and next steps

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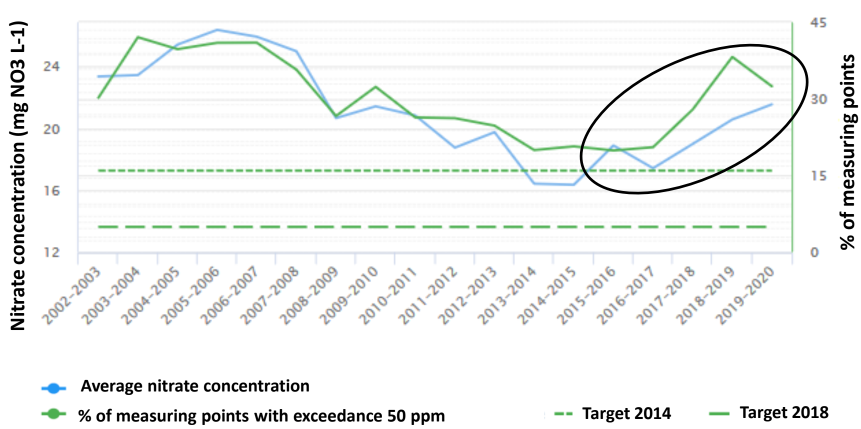
1. Nutrients and water quality in the North of Belgium (Flanders)

Nitrate in surface water in agricultural areas, Flanders, 2002-2020



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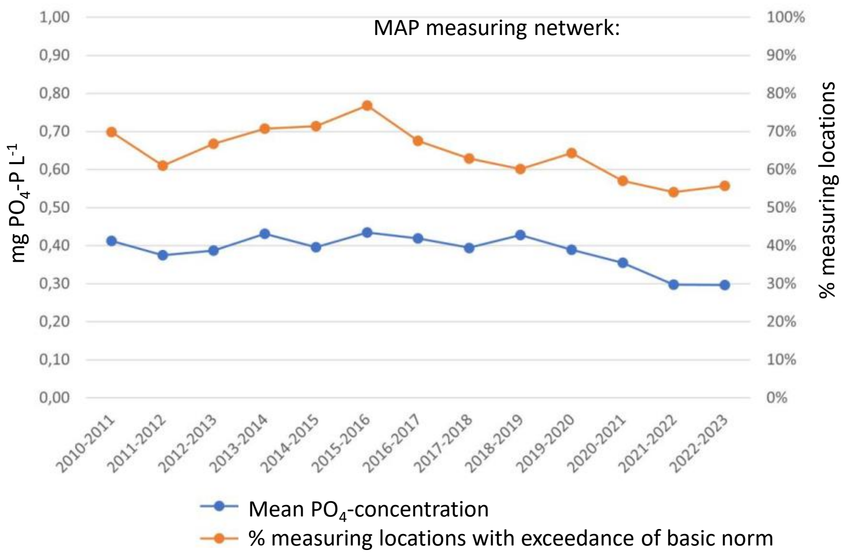
1. Nutrients and water quality in the North of Belgium (Flanders)



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1. Nutrients and water quality in the North of Belgium (Flanders)

Conclusions:

- Water quality with respect to nutrients not improving (enough), despite decades of action plans
- Role/potential of existing N and P fertilizer advice systems?

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2. Results of in-depth analysis of N and P fertilizer recommendations

Project commissioned by VLM to benchmark existing advice systems:

- In-depth analysis of advice systems
- Comparison of advices for range of real field situations
- Identification of bottlenecks and suggestions for improvements

2. Results of in-depth analysis of N and P fertilizer recommendations
2.1. Inventory of existing systems in Belgium

Following (Belgian) fertilizer advice services were addressed:

- Proefcentrum voor de Groenteteelt vzw (PCG);
- Proefstation voor de Groenteteelt vzw (PSKW);
- Bodemkundige Dienst van België (BDB);
- Inagro;
- Agrolab;
- Landbouwcentrum Granen Vlaanderen vzw (LCG);
- Koninklijk Belgisch Instituut tot Verbetering van de Biet vzw (KBIVB);
- UGent campus Bottelare

Response ≈ 0

From previous knowledge: most use a type of N balance approach

2. Results of in-depth analysis of N and P fertilizer recommendations

Rationale: Comparison of N and P fertilizer recommendations on a variety of fields and crops

- ➢ Ask for N and P fertilizer advice for a specific crop on each field
- ➢ Based on soil analysis by the individual labs
- ➢ Analysis and comparison:
  - response or not?
  - additional data requested from farmer?
  - magnitude of N and P fertilizer advice
  - time between request for N and P fertilizer advice, and reception of the actual advice?
  - Comparison to detailed N balance by consortium
  - Comparison to Demeter tool

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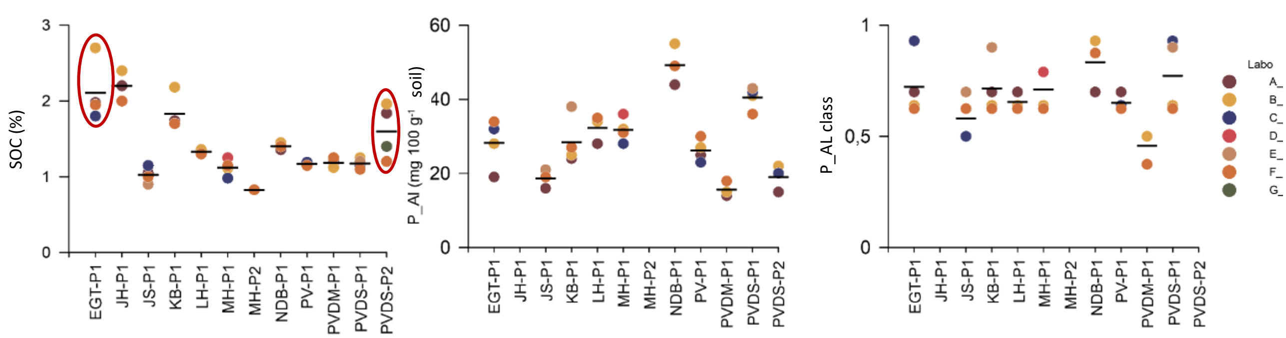
2. Results of in-depth analysis of N and P fertilizer recommendations

2.2. How do soil analyses of the same field compare between labs?



- SOC: mean CV: 8%, in agreement with expected variation, with outliers
- P-AL: mean CV: 13%, in agreement with expected variation, with outliers
- Interpretation P-AL (classes): suprisingly large differences

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2. Results of in-depth analysis of N and P fertilizer recommendations
2.3. How do N fertilizer advices of the same field-crop combination compare?

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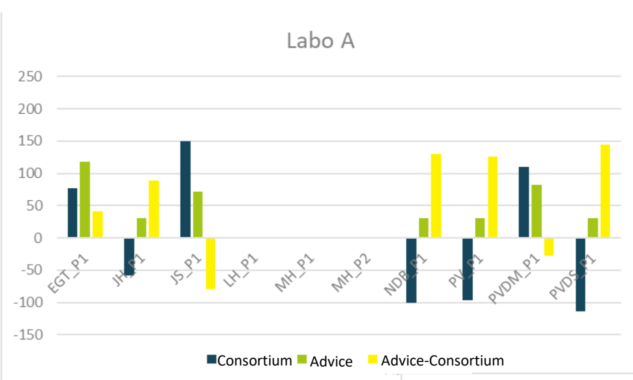
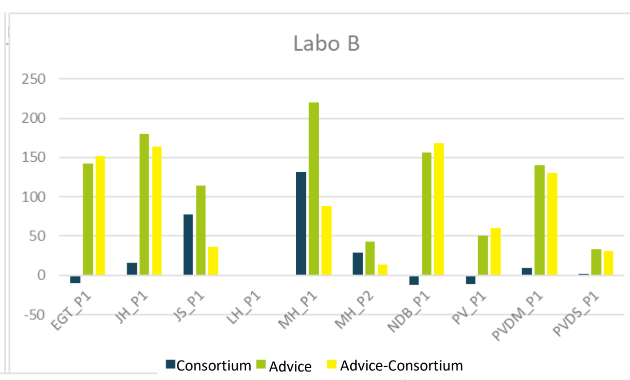
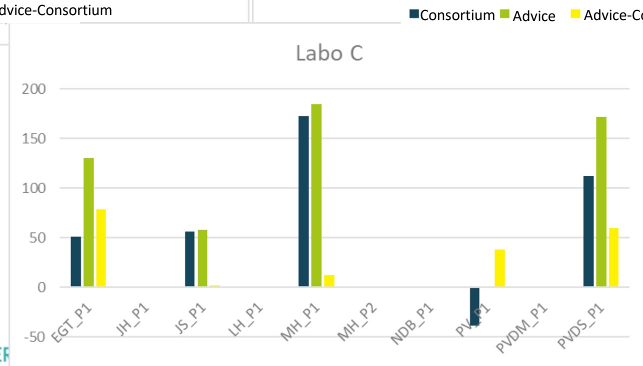




- Consortium: calculated by the project consortium based on detailed N balance
- Advice: advice received from the specific lab



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2. Results of in-depth analysis of N and P fertilizer recommendations

2.3. How do N fertilizer advices of the same field-crop combination compare?

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2. Results of in-depth analysis of N and P fertilizer recommendations

2.3. How do N fertilizer advices of the same field-crop combination compare?

Comparison to calculations based on Demeter tool (De)

Field / Labo	EGT_P1 Lab	EGT_P1 De	EGT_P1 Δ	JH_P1 Lab	JH_P1 De	JH_P1 Δ	JS_P1 Lab	JS_P1 De	JS_P1 Δ	LH_P1 Lab	LH_P1 De	LH_P1 Δ	MH_P1 Lab	MH_P1 De	MH_P1 Δ	NDB_P1 Lab	NDB_P1 De	NDB_P1 Δ	…	Mean
A	118	-28	**146**	30	-40	**70**	71	129	*-58*							30	-24	**54**		**43**
B	142	-60	**202**	100	59	**41**				114	-24	**138**	220	156	**64**	156	69	**87**		**100**
C	130	-45	**175**				58	44	**14**				185	185	0				…	**56**
D													170	171	*-1*					
E							0	-20	**20**											**82**
G																				*-46*

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2. Results of in-depth analysis of N and P fertilizer recommendations

2.4. How do P fertilizer advices of the same field-crop combination compare?

General principle:

at optimum soil P status (assessed with P-AL): P fertilizer = P removal by harvested crop parts

What is optimum P status?

Table 5 Detailed description of calibration methods for soil-P tests (used in Step 2 of soil-P recommendations). Crop and soil factors used in calibrations are given. The values presented refer to wheat cultivated on a loamy soil, pH 6.5

Jordan-Meille et al. 2013

Country	Soil P Test	Other parameters taken into account: Soil	Other parameters taken into account: Crop 'sensitivity'	P fertility categories, as a function of soil-P Test values (mg/kg): Very low	Medium	Excessive
Belgium (Flanders)	AL		2 classes	< 50	120–180	> 500
Hungary	AL	Texture, pH, carbonates	2 classes	< 30	61–100	> 161
Lithuania	AL	Texture and pH		< 21	45–66	> 88
Norway	AL			< 50	50–70	> 140
Slovenia	AL			< 26	53–109	> 175
Sweden	AL		3 classes	< 20	40–80	> 160
Denmark			3 classes	< 20	20–40	> 60

Is Belgium from a different planet?

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2. Results of in-depth analysis of N and P fertilizer recommendations

2.4. How do P fertilizer advices of the same field-crop combination compare?

Reported P-AL contents, P class, P fertilizer advice for the subsequent crop, and expected P fertilizer advice (kg P_2O_5 ha^{-1})

Lab	A				B				C			
Field	P-AL	Class	P-advice	expected P-advice		Class	P-advice	expected P-advice		Class	P-advice	expected P-advice
EGT_P1	19	High	30	0	28	rather high	50	0	32	7	60	0
JH_P1					45	rather high	30	0				
JS_P1	16	optimum	96	20					19	4	100	0
KB_P1	24	high	30	0	25	rather high	*60	0				
LH_P1	28	high	40	0	34	rather high	40	0				
MH_P1					32	rather high	60	0	28	6	70	0
NDB_P1	44	high	48	0	55	very high	0	0				
PV_P1	25	high	30	0	27	rather high	50	0	23	5	70	0
PVDM_P1	14	optimum	100	45	15	normal	110	30				
PVDS_P1					41	rather high	30	0	42	7	50	0
PVDS_P2	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NB	0

These P advices will inevitably lead to further P accumulation in the soil with undesirable environmental effects.

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3. Lessons learned and next steps
3.1. Agronomic and environmental implications

Agronomic

P fertilization:

- urgent need for updating (reducing!!) target values, and its implementation (e.g. no effect of 0 P fertilization during 7 years, De Neve et al. 2022)

N fertilization:

- mean deviation per field 'advisors - Demeter': -15 to +130 kg N ha^{-1}
- mean over all fields: +57 kg N ha^{-1}: ample space for agronomically meaningful reductions

3. Lessons learned and next steps
3.1. Agronomic and environmental implications

Environmental

P fertilization: much delayed mining of P saturated soils

Table: Differences in mean P advices between advisory bodies and advice that would be expected based on newly agreed P classes proposed by VLM

Lab		A	B	C	D	E	F
Advice	(kg P_2O_5 ha^{-1})	53	50	70	40	0	37
Expected advice	(kg P_2O_5 ha^{-1})	9	3	0	0	0	0
Advice - Expected	(kg P_2O_5 ha^{-1})	44	47	70	40	0	37

3. Lessons learned and next steps
3.1. Agronomic and environmental implications

Environmental

N fertilization:

Average higher N fertilization of 57 kg N ha^{-1} : increased losses by N leaching, e.g.

i) assume 60% is leached below rooting zone, 250 mm drainage yearly:

→ increase of NO_3^--N -concentration of 13.6 mg NO_3^--N L^{-1} in leachate

ii) assume median "attenuation factor" in Flanders of 5.3 (D'Haene et al. 2022):

→ NO_3^--N concentration in surface water increases by 2.6 mg NO_3^--N L^{-1}, or 11.4 mg NO_3^- L^{-1}

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3. Lessons learned and next steps
3.2. Policy advice

- All N fertilizer advice systems should use a detailed N balance approach
- Central commission for agreed and updated parameter values
- More support for farmers to interpret, implement and monitor fertilizer advices
- Impact of climate change on water quality (less effective nutrient uptake, changing mineralization patterns, more/less dilution/leaching)
- Supplement NO_3^--N residue analyses with reference fields and field N balance calculations

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3. Lessons learned and next steps

3.3. Next steps

- VLM has picked this up and is working on it
- All advisory services are working on a proposal for harmonization, under supervision of VLM, with our scientific involvement

Thanks for your attention!

https://www.vlm.be/nl/themas/waterkwaliteit/Mestbank/Achtergrond/cijfers-en-studies/afgeronde_studies/code_goede_bemestingsadviezen/Paginas/default.aspx

International Workshop

From yield-based to society-based fertilizer recommendations

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Posterpitch

Milan Franssen, Delphy

Nutri-Check Net, current and new fertilizer recommendation systems in Europe

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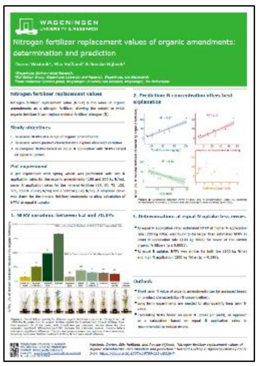
Nitrogen Fertilizer Replacement Values of organic amendments: Determination and prediction

Renske Hijbeek, Ellis Hoffland & Dorien Westerik



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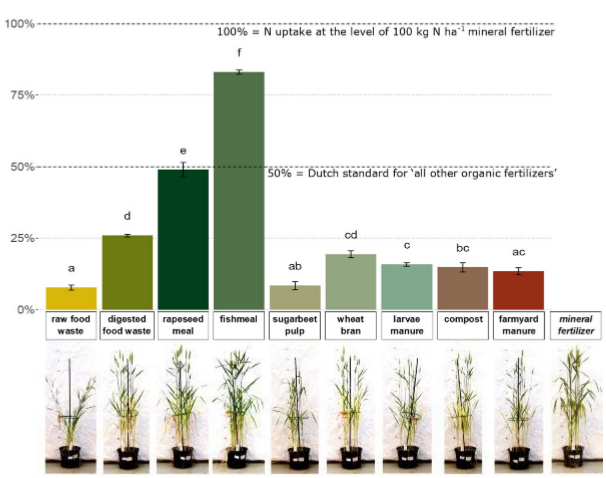
Nitrogen Fertilizer Replacement Value (NFRV)

"The extent to which organic fertilizer N can replace mineral fertilizer N"



NFRV variation: between 6.2 and 78.8%

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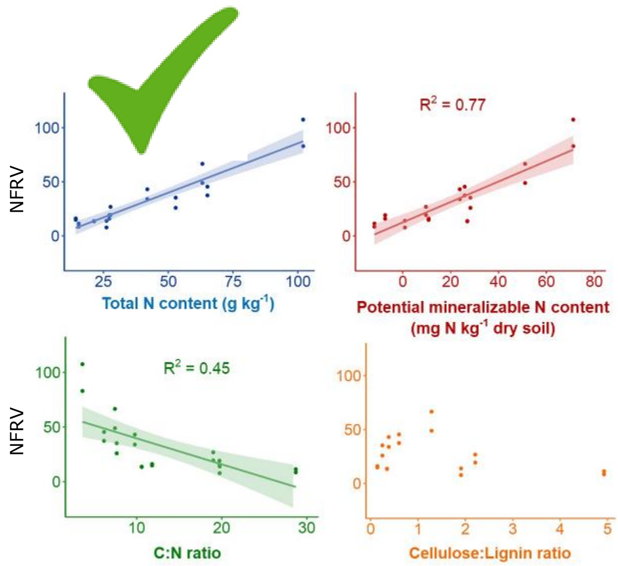
Prediction



N concentration offers best explanation

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Determination

- At equal N application: NFRVs differ, depending on N rate (100 or 200 kg N/ha) ($p \leq 0.0001$).
- At equal yield or N uptake: NFRVs are the same at either 100 or 200 kg N/ha

Determination at equal N uptake gives less errors

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Nutr Cycl Agroecosyst
https://doi.org/10.1007/s10705-023-10316-7

ORIGINAL ARTICLE

Nitrogen fertilizer replacement values of organic amendments: determination and prediction

Dorien Westerik · Ellis Hoffland · Renske Hijbeek

Received: 10 February 2023 / Accepted: 19 September 2023

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Introduction of the case study Flevoland

David de Wit

WUR Open Teelten

Lelystad, 16 April '24

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Content

1. Why case study
2. Flevoland
3. Casus farm Gert-Jan van Dongen (clay soil, Flevoland)

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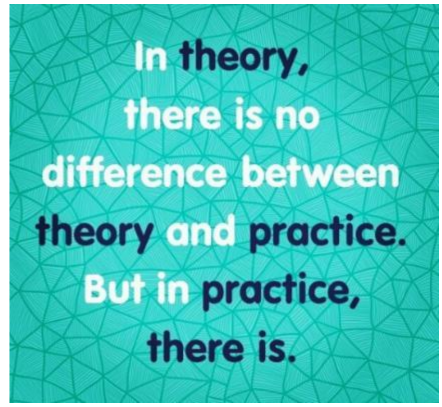
Why case study

- New advice based on literature
- Testing new advice in practice
- Understanding the change from the old advice
- Immediate feedback
- This autumn also on sandy soil



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Flevoland

Origin

- Polder reclaimed by sea (3m below sea level)
- Very fertile soil
- Reclaimed for agriculture
- Sea (salt water) transformed into lake (fresh water)

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Flevoland

Soil type

- Sandy soil on the edges of the Northeast P
- Light clay soil in the Northeast Polder
- Heavy clay soil in eastern and southern Fle

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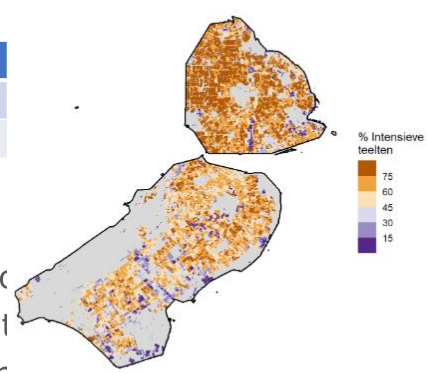
Flevoland

Land use

	Number of farms	Area (ha)
Arable farms	1300	61,600
Dairy farms	400	19,900

Characteristics

- North-East polder: ***Intensive*** arable crop ro
- Flevopolder: ***Less intensive*** arable crop rot
- Intensive collaboration arable and dairy farms



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Flevoland

Crops and yield

- Mostly arable crops for high-value food production or starting material
- Yields well above average in the Netherlands

Crop	Acreage (%)
Potato	21%
Cereals	19%
Grasses	13%
Onions	12%
Beets	11%
Bulbs	6%
Vegetables	5%
Corn	4%
Carrot and chicory	4%
Leguminous plants	2%

Crop	Mean yield (t/ha)
winter wheat	9,8 (+ 5%)
seed potato	38,5 (+ 8%)
sugar beet	96,5 (+15%)
seed onions	50,9 (+ 6%)
ware potatoes	49,6 (+ 4%)
silage maize	48,1 (+ 8%)
spring wheat	7,3 (+ 5%)
spring barley	7,9 (+19%)
onion sets	41,3 (- 13%)
winter barley	9,5 (+13%)

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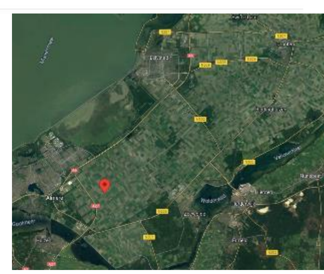
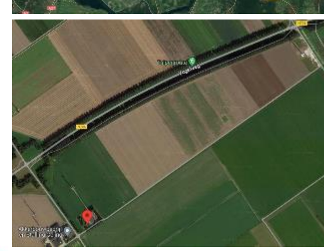
Casus clay soils v. Dongen

- Heavy clay soil
- Crops: winter wheat, sugar beets, green beans and flax
- Land leased for: ware potatoes, onions and tulip bulbs
- Used artificial fertilizers: NTS 27%, KAS27, NK16-30, foliar fertilizers
- Used organic fertilizers: solid goat manure, liquid fraction of digestate (after liquid-solid separation)
- Located in nutrient-polluted area (-20% on nitrogen use standard)





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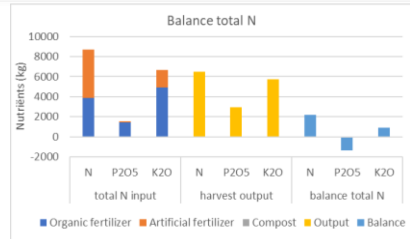
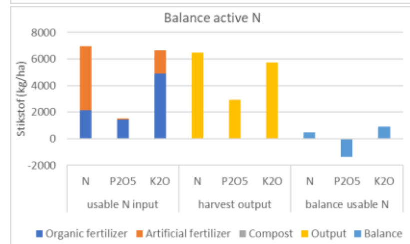
Casus clay soils v. Dongen

- Small nitrogen and potassium surplus
- Considerable deficit on the phosphate balance





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Casus clay soils v. Dongen

Choice of fertilizers based on:

- Legal use of nutrients
- Long-term agreements (digestat)
- Availability and price
- Needed for healthy soil and crop

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Discussion session 1 Questions

1. How do you rate the fertilizer recommendations in your country/region in terms of:
   - Up to date to actual knowledge and technology
   - Taking in to account societal requirements
   - Practical applicability by farmers

2. What are the most urgently needed improvements in fertilizer recommendations?

3. Is harmonization of fertilizer recommendations within Europe necessary? Why?

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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Session 2. Integrating organic matter, nitrogen and phosphorus recommendations and Guided fertilization systems

International Workshop

From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

EJP SOIL European Joint Programme

Ministerie van Landbouw, Natuur en Voedselkwaliteit

PPS BAAT BemestingsAdviezen Akkerbouw Toekomstgericht

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Program session 2

Keynotes and presentations

Christine Watson, SRUC
Growing our future: routes to sustainable soil and nutrient management

Bart Timmermans, LBI
Integrated carbon, nitrogen and phosphorus management: lessons learned from Dutch long-term experiments

Karoline D'Haene, ILVO
The calculation of the nitrogen mineralisation amount in fertilisation advices

Cathy Thomas, Rothamsted
Nitrogen recovery and losses with different types and rates of organic fertiliser in a long-term wheat rotation field trial

Discussion

Plenary recap

Poster pitches

Bart Timmermans, Louis Bolk Institute
NDICEA - calculating carbon and nitrogen dynamics in agricultural fields

Geert-Jan van der Burgt, Louis Bolk Institute
Integrating time related processes in nitrogen fertilization recommendation

Annemie Elsen, Bodemkundige Dienst Belgie N-INDEX expert system: A powerful tool in nitrogen recommendation

Koen Willekens, ILVO
Crops nutrient supply from different sources in soil

Goovaerts Ellen, Proefstation voor de Groenteteelt
Nitrogen advice in Flanders

Evelin Loit-Harro, Estonian University of Life Sciences
Comparison of Organic and Conventional Crop Management in Estonia since 2008

Dr. Susanne Klages ,agri.kultur
Update of Critical Values for plant analysis under present conditions in Saxony-Anhalt

Stefan Geyer, Francisco Josephinum Wieselburg: TerraZo - free application map creation and deployment based on field trials

Lex Slootweg, ICL: Controlled Release Fertilizers, a way to improve farmers nutrient use efficiency

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Keynote Christine Watson

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Integrating carbon, nitrogen and phosphorus: lessons learned from Dutch long-term experiments

PPS BBB: WP 2B Organic Matter and Fertilization

Bart Timmermans, Marjoleine Hanegraaf, Geert-Jan van der Burgt

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Quantifying performance of management practices in long-term experiments

>40 crop rotation systems

Northern sea-clay
PO+Kollumerwaard, tillage and cut and carry fertilizers

Reclaimed peat
BKV: tillage, compost, amendments, Tachetes

Central sea-clay
BASIS: tillage, composts, organic system

Southern sand
BKZ: tillage, composts, fertilization, organic system

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Organic matter Balance

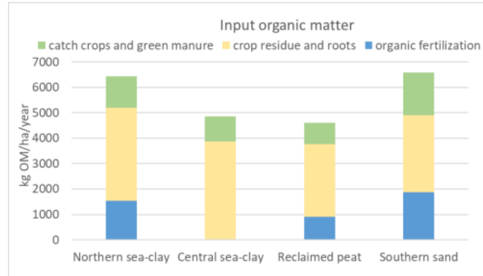
OM input and degradation: far larger than balance

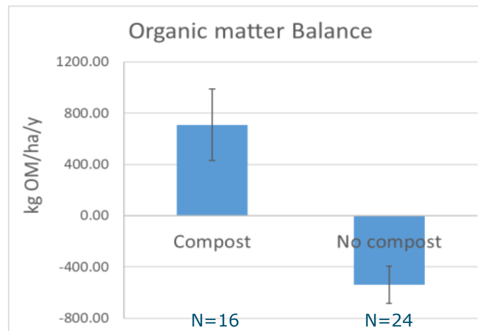
Annual SOM degradation: variable 0.5 % – 2.4 %

OM balance in many cropping systems <0
also in “standard “ systems

Compost: factor that makes balance positive
Explanations

- Intensive rotations (many cash + root crops)
- Mostly slurry and artificial fertilizers





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NUE and N-balance: taking the soil into account

Average NUE on sand: 53% (SE 2%)

Average NUE on clay/loam: 62% (SE 7%)

	BKZ standard	BKZ compost	BKV standard	BKV compost
Input Nitrogen (kg N/ha/jaar)	252	298	194	307
Crop uptake (kg N/ha/jaar)	199	200	164	181
Output nitrogen (kg N/ha/jaar)	129	129	118	128
Balance (kg N/ha/jaar)	124	169	76	180
NUE (classic) (%)	51	43	61	42
Leaching (kg N/ha)	115	112	80	95
Soil mutation (kg N/ha/jaar)	-7	40	-16	63
NUE with soil as source/sink (%)	50	50	56	52

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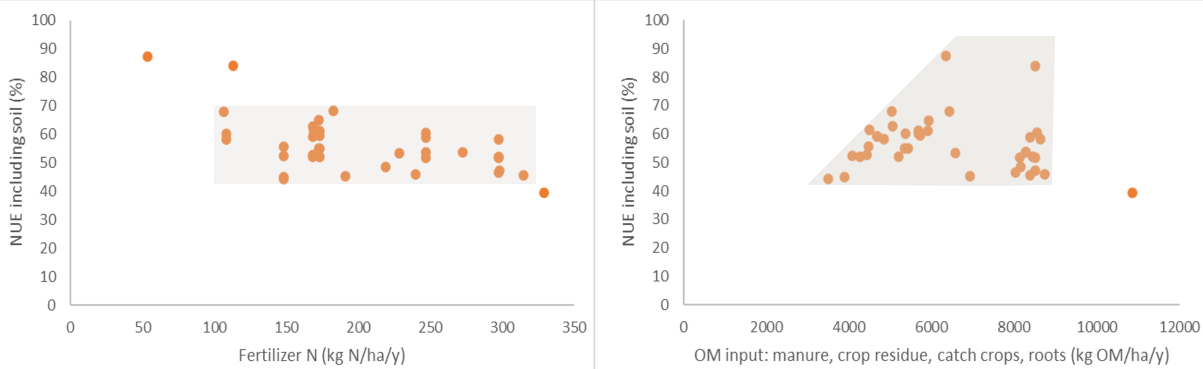
NUE including the soil: correlations



Higher NUE does not always mean lower input
Systems should be / can be adapted to increase NUE

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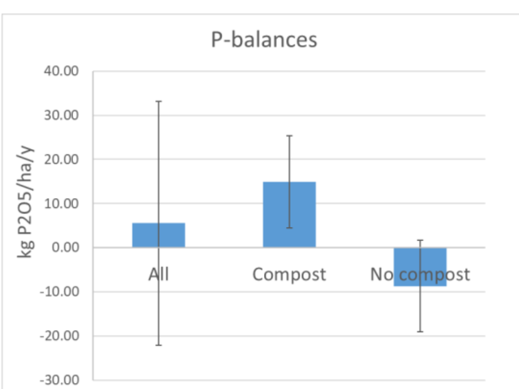
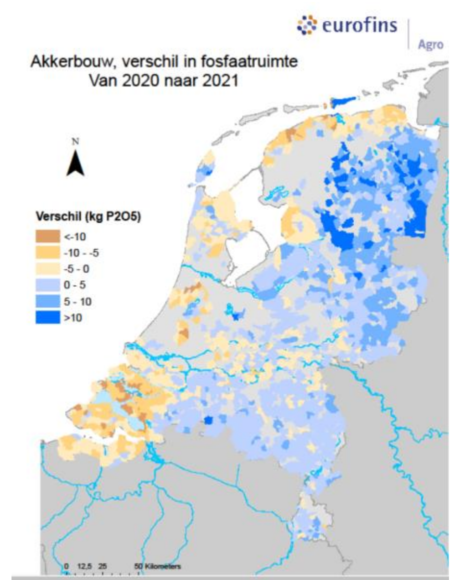
P-balance

Historically very high P-balances
Current P-balances almost zero

In our systems: average 5.5 kg P2O5/ha/y





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Step towards integration: *internal* and *external* OM input

Internal OM: example PO with *cut and carry* fertilizers

Plus points	Negatives
Closing systems	Long term: decrease in other mineral nutrient levels
Decreasing losses	Timing of nitrogen challenge
Much OM and N irt P	Not easy to fit in system

External OM: example BKV combi, compost but few catch-crops

Plus points	Negatives
Direct, high increase OM	Risk of unequallity in levels of nutrients on long term
Easy to fit in system	Risk of losses to environment
Many possible organic fertilizers	Risk pollutions

Extremes undesirable: we need a bit of both → balance

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Summary

Carbon – OM balance

- Most systems slightly negative
- Concerns: soil fertility and carbon credits? OM input (e.g. Compost) strong effect

Nitrogen – NUE

- Relevant to take soil as source/sink into account
- More input of OM does not always mean lower NUE
- Systems can be adapted to prevent losses

Phosphorus – P balance

- P-balance almost zero: negative and positive systems
- Balance linked to organic fertilizer input
- Policy change to less input in high productive area

Integration

- Optimizing / combining both internal and external OM

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THE CALCULATION OF THE NITROGEN MINERALISATION AMOUNT IN FERTILISATION ADVICES

KAROLINE D'HAENE &
GEORGES HOFMAN

17 april 2024

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Introduction

Literature study on nitrogen mineralisation rate (Dutch report)

Goal:

- Collect the research results
- Indicate the importance of different parameters
- Recommendations

Source: D'Haene & Hofman

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Introduction

Incorrect estimation of mineralisation rate:

- Too high: risk of yield reduction
- Too low: risk of high nitrate nitrogen residue in the soil in the autumn

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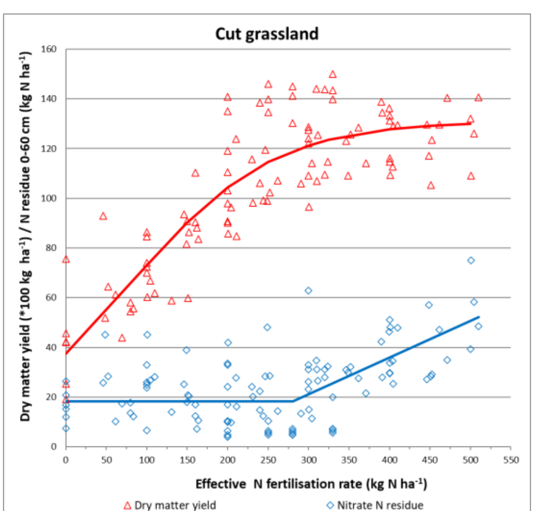
Introduction



Source: D'Haene *et al.* (2014)

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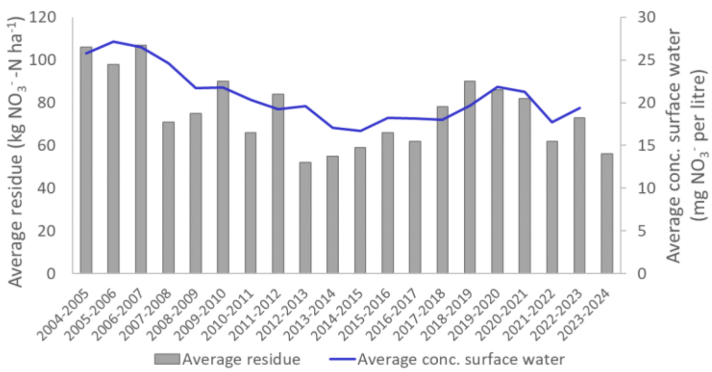
Inroduction

Incorrect estimation of mineralisation rate: Sources: VLM - VMM

- Too low: risk of high nitrate nitrogen residue in soil in autumn
  ⇒ risk of high nitrate concentration in surface water



Flanders

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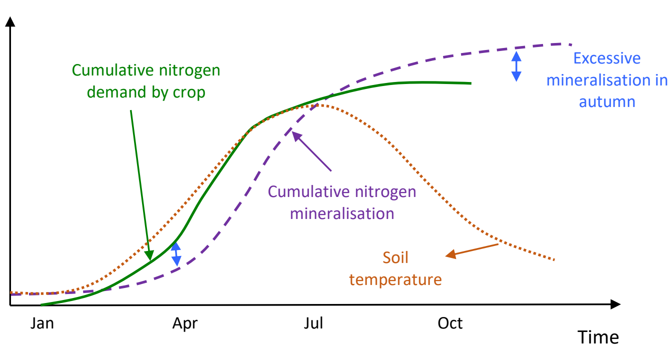
Introduction

- Lack of synchronisation of nitrogen mineralisation rate and nitrogen uptake



Source: De Neve (2017)

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Measuring methods and models

Different methods: lab and field methods of mineralisation rate, measurements of soil parameters, calculation methods and models

⇒ different (dis)advantages

⇒ difficult to predict mineralisation under field conditions

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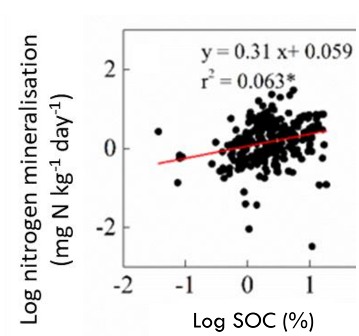
Soil parameters

- Soil organic carbon (SOC) / nitrogen



Source: Liu *et al.* (2017)

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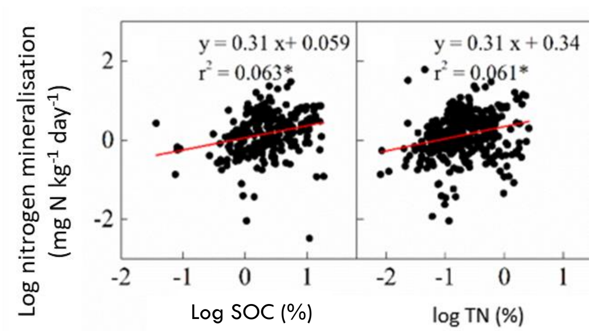
Soil parameters

- Soil organic carbon (SOC) / nitrogen



Source: Liu *et al.* (2017)

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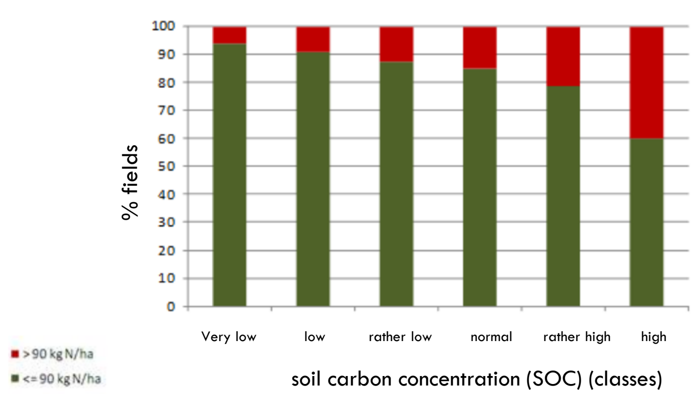
Soil parameters

- Soil organic carbon – nitrate nitrogen residue



Samples: 2014

Source: Nawara *et al.* (2021)

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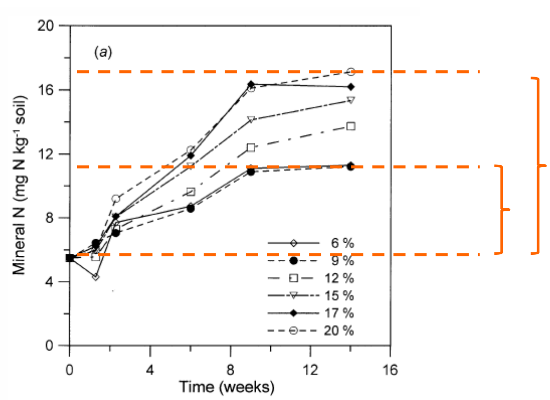
Soil parameters

- Effect soil moisture content

Source: De Neve & Hofman (2002)



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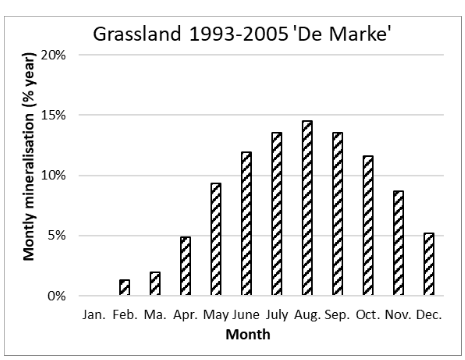
Weather conditions

The Netherlands



Source: Verloop *et al.* (2017)

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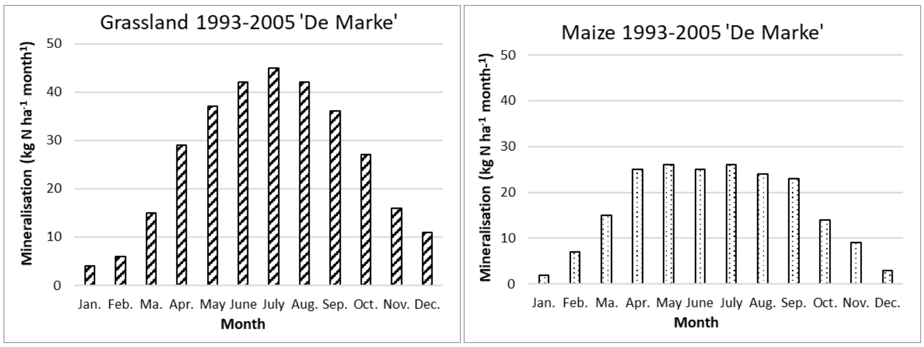
Management

- Grassland - arable land

The Netherlands



Source: Verloop *et al.* (2017)

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Management

- Frequent application of manure ⇒ higher N-mineralisation rate than expected based on SOC- or N concentration:

  2 options

  - Correction factor of mineralisation rate

    e.g. Wallonia x 0.9 - 1.2

  - Long term nitrogen efficiency of manure

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Management

- Soil disturbance
- Crop residue management
- Irrigation
- …

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Recommendations / conclusions

- Interaction between soil properties, field history (crop rotation and management) and weather conditions under field conditions
- Need to have a more uniform method to calculate the nitrogen mineralisation rate + transparency of the method
- Need to facilitate the data collection of fields
  - i.e. history of crop rotation and applied organic manure and general soil data
  - Introduction of digital soil passport

User-friendly tool with field data to estimate nitrogen mineralisation potential

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Recommendations / Conclusions

- Increase awareness of farmers on:
  - Impact of different factors on mineralisation rate:
    - Soil parameters
    - Field history of applied organic manure & management
  - Importance of good soil quality
  - Link between soil organic carbon content and nitrate nitrogen residue

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Recommendations / Conclusions

- Increase awareness of farmers on:
  - Importance of split fertilisation:
    - Takes into account previous weather conditions
    - Second application rate based on soil sampling
    - Reduction of start rate is needed
- Need of research on effect of:
  - Soil disturbance
  - Soil life

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The calculation of the nitrogen mineralisation amount in fertilisation advices

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Georges Hofman

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ROTHAMSTED RESEARCH

Nitrogen recovery with different types and rates of organic fertiliser over 8 seasons in a wheat rotation field trial

Cathy Thomas, Xavier Albano, Stephan Haefele

Sustainable Soils and Crops Department, Rothamsted Research, Harpenden, Hertfordshire, UK, AL5 2JQ



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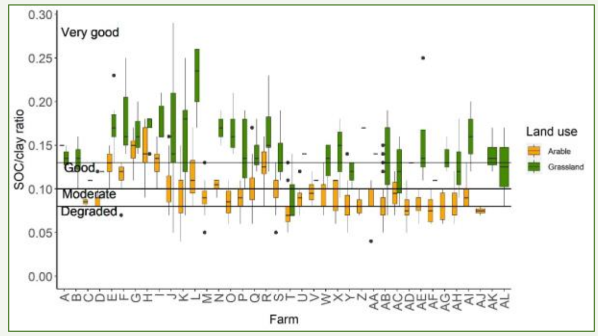
ROTHAMSTED RESEARCH

Why use organic fertiliser

- Mineral N fertiliser is susceptible to losses of ~40% (Withers *et al.*, 2014).
- Deficient organic matter in soil leads to degraded soil structure. There can also be yield and nutrition benefits from adding organic fertiliser (Thomas *et al.*, 2019).
- Carbon sequestration in soil as SOC becomes recalcitrant.
- GHG emissions from organic materials when left.
- Solid manures have up to 30% and slurries up to 50% NH_4, which can be volatilised or leached.
- Soil N immobilisation occurs with organic amendments with C:N ratio > 30 e.g. straw, which reduces the N available to the crop.

SOC in the Cotswolds farm cluster - arable vs grassland fields on the same farm



(Storkey *et al.*, 2024, submitted)

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ROTHAMSTED RESEARCH

Field trial materials and methods

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Fosters field trial 2013-2020

- Fosters winter wheat rotation field trial (2 plots per treatment) over 8 seasons 2013-2020.
- 4 types of organic fertiliser applied before drilling in early October:
    1. **FYM** (from composted cow dung)
    2. **Anaerobic digestate** (AD, fibre fraction from maize and vegetable waste)
    3. **Compost** (household food and garden waste)
    4. **Straw** (from previous season crop)
- 4 rates of amendment balanced for organic carbon: 1000 > 1750 > 2500 > 3500 kg C/ha^{-1}.
- Control with no organic amendment.
- All plots received inorganic N at 190 kg/ha^{-1} (AHDB recommend 220 kg/ha^{-1} for wheat).
- Dumas total C and N and moisture content analysis of amendments in each season.
- Dumas total C and N analysis of soil (0-23 cm) and crop in 2013 and 2020.
- Yield of straw and grain in each season.

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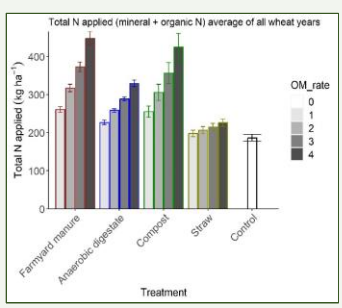
Organic fertilisers

C and N content (%) average of 8 seasons:

	C %	N %	C:N
FYM	35	2.6	14
AD	43	1.8	26
COMPOST	24	1.5	17
STRAW	45	0.5	92



- Total N decreases FYM < AD < compost < straw.
- Digestate fibre has ~30% and FYM ~10% available N (AHDB, 2023). In compost most N is organic (Hartz *et al.*, 2000).
- FYM and compost have lowest C:N ratio and straw very high C:N ratio.
- Total applied N decreased from FYM < compost < AD < straw.

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N balance calculation

Total N recovery % = $\frac{\text{crop N uptake + accumulated soil N}}{\text{total applied N (organic + inorganic)}}$ *** 100**

- **Crop N uptake kg/ha^{-1}** = straw + grain N concentration (average of 2013 and 2020) * straw + grain yield (each season)

- **Accumulated soil N kg/ha/yr^{-1}** = 2020 soil N – 2013 soil N/ 8 seasons

- Soil N kg/ha^{-1} = soil N % * Bulk Density/100*23/100*10000

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Field trial results

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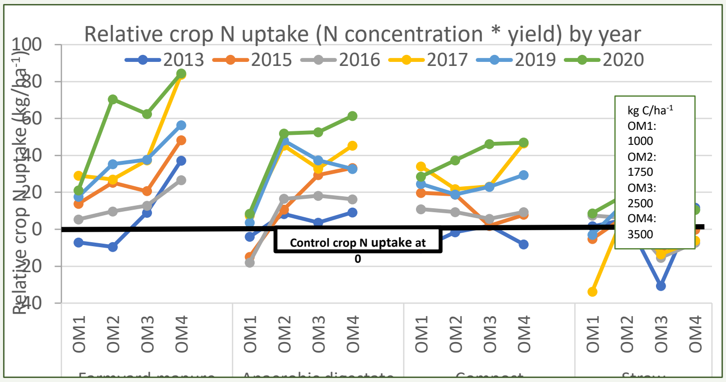
Relative crop N uptake from 2013-2020



		Relative crop N uptake (%) average
FYM	OM1	107
	OM2	114
	OM3	116
	OM4	130
	AVERAGE	117
AD	OM1	98
	OM2	116
	OM3	115
	OM4	117
	AVERAGE	112
Compost	OM1	109
	OM2	109
	OM3	109
	OM4	112
	AVERAGE	110
Straw	OM1	98
	OM2	106
	OM3	94
	OM4	102
	AVERAGE	100

- Yield/N uptake was higher in amended plots relative to the control, except with straw, and this difference increased with year, indicating that organic N continued to mineralise over time.
- Yield/N uptake decreased from FYM < AD < compost < straw – corresponding to the pattern of total N in the amendment and probably available N content. Compost has lower available N content.
- Straw often had lower yield than the control in the earlier seasons indicating mineral N fertiliser immobilisation due to the high C:N ratio.

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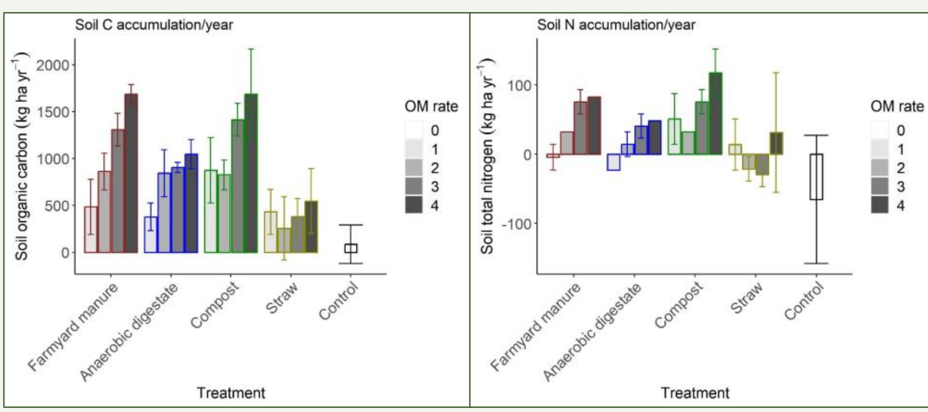
Soil total C and N accumulation in topsoil from 2013-2020



kg C/ha^{-1}
OM1: 1000
OM2: 1750
OM3: 2500
OM4: 3500

- Soil C and N accumulated most with FYM and compost and least with AD, straw and the control.
- The control and the lowest rate of AD and mid rates of straw mined the soil N.
- Therefore, the amendments with the highest C:N ratio mineralised the existing soil OM more extensively which led to greater N loss.

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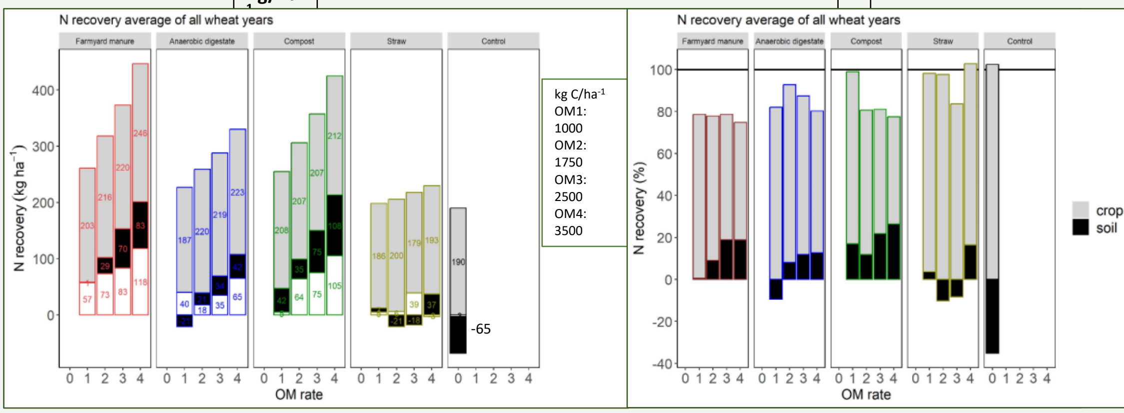
N recovery absolute and proportional to total N applied

Kg/ha-1 | %



- Proportional N loss was highest with the control at 35%, due to soil N mining, whilst having >100% crop recovery. Suggesting that 35% of mineral N fertiliser was lost rather and crop uptake was from N mineralised from the soil.
- Proportional N loss was ~20% with amendments.
- With compost rate 1 and straw rates 1 and 4 recovery was ~100% because of good crop N uptake and soil N accumulation at low input rates.

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% N recovery ANOVA

Analysis of variance					
Variate: N_recovery_%					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year stratum	5	26093.39	5218.68	54.54	
Year.*Units* stratum					
OM_type	4	3716.01	929	9.71	<.001
OM_rate	4	512.09	128.02	1.34	0.263
OM_type.OM_rate	8	5322.1	665.26	6.95	<.001
Residual	80	7655.03	95.69		
Total	101	43298.62			

Bonferroni test

OM_type.OM_rate

Message: some comparisons have missing sed's; these have been removed from the output.

	Mean	
Control OM0	67.66	a
Anerobic digestate OM1	72.65	ab
Farmyard manure OM4	74.82	ab
Straw OM3	75.31	ab
Compost OM4	77.51	abc
Farmyard manure OM2	77.78	abc
Farmyard manure OM1	78.64	abcd
Farmyard manure OM3	78.7	abcd
Anerobic digestate OM4	80.19	abcd
Compost OM2	80.62	abcd
Compost OM3	81.12	abcd
Anerobic digestate OM3	87.4	abcde
Straw OM2	87.41	abcde
Anerobic digestate OM2	92.77	bcde
Straw OM1	98.23	cde
Compost OM1	98.85	de
Straw OM4	102.84	e

- AD rate 2, straw rates 1 and 4 and compost rate 1 had significantly greater % recovery than the control.

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DNDC model

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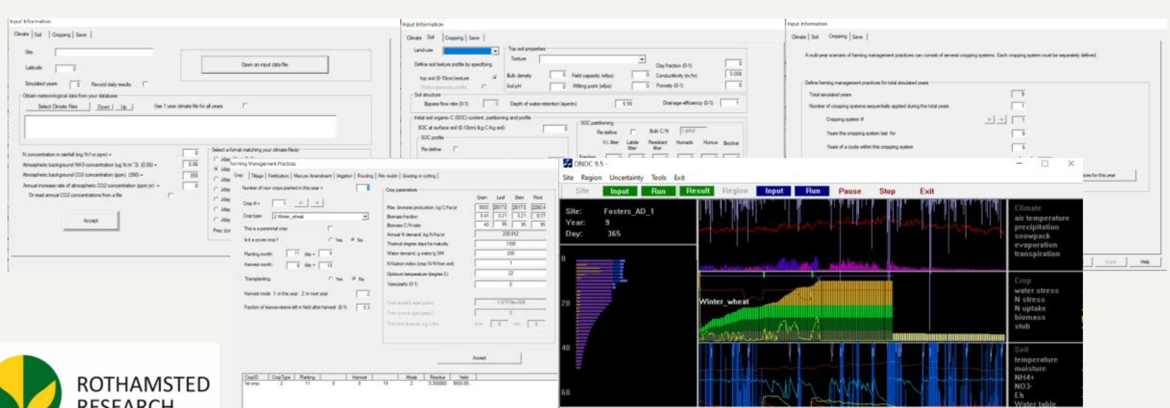
DNDC model input

The DeNitrification-DeComposition (DNDC) model combines nitrogen conversion and hydrological processes to simulate crop yields, nitrogen leaching, and greenhouse gas emissions
(Institute for the Study of Earth, Oceans, and Space, University of New Hampshire).

- 4 OM types x 4 OM rates + control x 8 seasons = 129 model simulations.
- The final average of the DNDC and observed data over 8 seasons were compared.



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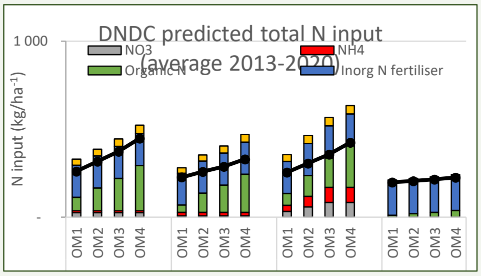
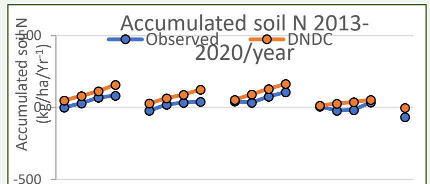
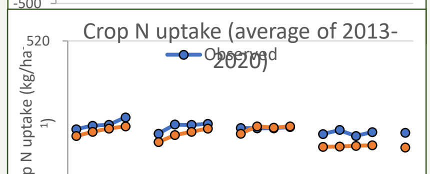
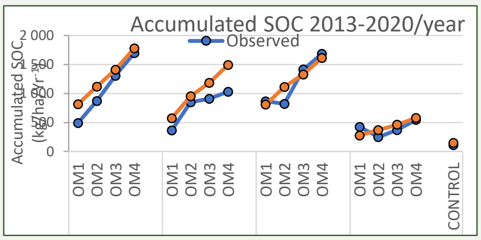
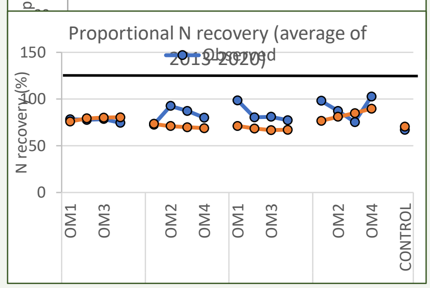
DNDC vs observed N recovery, average of 2013-2020











- **The model predicted higher amendment N input because it added significant inorganic N, except with straw. These values are questionable for AD and compost.**
- **It predicted compost to have much higher NO_3 input.**
- The SOC prediction was close to the observed.
- DNDC overestimated soil N accumulation and underestimated crop N uptake.
- However, the predicted total N recovery was very close for FYM and the control.

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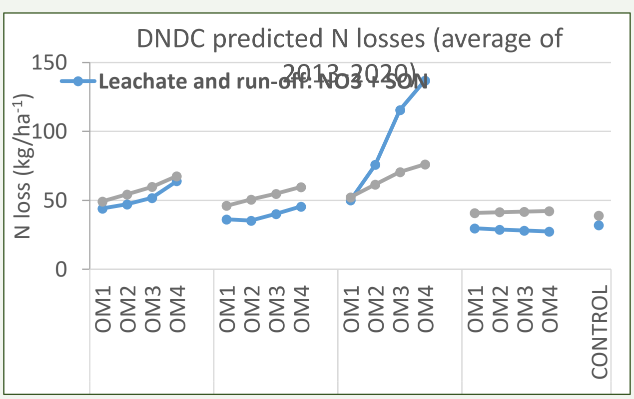
DNDC predicted mode of N loss



- DNDC predicted higher NH_4 than NO_3 in the amendments and therefore higher gaseous/NH_3 losses.
- However, compost was predicted to have higher NO_3 than the other amendments, and therefore greater NO_3 leaching/run-off.

ROTHAMSTED RESEARCH

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ROTHAMSTED RESEARCH

Conclusions and further work

- All amendments except straw increased yield/crop N uptake compared to the control, and this effect increased over time as more organic N was mineralised. The amended plots also accumulated significant soil N. Consequently, amended plots had greater total N recovery of ~ 80% compared to the control at 65%.
- Furthermore, a low rate of compost and the highest rate of straw had N recovery close to 100%. Due to low input of immediately available inorganic N and higher organic N content, but still greater crop N uptake and soil N accumulation compared to the control.
- Therefore, organic amendments can be applied for increased yield and soil improvement without excessive N loss compared to inorganic fertiliser alone, but different rates are appropriate for different types of amendment.
- Further work with DNDC will simulate combinations of OM rates and inorganic N rates at 90 < 120 < 150 < 180 < 210 < 240 kg/ha^{-1} to find the optimum for N recovery.

ROTHAMSTED RESEARCH

Acknowledgements

Lab group: Javier Hernandez, Sarah Dunham, Jo Carter, Stephan Haefele, Steve McGrath and temporary staff who did a lot of shovelling
Funding: BBSRC, Growing Health ISP

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Questions

1. How does yield/crop N uptake, SOC and SON change with different types and rates of organic fertiliser over 8 seasons?

2. What is the N recovery/loss with different types and rates of organic fertiliser over 8 seasons?

3. How does the DNDC model compare with observed data? What are the modes of N loss – gaseous and leaching predicted with the DNDC model?

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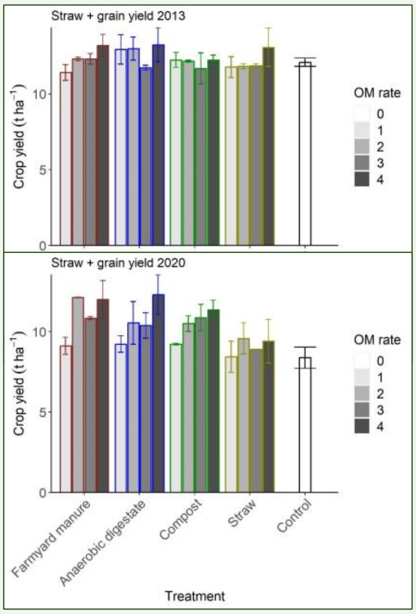


	OM 1	OM2	OM3	OM4	NONE
AD	1.28	1.24	1.23	1.21	
COMP	1.25	1.24	1.19	1.17	
FYM	1.28	1.24	1.20	1.17	
STRAW	1.28	1.28	1.26	1.24	
NONE					1.29
AVERAGE	1.27	1.25	1.22	1.20	

nature > scientific reports > articles > article

Article | Open access | Published: 30 April 2022

Analytical modelling of soil porosity and bulk density across the soil organic matter and land-use continuum

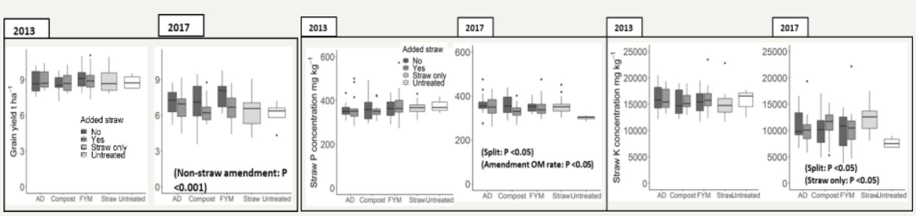
D. A. Robinson, A. Thomas, S. Reinsch, I. Lebron, C. J. Feeney, L. C. Maskell, C. M. Wood, F. M. Seaton, B. A. Emmett & B. J. Cosby

Scientific Reports **12**, Article number: 7085 (2022) | Cite this article

6973 Accesses | **20** Citations | **1** Altmetric | Metrics

53

Most organic N - 10-25% is mineralised in the first season following application and 5% thereafter



(Thomas *et al*., 2019)

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International Workshop

From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

EJP SOIL European Joint Programme

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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Bart Timmermans,
Louis Bolk Institute

NDICEA - calculating carbon and nitrogen dynamics in agricultural fields

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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Geert-Jan van der Burgt,
Louis Bolk Institute

Integrating time related processes in nitrogen fertilization recommendation

PPS BAAT
BemestingsAdviezen Akkerbouw Toekomstgericht

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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N-INDEX expert system: a powerful tool in nitrogen recommendation

Annemie Elsen
Bodemkundige Dienst van België
aelsen@bdb.be

Bodemkundige Dienst van België vzw

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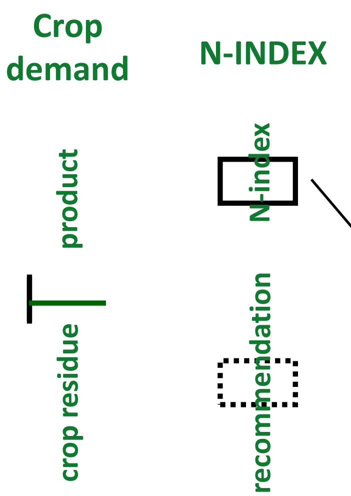
N-INDEX method



- + Mineral N (rooting depth)
- + Mineralisation:
  - + Organic matter (% C)
  - + Cover crop
  - + Crop residues
  - + Organic fertilizer
- \- Effect structure, low pH
- \- Leaching during growing period

Bodemkundige Dienst van België vzw

59

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Crops nutrients supply from different sources in soil

A two-year (2023-2024) field monitoring of N dynamics and overall nutrients availability in organically managed vegetable cropping systems

Koen Willekens, Jasper Vanbesien, Peter Vanhoof

International Workshop From yield-based to society-based fertilizer recommendations
16-18 April Lelystad the Netherlands

Europees Landbouwfonds voor Plattelandsontwikkeling: Europa investeert in zijn platteland

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ILVO

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I. **N dynamics**

Measurement of mineral N amount (NO_3^--N + NH_4^+-N) in 0-90 cm soil profile and crop N uptake in aboveground biomass, throughout the growing season,

→ Balances of plant available N

→ N mineralization rates (kg N per ha per day)

II. **Overall (potential) nutrients availability**

Measurement of electrical conductivity (EC) in an aqueous soil solution, with and without sugars, in 0-30 and 30-60 cm soil layers, at an early crop growing stage,

→ Current availability of nutrients in **mineral ionic** form

→ Potential nutrients release from **decomposition** of freshly amended organic material

→ Potentially available nutrients by **symbiosis** between plants and micro-organisms in the rhizosphere

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Ellen Goovaerts - Research centre for vegetable production

For the production of outdoor vegetables achieving a high quality is crucial, even more than yield. However vegetables are characterized by:

- A less developed root system
- A relative short growing period
- Harvest at a moment that N-uptake is high

proefstation VOOR DE GROENTETEELT

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The main principle of the KNS-system

N-advice from the system				Adjusting the advice	
Target value at a certain moment N-uptake by plant + Latent N: minimum amount of N necessary in the soil	-	**N delivered from the soil** Measured soil content on a certain depth depending on rooting depth + Mineralisation of the soil (kg N/ha/day)	-	**N delivered from other sources** N from crop residues, manure, catch crops, compost, ..	**= N advice to the farmer**

=> Fractioned fertilisation for crops with a longer growing period

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Comparison of Organic and Conventional Crop Management in Estonia since 2008

Rotation:
Spring Barley undersown with red clover – Red clover-Winter wheat – Field pea –Potato (4x)

- **Total dry matter yield** was significantly lower (A) in all organic treatments and N0
- Winter wheat **protein content** was the highest in N2 and N3, which received 100 and 150 kg of N/ha.
- **Nitrogen** treament **did not impact** the **arabinoxylan** and the **beta-glucan** content.
- **Soil phosphorus** content decreased in all organic treatments and in N3.
- Plant available **potassium** in soil decreased in all treatments
- **Soil microbial diversity** and **abundance** increased during the second rotation in most treatments. Decrease in bacterial diversity was seen N0 and N3.

www.emu.ee
Eesti Maaülikool
EMÜ Estonian University of Life Sciences

64

Susanne Klages, agri.kultur

Update of Critical Values for plant analysis under present conditions in Saxony-Anhalt

Topsector Agri& Food

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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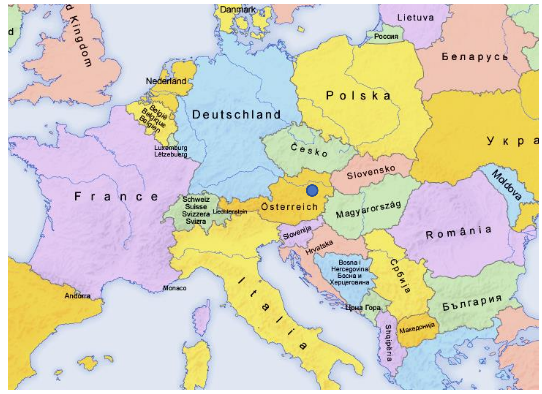
Francisco Josephinum, Wieselburg

INNO VATION FARM
FARMING FOR FUTURE



www.josephinum.at

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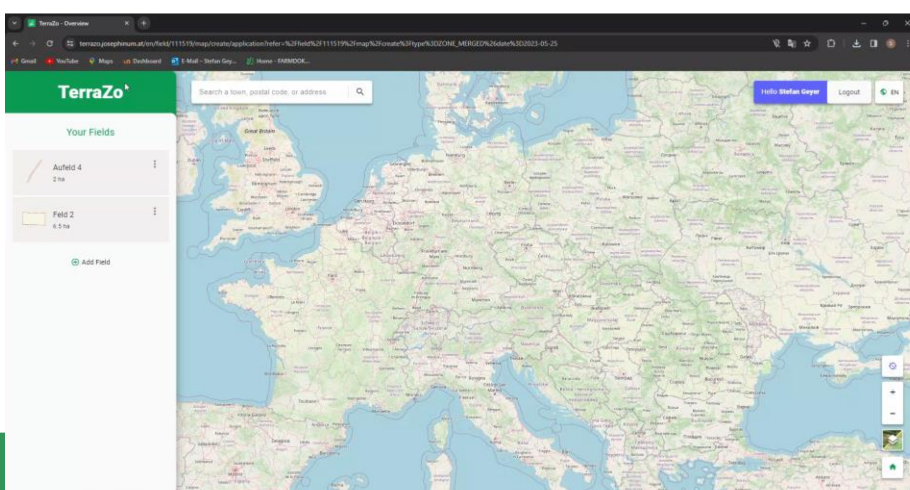
TerraZo Anwendung (www.terrazo.at)

INNO VATION FARM
FARMING FOR FUTURE



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Conclusion "Site-specific fertilization"

- New technologies contribute to improving N efficiency.
- The full potential has not yet been exploited
- Data can be used across fertilization
- Algorithms need to be made easily accessible to the public
- **Technologies accelerate knowledge transfer!**

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Fertilizer choice reducing Nitrogen emissions

Options to improve fertilizer recommendations:
a. Integrating organic matter, nitrogen and phosphorus recommendations
b. Integrating fertilizer choice in the recommendations
c. Guided fertilization systems
d. Fertilizer recommendations for Ca, S, Mg and micronutrients

Some options for Nitrogen:
*Fertilizers with Urease-inhibitors
*Fertilizers with Nitrification-inhibitors
*Controlled Release Fertilizers (CRF):
Biodegradable Coated Urea, Nitrogen is released based on soil temperature

ICL

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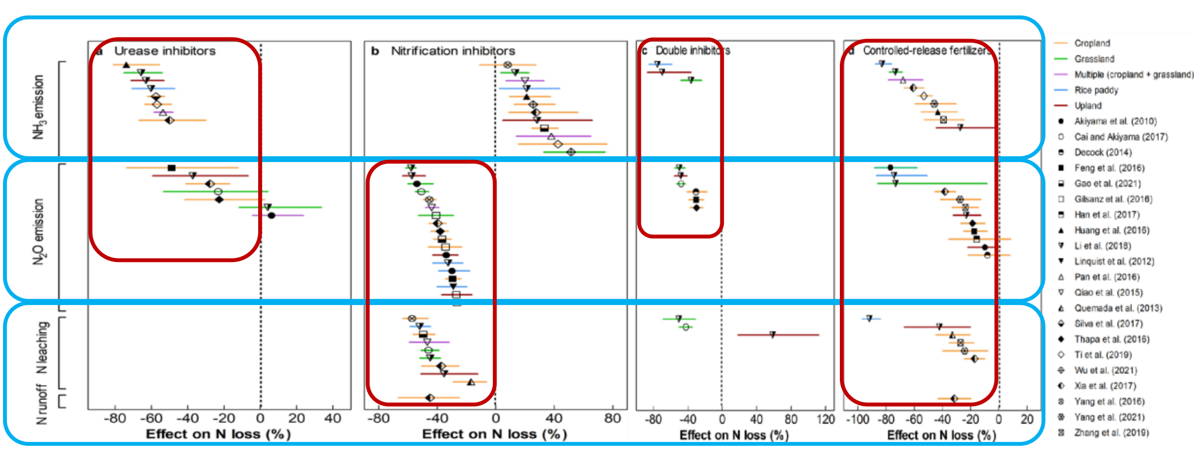
1. **CRF**s are very effective in reducing nitrogen losses from all pathways!

Published in Nature in 2022



ICL

From publication: Next-generation enhanced-efficiency fertilizers for sustained food security (Shu Kee Lam et al 2022, University of Melbourne)
results of 21 meta-analyses on the potential of EEFs to reduce N losses from food production systems at both regional and global scales.
Data included are already published and publicly available, with those publications properly cited in the reference list of the publication.

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Poster:

CRF-trial by Nutrient Management Institute,
The netherlands 2021

- Leaching
- Ammonia emissions
- N_2O emissions
- Yield
- Nitrogen Use Efficiency (NUE)

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Session 3. Fertilizer recommendations for Ca, S, Mg and micronutrients and Fertilizer choice recommendations

International Workshop
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1

Program session 3

Presentations

Sven Verweij, NMI
Fertilizer selection tool

Arjen Reijneveld, Eurofins
Advances in fertilization recommendations: A three-step approach incorporating new insights

Discussion

Plenary recap

Poster pitches

Hans-Werner Olfs, Osnabrück University of Applied Sciences
Measurements of plant-available P, K and Mg contents and pH of soils with the soil sensor system Stenon "FarmLab" as a basis for fertilizer recommendations for arable crops

Karolina Barcauskaite, Lithuanian Research Centre for Agriculture and Forestry
Do composts meet organic fertilizers quality requirements: Lithuanian case study?

Wieke Vervuurt, WUR
Long-term effects of phosphate fertilization

Wieke Vervuurt, WUR
Evaluation framework to predict the fate of organic materials

Hendrik Holwerda, WUR
Potential for reducing P fertilization without affecting crop yield

2

How to Choose the Best Fertilizer Plan for Your Farm: A Multi-Criteria Optimization Framework

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Interreg North-West Europe Co-funded by the European Union ReNu2Cycle

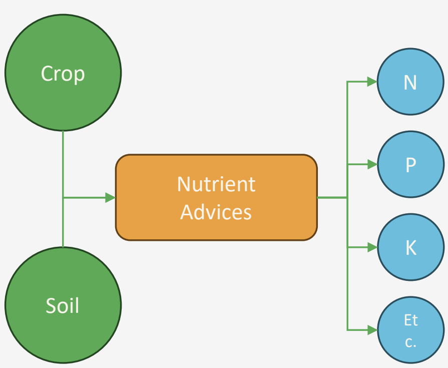
NutriBudget

nmi soil for life

SVEN VERWEIJ & ROMKE POSTMA

15 mei 2024

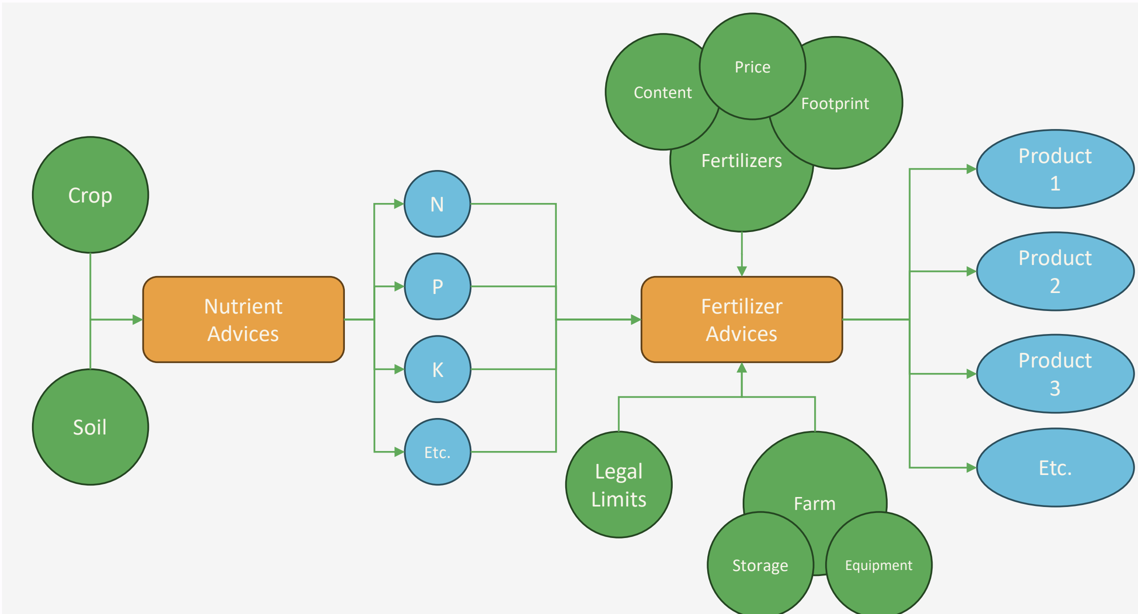
3



nmi soil for life

15 mei 2024

4



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5

How can we optimize fertilizer choice?

Cost function

- Evaluate the effects for a fertilizer choice
- Modules describe single processes
- Tradeoffs require common unit (e.g. €)
- Matrix calculation enabled

Optimizer

- Can be trained on many examples
- Uses gradient descent to minimize cost function
- Quick advices during interference enables feedback process with farmers

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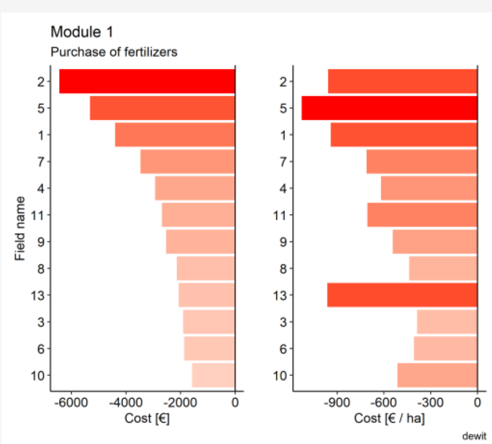
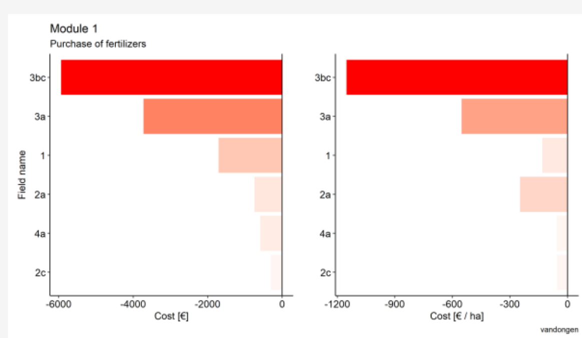
Modules in cost function

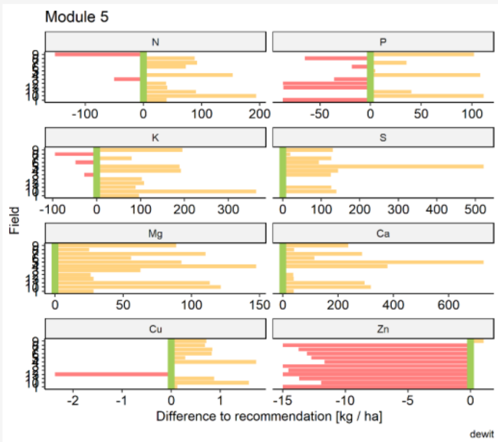
- **1.** Purchase of fertilizers
- **2.** Removal manure
- **3.** Storage of fertilizers
- **4.** Application of fertilizers
- **5.** Harvest of crops
- **6.** Legal limits
- **7.** Greenhouse gas emissions
- **8.** Ammonia emissions
- **9.** Nitrogen leaching to groundwater
- **10.** Nitrogen leaching to surface water
- **11.** Phosphate leaching to surface water
- **12.** Organic matter content of soil

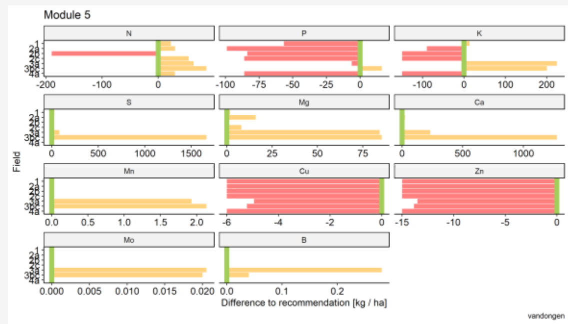
Results: Module 1





Results: Module 5





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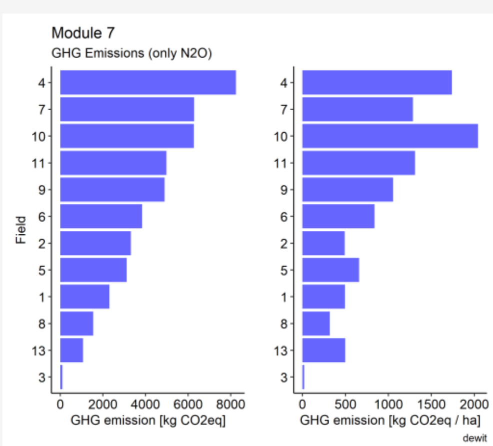
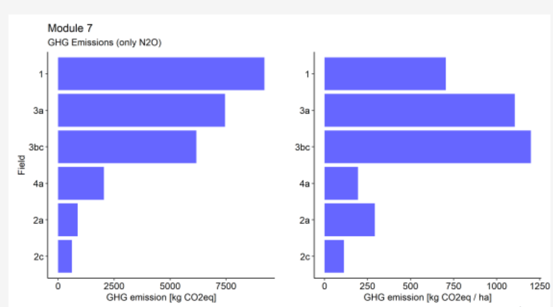
Results: Module 7





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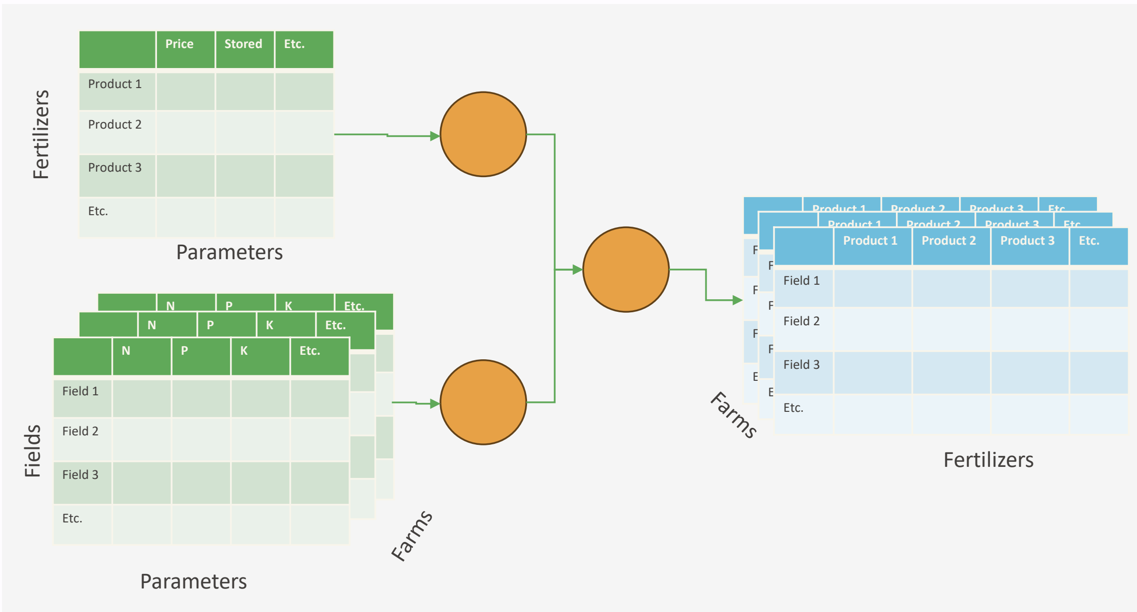

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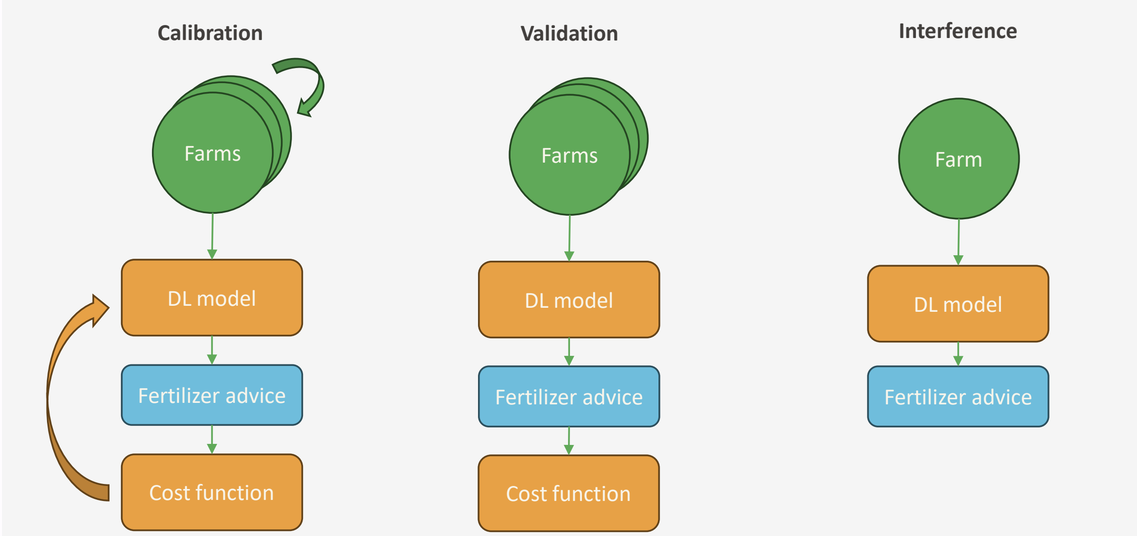
Creating an optimizer



nmi soil for life

15 mei 2024

12

apus: a R package to optimize fertilizer choice

- Open-source available
- Runs on CPU and GPU
- github.com/AgroCares/apus

```r
library(apus)

# Create a farm
apus ← Apus$new(farm_name = 'my farm')

# Add 1 or multiple fields
apus$addFields(
  b_id_field = 1L,
  b_area = 10000,
  b_lu = 'nl_2014',
  d_n_req = 270,
  d_p_req = 120,
  d_k_req = 50,
  d_n_norm = 230,
  d_n_norm_man = 170,
  d_p_norm = 75,
  b_lu_yield = 40000,
  b_lu_price = 0.3
)

# Train a model
apus$trainModel()

# Optimize for advice
advice ← apus$optimizeFertilizerChoice()
```

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Thanks for your attention

✓ Sven Verweij
✓ sven.verweij@nmi-agro.nl

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eurofins Testing for Life

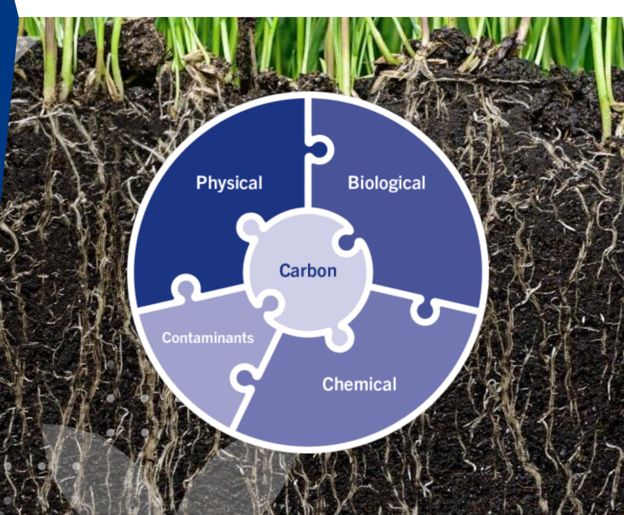
Advances in fertilization recommendations:

A three-step approach incorporating new insights

Dr. J.A. Reijneveld

Dr. K. Brolsma

Prof. Dr. Oene Oenema



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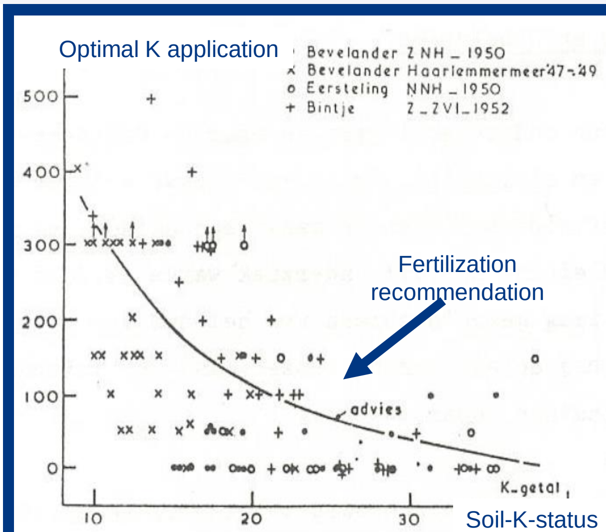
Soil testing and fertilization recommendations
Then

eurofins

Most current fertilization recommendations are based on soil fertility testing, and have been developed a few decades ago.

- **Optimal** economic **production**
- Prevent crop **quality** problems



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Soil testing and fertilization recommendations
Now

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The socio-economic environment and scientific insights have altered.

- Closing **yield** gaps
- Prevent crop **quality** problems
- Use **fertilizer in a prudent way**
- More resilient crops; **less crop protection**
- **Prevent health/fertility problems**

  humans, dairy cattle, horses, sheep
- **Beat climate change**
- **Clean water**
- **Biodiversity**

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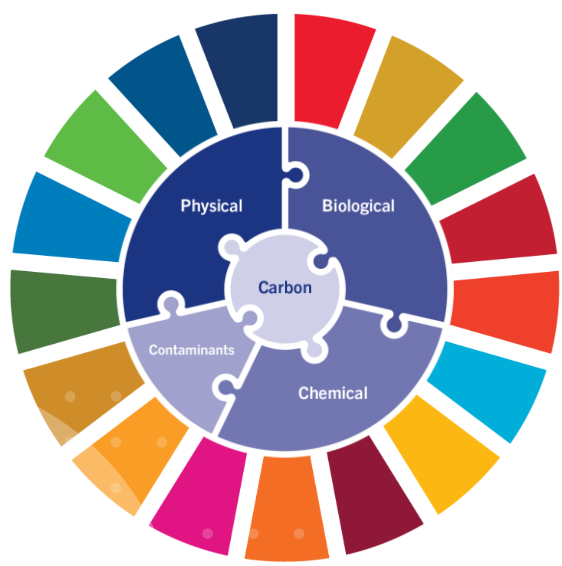
Soil health testing to monitor and guide for:

- Farmers/growers
- Agri-food industry
- Government
- Urban areas
- Nature

19

The healthier the **soil**, the better the contribution to the **Sustainable Development Goals**

Bouma, J.; de Haan, J.; Dekkers, M.S. Exploring Operational Procedures to Assess Ecosystem Services at Farm Level, including the Role of Soil Health. Soil Syst. 2022, 6, 34. *https://doi.org/10.3390/soilsystems6020034*



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Soil Health

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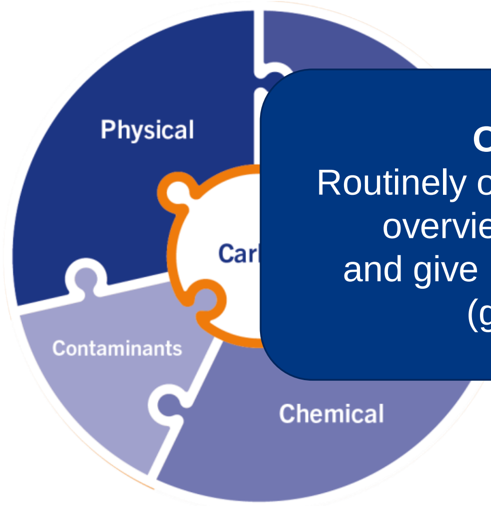

Objective:
Routinely offer comprehensive overview of soil health and give recommendations (guidelines)

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., Fleskens, L., Geissen, V., Kuyper, T. W., Mäder, P., Pulleman, M., Sukkel, W., van Groenigen, J. W., & Brussaard, L. (2018). Soil quality – A critical review. Soil Biology and Biochemistry, 120, 105–125.

21

Full soil health assessment + guidelines

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Commonly, **many different tests** are needed for a full health assessment

- Laboriou
- Expensi
- High env

and…the "traditional" soil tests
- are the basis of many fertilization recommendations
- and sometimes part of legislation

Not easy to make changes

22

3 step approach

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a three-step approach for introducing new broad-spectrum soil tests and new scientific insights in fertilization recommendations

I **Establishing new broad-spectrum soil tests and new scientific insights**

II **Creating translation models bridging old and new soil tests and recommendations**

III **Validation and implementation of new fertilization recommendations in practice**

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Testing for Life

Step I

Broad Spectrum Soil Tests

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Near Infra-Red Spectroscopy (NIRS)

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Near Infra-Red Spectroscopy (NIRS) as rapid broad-spectrum soil test in dried soil!

NIRS determinations provide assessments of a

< 20 seconds
>100 soil indices

Biology and Biochemistry, 43, 1649 – 1659.
Jaconi, A., C. Vos & A. Don. 2019. Near infrared spectroscopy as an easy an precise method to estimate soil texture. Geoderma, 337, 906 – 913.
Niederberger, J. B. Todt, A. Boča, R. Nitschke, M. Kohler, P. Kühn & J. Bauhus. 2015. Use of near-infrared spectroscopy to assess phosphorus fractions of different plant availabilty in forest soils. Biogeosciences, 12, 3415 – 3428.
Zhang. L. & R. Zhang. 2015. Fast detection of inorganic phosphorus fractions and their phosphorus content in soil based on near-infrared spectroscopy. Chemical Engineering Transactions, 46, 1405 – 1410.
Zornoza, R., C. Guerrero, J. Mataix-Solera, K.M. Scow, V. Arcenequi & J. Mataix Beneyto. 2008. Soil Biology and Biochemistry, 40, 1923 – 1930.

Soil Characteristic	Calibration							
	n	year	R^2	RPD	RMSE	Bias	Sres	Reference
N-total	55,947	2004	0.99	8.6	0.53	0.002	0.53	ISO 13878 [43]; NEN 6966 [28]
S-total	37,783	2004	0.97	5.5	0.21	−0.000	0.21	NEN 15587-2 [44]; NEN 6966 [28]
K-CEC	16,144	2006	0.79	2.0	2.19	−0.040	2.19	ISO 23470 [45]; NEN 6966 [28]
Ca-CEC	15,742	2006	0.97	5.5	17.53	0.483	17.52	ISO 23470 [45]; NEN 6966 [28]
Mg-CEC	15,732	2006	0.88	2.7	6.32	−0.015	6.32	ISO 23470 [45]; NEN 6966 [28]
pH-$CaCl_2$	89,075	2013	0.97	5.3	0.18	−0.004	0.18	Potentiometric ISO 10390 [30]
Soil organic carbon (SOC)	21,976	2004	0.99	12.9	4.93	0.066	4.93	ISO 10694 [46]
Soil organic matter (SOM)	24,825	2004	1.00	17.5	6.46	0.007	6.46	NEN 5754 [47]
Soil inorganic carbon (SIC)	15,864	2004	0.97	5.6	1.45	0.001	1.45	NEN-EN 15936 [48]
Clay (<2 µm)	49,121	2004	0.98	7.0	17.99	0.664	17.97	NEN 5753 [49]
Sand (>50 µm <2000 µm)	8,419	2015	0.96	4.7	58.39	1.390	58.37	NEN 5753 [49]
Effective CEC (ECEC)	16,122	2005	0.97	5.8	20.44	0.125	20.44	ISO 23470 [45], 2018; NEN 6966 [28]

Reijneveld, J.A.; van Oostrum, M.J.; Brolsma, K.M.; Fletcher, D.; Oenema, O. Empower Innovations in Routine Soil Testing. Agronomy 2022, 12, 191. https://doi.org/10.3390/agronomy12010191

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25

0.01 M $CaCl_2$

eurofins

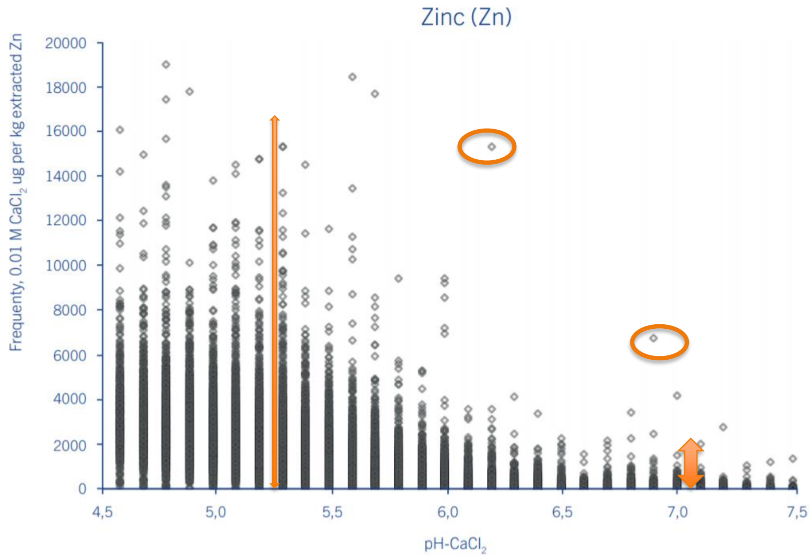
- The NIRS-chemical characteristics are often soil quantity measurements
- Measuring soil intensity is often not possible: 0.01 M $CaCl_2$ for
  - NO_3, NH_4, DON, S, P, K, Mg,
  - Na,
  - Fe, Zn, Mn, Cu, Mo, B and Co, Se, Si
  - Bio available (heavy) metals like Cd, Al, Cr, Pb
- Method used worldwide, so a lot of literature and results of field trials
- Comparable ionic strength as the average salt concentration in many soil solutions
- Various nutrients in single extract, which allows considering relationships between nutrients
- Measured nutrients reflect the availability at the pH of the soil solution

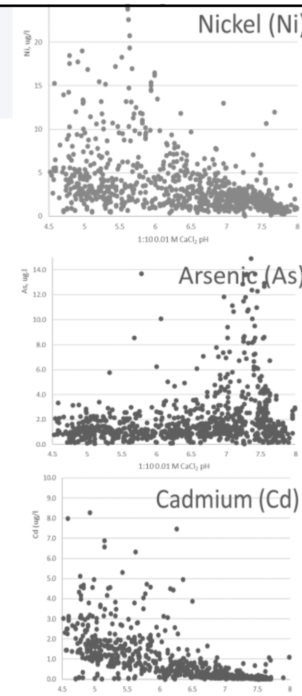
Houba V.J.G., Novozamsky, I., Lexmond, T.M. & Van der Lee, J.J. 1990. Applicability of 0.01 M CaCl2 as a single extraction solution for the assessment of the nutrient status of soils and other diagnostic purposes. Communications in Soil Science and Plant Analysis, 21, 2281 – 2290
Houba V.J.G., Novozamsky, I. & Van der Lee, J.J. 1994. Status and future of soil and plant analysis. Communications in Soil Science and Plant Analysis, 25, 753 – 765.
Houba, V.J.G., P.J. van Erp, M. Fotyma, J. Loch & J. Baier. 1996. Development and testing of a universal soil extraction method for the evaluation of soil fertility and soil pollution. Communications in Soil Science and Plant Analysis, 27, 233.
Van Erp, P.J. 2002. The potentials of multi-nutrient soil extraction with 0.01 M CaCl2 in nutrient management. PhD thesis Wageningen University, The Netherlands.
Miles et al. (2014) promoted Si-0.01 M CaCl2 for sugar cane in South Africa
K-0.01 M CaCl2 showed a high correlation with rice parameters in Iran by Kavoosi et al. (2003)
Finger millet yield (India) was positively and significantly correlated with K-0.01 M CaCl2 (Srinivasarao et al., 2014),
Sürücü et al.,2013 (Turkey) found that Mn-0.01 CaCl2 was the best out of 16 soil tests to relate to tea parameters, and
Spargo et al. 2017 (USA) used it for S determination in field and forage crops.

26

26

Effect of pH on soil intensity





27

Intensity, buffering, quantity system can be introduced

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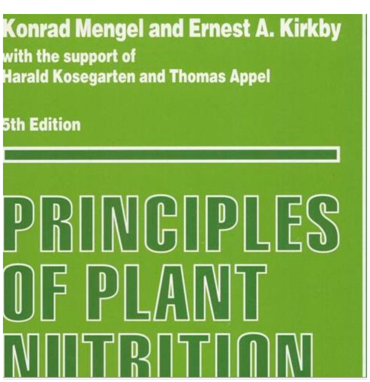

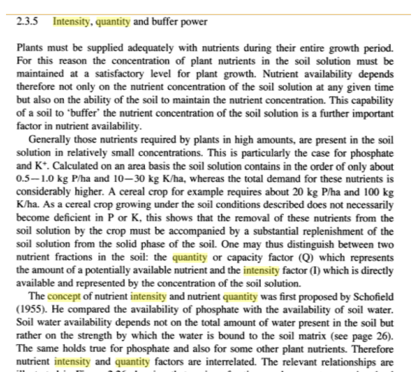

2.3.5 Intensity, quantity and buffer power

Plants must be supplied adequately with nutrients during their entire growth period. For this reason the concentration of plant nutrients in the soil solution must be maintained at a satisfactory level for plant growth. Nutrient availability depends therefore not only on the nutrient concentration of the soil solution at any given time but also on the ability of the soil to maintain the nutrient concentration. This capability of a soil to 'buffer' the nutrient concentration of the soil solution is a further important factor in nutrient availability.

Generally those nutrients required by plants in high amounts, are present in the soil solution in relatively small concentrations. This is particularly the case for phosphate and K^+. Calculated on an area basis the soil solution contains in the order of only about 0.5—1.0 kg P/ha and 10—30 kg K/ha, whereas the total demand for these nutrients is considerably higher. A cereal crop for example requires about 20 kg P/ha and 100 kg K/ha. As a cereal crop growing under the soil conditions described does not necessarily become deficient in P or K, this shows that the removal of these nutrients from the soil solution by the crop must be accompanied by a substantial replenishment of the soil solution from the solid phase of the soil. One may thus distinguish between two nutrient fractions in the soil: the quantity or capacity factor (Q) which represents the amount of a potentially available nutrient and the intensity factor (I) which is directly available and represented by the concentration of the soil solution.

The concept of nutrient intensity and nutrient quantity was first proposed by Schofield (1955). He compared the availability of phosphate with the availability of soil water. Soil water availability depends not on the total amount of water present in the soil but rather on the strength by which the water is bound to the soil matrix (see page 26). The same holds true for phosphate and also for some other plant nutrients. Therefore nutrient intensity and quantity factors are interrelated. The relevant relationships are illustrated in Figure 2.26 showing that various fractions and parameters are involved

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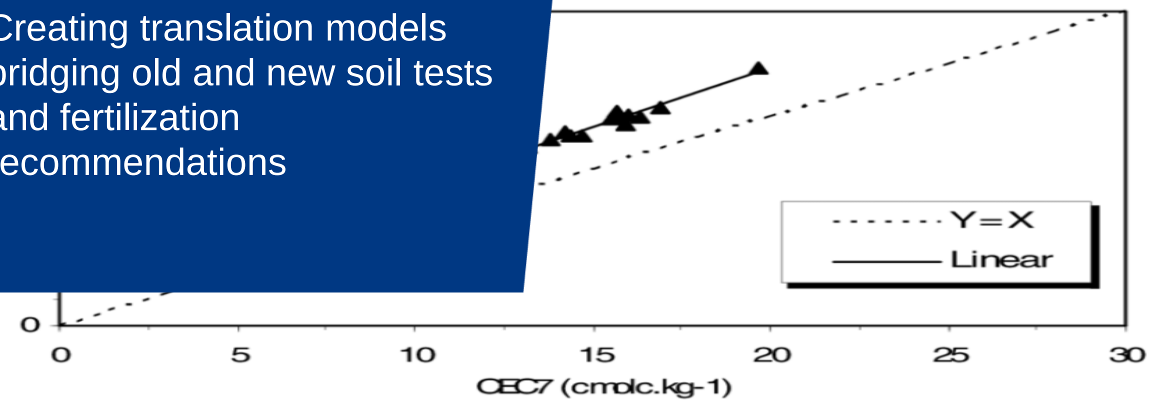
Testing for Life

Step II

Creating translation models bridging old and new soil tests and fertilization recommendations



Relationship between the cation exchange capacity measured with the cobalt hexamine trichloride method and with the Metson method It appears that the value of the CEC results from the cumulated properties of the clay and the organic matter. The fact that there is a measurement difference between both methods according to their implementation (pH of the soil.

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Translation models from conventional method to new broad spectrum soil test results

For example: for Mg-NaCl

- Translation model with 0.01 M $CaCl_2$ (r^2 0.88)
- Translation model with 0.01 M $CaCl_2$ and Mg-CEC (NIRS) r^2 = 0.97

So, the new results can be presented, and the old knowledge can be used (for the fertilization recommendations).

Element	Conventional Method	Reference of CM	R^2	Reference Step 2
				De Haas et al., al., 2014 [22]
				1]; Baier & Haas et al. [52]
				[58]; 01 [59]
				005 [52]
Mi	hydroquinone			, 2005 [52]
Cu	HNO_3; 1: 10 (w/v) 0.43 M Nitric acid	Henkens, 1961 [60]; Anonymous, 2012a; 2012b [14,54]	0.87	De Haas et al., 2005 [52]
Co	1: 40 (w/v) 0.4 M Acetic acid	Henkens, 1959 [61]; Anonymous, 2012b [54]	088	De Haas et al., 2005 [52]
B	Hot water; 1: 10 (w/v) hot water	Berger & Truog 1939 [62]	0.74	Novozamsky et al., 1990 [63]
pH	KCl; 1: 5 (v/v) 1 M potassiumchloride	Anonymous, 2012a; 2012b [54,55]	0.98	Houba et al., 1990 [24]; Fotyma et al., 1998 [64]

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Testing for Life

Step III

Validation and implementation of new fertilization recommendations in practice

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New fertilization recommendations

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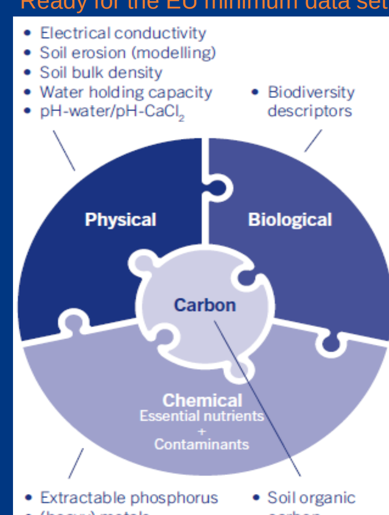
This approach allowed us to introduce new fertilization recommendations

- including the soil nutrient intensity-buffering-quantity concept
- A soil-based and crop-based recommendation
- an assessment of all essential nutrients, as well as soil biological indices.

Ready for the EU minimum data set



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32

Agronomical validation and communication

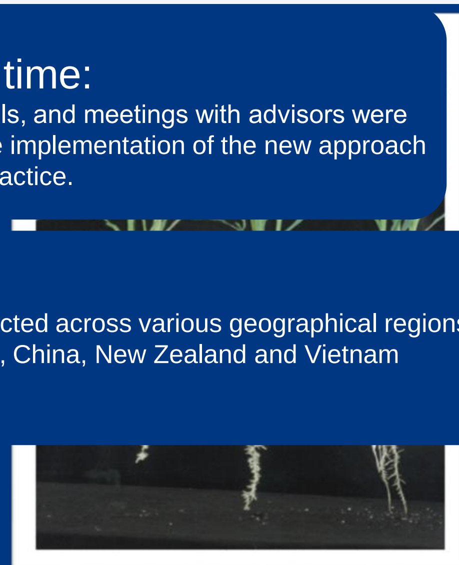
- M
- P
- Fi
- Pr
- Farmers' study group
- **Research pr**

(Wieke Vervuu

Relation s

Use of exis

- **Future: living lab + lighthouse studies**



At the same time:

communication campaigns, farmers' field schools, and meetings with advisors were organized to explain the concept and improve the implementation of the new approach and soil tests in practice.

Scalable system successfully conducted across various geographical regions, including European countries, China, New Zealand and Vietnam

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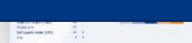
Broad spectrum soil test results used for advice reports ("tools")

1. Soi

"Tools" to provide guidance for land users to attain healthier crops and soils, and thereby contributing to the realization of the SDGs

2. S



3. Soil Health Indicator

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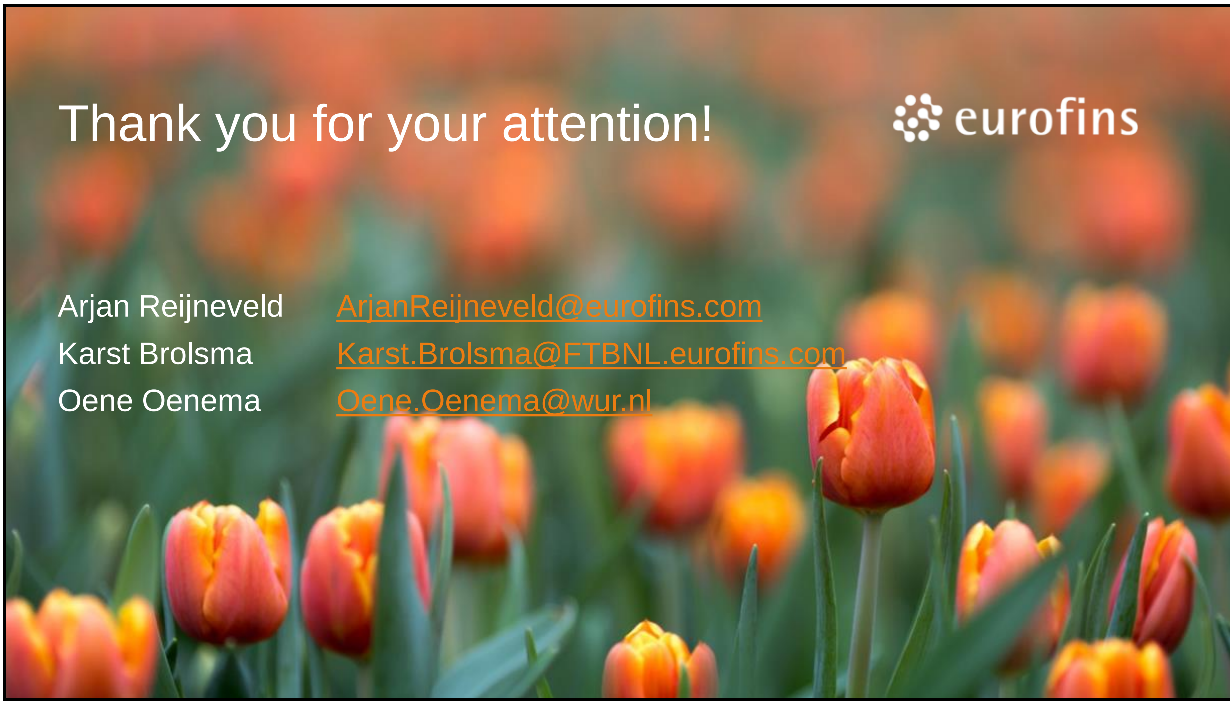

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International Workshop

From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

EJP SOIL European Joint Programme

PPS BAAT BemestingsAdviezen Akkerbouw Toekomstgericht

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Stenon´s FarmLab for in-field soil analysis

HOCHSCHULE OSNABRÜCK
UNIVERSITY OF APPLIED SCIENCES

✓ Stenon claims

- Equivalent to lab data
  - Soil pH
  - Plant available P/K/Mg
  - Soil mineral N
  - Total C/N
  - Soil moisture
  - ……..
- Fast & reliable

✓ Certified by the DLG

(German Farmers association)

Equivalence Stenon FarmLab versus lab analyses

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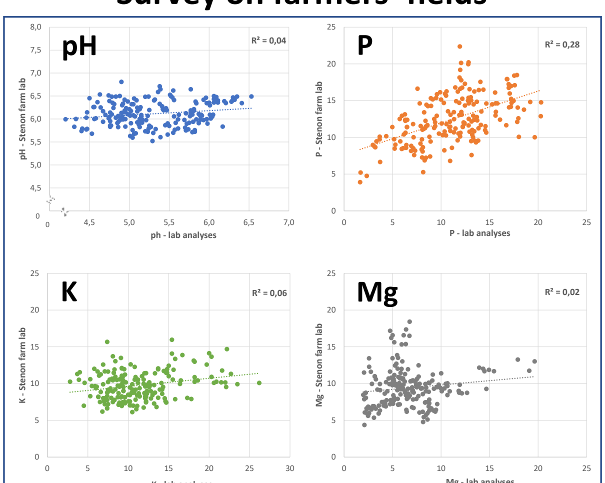
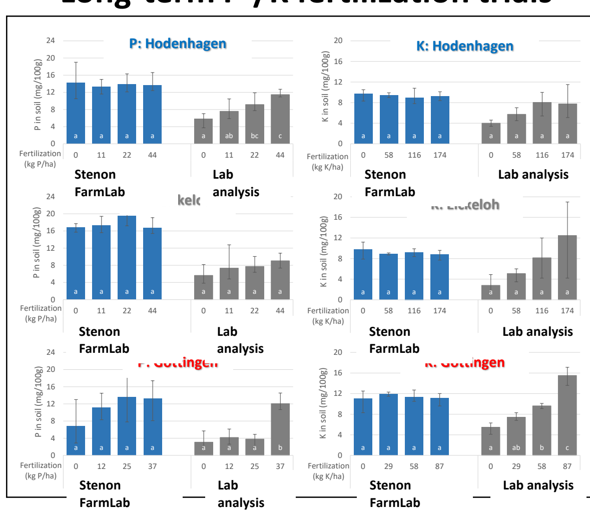
Survey on farmers' fields



Long-term P-/K fertilization trials



Do composts meet organic fertilizers quality requirements: Lithuanian case study?

LAMMC
LITHUANIAN RESEARCH CENTRE FOR AGRICULTURE AND FORESTRY

Karolina Barčauskaitė
Lithuanian Research Centre for Agriculture and Forestry, Instituto Av. 1, Akademija, 58344 Kedainiai, Lithuania

Table 1. Agrochemical indicators in different types of compost produced in Lithuania, 3-year results

Quality indicators	Compost type				
	GWC	FWC	SSC	CMC	DC
Total nitrogen, %	0.76	2.22	2.69	2.42	3.04
Total phosphorus, %	0.25	0.53	1.80	1.01	1.56
Total potassium, %	0.59	1.9	0.37	2.76	0.58
Total amount of main nutrients, %	1.60	4.65	4.68	6.19	5.18
Organic carbon content, %	8.90	16.10	17.70	21.70	37.90

Note: GWC-green waste compost, FWC-food waste compost, SSC-sewage sludge compost, CMC-cattle manure compost, DC-digestate compost

very low · *low* · *average* · *doesn't meet OF* · *very high* · *meet OF*

Table 2. Concentration of heavy metals in different types of compost produced in Lithuania, 3-year results

Heavy metals, mg/kg	Compost type				
	GWC	FWC	SSC	CMC	DC
Cd	0.24	0.13	2.37	0.18	0.21
Pb	23.40	7.97	56.73	3.77	2.60
Ni	6.43	3.63	41.33	2.80	7.53
Cu	40.17	18.03	196.20	26.40	19.63
Zn	268.37	113.43	1204.33	149.83	288.57
Cr_{otal}	13.50	7.87	60.17	3.93	3.23
Hg	0.22	0.01	0.22	0.00	0.02

- Composts from green and food waste are classified as soil improvement substances. Cattle manure composts could be considered as multi-nutrient organic fertilizers while digestate composts meet the mono-nutrient organic fertilizers requirements.
- Sewage sludge composts are rich in nutrients however high amount of heavy metals Cd and Zn is a limiting factor of these composts' use.
- Lithuanian policy recommendations regulate the total Cr amount in composts, but not hexavalent chromium as recommended to determine it in EU document. There is a gap in the data of Cr (VI) in Lithuanian compost samples.
- We suggest consider to evaluate the nutrient/contaminants ratio while talking about organic fertilizers such as compost quality.

karolina.barcauskaite@lammc.lt
https://www.researchgate.net/profile/Karolina-Barcauskaite-2

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Wieke Vervuurt, WUR

Long-term effects of phosphate fertilization

bo voor de akkerbouw van morgen · Topsector Agri & Food · Ministerie van Landbouw, Natuur en Voedselkwaliteit · PPS BAAT BemestingsAdviezen Akkerbouw Toekomstgericht

40

Wieke Vervuurt, WUR

Evaluation framework to predict the fate of organic materials

PPS BAAT
BemestingsAdviezen Akkerbouw Toekomstgericht

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Effects of Long-term Phosphate Fertilization on Soil P Pools and Crop Available P.

Background

- Maintain certain P stock in soil for optimal yield by fertilization
- Prevent too high input to minimize environmental risk and reduce usage of non-renewable resource

Long-term experiments

- Noncalcareous sandy soil and calcareous loamy soil
- Cumulative P balance of -1000 to 4000 kgP/ha after 50 years
- Measured Crop yield, P uptake, Soil Test Phosphorus

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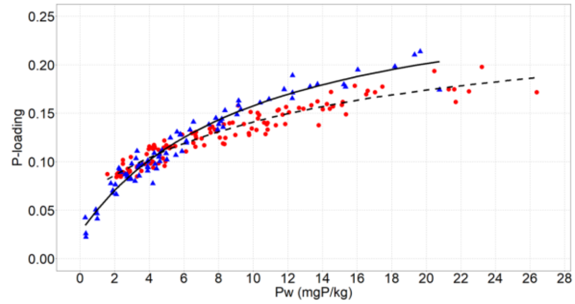
Some results

- P-loading onto oxides seems to govern P in solution, also in calcareous soil.
- Critical Pw levels for potato
  Loam soil: 5 mgP/kg (14 mgP2O5/L)
  Sandy soil: 9 mgP/kg (23 mgP2O5/L)
- Low leaching rates: Fertilization with low environmental losses and optimal yield is manageable at both sites.



Loamy soil	P leaching (mgP/L)		**Sandy soil**	P leaching (mgP/L)	
P dosage	35 cm depth	75 cm depth	P dosage	35 cm deep	155 cm deep
0	0.02	0.01	0	0.04	0.02
35	0.03	0.01	20	0.1	0.04
70	0.01	0.02	39	0.1	0.04
105	0.04	0.01	79	0.15	0.01
			105	0.1	0.02

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Session 4. Integrating fertilizer recommendations to a fertilizer plan on field and farm level

International Workshop
From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

1

Program session 4 and closing of the workshop

Presentations

Frank Liebisch, Agroscope
The Swiss fertilizer recommendation

Janjo de Haan, WUR
Integration of fertilizer recommendations to farm level

Panel discussion

Leader: André Hoogendijk

Members:
Gert Jan van Dongen *farmer*
Harm Brinks *Delphy*
Arjan Reijneveld *Eurofins*
Geert-Jan van Roessel *LambWeston*

Discussion

Discussion

Plenary recap

Closing of the workshop

Pitches WP-leaders PPS BAAT

Formulation of needed actions and possible follow ups

2

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Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Département fédéral de l'économie,
de la formation et de la recherche DEFR
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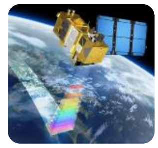
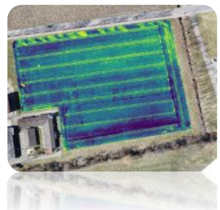
The Swiss fertilizer recommendation - historic development, current status, integration in legislation and ways forward to sustainable nutrient management





Liebisch F. et al.

Agroscope, Gewässerschutz und Stoffflüsse, 8046 Zürich, Schweiz

Agroscope

www.agroscope.ch I good food, healthy environment

3

Outline

- Historic development and current fertilizer recommendation
- Examples for ways forward for fertilizer recommendation
- The NGO Nitrate project ahead of legislation?!

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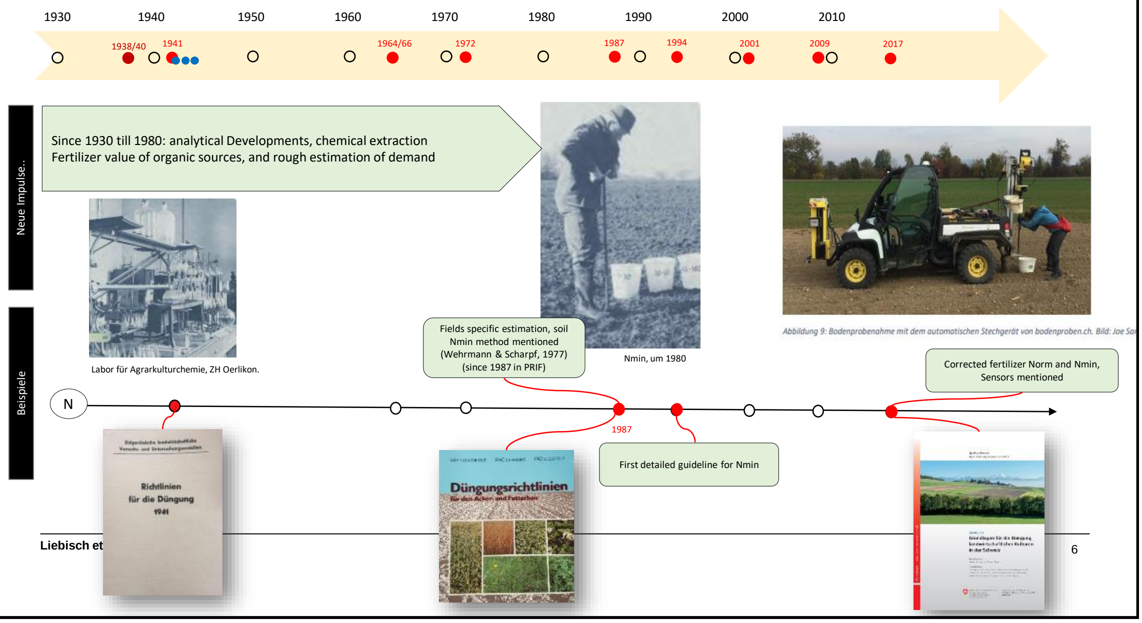
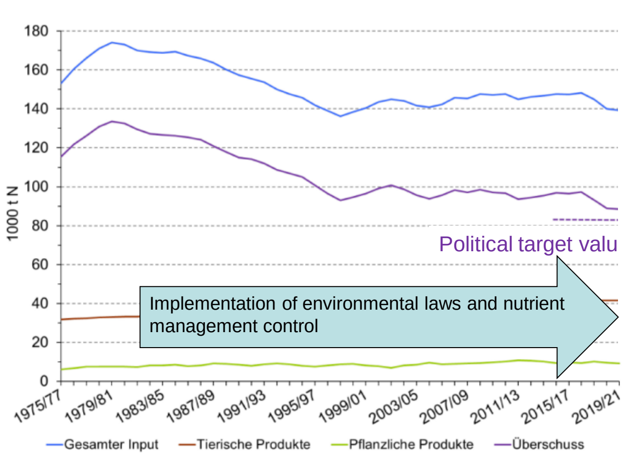
History of fertilizer guidelines in Switzerland



The Swiss agricultural Nitrogen balance (farm gate) indicates inefficient nutrient managment

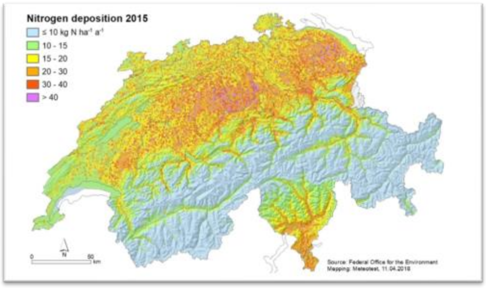


The Swiss N cycle Ø 2019-2021 (in thousand t), Spiess und Liebisch 2023

~ 37 % N recovery / use

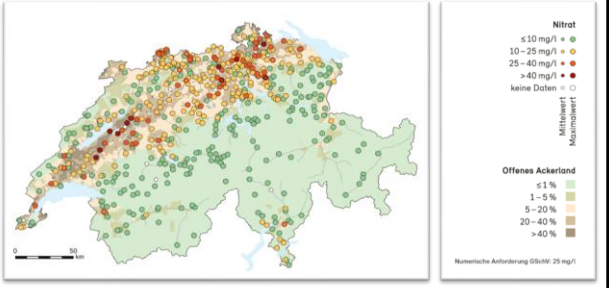
In Switzerland N use in agriculture is linked to environmental problems

Nitrogen deposition, modelled



High N deposition is strongly related to high animal density and thus Ammonia emissions, (Rihm, B., Künzle, T. , 2019: Mapping Nitrogen Deposition 2015 for Switzerland)

Nitrate in drinking water resserves



15-20% of measured reserves are above the quality threshold, mostly under intensive agricultural use (FOEN, 2019)

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The principles of fertilization (PRIF): the base for fertilization norms and corrections

Fertilization Norm (kg N/ha Table 9)

↓

Correction according to the soil, climate and management

↓

Correction according to the nutritional status of the plant and the soil in situ, precision methods

Base

Used in legal context

Good practice

Available, use not binding

Best practice?

Partly available, emerging, to be developed and integrated

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W. Richner et al. GRUD, Agrarforschung 06 2017, https://www.agrarforschungschweiz.ch/archiv
T. Guillaume, F. Liebisch

PRIF Methods for N correction:

N_{min} & Adjusted Norm

Ref. value - N_{min} - Correction factors = Recommendation


S. Schönmann during sampling in the Nitrate project (NGO)

- Time-intensive and expensive
- Direct measurement in the soil

Norm   Correction factors   Recommendation

$= Norm + f_{yield} + f_{SOM} + f_{mech} + f_{PC} + f_{OF} + f_{precip} + f_{ST}$

Düngungsnorm (kg N/ha, Tabelle 9)

Korrektur in Abhängigkeit des Ertrages (Tabelle 11 [1])

+/–

Korrekturen nach Boden-, Klima- und Anbaubedingungen

1. N-Mineralisierungspotenzial des Bodens und Tongehalt:	Tabelle 12
2. Vorfrucht:	Tabelle 13
3. Nachwirkung von organischen Düngern:	Tabelle 14
4. Winter- und Frühlingsniederschläge:	Tabelle 15
5. Hacken nach dem Auflaufen der Kultur:	Tabelle 16
6. Auswirkungen der Bedingungen im Frühling auf die Mineralisierung von OS:	Tabelle 17

=

zu düngende N-Menge (kg N/ha)

X

- Based on model-predictions and more information about the field is required i.e. previous crop,
- Free of costs, digitally available (soon)

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International Comparison of fertilizer recommendation

TABLE 4 Components (inputs and outputs) included in the nitrogen budget by each country, ranked in decreasing order of number used.

	Outputs (direct or through coefficient)					Inputs (or not needed to be brought)										
	S_{end}	C_{end}	L	A	AUC	S_{start}	C_{start}	Hu	Past	CR	IC	Ir	M_1	M_{n-1}	Atm D	AdY
	Soil end	Uptake	Leach.	Atmos. Losses	Apparent Use Coef.	Soil start	Crop start	Humus min.	Pasture min.	Crop residues	Interm. crops	Irrigat.	Manure	Manure Year-1	Atmos. deposition	Adjust. of the yield
France	■	■			■	■	■	■	■	■	■	■	■			
Italy		■	■	■		■		■		■	■		■	■	■	
Switzerland		Norm	Verluste					■	■	■	■		■	■		■
Belgium (Wal.)		■				■	■	■	■	■	■		■	■		
Germany		■				■		■	■	■	■		■	■		■
United Kingdom		■	■		■	■	■	■	■	■			■			
Spain	■	■	■		■	■				■					■	
The Netherlands	■	■				■	■	■		■						■
Ireland		■							■	■	■		■			■
Luxembourg																■

~ SuisseBilanz

Note: C_{Start} = Nitrogen alre…
and variety criteria for cere…
harvest; Hu = Nitrogen ne…
type of residues; IC = Effe…
M_1 = Nitrogen from the or…
brought the year before; L…
prevailing during its spreading.

Fertilizer planning or good fertilization is mandatory (not binding)
The legal enforcement tool for nutrient management ist the Suisse Bilanz

- Integrates no additional sources of N then fertilizer (no environment, soil or management factors)
- Allows environmental losses
- Average on farm level

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Lionel Jordan-Meille et al. 2023 Comparison of nitrogen fertilisation recommendations of West European Countries. https://doi.org/10.1111/ejss.13436

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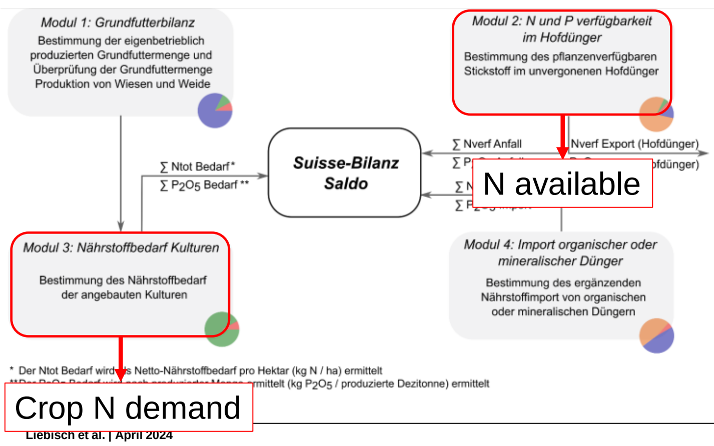
Swiss farmers need to prove an even balance between N input from animal production and fertilizers and crop N demand at farm level → the **Suisse-Balance**



- changes in livestock, manure and field management improved agricultural production
- society and policy ask for more sustainable nutrient management.
- Broader knowledge base
- No deep revision since 90ies

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Color in pie chart explains data sources for the modules

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Ways forward for fertilizer recommendation

- Integrating a model into the suisse balance to use current knowledge on the feed and manure cascade and N use
- Making better use of soil extraction information, soil and climate factors
- Digital transformation, software and web support
- Remote sensing and precision farming

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Département fédéral de l'économie,
de la formation et de la recherche DEFR
Agroscope

Evaluating a model implementation for an improved nitrogen management regulation in Switzerland

Liebisch, F., Mayer, J. & Epper, C.A.
Agroscope, Gewässerschutz und Stoffflüsse, Zürich

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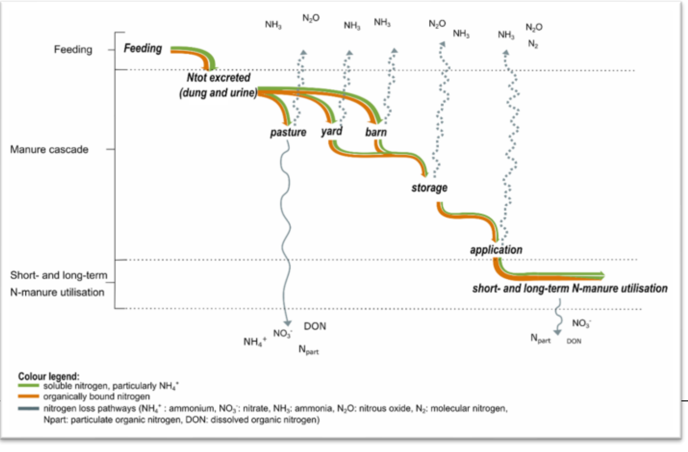
Base and aim of the study

- Integrate actual knowledge into the balance
- Allow evaluation of loss reduction measures along manure cascade
- Compare current and modelled N available from animal manure



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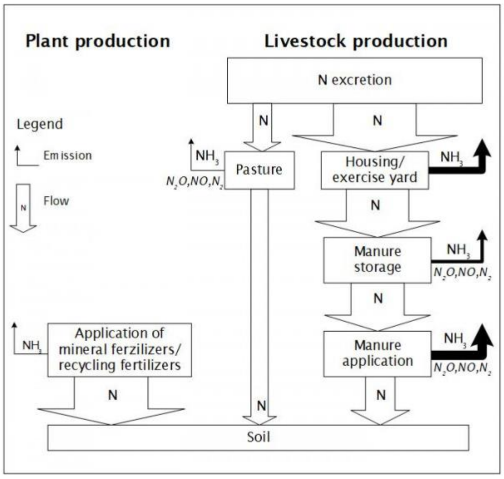
Methodology: Modelling the manure cascade and loss reduction measures



- Flux model

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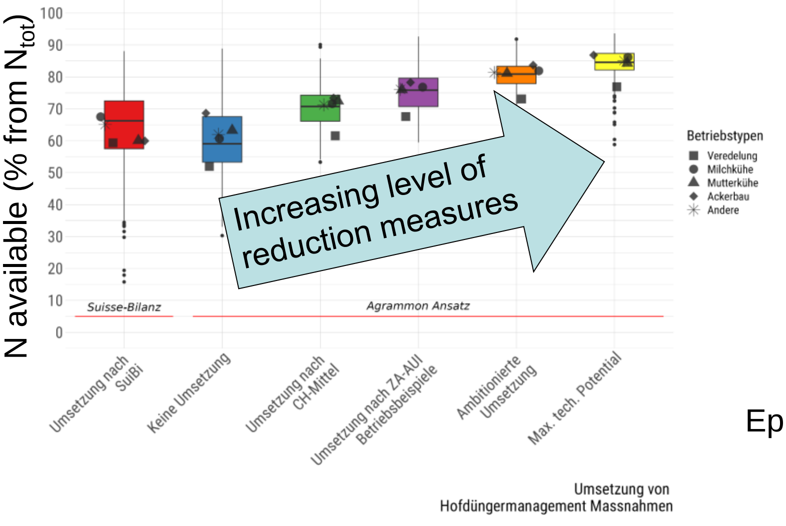
Agrammon, 2022. https://agrammon.ch/

16

16

Current Balance underestimates available N Model is farm specific and allows targeted implementation of meassures



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17

17

P-K Fertilizer recommendation in Switzerland

1. Soil K Test for available K

HNO3
Mehlich3
BaCl2
AA-EDTA, AA, AL
Bray
CO_2-H_2O, H_2O

Madaras and Koubova 2015
Zebec et al. 2017

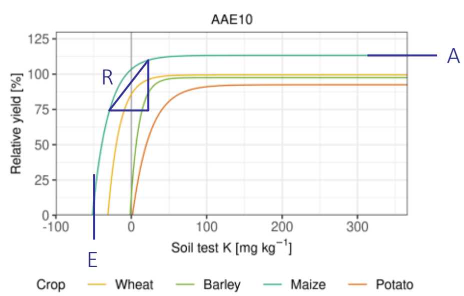
2. Yield calibration
yield ~ soil K + soil clay content

Acker- und Futterbau					
AAE10-K	Tongehalt der Feinerde (%)				
mg K/kg	< 10	10–19,9	20–29,9	30–39,9	≥ 40
0–19,9	1,5	1,5	1,4	1,4	1,2
20–39,9	1,5	1,4	1,4	1,4	1,2
40–59,9	1,4	1,4	1,3	1,2	1,0
60–79,9	1,4	1,2	1,2	1,2	1,0
80–99,9	1,2	1,2	1,2	1,0	1,0
100–119,9	1,2	1,2	1,0	1,0	1,0
120–139,9	1,2	1,0	1,0	1,0	0,8
140–159,9	1,0	1,0	1,0	1,0	0,8
160–179,9	1,0	1,0	1,0	0,8	0,8
180–199,9	1,0	1,0	0,8	0,8	0,6
200–219,9	1,0	0,8	0,8	0,8	0,6
220–239,9	0,8	0,8	0,8	0,6	0,6
240–259,9	0,8	0,8	0,6	0,6	0,4
260–279,9	0,8	0,6	0,6	0,6	0,4
280–299,9	0,6	0,6	0,6	0,4	0,0
300–319,9	0,6	0,6	0,4	0,4	0,0
320–339,9	0,6	0,4	0,4	0,0	0,0
340–359,9	0,4	0,4	0,0	0,0	0,0
360–379,9	0,4	0,0	0,0	0,0	0,0
380–399,9	0,0	0,0	0,0	0,0	0,0
400–419,9	0,0	0,0	0,0	0,0	0,0
≥ 420	0,0	0,0	0,0	0,0	0,0

3. Boden K Versorgungsklassen

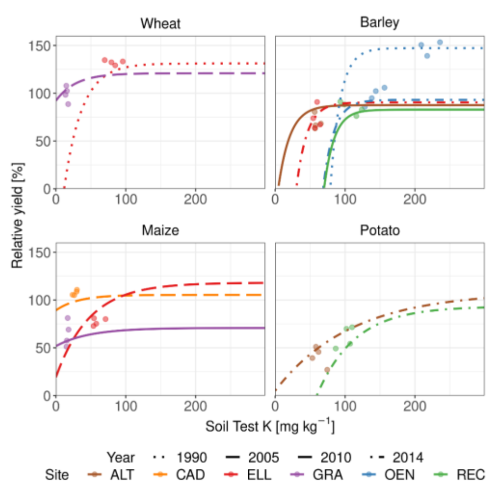
PRIF, 2017

Yield effect of soil K



Covariables: crop + fertilization + Ca + Mg + clay content + pH + temperature + precipitation

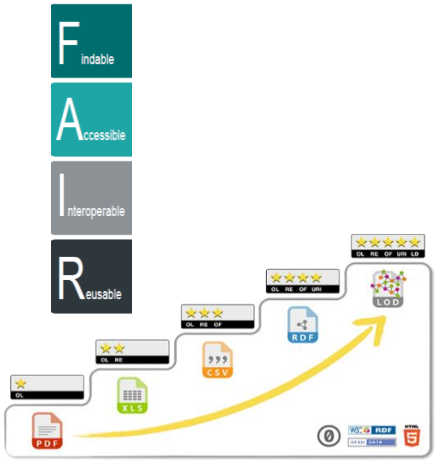
Random effects on asymptote: year / location



$$\text{relativer Ertrag} = A * (1 - e^{-R * (STP + E)})$$

Project WebGRUD

Pilotproject to get the book / fertilizer recommendation into the digital age (Open Government Data)



Daten oder Datenmodell

maschinenlesbar, vollständig,

aktuell, durch Metadaten beschrieben und soweit möglich, Rohdaten.

offene Nutzungsbedingungen, nicht proprietär.

uneingeschränkt und diskriminierungsfrei,

einfach auffindbar, permanent verfügbar.

Machine readable formats

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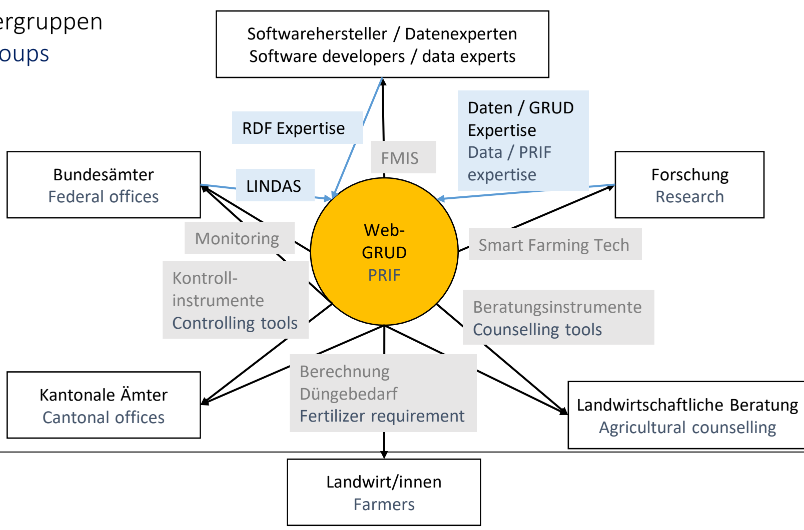
Lösung und erwartetes Ergebnis
Solution and expected outcome

WebGRUD Nutzergruppen
WebPRIF user groups



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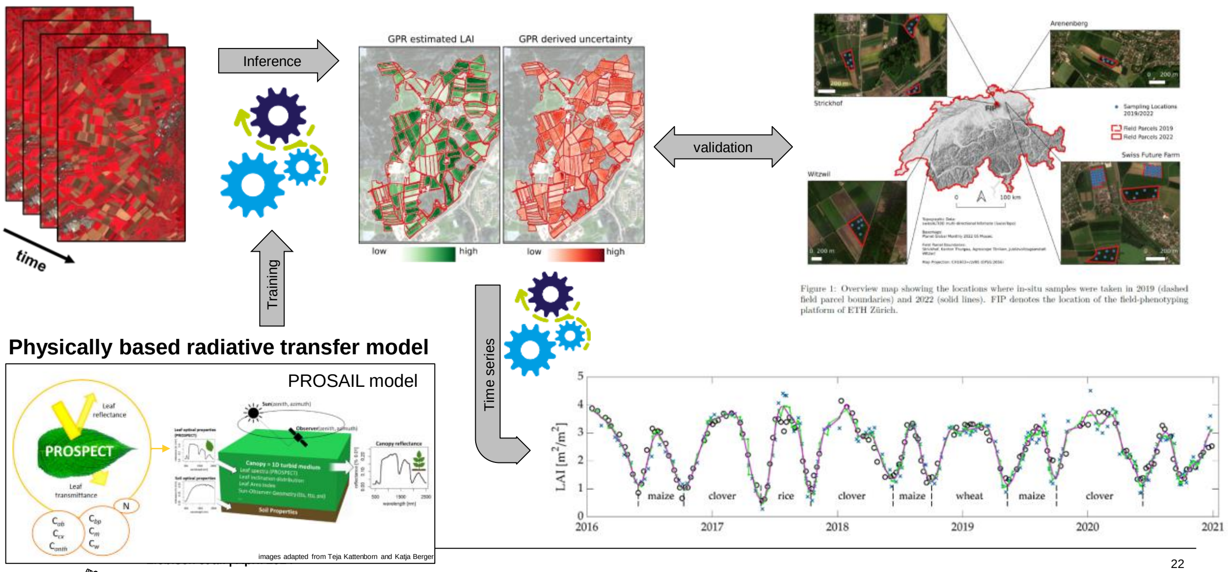
Remote sensing systems: Vegetation status and productivity



EOA
Earth Observation of Agroecosystems team

Thanks a lot to our partners!
(ETH CS, HAFL, Strickhof, SwissFutureFarm, Arenenberg)

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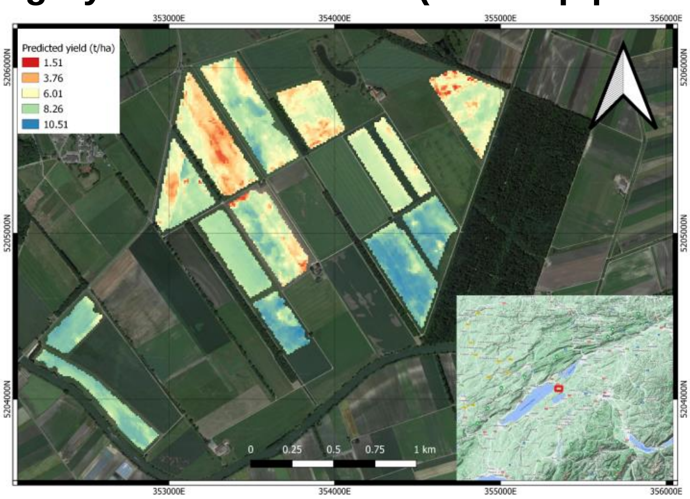
Yield mapping: combination of combine harvester data, satellite imagery and climate data (soil map planned)



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Liebisch et al. | April 2024

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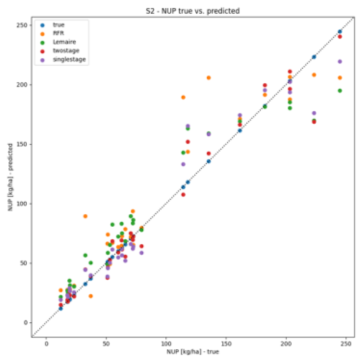
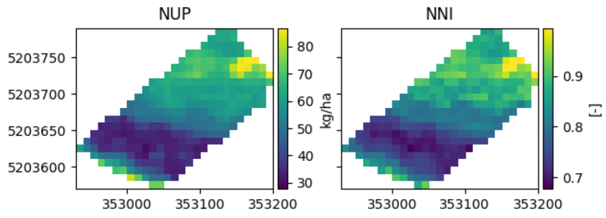
Perich et al. 2023, field crops research

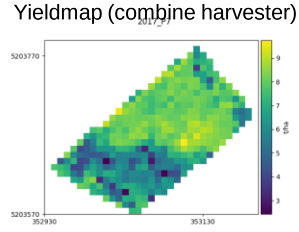
23

Outlook: Remote sensing based in season N status detection





Yieldmap (combine harvester)



Liebisch et al. | April 2024

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Perich et al. in preparation

24

Outlook: Satellite-based N status estimation explains up to 57% of the crop yield variation at field level.

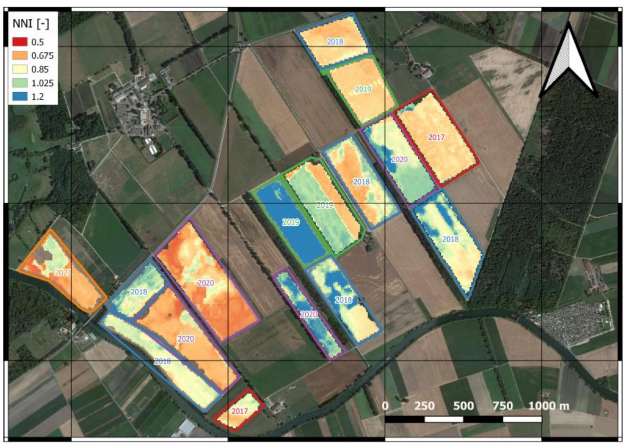

Figure 6: End of April composite of the N nutrition index (NNI) of all winter wheat fields from 2017–2021 of the example farm located in western Switzerland. The field borders are coloured according to the individual years.

Concept for satellite-based modelling of nitrogen status in winter wheat - under Review

Soil map not yet integrated

Liebisch et

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KANTON solothurn TerrAquat Kanton Bern Canton de Berne Agroscope Nitratkommission Niederbipp-Gäu-Olten Bildungszentrum Wallierhof INFORAMA

Critical N

Groundwater-conserving, productive agriculture through site-adapted nitrogen fertilization

- Applied scientific support project in the Nitratprojekt NGO
- Demo trials and on-farm testing of current fertilization methods and increase knowledge / acceptance
- Legal integration, decision support tools
- **Reduce N losses into groundwater under the critical N load of 30 kg N ha^{-1} while maintaining productivity?**
  - Challenges: technical limitations in measurements, data quality from on-farm experiments

Liebisch et al. | April 2024 26

https://so.ch/verwaltung/bau-und-justizdepartement/amt-fuer-umwelt/wasser/grundwasser/schutz/das-nitratprojekt-niederbipp-gaeu-olten/das-forschungsprojekt-criticaln/

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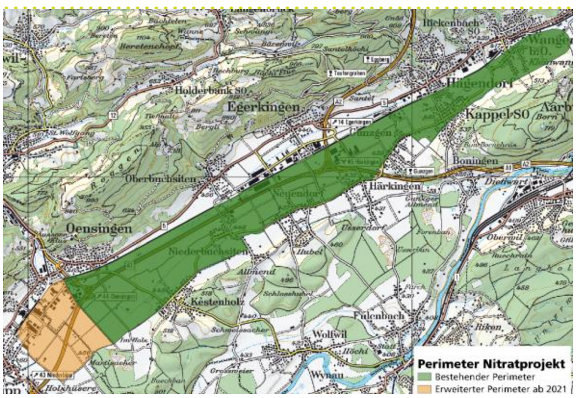
Largest Nitrate project in Switzerland (Nitrate vulnerable zone ...)



Perimeter 2000/2003

Erweiterung 2021

Flächen und Betriebe im Projektgebiet per Ende 2022			
	SO	BE	SO und BE
	total	total	Total
Landwirtschaftliche Nutzfläche im Projektgebiet [ha]	1124	259	1383
Davon am Nitratprojekt beteiligt (Vertragsflächen) [ha]	1031	52	1083
Anz. Betriebe im Projektgebiet	96	30	126
Anz. Betrieb mit Beteiligung am Projekt (mit Verträgen)	82	11	93

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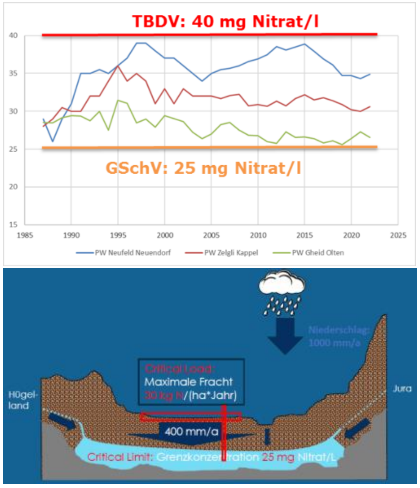
Used Measures are not sufficient



- Since 90ies above quality level
- Project aim: 25 mg Nitrat/l
- Todays measures und paricipation is right and important, but not sufficient

- **Max acceptable N-loss:**
  Ø 30 kg N / (ha*Jahr)
- Average loss today:
  Ø 51 kg N/(ha*Jahr)

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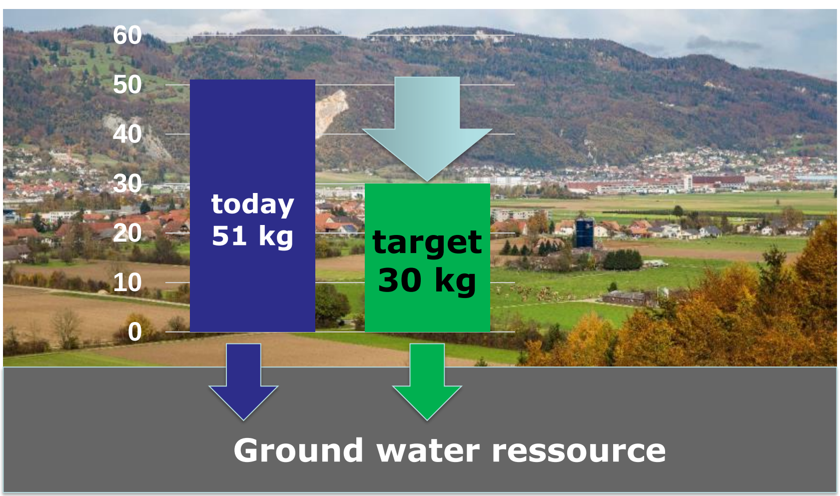
Target N surplus acceptable



Ø 30 kg N /ha = Grundwasserschutz und Produktion

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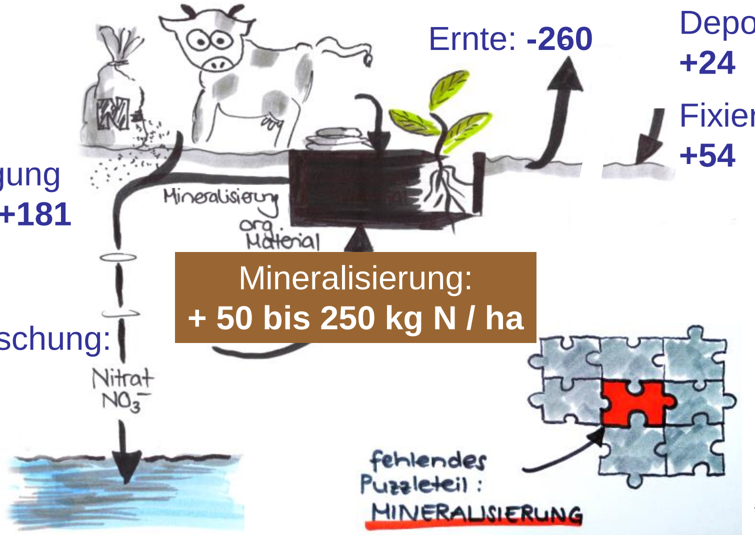
N-Balance arable crops

NitroGäu

Zahlen in kg N ha^{-1} $Messperiode^{-1}$



Ernte: **-260**

Deposition **+24**

Fixierung **+54**

N Düngung (total): **+181**

Mineralisierung:
+ 50 bis 250 kg N / ha

Auswaschung: **- 71**

H. Wey (2021)
Bünemann et al. (2022)

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20. September 2023 • Folie 30

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Project to innovate current nutrient managment system

- Test and teach fertilizer recommendation
- Develop a target oriented subsidy system
- Optimize processes (sampling and advice)
- Education of farmers and advisors
- Show case for agricultural policy makers

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Conclusion for fertilizer recommendation in Switzerland, what should we do ?

- Regular revision with regard to yield, varieties, methods ….
- Binding and quantitative integration in legislation and law enforcment instruments
- Consequent digital transition (seamless data exchange between practice, federal and cantonal authorities … and research)
- Focus on knowledge exchange and education

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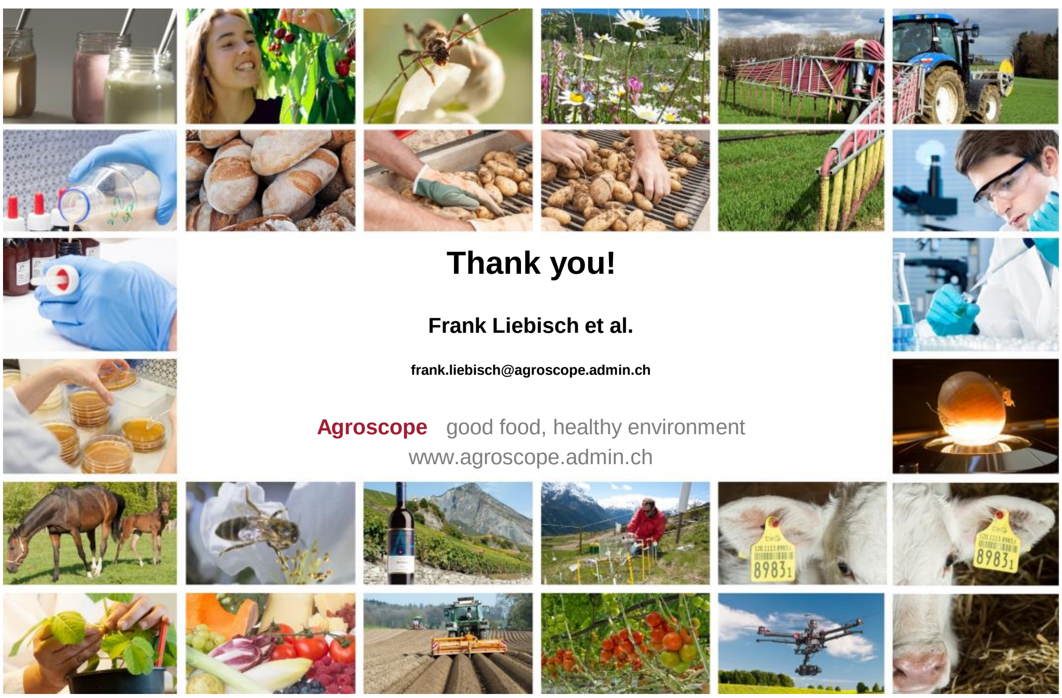

Thank you!

Frank Liebisch et al.

frank.liebisch@agroscope.admin.ch

Agroscope good food, healthy environment

www.agroscope.admin.ch

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International Workshop

From yield-based to society-based fertilizer recommendations

16-18 April 2024 Lelystad

EJP SOIL
European Joint Programme

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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Integration of fertilizer recommendations to farm level

Janjo de Haan, Wim van Dijk & Romke Postma

International Workshop From yield-based to society-based fertilizer recommendations

16 April 2024

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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Need of integration of fertilizer recommendations to farm level

Current recommendations

1 nutrient in 1 crop in 1 field

Societal goals on higher scale levels

Organic manure has multiple nutrients

Mg K Ca P N S

The farm is the decision unit

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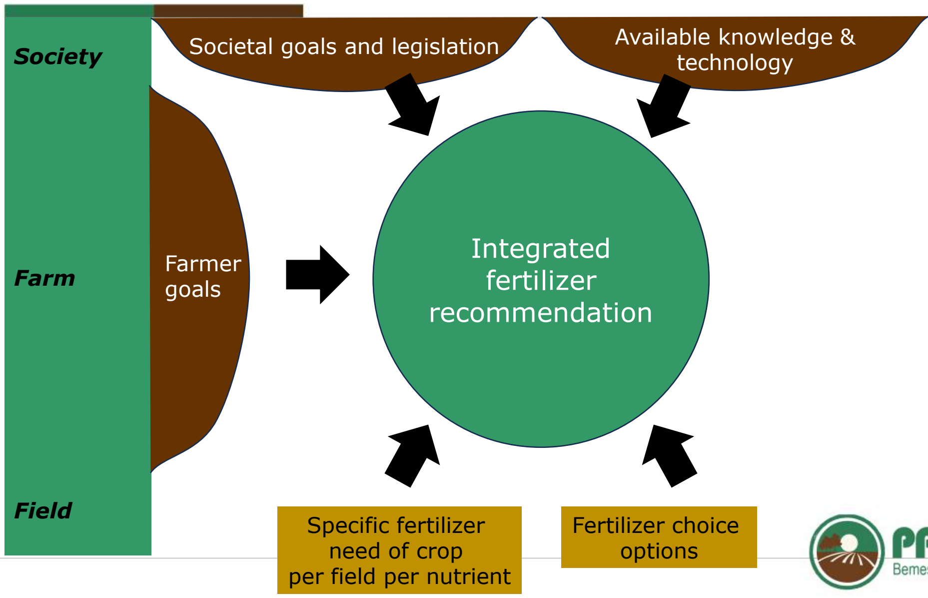
Integration approaches



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Farmers goals and fertilization

Continuity of farm operations

- Yield and product quality
- Financial return €
- Soil fertility/ soil health

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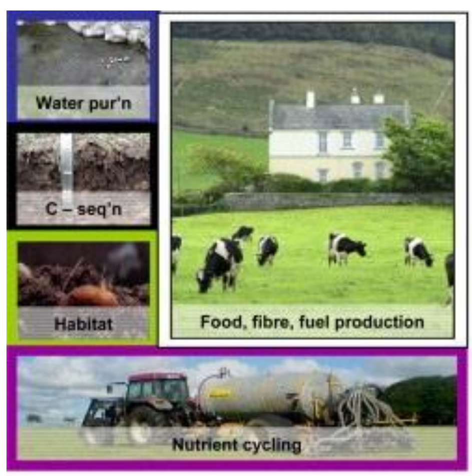
Societal goals and fertilization

From Landmark.eu

- Water regulation
  - Water quality ground & surface water
    - Nitrate Directive, Water Framework Directive
  - Climate change adaptation
- Climate change mitigation
  - Reduction Greenhouse Gas emissions
  - Carbon Sequestration
- Nutrient cycling
- Biodiversity, habitat provision
- Food, fibre, fuel production



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Legislation in the Netherlands

Nitrate action plan

- Usage standards of N-total, P-total, N in animal manure
- Usage and cropping instructions e.g.
  - Manure application periods
  - Catch crops
  - 'Extensive' crops

Common Agricultural Policy

- Eco schemes

Other aspects only voluntarely

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Indicators societal goals

A. Groundwater quality
   1. N and P surplus
   2. Mineral N in soil in November

B. Surface water quality
   3. Surface runoff risks N & P?

C. Greenhouse gas emissions
   4. Indirect & direct emissions of CO_2
   5. Indirect & direct emissions of N_2O

D. Carbon sequestration
   6. Organic matter / carbon balance

E. (Soil) biodiversity
   6. Organic matter balance
   7. Ammonia emission

F. Climate adaptation & water regulation
   6. Organic matter balance
   8. CEC-occupation
   9. pH

G. Nutrient recycling
   10. Share of fertilizer from non-renewable sources

Methods and target values need to be established

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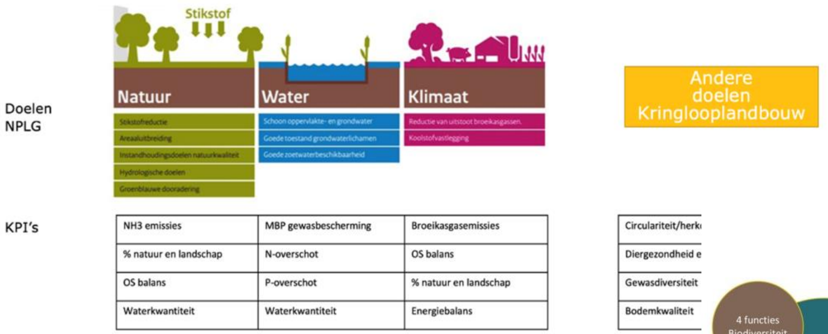
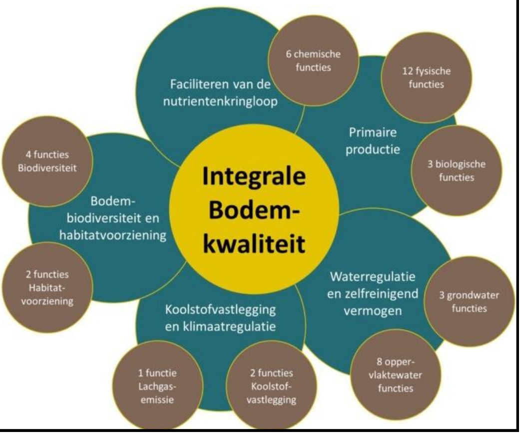
Links to other assessment systems in development



Crirical Performance Indicators for Circular Agriculture
KPI-K

Soil Health Assessment
BLN 2



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Ambition on integration

First step

- Optimized fertilizer recommendations
  - For farmers goals
  - Which complies to legislation
- Calculation of societal impact
  - Insight in effects on societal goals
  - No optimization
- Give insight in effects of reduced fertilization schemes

Ultimate ambition

- Optimized fertilizer recommendation within constraints of farmer, legislation and societal goals
- Insight in trade-offs between goals

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Challenges in integration

- Issues at different scales
- Establishment of target values at farm and field level
- Risk of lack of window of solution
- Priorities in issues: political decisions

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Process of first step integration, first ideas

1. Have your goals and targets ready
2. Establish crop needs per field and nutrient
3. Fertilizer choice
4. Integrate at field and farm level
5. Confront fertilization needs with goals
6. Optimize to comply with legislation and fulfill goals

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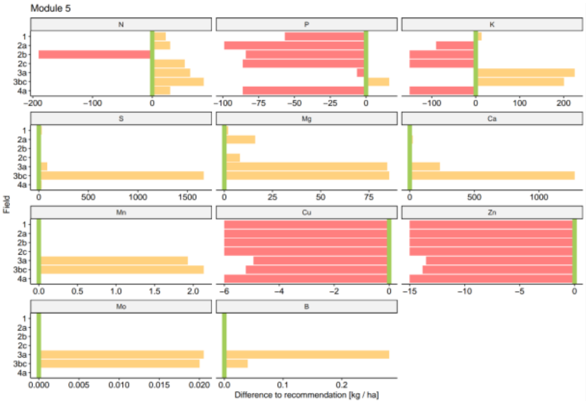
Integration in PPS BAAT

Actions

- First session for farm of Gert-Jan van Dongen
- Further development and tests in future with
  - Practical farms
  - Long term system experiments

Aspects

- Methodology development
- Practical applicability



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To conclude

Integrating fertilization recommendations at farm level is complicated but needed

Ideas are welcome how to realize this

New

Methodology in development

- First steps
  - Optimize to comply to legislation
  - Give insight in societal effects
- Ultimate ambition
  - Optimized fertilizer recommendations at farm level

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Panel discussion

Leader:

André Hoogendijk *BO Akkerbouw*

Members:

Gert Jan van Dongen *farmer*

Harm Brinks *Delphy*

Arjan Reijneveld *Eurofins*

Geert-Jan van Roessel *LambWeston*

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Discussion session 4 Questions

1. Is integration of fertilizer recommendations to farm level really needed?
2. How can farmers goals and societal goals best be combined in the fertilizer recommendations?
3. How to deal with the scale issue: translate national and regional goals to goals at farm level?
4. How do we keep fertilizer recommendations transparent and practical applicable for farmers?

Ministerie van Landbouw, Natuur en Voedselkwaliteit

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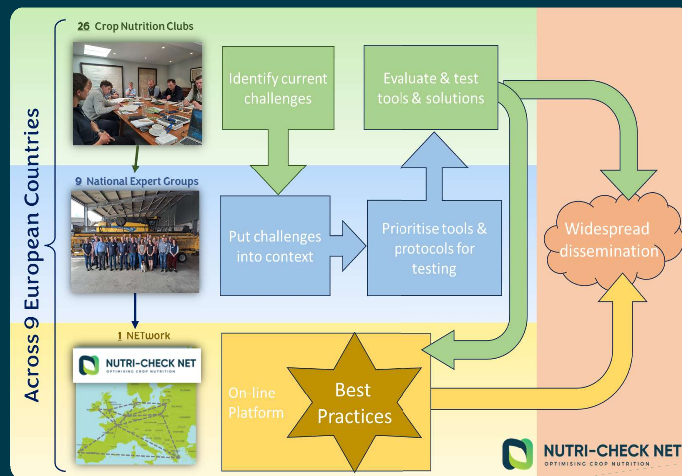
NUTRI-CHECK NET

OPTIMISING CROP NUTRITION

Developing a Measure-to-Manage approach for Crop Nutrition across Europe

Milan Franssen - Harm Brinks, Delphy BV, Netherlands

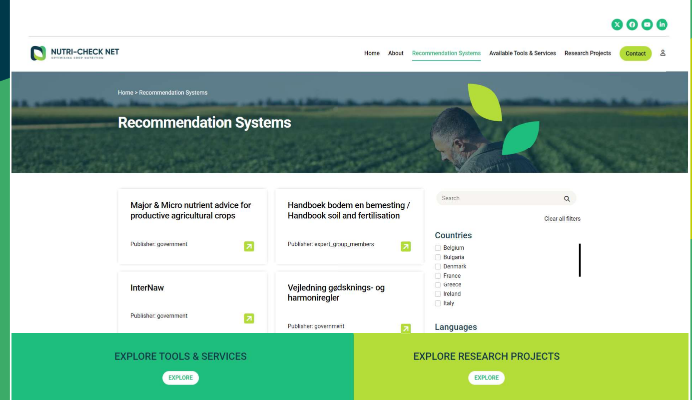
- Nutrient-use-efficiency is a primary challenge for arable farming throughout Europe.
- On-Farm nutrition decisions are often based on experience and guesswork, with farmers in different countries implementing a varying degree of decision-support systems, tools and analyses.
- NUTRI-CHECK NET is a European project which is addressing crop nutrition decision making on arable farms.
- The project is establishing a self-sustaining, multi-actor Thematic Network to build farm-level adoption of best field-specific nutrient management practices.
- Precise farm-specific decisions must derive from on-farm knowledge, inquiry, and confidence.
- Information on systems and tools to improve crop nutrient decision making should be available to farmers throughout Europe.



- An inventory of existing recommendation systems, projects, and commercial tools & services has been prepared by partners in **9 countries.**
- The target crops are **wheat, maize and potato.** Target nutrients are **NP** (and K).
- A total of **13 recommendation systems, 811 projects,** and **211 commercial tools & services** have been **assessed**.
- National Expert Groups are involved to assess quality and quantity of the assessment.
- **26 Crop Nutrition Clubs** select tools and assess 'Requirements', 'Refinements' and 'Outcomes' of each crop's nutrition through each season.

Observations:

- National recommendation systems are using different methodologies for sampling and analysis, which complicates benchmarking.
- Tools & services range from soil sensors, to laboratory services, to satellite imagery and mineralization prediction models.
- Only a few technologies are specifically used in a single country.
- Few commercial tools & services were identified in 2> countries.



- The contents of the inventory, are published online through a customised NUTRI-CHECK NET platform.
- This platform serves as EU-wide inventory for farmers, advisors, researchers, and other entities.

nutri-checknet.eu

Funded by the European Union

UK Research and Innovation

Funded by the European Union and UK Research and Innovation (UKRI) . Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, European Commission or UKRI. Neither the European Union, European Commission nor UKRI can be held responsible for them.

PARTNERS

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WAGENINGEN UNIVERSITY & RESEARCH

Nitrogen fertilizer replacement values of organic amendments: determination and prediction

Dorien Westerik[1], Ellis Hoffland[2] & Renske Hijbeek[3]

[1]Wageningen Environmental Research,
[2]Soil Biology Group, Wageningen University and Research, Wageningen, the Netherlands
[3]Plant Production Systems group, Wageningen University and Research, Wageningen, the Netherlands

Nitrogen fertiliser replacement values

Nitrogen fertilizer replacement value (NFRV) is the value of organic amendments as a nitrogen fertilizer, showing the extent to which organic fertilizer N can replace mineral fertilizer nitrogen (N).

Study objectives

1. To assess NFRVs of a range of organic amendments.
2. To assess which product characteristics explain observed variation.
3. To compare NFRVs based on equal N application with NFRVs based on equal N uptake.

Pot experiment

A pot experiment with spring wheat was performed with two N application rates for the organic amendments (100 and 200 kg N/ha), seven N application rates for the mineral fertiliser (25, 50, 75, 100, 125, 150 & 200 kg N/ha) and a control (0 kg N/ha). A response curve was drawn for the mineral fertiliser treatments to allow calculation of NFRV at equal N uptake.

1. NFRV variation: between 6.2 and 78.8%

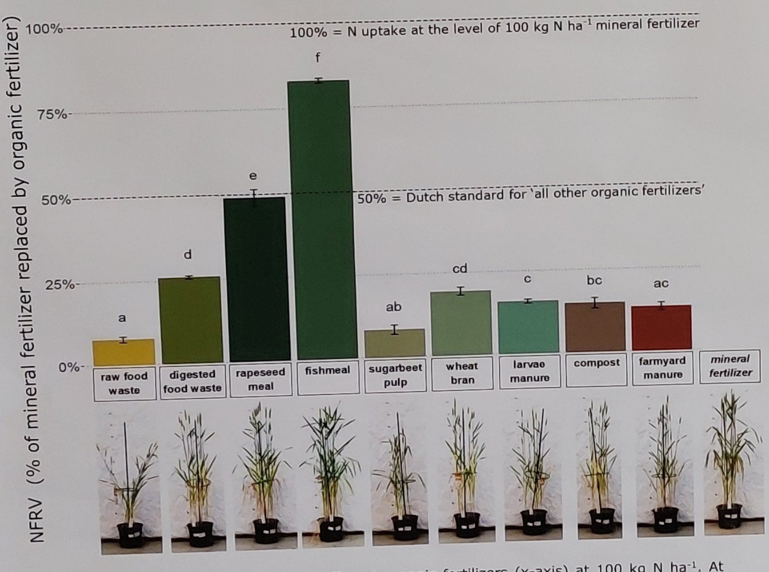

Figure 1: Found NFRVs (y-axis) for different organic fertilizers (x-axis) at 100 kg N ha^{-1}. At 100% the N uptake from an organic fertilizer equals the N uptake from mineral fertilizer. Error bars represent SE of the mean, with 3 replicates per treatment. Letters above the bars represent significant differences ($p<0.05$) between the treatment means: common letters indicate no significant difference. The pictures below represent one replicate of each treatment, including the mineral fertilizer treatment (100 kg N ha^{-1}) as a visual reference.

2. Prediction: N concentration offers best explanation

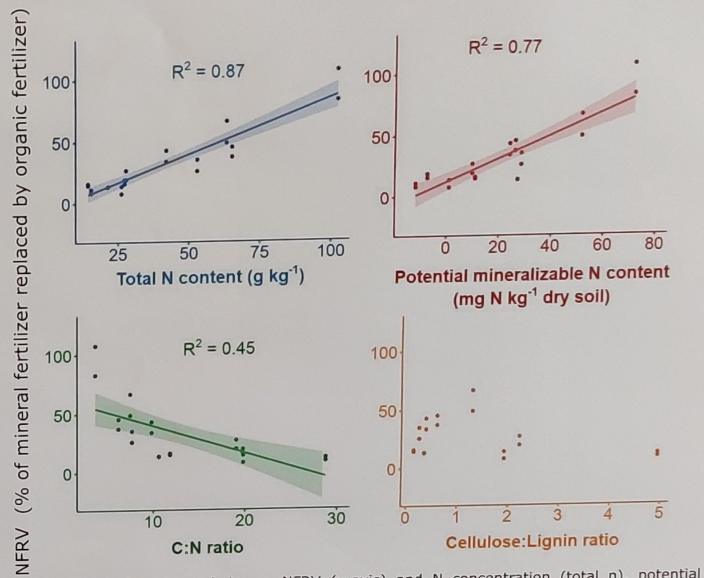

Figure 2: Covariance between NFRV (y-axis) and N concentration (total n), potential mineralizable N content, C:N ratio and cellulose:lignin ratio (x-axes) ($p<0.001$).

3. Determination: at equal N uptake less errors

- At equal N application rate: estimated NFRV at higher N application rate (200 kg N/ha) was found to be larger than estimated NFRV at lower N application rate (100 kg N/ha) for seven of the eleven organic fertilizers ($p \leq 0.0001$).
- At equal N uptake: NFRV was similar for both low (100 kg N/ha) and high N application (200 kg N/ha) ($p = 0.596$).

Outlook

- Short term N value of organic amendments can be assessed based on product characteristics (N concentration).
- Long term experiments are needed to also quantify long term N value.
- Calculating NFRV based on equal N uptake (or yield), as opposed to a calculation based on equal N application rates is recommended to reduce errors.

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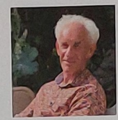
Westerik, Dorien, Ellis Hoffland, and Renske Hijbeek. "Nitrogen fertilizer replacement values of organic amendments: determination and prediction." Nutrient Cycling in Agroecosystems (2023): 1-14. https://doi.org/10.1007/s10705-023-10316-7

Louis Bolk Instituut

NDICEA stikstofplanner



B.G.H. Timmermans[1], G.J. van der Burgt

[1]Louis Bolk Institute | Contact: b.timmermans@louisbolk.nl

The NDICEA model: calculating carbon and nitrogen dynamics in agricultural fields

Introduction

NDICEA (van der Burgt *et al.*, 2006) is a dynamic model to calculate long term carbon balances and nitrogen dynamics for agricultural crop rotations and grassland systems on field scale. It uses daily local weather data and can quantify carbon sequestration and nitrogen mineralization. The aim of the NDICEA model is to evaluate and predict mineral nitrogen and organic matter in the soil, which can be used when improving nitrogen fertilizer recommendations.

Methodology

- The model quantifies mineralization of organic matter and nitrogen using current conditions (soil characteristics, weather data) and the management of a field in the past years.
- Extensive lists of fertilizers, manures and crops with their characteristics are included
- Crop yields are target-oriented: the farmer sets them according to his experience or expectation

Conclusions

NDICEA provides valuable insights in long term soil fertility and short and long term nitrogen dynamics that can be used to gain insights in nitrogen efficiency and loss. It offers the possibility to quantify processes, and to evaluate alternative scenarios aiming at a higher nitrogen use efficiency, organic matter balance or carbon sequestration.

Calculations

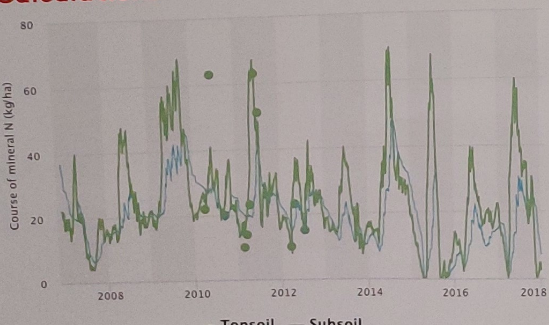


Fig 1. Mineral nitrongen data and calculations

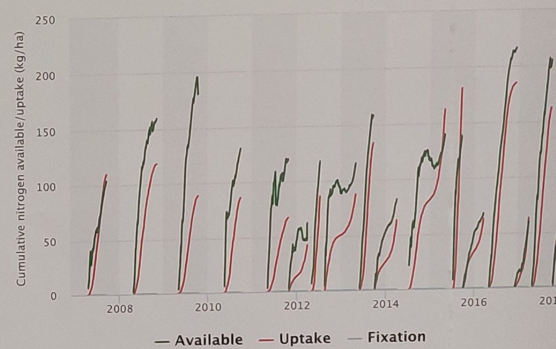


Fig 2. N- availability and N-uptake for each crop

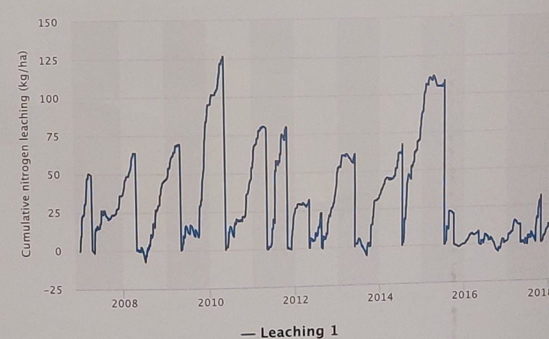


Fig 3. Nitrogen leaching

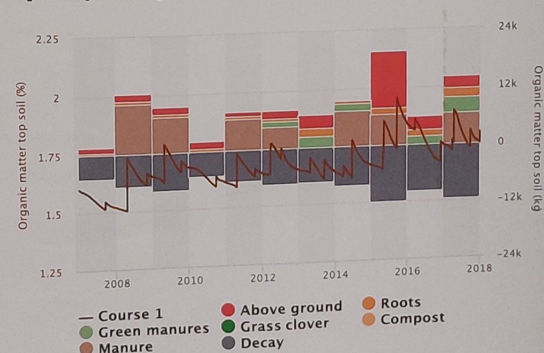


Fig 4. Long term organic matter balance

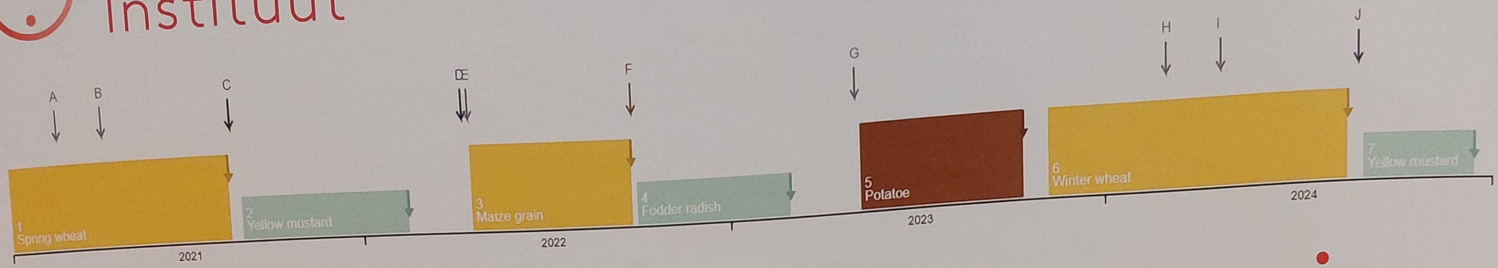
More info

References

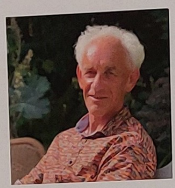
Janssen, B. H. (1984). A simple method for calculating decomposition and accumulation of 'young' soil organic matter. Plant and Soil, 76, 297-304.

Janssen, B. H. (1996). Nitrogen mineralization in relation to C:N ratio and decomposability of organic materials. Plant and Soil, 181, 39-45. https://doi.org/10.1007/bf00011290

... The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. Nutr Cycl Agroecosyst, 74,



Integrating time related processes in nitrogen fertilization recommendation



B.G.H. Timmermans[1], G.J. van der Burgt
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Nitrogen Use Efficiency (NUE)

The generally accepted calculation of NUE is

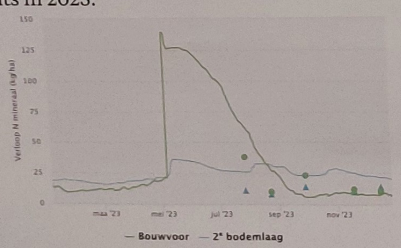
$N_{product} / N_{fertilizer}$ at crop level.

For a conventional arable farm the NUE is calculated for the 2023 potato crop (input 125 kg ha^{-1} N; output 165 kg ha^{-1} N) and for the rotation in four ways (data in kg ha^{-1} N):

A. As above mentioned: NUE_{crop} = 132%
B. Change in soil-N stock* (-172) included:
   $NUE_{crop} (N_{product} / (N_{fert} - N_{stock}))$ = 56%
C. As B, deposition +19 included:
   $NUE_{crop} (N_{product} / (N_{fert} - N_{stock} + N_{dep}))$ = 52%
D. As C, calculation over 2021-2024:
   Average input 270, output 159, stock change +224
   $NUE_{rotation}$ = 244%

A positive N-stock change is not N-loss but investment in the soil

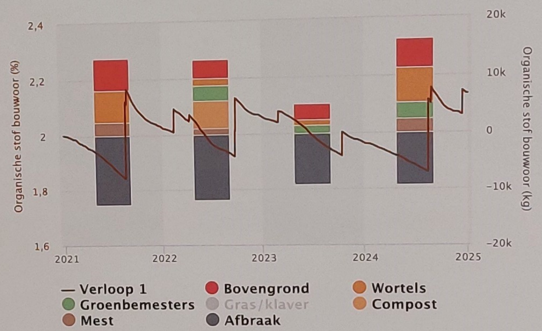
* N-stock change is calculated with the NDICEA nitrogen and carbon model, validated for this field by means of inorganic N measurements in 2023:



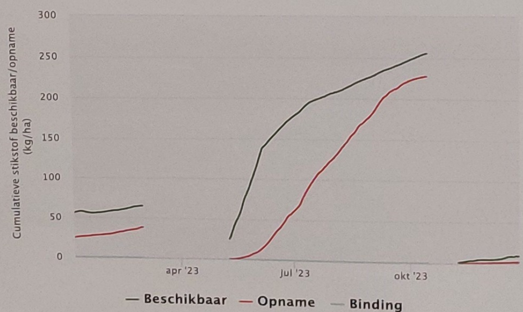
Conclusion:
- Deposition and change in soil N stock should be included in the NUE approach
- A one-year (crop) approach in NUE calculation is inadequate in situations with a substantial change in N-stock

Fertilizer-N recommendation

Two year history of the 2023 potato crop shows Soil Organic Matter increase (2.00 -> 2.06% in 0-30 cm).



The model-predicted SOM decrease in 2023 until harvest is 2.06 -> 1.92%, leading to a substantial expected net N-mineralization. Formal N-recommendation for the 2023 crop would have been 150-175 kg available N ha^{-1}. Driven by own experience and this model information, the farmer decides to apply 125 kg N ha^{-1}, which turns out to be sufficient.



Conclusion:
- Knowledge of quantified N-release out of historical agronomy leads to a better N-fertilizer recommendation.

Bodemkundige Dienst van België vzw

N-INDEX expert system: a powerful tool in nitrogen recommendation

Annemie Elsen, Bodemkundige Dienst van België
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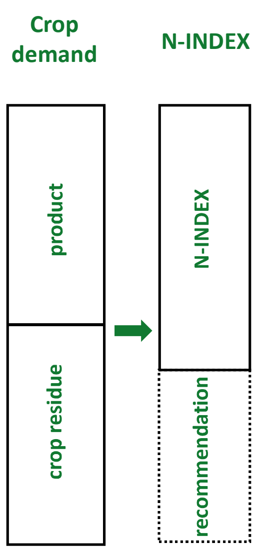
The expert system N-INDEX calculates **field-specific nitrogen fertilization recommendations for arable crops, vegetables, fruit cultivation and pasture** in temperate regions, based on mineral nitrogen analyses. The N-INDEX indicates how much nitrogen becomes available for the crop during the growing season. Not only the amount of mineral nitrogen in the soil at the time of sampling is taking into account, also the expected nitrogen mineralization in the coming months.
The N-INDEX system is based on 18 factors. To calculate all these factors, both the field history and the field characteristics should be well known. Therefore, at time of sampling, an extensive questionnaire is filled out by the farmer and the sampling staff. Based on the gathered information and the results of the mineral nitrogen content of the soil (based on analysis of the soil sample) the N-INDEX is calculated.
The calculation of the nitrogen fertilization advice (Y) based on the N-INDEX is formulated as follows: Y = A-b*N-INDEX, with A the total nitrogen demand of the crop.

N-INDEX Method



INPUT

Soil analysis	soil sampling (0-30-60-90 cm) mineral N (NO3-N, NH4-N) texture + pH-KCl
Parcel	previous crop soil conditions liming / organic fertilizer / N-fertilizer green manure
Crop	crop / variety sowing date / developmental stage

EXPERT system

$$\textbf{N-INDEX} = x_1 + x_2 + x_3 + \ldots + x_{16} + x_{17} + x_{18}$$

(1) (2) (3)

(1) available mineral nitrogen and nitrogen uptake by the crop at time of sampling:
mineral nitrogen soil analysis, cultivation technique, crop development
(2) mineral nitrogen to be delivered by the soil during growing season:
soil humus, crop residues, cover crops and already applied organic fertilizers
(3) reduced mineral nitrogen availability during the growing season:
low pH, leaching, volatilization, denitrification and leaching

OUTPUT

N-fertilisation recommendation = A – b***N-INDEX**

N-INDEX Recommendation

Winter wheat
Beginning growing season

STAALNAME

Staalnamenummer BDB:	22285823	Perceelsnaam:	*Achter stal*
Datum staalname:	25/01/2023	Perceelsnummer:	
Datum ontvangst:	27/01/2023	GPS coördinaten:	N 50.8xxx E 3.6xxxxx
Landbouwernummer:		Staalnamediepte:	90 cm
Opdrachtgever aanwezig:	neen	Toestand perceel:	normaal
Bemonsteringsnummer SNapp:			

ONTLEDINGSUITSLAGEN E N BEOORDELING

Bodemlaag	Grondsoort	Nitraat-N (NO_3^--N) kg N/ha	Ammonium-N (NH_4^+-N) kg N/ha	Zuurtegraad (pH-KCl)	Totaal organische koolstof (TOC) %
0-30 cm	Leem	11	6	5.8 Laag	1.26
30-60 cm	--	14	<4	N-INDEX* 138 Lager dan normaal	
60-90 cm	--	18	<4		
Minerale N-reserve (0-90 cm)		43	<14		

Bodemreserve — Verwachte N-mineralisatie
0% — Procentuele N-index — 100%

BEMESTINGSADVIES: WINTERTARWE

Voor de berekening van het bemestingsadvies wordt in functie van de vermelde zaai/plantdatum rekening gehouden met de door het gewas reeds opgenomen hoeveelheid stikstof.

Variëteit (zaaidatum)	Groeiregulator	N-bemestingsadvies	N-fractionering	
GEDSER (12/10)	2 x	191 kg N/ha	eerste fractie tweede fractie derde fractie	86 kg N/ha 58 kg N/ha 47 kg N/ha

Het hoger vermelde bemestingsadvies kan in tegenspraak zijn met de wettelijk toegelaten dosis op dit perceel. Het geformuleerde advies is gericht op een **landbouwkundig optimaal rendement**, rekening houdend met de bodemvoorraad.

TEELTSPECIFIEKE TOELICHTINGEN BIJ STIKSTOFBEMESTINGSADVIES

- De stikstofbemesting bij voorkeur gefractioneerd toedienen bij de volgende ontwikkelingsstadia van de tarwe :
  - eerste fractie : uitstoeling
  - tweede fractie : stengelstrekking
  - derde fractie : laatste blad
- De pH is laag. Om de bekalkingsdosis juist te berekenen is het noodzakelijk een standaardgrondontleding uit te voeren.

Potato
During growing season

STAALNAME

Staalnamenummer BDB:	22264246	Perceelsnaam:	*ARMEN*
Datum staalname:	29/05/2022	Perceelsnummer:	2022_102
Datum ontvangst:	01/06/2022	GPS coördinaten:	N 51.10xxxx E 4.9xxxxx
Landbouwernummer:	xxxxxxxx	Staalnamediepte:	60 cm
Opdrachtgever aanwezig:	neen	Toestand perceel:	normaal
Bemonsteringsnummer SNapp:	xxxxx		

ONTLEDINGSUITSLAGEN EN BEOORDELING

Bodemlaag	Grondsoort	Nitraat-N (NO_3^--N) kg N/ha	Ammonium-N (NH_4^+-N) kg N/ha	Zuurtegraad (pH-KCl)	Totaal organische koolstof (TOC) %
0-30 cm	Grof zand	93	8	5.4 Gunstig	1.77
30-60 cm	--	47	<4	N-INDEX* 253 Hoger dan normaal	
60-90 cm	--	--	--		
Minerale N-reserve (0-60 cm)		140	<12		

Bodemreserve — Verwachte N-mineralisatie
0% — Procentuele N-index — 100%

BEMESTINGSADVIES: AARDAPPELEN

Voor de berekening van het bemestingsadvies wordt in functie van de vermelde zaai/plantdatum rekening gehouden met de door het gewas reeds opgenomen hoeveelheid stikstof.

Variëteit	Bestemming	N-bemestingsadvies	N-fractionering	
FONTANE	Friet	33 kg N/ha	Voorraadbemesting Bijbemesting	0 kg N/ha 33 kg N/ha

Het hoger vermelde bemestingsadvies kan in tegenspraak zijn met de wettelijk toegelaten dosis op dit perceel. Het geformuleerde advies is gericht op een **landbouwkundig optimaal rendement**, rekening houdend met de bodemvoorraad.

TEELTSPECIFIEKE TOELICHTINGEN BIJ STIKSTOFBEMESTINGSADVIES

- De bijbemesting toedienen bij het begin van de knolvorming.

Crops nutrients supply from different sources in soil

Koen Willekens, Flanders Research Institute for Agriculture, Fisheries and Food, Merelbeke, Belgium
Jasper Vanbesien, Inagro research & advice in agriculture and horticulture, Belgium
Peter Vanhoof, Organic Forest Polska, Poland

Introduction

A two-year (2023-2024) field monitoring of N dynamics and overall nutrients availability is performed in 6 organically managed fields with a vegetable-arable crop rotation as a part of the Demo Project 'Organic fertilization practice secures good water quality'.
This demonstration project is financed by the Flemish government and the European Agricultural Fund for Rural Development (EAFRD).
The monitoring approach is illustrated by the first-year data of 2 fields with a cauliflower main crop, field A with an early and field B with a late planted crop.

Monitoring approach

I. N dynamics

Mineral N amount (NO_3^--N + NH_4^+-N) in 0-90 cm soil profile & crop N uptake in aboveground biomass is measured at multiple time points during the growing season.

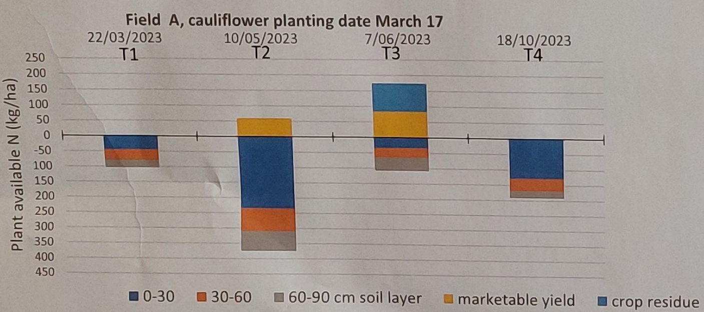
- T1: before fertilization and tillage in spring
- T2: under a young crop at an intermediate sampling moment
- T3: at crop harvest
- T4: at the end of the growing season in autumn

Plant available N = mineral N amount in the soil profile + crop N uptake
Plant available N balance is the difference between subsequent amounts of plant available N
Plant available N balance reflects apparent N-release from soil organic matter and organic amendments in the considered balance period

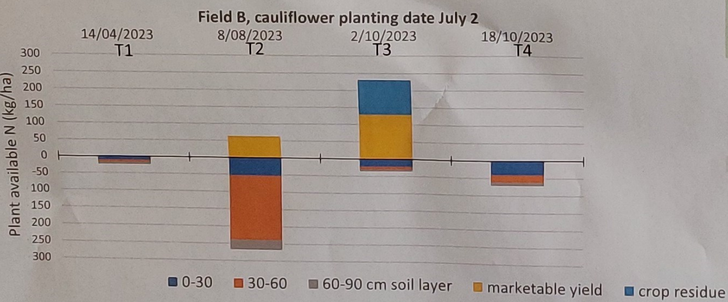
II. Overall (potential) nutrients availability is measured for the 0-30 and 30-60 cm layers at T2 (in an early growing stage of the crop) by Electrical Conductivity (EC) measurements (bio-electronic measurements according to Peter Vanhoof) in an aqueous soil solution, one without and one with sugar addition, the latter to mimic plant exudates in the rhizosphere. Three different nutrients sources can be distinguished:

- Current availability of nutrients in mineral ionic form
- Potential nutrients release from decomposition of freshly amended organic material
- Potential available nutrients by symbiosis between plants and micro-organisms in the rhizosphere

Results

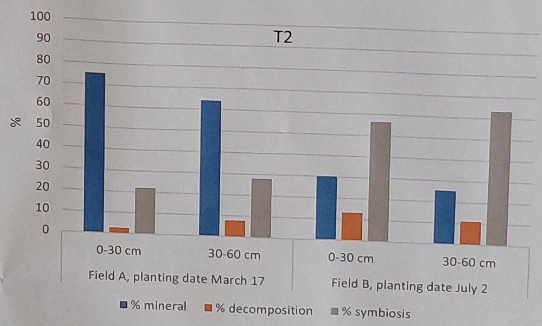


	Field A	Field B
texture	sandy loam	sandy loam
%OC	3,5	1,2
C/N	20	10
pH-KCl	6,8	6,7
Fertilization (kg N/ha)		
farm yard manure (cattle)	200	105
pig slurry effluent		110
commercial organic fertilizer	100	30
Preceding crop	grass-clover ley	grass-clover ley



Field		plant available N		apparent N release		
planting date	time point	kg/ha	balance period	kg/ha	kg/ha/day
Field A	T1	104	T1 - T2 (49 days)	330	6,7
March 17	T2	434	T2 - T3 (28 days)	-152	-5,4
	T3	282	T1 - T3 (77 days)	179	2,3
Field B	T1	24	T1 - T2 (116 days)	307	2,6
July 2	T2	331	T2 - T3 (55 days)	-65	-1,2
	T3	267	T1 - T3 (171 days)	243	1,4

Field	soil layer	T2 mineral	decomposition	symbiosis	total
planting date	cm		µS/cm		µS/cm
Field A	0-30	277	10	81	368
March 17	30-60	153	19	67	239
Field B	0-30	136	60	255	451
July 2	30-60	120	53	299	472



Discussion

- ✓ Highly positive apparent N release in the beginning of the growing season (T1-T2) which can be accounted for in determining the base fertilization level in the following growing seasons
- ✓ Negative N release values, i.e., apparent N immobilization, under a more developed crop with well-developed rooting system providing exudates to symbiotic micro-organisms in the rhizosphere (T2-T3)
- ✓ Field A compared to Field B:
  - Higher mineral N amounts throughout the whole growing season
  - Higher availability of nutrients in mineral form at T2
  - Considerably lower potential nutrients availability by symbiosis at T2
- ✓ Top dressing level at T2 can be based on (potential) nutrients availability from different sources (bio-electronic and mineral N measurements)

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The importance of a good advisory system for outdoor vegetables

For the production of outdoor vegetables achieving a high quality is crucial, even more than yield.
However vegetables are characterized by:

- A less developed root system
- A relative short growing period
- Harvest at a moment that N-uptake is high

=>Fertilisation is a challenge when striving for a low residue of nitrogen in the soil to avoid leaching to surface / groundwater

Ellen Goovaerts - Research centre for vegetable production

The main principle of the KNS-system

N-advice from the system				Adjusting the advice	
Target value at a certain moment N-uptake by plant + Latent N: minimum amount of N necessary in the soil	-	**N delivered from the soil** Measured soil content on a certain depth depending on rooting depth + Mineralisation of the soil (kg N/ha/day)	-	**N delivered from other sources** N from crop residues, manure, catch crops, compost, …	**= N advice to the farmer**

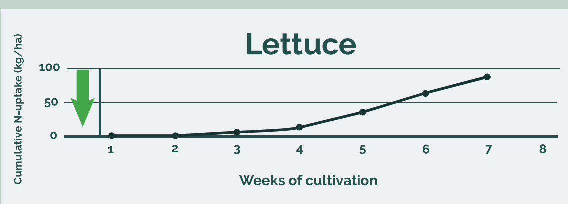
=> Fractioned fertilisation for crops with a longer growing period

When is the best timing for using the system?

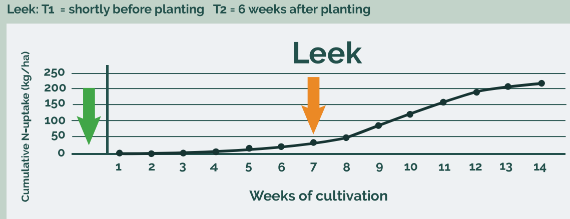
T1
- Shortly before planting
- Minimal 4 weeks after application of manure
- Soil content of 30 cm layer is taken into account
- Especially for crops with short growing period

T2
- And/or at the breaking point of N-uptake curve
- Soil content of 0-30 cm and 30-60 cm layer is taken into account

Lettuce: T1 = shortly before planting



Leek: T1 = shortly before planting T2 = 6 weeks after planting



The advantages of the system

- Advices based on soil measurements (N-content)
- Fractionated fertilisation for crops with longer growing period minimises the risk of leaching by lowering the N-dose at planting
- Soil samples provides a deeper view in soil mineralisation and nitrogen release from catch crops or harvest residues
- Fertilisation can be adapted to unpredicted climate conditions (eg. rain)
- There is a higher opportunity for managing the amount of residual nitrogen at harvest
- There is a lower risk of nitrogen leaching for outdoor crops

The challenges

Not everything can be measured, we also have to use estimated values for:

- Mineralisation: how many kg N/ha/day must be encounted?
  - Depending on history in use of organic matter
  - Depending on growing period/soil temperature
  - Range between 0.5 – 1.5 kg N/ha/day
- The amount of nitrogen released from catch crops depends on
  - type, date of sowing, development, C/N-content, date of incorporation
- The amount of nitrogen released from harvest residues depends on
  - type, plant variety; method of harvesting (fresh market – industry)
- Row/band fertilisation
  - Sampling method/interpretation of soil analyses
- To keep the system (base 1989) fertilisation trials and projects are needed

Conclusion:

Good advices demands, an up to date KNS-system in combination with:

- A maximum of input from the field to the adviser
- A correct way of soil sampling and analysing
- Confidentiality between farmer and adviser

proefstation
VOOR DE GROENTETEELT

Comparison of Organic and Conventional Crop Management in Estonia since 2008

Evelin Loit-Harro, Mailiis Korge, Maarika Alaru, Indrek Keres, Banafsheh Khaleghdoust, Vyacheslav Eremeev, Kaidi Möll, Are Selge, Liina Talgre

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Eesti Maaülikool
Estonian University of Life Sciences

Introduction

- The aim of agriculture is to produce food of **high nutritional quality** in sufficient **quantity**, while being **sustainable** and protecting soil.
- There is a shift towards reduced fertilizer use and increase of organic cropping.
- Cereal grains contain starch, proteins and also **dietary fibers**, such as arabinoxylan (AX) and beta-glucan (BG), proven to have essential functional properties.
- The aim of the study was to compare the organic and conventional cropping within the same legume-rich crop rotation, to see the impact on **soil, crop yield and quality**.

Methods

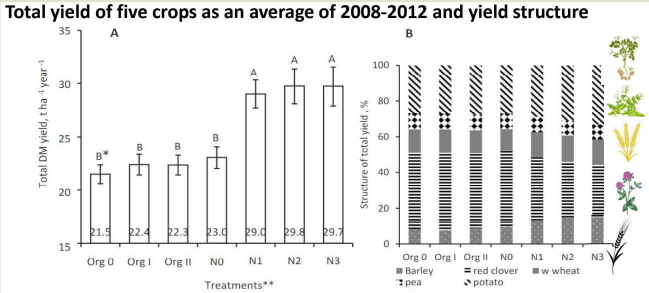
- **Long-term field crop rotation experiment** located at the Estonian University of Life Sciences in Tartu County (58°22′ N, 26°40′ E) started in **2008.**
- Soil type is Stagnic Luvisol (sandy loam surface texture, C 1,38%, pH 6,0).
- **Rotation**: spring barley with undersown red clover, red clover, winter wheat, field pea, potato (all in four replications) with **fertilizer treatments**:
- **Collected**:
  - Soil
  - Yield
  - Quality
  - Dietary fiber

Conventional	Organic
N0: N0 (control, N0P0K0)	Org 0 (no fertilizers, no pesticides)
N1: N50 (N40–50*P25K95)	Org I (cover crops as green manure)
N2: N100 (N80–100*P25K95)	Org II (cover crops, cattle manure)
N3: N150 (N120–150*P25K95)	

* lower N rate for spring barley undersown with red clover and higher for wheat and potato

Results

Total yield of five crops as an average of 2008-2012 and yield structure

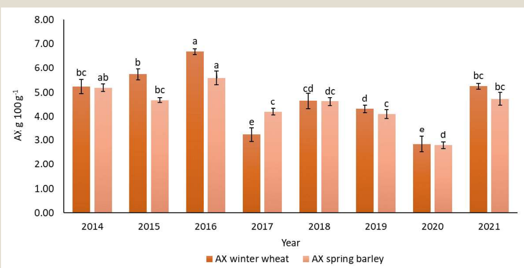


Total dry matter yield was significantly lower (A) in all organic treatments and N0 (average of 2008-2012). Barley and wheat yield was higher (B) in conventional treatments, while red clover biomass was lower. (Keres et al 2020)

Winter wheat Fredis protein content dough quality indicators as an average of 2012-2017

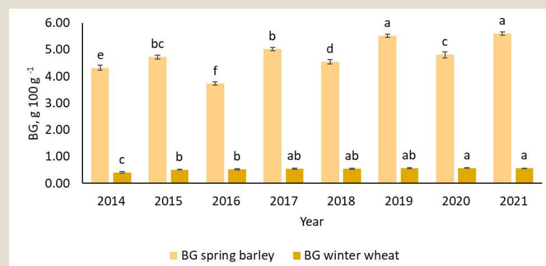
Indicator	Org 0	Org I	Org II	N0	N1	N2	N3
Protein, %	11.2 ± 0.7	11.5 ± 0.6	11.3 ± 0.9	11.3 ± 0.6	11.6 ± 1.1	12.9 ± 1.1	13.6 ± 0.7
Water absorbtion,%	57 ± 0.8	57 ± 0.7	57 ± 0.8	58 ± 0.6	58 ± 0.7	60 ± 0.9	61 ± 0.4
Dough development time, min	2.08 ± 0.2	2.02 ± 0.2	2.02 ± 0.2	2.24 ± 0.3	2.16 ± 0.2	3.00 ± 0.3	3.54 ± 0.2
Dough stability, min	4.20 ± 0.55	4.17 ± 0.42	4.07 ± 0.50	4.39 ± 0.43	4.28 ± 0.55	5.08 ± 0.40	6.20 ± 0.38

Winter wheat **protein content** was the highest in N2 and N3, which received 100 and 150 kg of N/ha. Flour water absorption and dough development was the best in conventional treatments with higher N rate. (Keres et al 2021)

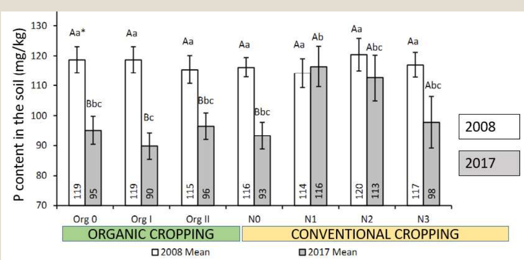


letters on bars refer to comparison between different cropping years of the same species; bars with the same letter are not significantly different (P <.05)

- **Nitrogen** treament **did not impact** the **arabinoxylan** and the **beta-glucan** content.
- Annual weather had impact on AX and BG.
- Higher temperatures during tillering and grain filling period increased AX values (Korge *et al*. 2023).
- More precipitation during grain filling decreased BG content (Khaleghdoust *et al.* 2024).

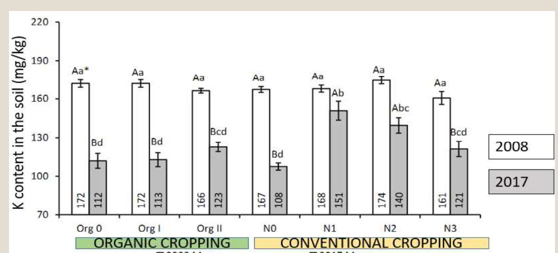


letters on bars refer to comparison between different cropping years of the same species; bars with the same letter are not significantly different (P <.05)

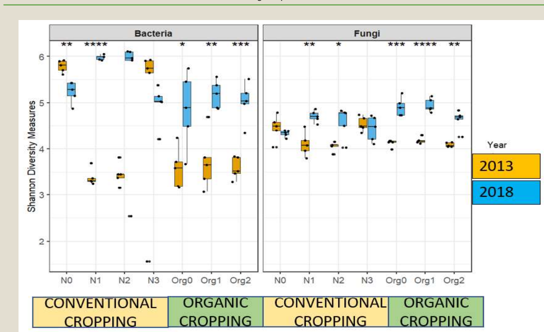


Plant available P content (mg kg–1) in the soil at the beginning of the field trial and after ten years. 2008 Mean: $F(6, 133)=1.268$, $p=0.276$; 2017 Mean: $F(6, 133)=2.754$, $p=0.0149$; *different large letters indicate a significant difference between years, and different small letters indicate the difference between treatments in a given year

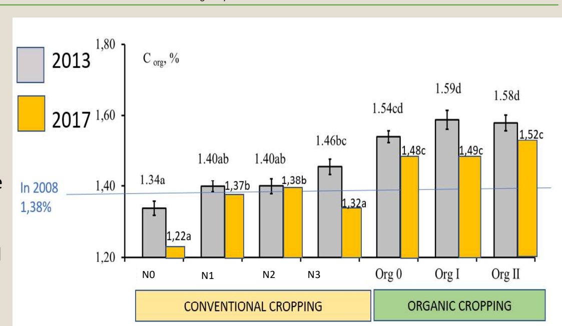
- **Soil phosphorus** content decreased in all organic treatments and in N3.
- Plant available **potassium** in soil decreased in all treatments.
- Use of winter cover crops and composted cattle manure in the organic system did not maintain the levels of P and K in the soil at baseline (Keres *et al*. 2020).



Plant available K content (mg kg–1) in the soil at the beginning of the field trial and after ten years. 2008 Mean: $F(6, 133)=1.268$, $p=0.276$; 2017 Mean: $F(6, 133)=8.215$, $p<0.001$; *different large letters indicate a significant difference between years, and different small letters indicate the difference between treatments in a given yea



- **Soil microbial diversity** and **abundance** increased during the second rotation in most treatments.
- Decrease in bacterial diversity was seen N0 and N3.
- Treatments with low to average mineral nitrogen input were favorable for soil microbes (Esmaeilzadeh-Salestani *et al*. 2021).
- **Soil organic carbon** content increased after the first rotation (except in N0), but decreased after the second rotation in N3, Org I and Org II.



Eesti Teadusagentuur
Estonian Research Council
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Investing in your future

References: Keres et al 2020 Long-term effect of farming systems on the yield of crop rotation and soil nutrient content. Agricultural and Food Science; **Keres et al 2021** The Combined Effect of Nitrogen Treatment and Weather Conditions on Wheat Protein-Starch Interaction and Dough Quality; **Korge et al. 2023**. The influence of cropping system, weather conditions and genotype on arabinoxylan content in wheat and barley grains. J. Cereal Sci.; **Khaleghdoust et al. 2024**. Barley and wheat beta-glucan content influenced by weather, fertilization, and genotype. Front. Sustain. Food Syst.; **Esmaeilzadeh-Salestani et al 2021** Cropping systems with higher organic carbon promote soil microbial diversity, Agriculture, Ecosystems & Environment

ANAPLANT - Critical values for plant analysis: update/validation for Saxony-Anhalt

S. Klages[1], W. Haberkern[1], M. Erb-Brinkmann[2], S. Siegmund[3], W. Bannach[3]

[1]agri.kultur, Messel, [2]PHYTOsolution, Freyburg, [3]IAU, Freyburg

Background

Plant analysis is one method to adjust fertilization (later) during the plant production period. Introduced in the 60ies and updated in the 80ies and 90ies of last century, Critical Values (CV) are target concentrations in plant tissue linked to target yields and/or qualities. (Current nutrient concentrations in plant tissue are compared to CVs or -ranges to detect fertilization needs). In the Saxony-Anhalt region, plant analysis in former GDR-times was traditionally used to apply limited amounts of fertilizers most economically. Now, the environmental impact of fertilizer use dominates the common interest, while frame conditions (e.g., increasing droughts, reduced air-pollution) under which CVs originally have been developed changed substantially.

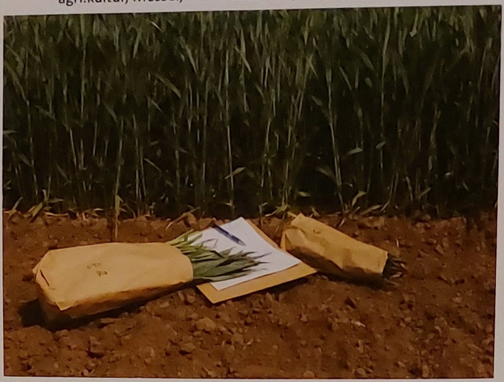


Figure 1: sampling

Aim of the project

The EIP-Agri financed project (duration 4/2022 until 12/2024) aims at the update/validation of CVs used in the German Federal State of Saxony-Anhalt. Figures applied at present in lab routines refer to different stages of crop development and were deduces by Vielemeyer and Hundt (1991), Bergmann (1993) and supplemented by own recent research. These reference ranges were compared with CVs

(a) calculated from mean nutrient concentrations of high yielding subsets (Beaufils, 1973, Walworth und Sumner, 1987, Parent und Dafir, 1992) and

(b) deduced from a Boundary Line around scatter plots of the relation nutrient concentration/yield and the CV as maximum (Heym and Schnug, 1995; Klages, 2012).

Materials and Methods

On farm research and sampling of fertilizer trials

Sampling plant- and soil-samples at defined growth stages, recording GPS-sampling positions

Plant analysis with inductively coupled plasma optical emission spectrometry (ICP): N, P, K, S, Ca and Mg according to methods VDLUFA II 3.5.2.7 2004 and VDLUFA VII 2.2.26 2003, B, Fe, Cu, Mn, Mo and Zn according to methods VDLUFA VII 2.2.26 2003

Soil analysis: N_{tot} according to Dumas, P and K according to VDLUFA I (CAL): A 6.2.1.1, Mg according to VDLUFA I (Schachtschabel) 6.2.4.1 and Ca as NH_4Cl-pulping and B, Fe, Cu, Mn, Mo and Zn according to VDLUFA I, A.13.1.1 2004 CAT-method; pH according to VDLUFA I, A 5.1.1 1991, soil group according to VDLUFA I, D 2.1 and humus content as explained in ÖNORM L1081 209-11

At the end of the season, farmers/researchers were interrogated concerning details of crop cultivation: fertilizer applied (N, P_2O_5, K_2O, MgO and CaO in kg/ha, farmyard manure as tons or CBM/ha, B, Mn, Cu, Zn, Fe as yes/no-information), irrigation, date of application/irrigation, yield, qualities achieved (raw protein, sugar, starch)

We set up a database with PostgreSQL. We use Python for the calculation and comparison of CV obtained according to the methods cited above and for visualising the results. We use SPSS to perform statistical evaluation of different subsets.

Preliminary Results

Due to a delayed project start in 2022, samples were taken mostly in the later development stages, in 2023 in earlier stages: these early sampling periods are more relevant in case foliar fertilization in the current vegetation period is considered. Figure 2a exemplarily shows mean values and standard deviation for potassium at different growth stages of winter wheat in two sampling periods. In Figure 2b, these values are compared to those of the high yielding subsets (top 20 %).

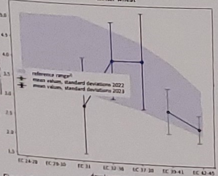


Figure 2a: mean values and standard deviations of foliar concentration of potassium in winter wheat.

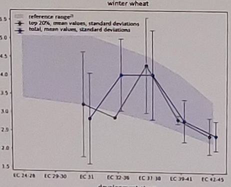


Figure 2b: CV and values for total sample size for potassium compared to present reference range.

Statistically, yield and raw protein content in both years were identical[1]. However, while yields differed considerably between the high yielding subset and the rest, there was no significant difference between both subsets in concentration of most nutrients[1].

As a linear positive relation between nutrient concentration in plant samples and yield/qualities is a prerequisite for the deduction of CV according to Beaufils (1973) Walworth and Sumner (1987) Parent und Dafir (1992), meaningful CV could not be deduced with this procedure.

[1] Mann-Whitney-U-Test, Kruskal-Wallis-test, median and distribution.

Literature

Bergmann, W. (1983): Ernährungsstörungen bei Kulturpflanzen. Gustav Fischer-Verlag, Jena.

Beaufils, E.R. (1973): Diagnosis and Recommendation Integrated System (DRIS): A general scheme for experimentation and calibration based on principles developed from research in plant nutrition. Soil Sci. Bull. of Univ of Natal, 1, 1-132.

Preliminary Results

Boundary lines were programmed according the general equation

f(x) = y_max + a_l * (x - x_max)^2   in case x < x_max,
f(x) = y_max + a_r * (x - x_max)^2   in case x > x_max

as spline/parabola with different slopes left and right of the optimum. Figure 3 shows exemplarily the boundary line for potassium in development stage 31 of winter wheat.

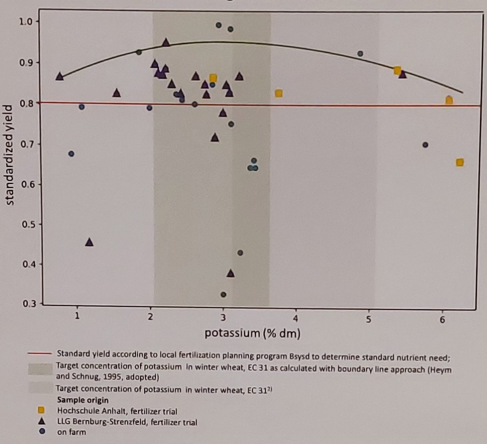


Figure 3: boundary line for development stage 31 of winter wheat

Target concentration of potassium as calculated with the boundary line approach currently is far lower (2.1 – 3.6 % dm) as published by Bergmann (1993) (3.2 – 5.1 % dm). As samples are only available from two years so far, results may alter when considering further sampling periods. Yield levels of fertilizer trials were comparable to those harvested on farm.

Obviously, the deduction of boundary lines works better the higher the number of pairs of ‚yield-nutrient' values are. Further, the dispersion of values may hamper an evident shape (outliers, broad dispersion).

In Table 1, differences of present target ranges[2)] in comparison to analysed plant nutrients in 2023 are listed for the crops investigated: in some cases, considerable differences justify further research towards an adaption of CVs.

	winter barley	winter wheat	winter rye	sugar beet	grain peas	potatoes	maize	winter rapeseed
N (% dm)	0	-1	-1	1	-2	2	2	3
Ca (% dm)	1	-1	0	0	-1	0	0	2
P (% dm)	0	0	0	0	-3	0	0	1
K (% dm)	1	0	0	1	1	2	1	1
Mg (% dm)	0	-3	-3	0	0	2	1	0
S (% dm)	3	1	0	0	-1	0	1	3
B (ppm)	0	-2	-2	0	-1	2	1	1
Mn (ppm)	0	-2	0	0	1	1	1	1
Cu (ppm)	0	-1	-1	0	1	1	1	0
Zn (ppm)	1	-2	-2	0	0	0	0	1
Fe (ppm)	0	-2	-1	-2	0	0	0	0
Mo (ppm)	-3	-3	-3	0	0	-3	-3	0

currently applied target ranges[2)] < means of all samples taken	-3
	-2
	-1
currently applied target ranges[2)] = means of all samples	0
currently applied target ranges[2)] > means of all samples taken	1
	2
	3

Table 1: comparison of currently applied target ranges[2)] to mean plant nutrient concentrations measured in 2023
[2)] according to Bergmann (1993), Vielemeyer and Hundt (1991)

Literature

Heym, J., Schnug, E. (1995): A mathematical procedure for the development of boundary lines form XY scattered data. Aspects of applied biology, 43, 317-142.

Klages, S. (2012): Evaluation of the mineral status of organically grown cotton in Egypt. Dissertation. Technischen Universität Carolo-Wilhelmina zu Braunschweig, Fakultät für Lebenswissenschaften (http://www.digibib.tu-bs.de/?docid=00042509).

Parent, L.-E., Dafir, M. (1992): A theoretical concept of compositional nutrient diagnosis. J. Am. Soc. Hortic. Sci. (117), 239-242.

Vielemeyer, H.-P., Hundt, I. (1991): Written communication. Institute for plant nutrition and ecotoxicology, Jena.

Walworth, J.L., Sumner, M.E. (1987): The diagnosis and recommendation integrated system (DRIS): Soil Sci., 6, 149-188.

Discussion

We could show, that a deduction of CVs in plant tissue in order to determine nutrient supply of crops via a high yielding subset failed as there was no significant difference in nutrient composition between the high-yielding subset and the rest. Using the boundary line approach, reasonable CVs respectively -ranges in plant tissue could be calculated.

However, results could be explained as follows:

Under favourable conditions, there is a linear relationship between nutrient concentration in leaf tissue and crop harvest/quality. A high yielding subset can be defined, for which nutrient concentrations are also elevated (Figure 4).

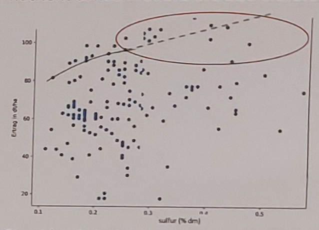


Figure 4: hypothetic relation nutrient concentration in plant tissue/yield under favourable conditions

Under unfavourable conditions, this relation is decelerated, no high yielding subset with a significant elevated nutrient composition can be defined. The boundary line in this case marks as CV the lowest nutrient concentration with which under these conditions high yields could be attained. For reaching this CV, usually lower fertilizer rates are sufficient (Figure 5).

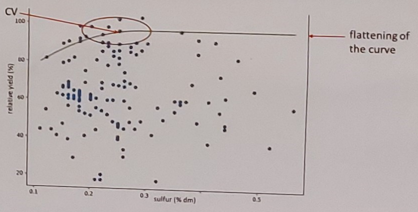


Figure 5: hypothetic relation nutrient concentration in plant tissue/yield under unfavourable conditions

Conclusions

Being subject to climate change, factors like water supply (eg., droughts, heavy rainfall) or temperature (eg., spring frost) nowadays gain increasing relevance in the limitation of yield perspectives.

CV particularly need adaption in regions like Saxony-Anhalt, where high soil qualities meet generally low precipitation, recently even heavy droughts. For this purpose, the boundary line approach is suitable.

Leaf analysis under these unfavourable conditions can help to diagnose nutrient deficiencies in early growth stages, in order to adjust fertilization according to location-adapted yield expectations.

On farm research proved to be suitable to adjust CVs. Compared to sampling only fertilization trials, the dispersion of sampling areas is of far larger scale. Moreover, on farm research also enables short-term data collection for crops and nutrients for which no targeted fertilizer trials are carried out.

The adjustment of CVs for sulfur due to reduces air-pollution seems necessary.

CVs for plant nutrients which after three years of testing need adjustment will be published after the project is completed.

Project partners

agri·kultur Beratung Organisation Kultur

PHYTO solution

Cooperating project

NutriNet

SACHSEN-ANHALT

EUROPÄISCHE UNION
ELER
Europäischer Landwirtschaftsfonds für die Entwicklung des ländlichen Raums

Federal Ministry
Republic of Austria
Agriculture, Forestry, Regions
and Water Management

DaFNE

TerraZo - Free creation of application maps and deployment based on field trials

Materials & Methods

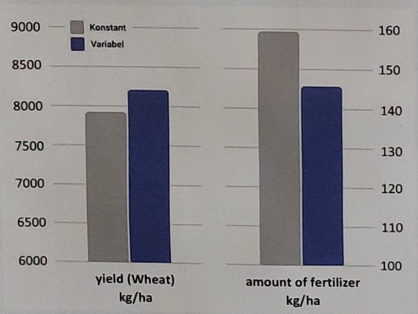
Location: Josephinum Research Wieselburg

Based on Sentinel-2 satellite data and field trials, vegetation indices are calculated, and using models, fertilization recommendations are generated for each specific area. The application maps that are generated can be easily exported and imported into compatible tractor terminals, enabling seamless utilization in the field. Alternatively, smartphones or tablets can be used for site-specific fertilizer application.

Results

Variable and site-specific N-fertilization leads to a reduction in operational costs and a demand-driven plant nutrition. Additionally, site-specific fertilization ensures a balanced N-balance, higher N-efficiency, and lower greenhouse gas emissions.

Figure



Constant vs. variable N-fertilization
© Josephinum Research

Creation of application maps
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TerraZo
© Josephinum Research

Conclusion

As part of the research project, it has been found that the creation of application maps requires not only technical expertise but also the consideration of agronomic and location-specific characteristics of the fields. Both aspects are taken into account in the project to simplify technical barriers for the user and support site-specific fertilization by proposing fertilizer quantities. Importantly, the user has the flexibility to customize all suggestions to accommodate personal preferences and experiences. Another important point is that when we able to established such a system on a wide scale, new knowledge is transferred directly to the point of application. By incorporating advanced technologies and data-driven approaches, practice and science can benefit from each other and more informed nutrient management decisions can be made.

HBLFA Francisco Josephinum
Wieselburg

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A new controlled-release fertilizer with a fully biodegradable coating reduces nitrogen losses to the environment

Authors: Adi Perelman, Cristian Terrones, Cristian Filote, Ronald Clemens, Scott Garnett
ICL Growing Solutions - Israel, The Netherlands, United Kingdom

Introduction

Nitrogen (N) is crucial for plant nutrition and agricultural systems' sustainability and economic viability[1]. N is highly dynamic thus it challenging to efficiently manage it, particularly in intensive agricultural systems where huge N inputs may lead to substantial losses through surface runoff, leaching to ground waters, and gaseous emissions to the atmosphere. There are several ways to reduce the risk of N losses, like urease inhibitors, nitrification inhibitors, and controlled-release fertilizers (CRFs). The challenge of new fertilizer technologies is to reduce N losses from agricultural systems and to increase Nitrogen Use Efficiency (NUE)[2].

This study aimed to assess N loss reduction to the environment when using CRFs compared to uncoated urea.

Materials and Methods

Experimental design
The trial was executed by NMI b.v. (Nitrogen Management Institute, The Netherlands) in 2021.

A pot experiment with red beetroot (*Beta vulgaris vulgaris*) was set up using loamy-sandy soil with a high pH (>7.5). The experiment consisted of four treatments

1. Zero N (control)
2. Urea 46%N | 1 x N | 100% N rate as base fertilizer
3. Urea 46%N | 2 x N | 50% as base fertilizer and 50% as top-dressing
4. CRF* 40%N | 1 x N | 100% N rate as base fertilizer

The trial was set up in a randomized block design with 4 replicates per treatment. All treatments received 150 kg N ha^{-1}, full rate as base fertilization or split applications, except for the control. All treatments received the same amount of P, K, Ca, Mg, and S.

** The CRF product is fully coated urea by ICL's new biodegradable coating technology -* ***eqo.x®***

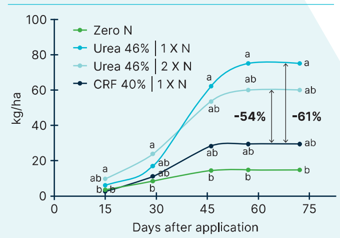
Measurements
NH_3 and N_2O emissions, and total N leached were measured throughout the trial. At the trial's end, total plant biomass and Nitrogen Use Efficiency were assessed.

Conclusions

Compared to regular urea, CRFs

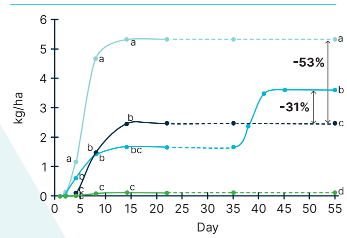
Results

Cumulative total N leached



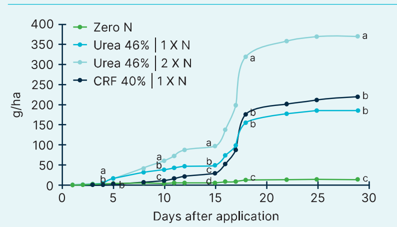
After 72 days, by using CRF 40%N, total N lost by leaching was reduced, in average, by 58% compared to conventional urea.

Cumulative ammonia losses



After 14 days, N losses as NH_3 volatilization were significantly reduced by 53% comparing CRF 40%N with Urea 46%N, applied at the same time and rate, and by 31% when compared to split application of urea.

Cumulative N_2O emmisions

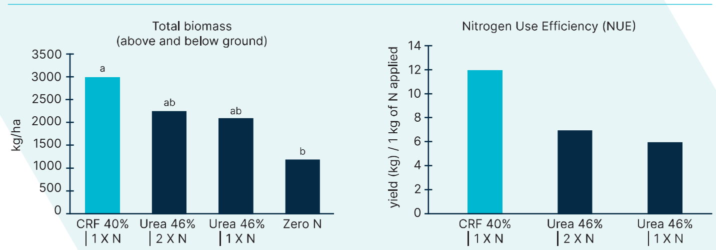


In the first 30 days, N losses as N_2O were significantly higher for Urea 46%N | 1 x N compared to split application of urea and CRF 40%N. At this moment, Urea 46%N | 2 x N received only 50% of the total N.

The N_2O emissions after 72 days varied between 0.17 and 0.5 kg N/ha but there were no statistically significant differences between treatments for the total cumulative N_2O emissions.

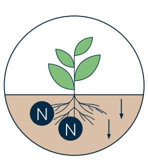
However, CRF 40%N lowered N_2O emissions by -11% compared to regular urea applied at the same rate and time.

Improved yield and Nitrogen Use Efficiency

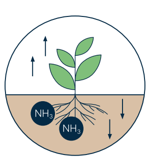


Less N losses lead to higher NUE therefore higher yields. In this trial, CRF 40%N improves NUE by more than 80% and increases yield by more than 30% compared to average results recorded by both treatments where urea was used.

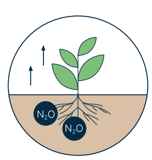
NUE calculated as Agronomic Efficiency = (YF-Y0)/N applied
Different letters indicate significant differences ($p < 0.05$).



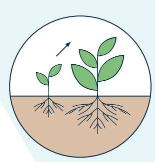
Reduce N leaching, **up to 60%**



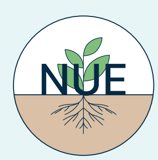
Reduce NH_3 volatilization, **up to 60%**



Reduce N_2O emissions, **over 10%**



Increase yield by **more than 30%**



Increase NUE by **more than 80%**

References: [1] Zaman, M., & Blennerhassett, J. D. (2010). Effects of the different rates of urease and nitrification inhibitors on gaseous emissions of ammonia and nitrous oxide, nitrate leaching and pasture production from urine patches in an intensive grazed pasture system. *Agriculture, Ecosystems and Environment*, 136(3–4), 236–246.
[2] Minato, E. A., Cassim, B. M. A. R., Besen, M. R., Mazzi, F. L., Inoue, T. T., & Batista, M. A. (2020). Controlled-release nitrogen fertilizers: Characterization, ammonia volatilization, and effects on second-season corn. *Revista Brasileira de Ciencia Do Solo*, 44.

Measurements of plant-available P, K and Mg contents and pH of soils with the soil sensor system Stenon “FarmLab” as a basis for fertilizer recommendations for arable crops

Hans-Werner Olfs

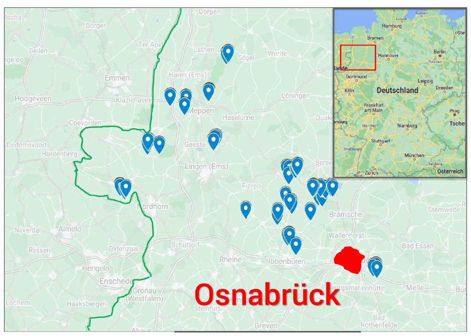
Background

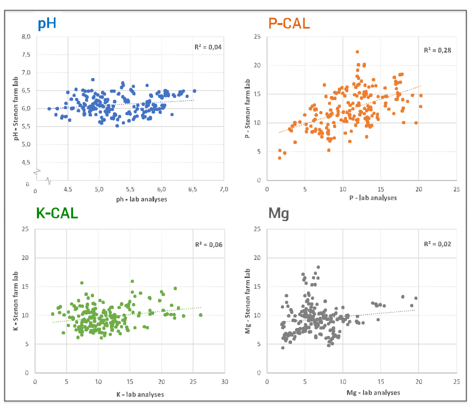
- To achieve optimal nutrient availability for plants, fertilizer application rates should take into account the soil status of plant-available nutrients.
- Regular soil sampling and subsequent laboratory analysis are therefore common agricultural practice.
- These procedures are laborious, time-consuming and costly, and the delivery of the lab results to farmers often takes longer.
- So-called "in-situ" soil analysis using various soil "sensors" might offer a quick and cheap alternative procedure.

Objective

- Stenon offers the FarmLab for on-field soil analysis with 2 sensors
  - Electrical impedance spectroscopy
  - Optical spectroscopy (UV/Vis)
- Stenon claim: a comprehensive soil characterization (soil mineral N, plant available nutrients such as P, K, Mg, but also soil organic matter and pH) is possible.
- Independent check of the comparability between results of the standard laboratory tests and the FarmLab system is necessary.

Survey on farmers’ fields





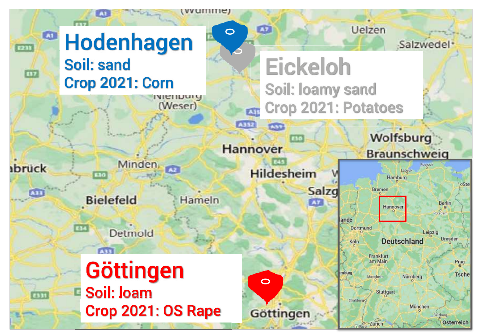
M&M

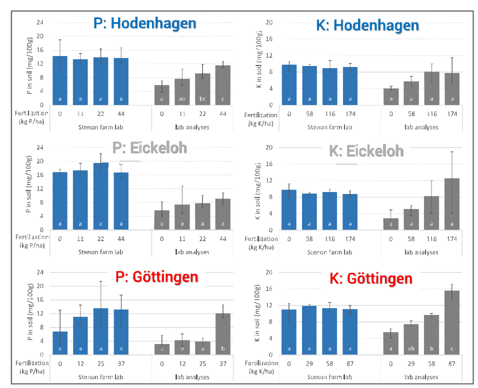
- Survey study in western Lower Saxony on 64 farmers’ fields
- 3 FarmLab measurements at each of the corners of a 2 m triangle
- 3 individual soil samples from each triangle corner
- Soil drying/sieving => standard lab analysis (pH, plant available P/K/Mg)
- Regression analysis based on 192 data pairs for each soil parameter

Results

- Typical variation in lab soil pH values for sandy soils (4.2 – 6.5), while FarmLab values show only a pH range from 5.5 – 6.8
- Soil P range similar for lab analysis and FarmLab, but fewer values at the low end for FarmLab
- Soil K range for FarmLab much smaller (6.1 – 16.0 mg/100 g) compared to lab analysis (2.8 – 26.2 mg/100 g)
- Very few FarmLab Mg values below 5 mg/100g
- Correlations between lab and FarmLab values for all 4 soil parameters are very low ($R^2 = 0.02 – 0.28$)

Long-term P-/K fertilization trials





M&M

- Studies on 3 P and 3 K long-term field trials of the University of Göttingen (plot size 8 x 10 m)
- 4 treatments (each with 4 replications):
  - unfertilized control
  - 0.5 x P-/K crop offtake
  - 1 x P-/K crop offtake
  - 1.5- (or 2-) x P/K crop offtake
- 1 FarmLab measurement + soil sampling (0 – 30 cm) in the center of each plot
- Soil drying/sieving => standard lab analysis (pH, plant available P/K/Mg)
- Regression analysis for each individual P/K trial

Results

- 22 (out of 24) regression analysis show R^2 values < 0.2 for the relationship between FarmLab and lab data (6 trials x 4 parameters)
- **P trials:**
  - ➢ FarmLab data indicate considerably higher soil P values compared to standard soil analysis on light sandy soils
  - ➢ Lab data: good differentiation for soil P according to long-term P application rates
  - ➢ FarmLab: no differentiation for the light sandy soils
- **K trials:**
  - ➢ For all K treatments on the 3 trial sites FarmLab data indicate similar soil K status (9 – 12 mg /100 g soil)
  - ➢ Lab data: clear differentiation at all 3 experimental sites
  - ➢ FarmLab data: no differences between the 4 lang-term K application rates

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Do composts meet organic fertilizers quality requirements: Lithuanian case study?

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INTRODUCTION

Waste generation and environmental pollution pose significant challenges worldwide, with annual levels of pollution and waste steadily increasing. complexities of waste management have intensified in recent decades, necessitating the selection of appropriate treatment methods. Waste managem remains a particularly sensitive issue in developing and densely populated countries, and determining optimal strategies remains an ongoing questi Composting organic biodegradable waste stands as a crucial and well-established component of waste management practices in Europe. The first polic where composting was involved, were published in 2005 in Lithuania. Ministry of Environment of the Republic of Lithuania released a set of guideli about the proper management of organic waste, including composting. Later, these guidelines were improved several times to fully fulfill the sustaina development of waste management in the country. Same year, as the first policy about the waste management was released, the Association of Regio Waste Management Centers was established. Currently, 10 regional waste management centers are operating in Lithuania.

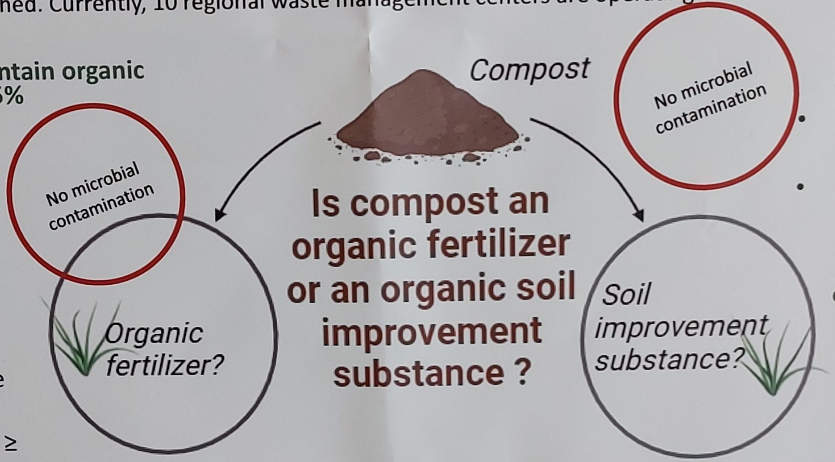
Soild organic fertizers: shall contain organic carbon content ≥ 15%

A) Mono-nutrient

- Total nitrogen (N) ≥ 2.5%
- Total phosphorus pentoxide (P_2O_5) ≥ 2%
- Total potassium oxide (K_2O) ≥ 2%

B) Multi-nutrient

- Total nitrogen (N) ≥ 1%
- Total phosphorus pentoxide (P_2O_5) ≥ 1%
- Total potassium oxide (K_2O) ≥ 1%
- The sum of those nutrient contents shall be at least 4 % by mass



Organic soil improvements

- Shall contain ≥ 20 % or mor dry matter
- Organic carbon content ≥ 7. % by mass

Heavy metals limits for organic fertilizers & organic soil improvements:

Heavy metal	Conc., mg/kg
Cd	1.5/2
Cr (VI)	2
Hg	1
Ni	50
Pb	120
Zn	800
Cu	300

VARIOUS ORIGIN COMPOSTS' QUALITY

Table 1. Agrochemical indicators in different types of compost produced in Lithuania, 3-year results

Quality indicators	Compost type				
	GWC	FWC	SSC	CMC	DC
Total nitrogen, %	0.76	2.22	2.69	2.42	3.04
Total phosphorus, %	0.25	0.53	1.80	1.01	1.56
Total potassium, %	0.59	1.9	0.37	2.76	0.58
Total amount of main nutrients, %	1.60	4.65	4.68	6.19	5.18
Organic carbon content, %	8.90	16.10	17.70	21.70	37.90

Note: GWC-green waste compost, FWC-food waste compost, SSC-sewage sludge compost, CMC-cattle manure compost, DC-digestate compost

very low · *low* · *average* · *doesn't meet OF* · *very high* · *meet OF*

Table 2. Concentration of heavy metals in different types of compost produced in Lithuania, 3-year results

Heavy metals, mg/kg	Compost type				
	GWC	FWC	SSC	CMC	DC
Cd	0.24	0.13	2.37	0.18	0.21
Pb	23.40	7.97	56.73	3.77	2.60
Ni	6.43	3.63	41.33	2.80	7.53
Cu	40.17	18.03	196.20	26.40	19.63
Zn	268.37	113.43	1204.33	149.83	288.57
Cr_{otal}	13.50	7.87	60.17	3.93	3.23
Hg	0.22	0.01	0.22	0.00	0.02

CONCLUSIONS

- Sewage sludge composts are rich in nutrients however high amount of heavy metals Cd and Zn is a limiting factor of these composts' use.
- Composts from green and food waste are classified as soil improvement substances. Cattle manure composts could be considered as multi-nutrient organic fertilizers while digestate composts meet the mono-nutrient organic fertilizers requirements.
- Lithuanian policy recommendations regulate the total Cr amount in composts, but not hexavalent chromium as recommended to determine it in EU document. There is a gap in the data of Cr (VI) in Lithuanian compost samples.

Acknowledgments

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Long-term effects of phosphate fertilization

Vervuurt, W., van Geel, W.C.A., Regelink, I. and de Haan, J.J.

Introduction

In agriculture there is a growing need to use phosphorus fertilizer more efficiently because of P related environmental problems and diminishing P reserves. Legislation in the Netherlands restricted the maximum supply of phosphate on agricultural soils to minimize losses to the environment. Concerns about soil fertility and yield losses arose. A long-term phosphate trial was initiated and preserved to quantify the effects of P-fertilization levels on crop growth as well as on soil phosphate levels and phosphate losses.

Methods

The experiment on a marine light clay soil started in 1990 with four levels of P- fertilization. In 2005 each treatment was split: fertilization was continued in one part and discontinued in the other. Resulting in these treatments and fertilization (kg P_2O_5 ha^{-1} yr^{-1}):

	1990-2004	2005-2022
P1-0	0	0
P1-70	0	70
P2-0	70	0
P2-70	70	70
P3-0	140	0
P3-140	140	140
P4-0	280	0
P4-280	280	280

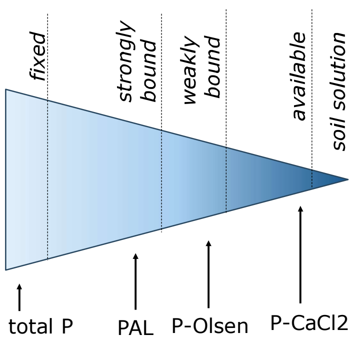

Figure 1. Phosphate fractions in the soil.

Crop yiels were monitored and phosphate fractions (P-$CaCl_2$, Pw, P-AL and total P) were determined in the soil (0-30cm and 30-60cm).

Effects on yields

- An optimum yield was obtained by 70 kg P_2O_5 ha^{-1} yr^{-1} at a soil phosphate level that is considered as optimal.
- Yield losses occurred at fertilized and unfertilized plots with lower soil phosphate levels.
- Higher soil phosphate levels in combination with and without fertilization did not affect yields.

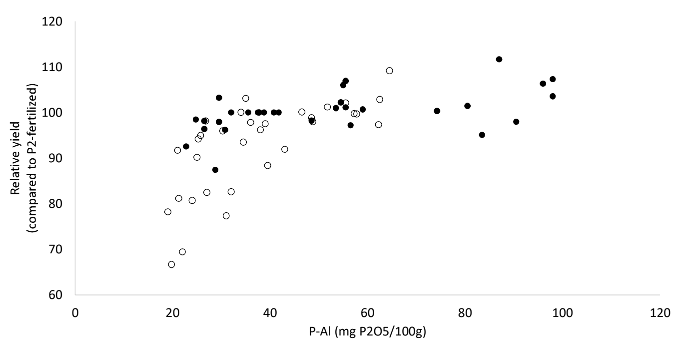

Figure 2. Relative crop yields for fertilized treatments (filled) and not fertilized treatments (open) in the period 2006-2022, for crops with a high P need (potato, onion, maize, beans).

Effects on soil

- Different levels of fertilization led to divergent soil phosphate levels in the soil layers 0-30cm and 30-60cm.
- Discontinuation of fertilization led to sharp decreases in soil phosphate levels.
- The P_2O_5 surpluses did not lead to proportionate changes in the soil P_2O_5 stock at 0-30cm.
- Losses were difficult to quantify.
- At high fertilization rates P-$CaCl_2$ stabilized while the P stock measured with P-Al further increased.

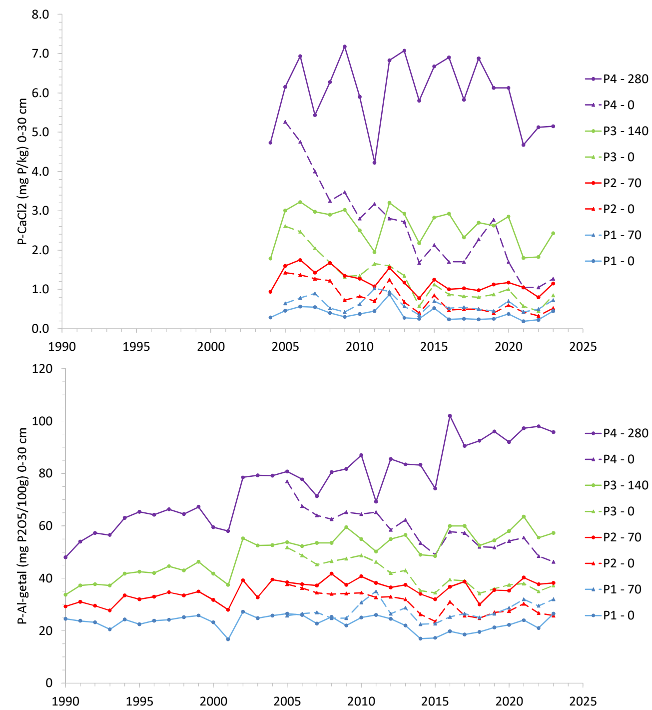

Figure 3. The soil phosphate levels measured as P-CaCl2 (top) and as P-Al (bottom) in the layer 0-30cm.

Conclusions

- At sub optimal soil phosphate levels, fertilization is needed to reach optimal yields and improve the soil phosphate levels.
- At high soil phosphate levels, fertilization is not needed to reach optimal yields. The current limit of 40 kg P_2O_5 ha^{-1} yr^{-1} is sufficient to reach optimal yields at high phosphate levels.
- At low soil phosphorus levels, mining did not lead to a further decrease.
- At high soil phosphorus levels, mining did not lead to stabilized levels after 18 years.

Acknowledgements

Vervuurt, W., van Geel, W.C.A., Regelink, I. and de Haan, J.J. (2023). Lange termijn effecten fosfaatbemesting op een bouwlandproef in Lelystad: meetresultaten van de periode 2005-2020. Wageningen University & Research, WPR-OT 1000. doi: 10,18174/588813

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Evaluation framework to predict the fate of organic fertilisers

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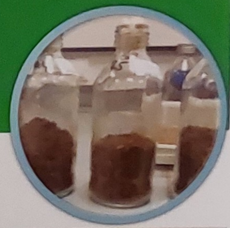

Background

We are transitioning towards a circular economy that aims to reuse waste streams such as sewage sludge, surplus of manure, and organic household waste. Treatment and reuse of these waste streams will lead to new organic fertilisation products. The overarching project includes assessment of agronomic, environmental, health and economic aspects. This study focuses on the agronomic impact.

Objective

Developing a simple and quick method to predict the agronomic impact of organic products, to speed up the acceptance or rejection of new organic products, thus contributing to the transition towards circular economy.

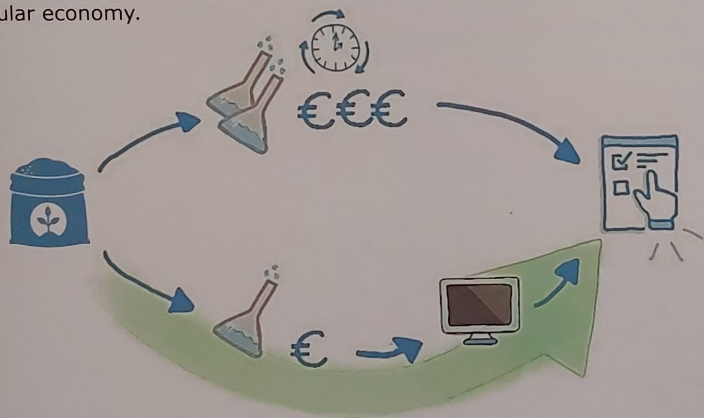

Figure 1. Two routes for investigating the carbon and nitrogen turnover: incubation experiments (top) or simple laboratory analyses and modelling based on this study (bottom).

Introduction & methodology

- By analysing carbon and nitrogen-related characteristics of 16 very different organic products in incubation experiments as well with simple laboratory analyses, an extensive dataset was created.
- This dataset was used to calibrate sizes of a quickly and a slowly decomposable pool, as defined in the model RothC.
- Simple analyses were coupled to the size of the quickly decomposable pool by regression analysis. N turnover followed from organic matter decomposition and C/N ratios assigned to pools.

Figure 2. The organic products used in this study.

Results

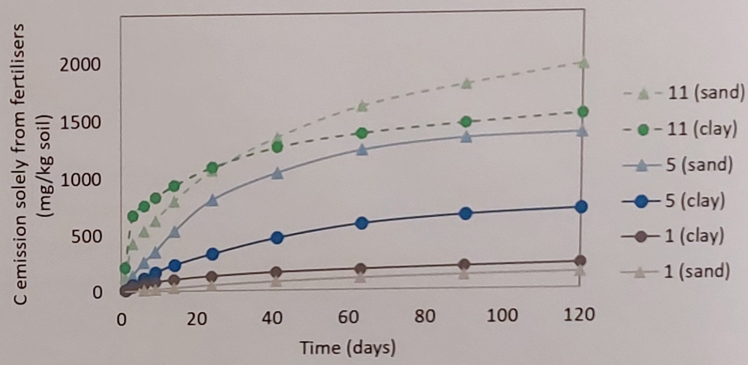

Figure 3. Measured C-CO2 emission due to fertiliser decomposition over time, for sandy and clay soil. With 11 = cattle slurry, 5 = dairy sludge, 1 = champost.

- Simple laboratory analyses (total nitrogen content, a pyrolysis parameter and a MicroResp. parameter) could predict the size of the easily decomposable fraction of carbon (fDPM) of an organic fertilising product, enabling the prediction of carbon dynamics.
- For N mineralisation, an overestimation was found, meaning that just using a fixed C/N ratios of each of organic pools in RothC is a too simple approach

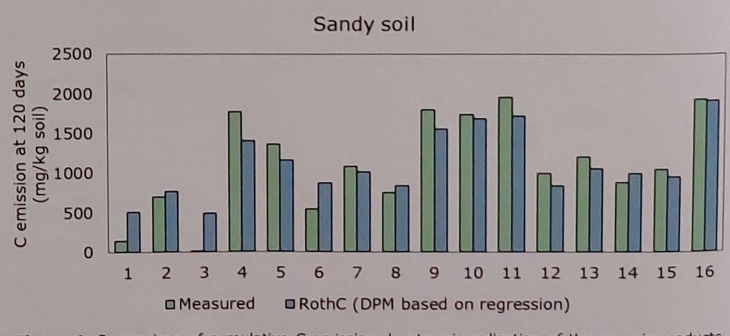

Figure 4. Comparison of cumulative C emission due to mineralisation of the organic products over 120 days in sandy soil, from i) the incubation experiment, and ii) the RothC model with DPM based on regression.

Conclusions

- The evaluation framework tool can, with a simplified method, help to predict the expected effects of an organic fertiliser on carbon storage in soils.
- The method of using fixed C/N ratios per pool was too simplistic to explain N turnover
- The methodology will be tested and validated within a follow-up project: *Validation of a assessment system for organic fertilisers*

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Effects of Long-term Phosphate Fertilization on Soil P Pools and Crop Available P.

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Soil Chemistry and Chemical Soil Quality & Sustainable Soil Management

Background

- Phosphate is strongly bound by soil particles and natural P availability is therefore very low.
- P fertilization is thus needed to increase the soil P stock to a certain amount for optimal crop growth.
- To the contrary, a high soil P stock created by excessive P fertilization increases the risk on environmental losses and wastes finite phosphate reserves.
- This requires tailored fertilization advice accounting for the effect of soil P sorption properties.

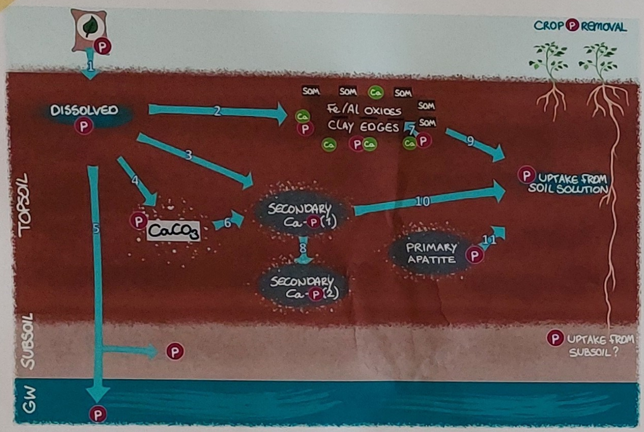

Figure 1. This figure shows the most important pathways of phosphorus binding of mineral applied P fertilizer. Depending on the specific soil properties, these processes govern the bio-availability of applied P fertilizer.

Objective

To understand:

A) Phosphate sorption in P pools with variable reactivity to the soil solution.

B) The relation of soil type with the quantitative importance of calcium-phosphate precipitation versus phosphate adsorption to oxides.

C) The relation of soil P availability tests with crop yield and environmental losses.

Methods

We used two Dutch long-term fertilization experiments to gain insight in P sorption mechanisms. The LTEs are situated on a calcareous loamy soil in Flevoland and a noncalcareous sandy soil in Drenthe. Both LTEs were initiated in 1971 and are still maintained. Mineral P fertilizer has been applied yearly with various dosages. This resulted in cumulative P surpluses of -1000 to +4000 kg P/ha after 50 years. Various arable crops have been cultivated for which crop yield and phosphate uptake has been measured yearly.

Figure 2: LTE on calcareous loam soil near Marknesse. Clay 20%; pH 7.5; OM 3.6%; 9% $CaCO_3$.

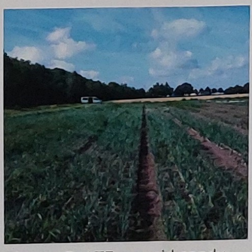

Figure 3: LTE on acid sandy soil near Wijster. Clay: 4%; pH 5.0 OM 4.5%.

Results

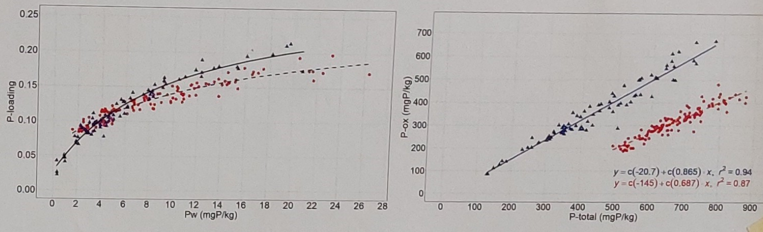

Figure 4: In blue triangles the sandy soil is shown and in red dots the loamy soil.
Left) Water extractable P (Pw) is related to P-loading ($P_{ox}/[Al_{ox}+Fe_{ox}]$). The comparable relation for both sites suggests that P in solution is likely governed by the relative loading of oxides particles for both soil types.
Right) Ammonium-oxalate extractable P is compared to total P. Part of applied P is lost from the ammonium-oxalate extractable pool to very stable pools only extractable by strong acid. This loss is highest on the calcareous loam soil with 30-35% of applied P.

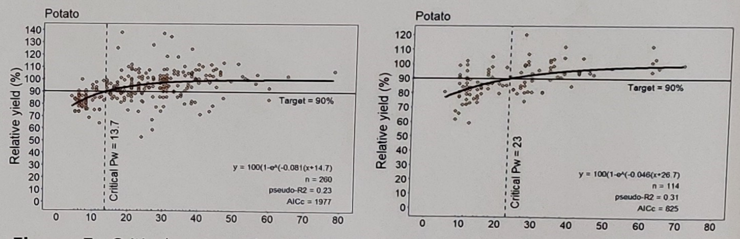

Figure 5: Critical water-soluble P levels for optimal crop growth have been determined by fitting crop yield to Pw by Mitscherlich equations. This shows that the sandy soil (Right) requires a higher level of water-soluble P than the loamy soil (Left) for optimal potato growth. STPs $P\text{-}CaCl_2$ and P-AL indicated a similar difference.

Loamy soil	Total P (mgP/L)		Sandy soil	Total P (mgP/L)	
P dosage (kgP/ha)	35 cm depth	75 cm depth	P dosage (kgP/ha)	35 cm depth	155 cm depth
0	0.02	0.01	0	0.04	0.02
35	0.03	0.01	20	0.1	0.04
70	0.01	0.02	39	0.1	0.04
105	0.04	0.01	79	0.15	0.01
			105	0.1	0.02

Table 1: Over the period of 2003 to 2011, soil moisture has been sampled with rhizon samplers at 35 and 75 cm depth. P leachate concentrations remained low for all P dosages and were only enhanced by P fertilization at 35 cm depth.

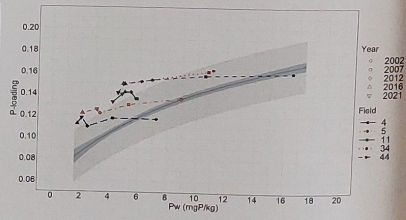

Figure 6: P fertilization has been withheld for 25 years at the loamy soil after 25 years of surplus fertilization. Water-soluble P declined faster than expected based on the relation between P loading and water-soluble P acquired for yearly fertilized plots.

Conclusions

- P-loading onto oxides seems to govern P in solution for both soil types.
- On the calcareous loam soil P losses to very stable pool are substantial.
- Critical STP values are not generic. Following generic fertilization recommendations may lead to inefficient P fertilizer usage.
- At both sites, P leaching was only minorly enhanced for treatments receiving P fertilization rates of 4x crop uptake for more than 30 years.
- When P fertilization is withheld, water-soluble P declines with an enhanced rate compared to the reduction of P-loading.

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