


40 YEARS OF RESEARCH ON NITROGEN

Proceedings Side Event

Nutrient Management & Decision-Support Systems

June 27, 2018

Agrocampus Ouest
Rennes, France

20th Nitrogen WORKSHOP

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Side Event of the 20th Nitrogen Workshop
June 27, 2018, Agrocampus Ouest, Rennes, France

The French Joint Technology Network “Fertilisation & Environment” (RMT F&E[1]) and the French Committee for the Study and Development of Rational Fertilisation (COMIFER association[2]) co-organise just after the 20th N Workshop, a side event to share knowledge and experience about **nutrient management tools used worldwide**.

The side event links the knowledge of processes affecting nitrogen and other nutrient cycling and their use for managing cropping and livestock systems.

This seminar focuses on decision-support tools for inorganic and organic crop fertilisation, and diagnostic tools for nutrients management. It aims to provide a rather large overview of approaches developed in various European countries and beyond, and to discuss them according to several aspects:

- The conceptual bases of decision-support tools: which approaches are developed in which countries? What operating scales (field, farm, region) do these decision-support tools cover? What farming systems are addressed?
- What tools are available for joint management of several nutrients?
- What tools are available for managing multiple nutrients at the same time?
- National and European regulations: to what extent are they integrated in tools, and how?

These issues will be addressed over the course of one day, on June 27, 2018, combining
- Workshop of tool demonstrations,
- Poster presentations,
- Oral presentations in plenary session.

Scientific bases and implementation strategies will be compared through these sessions.

[1] See a brief presentation on page iii
[2] See a brief presentation on page iii

Scientific committee:

- François LAURENT	Arvalis, France
- Cécile LE GALL	Terres Inovia, France
- Christine LE SOUDER	Arvalis, France
- Jean-Marie PAILLAT	CIRAD, France
- Virginie PARNAUDEAU	INRA, France
- Sylvie RECOUS	INRA, France

Organising committee:

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- Pascal DUBRULLE	INRA, France
- Olivier GODINOT	Agrocampus Ouest, France
- Mathilde HEURTAUX	ACTA, France
- Tiphaine LABBÉ	INRA, France
- Fiona OBRIOT	LDAR, France
- Jean-Marie PAILLAT	CIRAD, France
- Virginie PARNAUDEAU	INRA, France
- Sylvie RECOUS	INRA, France
- Bernard VERBÈQUE	Chambre d'Agriculture du Loiret, France

The French Joint Technology Network "Fertilisation & Environment" (RMT F&E)

Since 2007, the "RMT F&E" brings together, develops and synergises the scientific and technical skills mobilised around fertilisation and the sustainable management of biogeochemical cycles, to better meet the needs of farmers.

This dynamic network consists of 34 different partners implied in agricultural research (including two Belgian and one Swiss), training, and development. Around 100 people share knowledge and references, develop common databases and tools, and explore new research questions and new ways of managing biogeochemical cycles and soil fertility.

Several collaborative research and development projects are carried out on various topics related to agro-ecology, particularly on:

- Nitrogen performance of cropping systems
- Characterisation and use of organic waste products (e.g. digestates of anaerobic digestion)
- Nitrogen losses by ammonia volatilization and nitrate leaching, search for solutions
- Bio-indicators of soil functioning
- Territorial approaches to systems and practices...

The references thus acquired feed various tools for decision support and environmental diagnostics, which are developed within the network.
In the end, this network promotes technical and scientific consensus.

For further information: http://www.rmt-fertilisationetenvironnement.org
This Network is supported by the French Ministry of Agriculture

The French committee for the study and development of rational fertilisation

The French committee for the study and development of rational fertilisation (COMIFER)

COMIFER, founded in 1980, is a non-profit organisation. It establishes a permanent dialogue among all actors involved in crop fertilisation in order to collectively develop and promote methods and encourage innovative solutions that contribute to a performing and environment-friendly agriculture.

As a key player alongside the public authorities, the COMIFER carries out technical studies in response to requests from the French administration.

>>> Events:
Rational fertilisation and analysis Congress
Since their creation in 1993, these biennial meetings that stand every odd year, have become a key appointment for professionals in crop fertilisation and soil fertility management.
Technical seminars shed regularly new light on agronomic issues and enable discussion on current challenges and exchanges on best practices, on topics such as: "Reason the nitrogen fertilisation referring to the Comifer balance method" (2013) or "Recycled Phosphorus in agriculture: potential, products, quality, regulation" (2017).

>>> Working groups: P K Mg - Soil acidity - Nitrogen and Sulfur - Recycled organic waste products - Fertility and biological activity of soil.

To join COMIFER, subscribe the newsletter, download symposium proceedings...: www.comifer.asso.fr

Nutrient Management & Decision-Support Systems

SIDE EVENT PROGRAMME

June 27, 2018 ■ 8 a.m. - 5 p.m.
Agrocampus Ouest, Rennes, France

20th Nitrogen WORKSHOP

MORNING

Tool demonstration workshop and Poster session

• **8:00 - 9:00**

Registration, posters and demonstrations installation by authors
Main hall, second hall, and classrooms

• **9:00 - 9:15**

Introduction to the Side event
Matagrin amphitheatre

• **9:15 - 10:30**

First session of tools demonstrations
Different classrooms

• **10:30 - 11:30**

Coffee break and poster sessions

• **11:30 - 12:30**

Second session of tools demonstrations
Different classrooms

The workshop will consist of a demonstration of 9 decision-support tools for mineral or organic fertilisation and nutrients management.
These demonstrations will take place in parallel, and participants will have the possibility to interact with authors of several tools.

> SOL-AID (Beff, L. et al.), SYST'N (Parnaudeau, V. et al.)
Room 1

> FARMSTAR (Kammoun, B. et al.)
Room 2

> MANNER-NPK (Sagoo, E. et al.), COWNEX (Faverdin, P. et al.)
Room 3

> N-PERENNES (Cahurel, J.-Y. et al.), AZOFERT® (Obriot, F. et al.)
Room 4

> VEGSYST-DSS (Gallardo, M. et al.), FERTIWEB® (Le Souder, C. et al.)
Room 5

Poster session

Main hall and second hall

Posters will be displayed throughout the day with a one-hour session in the morning with authors during the coffee break.

12:30 - 14:00: Lunch buffet
Main hall, dining room and outdoors

AFTERNOON

Plenary session - Matagrin amphitheatre

• **14:00 - 14:40**

Invited speaker: Van Doorslaer, B. (European Commission, DG Agriculture and Rural Development)
The «N» in New Common Agricultural Policy

• **14:40 - 15:00**

Hutchings, N.J. (Aarhus University)
Modelling nitrogen flows and losses on dairy livestock farms

• **15:00 - 15:20**

Ramos-Castillo, M. (Veolia)
Smartagri: optimization of organic amendments applications

• **15:20 - 15:40**

Sagoo, E. (ADAS)
Manner-NPK nitrogen model

• **15:40 - 16:00**

Genermont, S. (INRA)
Cadastre_NH_3: a new framework to estimate spatio-temporal ammonia emissions after N fertilization in France

• **16:00 - 16:20**

Young, M. (WUR)

A decision-support framework for the integrated evaluation of agricultural management impacts on crop yield, soil quality and environment.

• **16:20 - 16:30**

Conclusion

16:30 - 17:00: Farewell café

POSTERS

MAIN HALL

1• SERDAF, a soil-specific nutrient management expert system for sugarcane fertilization in Reunion Island

Versini, A., Bravin, M.N., Ramos, M., Albrecht, A., Todoroff, P., Collinet, M., Thuries, L.

2• Decision support tool for spring N fertilisation of winter oilseed rape–estimation of N uptake in late autumn using UAV

Engström, L., Wetterlind, J., Söderström, M., Piikki, K., Stenberg, B.

3• A milk urea model to better assess nitrogen excretion and feeding practice in dairy systems

Edouard, N., Dumercy, L., Brun-Lafleur, L., Rouille, B., Faverdin, P.

4• Adapting SYST'N for modelling Alfafa growth

Bedu, M., Reau, R., Dupont, A., Dubrulle, P. Parnaudeau, V.

5• "QN Method" - FARMSTAR: A nitrogen management tool on winter wheat based on remote sensing diagnostic and agronomic prognosis

Soenen, B., Le Bris, X, Closset, M., Bonnard, A., Kammoun, B.

6• Sol-AID: a web application to estimate soil Nitrogen mineralization available for crops in Brittany

Beff, L., Lambert, Y., Squividant, H., Lemercier, B., Vincent, S., Pichelin, P., El azhari, A., Morvan, T.

7• MANNER-NPK nutrient management software: Maximising impact and farmer uptake

Sagoo, E., Nicholson, F.A., Williams, J.R., Thorman, R.E., Bhogal, A., Misselbrook, T.H., Chadwick, D.R.

8• The Joint Technology Network "Fertilisation & Environment" (RMT F&E): Teams, Projects and Tools mobilized around the management of biogeochemical cycles in agricultural systems

Heurtaux, M., Dubrulle, P., Laurent, F., Le Gall, C., Obriot, F., Paillat, J.M., Recous, S., Verbèque, B.

POSTERS

SECOND HALL

9• COMIFER labeling of calculation tools for the predictive dose of nitrogen: approach and outlook

de Bandt, M., Leconte, L., Agasse, S., Dizien, C., Dubrulle, P., Eveillard, P., Hervé, M., Heurtaux, M., Lambert, M., Laurent, F., Le Roux, C., Le Souder, C., Leduc, D., Recous, S., Verbèque, B.

10• ELFE, a database to determine greenhouse gases and ammonia emissions factors from livestock

Vigan, A., Hassouna, I., Robin, P., Guingand, N., Espagnol, S., Edouard, N., Lorinquer, E., Loyon, I., Genermont, S., Eugene, M., Lagadec, S., Brame, C., Klumpp, K., Ponchant, P., Eglin, T.

11• Diagnosis of N losses in cropping systems in water protection areas from specific stakeholders

Reau, R., Bedu, M., Gratecap, J.B., Pucel, F., Parnaudeau, V.

12• The online support-tool "RAX": fertilization recommendation with slurry in grasses and forage crops

García, M.I., Báez, D., Castro, J.

13. VegSyst-DSS to calculate N and irrigation requirements IN vegetables grown with fertigation in mediterranean greenhouses

Gallardo, M., Arrabal, F., Padilla, F.M., Peña-Fleitas, M.T., Thompson, R.B.

14• SMARTAGRI: optimization of organic amendments applications

Ramos-Castillo, M., Naves-Maschietto, G., Bisinella de Faria, A. B., Benoist, T., Megel, R., Gouvin, G., Pajean, C., Albuquerque, M., Orvain, M., Revallier, A.

15• From AzoFert® to N-Perennes: adaptation of a dynamic decision support tool for annual crops fertilization to perennial species

Obriot F., Le Roux C., Cahurel J.Y., Dubrulle, P., Recous S.

16• Cadastre_NH_3: a new framework to estimate spatio-temporal ammonia emissions after N fertilization in France

Genermont, S., Dufosse, K., Ramanantenasoa, M.M.J., Maury, O., Gilliot, J-M.

17• A decision support framework for the integrated evaluation of agricultural management impacts on crop yield, soil quality and environment

Young, M., Ros, G.H., De Vries, W.

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TOOLS DEMONSTRATION

SOL-AID: A WEB APPLICATION TO ESTIMATE SOIL NITROGEN MINERALIZATION AVAILABLE FOR CROPS IN BRITTANY

Beff, L.[1], Lambert, Y.[2], Squividant, H.[1], Lemercier, B.[1], Vincent, S.[1], Pichelin, P.[1], El Azhari, A.[1], Morvan, T.[1]

[1] UMR SAS, AGROCAMPUS OUEST, INRA , Rennes, France ; [2] Chambre d'agriculture de Bretagne, Rennes, France

INTRODUCTION

In Brittany, 59% of the area is used for agriculture. Optimizing Nitrogen (N) fertilization is then essential to achieve good crop yields and minimize environmental issue such as nitrate leaching. This requires correctly predicting the amount of N resulting from soil organic nitrogen mineralization (*Mh*), usable by the crop, which can vary greatly depending on climatic conditions, soil properties and cropping system.

A recent study made on soil N mineralization in Brittany shows that *Mh* was quite variable (from 50 to more than 250 $kgN.ha^{-1}$ between March and October) (Lambert et al. 2016), and a new predictive model based on the following formalism was parameterized: *Mh = Vp . tn* with *Vp*, the potential mineralization rate (which depends of soil properties and land management) and *tn*, the normalized time which is a climate normalization allowing the integration of soil temperature and water content into *Mh* estimation (Brisson et al. 2008). Because this new model is more complex than the current regional recommendations, it seems us essential to develop a web application to help the farmers to use it. Indeed, farmers usually do not have soil analysis results for all their fields and moreover, they do not have an access to the meteorological databases required for the calculation of *tn*. Therefore, UMR SAS INRA-Agrocampus and Regional Chamber of Agriculture of Brittany have decided to develop a web application, Sol-AID. This application should be operational in 2020 and a first version will be available at the end of 2018. In addition, a field experiment aims to evaluate the model (N response curve) on 24 fields during 3 years.

MODEL/TOOL DESCRIPTION

Sol-AID is developed mainly for farmers and fertilization advisers to help them to properly estimate *Mh* at the field scale with the new predictive model. This application is made of different modules.

Soil module

The Brittany soil map (1:250 000), gives cartographic units of soil. In each unit, there is usually more than one soil type which can be quite different (e.g. localization, soil properties, geology). Determining the soil type is therefore essential in agronomy such as for estimating *Mh*. For that, we develop a simple method to help the farmer determining the soil type of their fields. From the cartographic unit of the soil (defined with field position), a decision tree is proposed to the farmer, with simple questions such as the localization in the landscape or the presence of soil crust, to define its soil type. A data base contains the soil properties for *Mh* estimation for all soil types of Brittany.

Cropping system module

Inserting land management in the model is not straightforward. We therefore developed an indicator of the cropping system, *I_Sys*, which estimates the N restitution to soil from crops of the rotation and manure application for the past 15 years. With simple questions on their land management, the farmer will determine the type of cropping system of its fields for which value of *I_Sys* are associated.

Climate module

Because we cannot predict the climate of the next crop year, a provisional *tn* is estimated. It is the average of the *tn* determined for the weather of the 20 past years. STICS crop model is used to automatically calculate this provisional *tn* with (i) weather data base, (ii) the soil properties and (iii) the crop of the field (Brisson et al. 2008). The provisional *tn* is then used in *Mh* calculation. An actualization of *tn* could be done with the weather of the current year, for the period prior to fertilizer inputs.

Mh module

Mh is automatically calculated with data coming from other modules (soil properties, *I_Sys* and *tn*). The values will be directly available on the web interface of Sol-AID.

RESULTS

Figure 1 presents a capture of the screen of the web application. A user-friendly interface makes it easy to inform and use the application. The results are easily displayed by user and are stored in a data base.

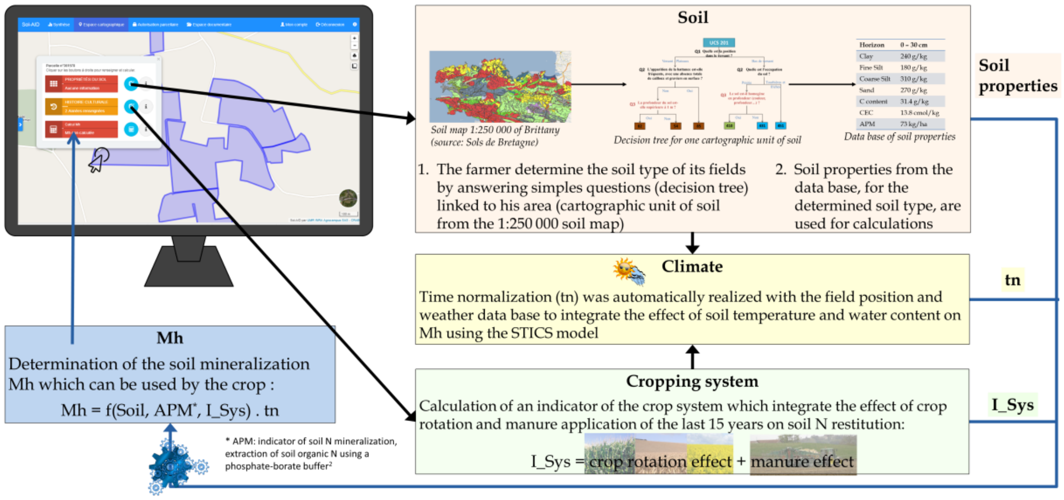

Figure 1: Capture of the Sol-AID interface with the link to the calculation and determination modules (soil, climate, cropping system and Mh). Mh is the mineralization of soil organic nitrogen, tn is the normalized time (climate normalization) and I_Sys is the indicator of the crop system.

CONCLUSION

Sol-AID will be available in 2020 and will be a user friendly web application to easily estimate *Mh* considering soil properties, cropping system and climate.

Acknowledgements: This work was financially supported by AELB, Regional Council of Brittany and DRAAF

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Brisson, N., Launay, M., Mary, B., Beaudoin, N., 2008. Conceptual Basis, Formalisations and Parameterization of the STICS Crop Model. INRA, Rd 10, 78026 Versailles Cedex, France, Editions Quae.

Lambert, Y., Morvan, T., Beff, L., 2016. Les bilans mesurés et leurs composantes. Journée de synthèse scientifique - Réseau Mh: Vers un nouveau raisonnement de la fertilisation azotée en Bretagne?, Locminé, France, pp. 21-26.

SYST'N®

Parnaudeau, V.[1], Dupont, A.[2], Dubrulle, P.[2], Bedu, M.[1], Dupas, R.[1], Jeuffroy, M.H.[3], Lefevre, L.[1], Recous S.[4], Reau, R.[3]

[1] UMR SAS-INRA/Agrocampus Ouest, France; [2] UMR Agronomie – INRA, France; [3] UR AgroImpact – INRA, France, [4] UMR FARE – INRA, France

INTRODUCTION

To reduce N emissions from cropping systems, one of the most acute issues remains the improvement of nitrogen management, based on assessment and diagnosis of nitrogen use by the plant, N losses and impacts in agricultural systems. A software, called Syst'N®, has been developed in the French network "RMT Fertilisation et Environment", by sharing knowledge on N fluxes in agricultural systems between agricultural scientists and stakeholders. This tool includes a dynamic nitrogen model to calculate N losses at the crop sequence time scale and user-friendly graphical interfaces.

TOOL DESCRIPTION

Nitrogen dynamics model

The biophysical model included in Syst'N is a 1D soil-crop model. It simulates soil nitrogen (N) transformations, crop growth, N uptake, water balance and N losses to water (as NO_3^-) and air (as NH_3, N_2 and N_2O) on a daily time step. Input data include description of a crop sequence, agricultural management practices (nitrogen fertilisation and tillage), soil and climate. The biophysical model was evaluated for a range of crops (wheat, barley, corn, pea, rapeseed, alfalfa and sunflower) and catch crops (white mustard, ryegrass) (Parnaudeau et al., 2012). Syst'N equations combine existing submodels previously published: STICS for water and nitrate budgets in soils, AZOFERT for mineralization of soils and crop residues, AZODYN for crop N uptake, NOE for N2 and N2O emissions and VOLT'AIR for NH_3 emissions (see Cannavo et al. (2008) for a description of the equations used). These models were selected to function with input data that are generally available for identified end-users.

Graphical interfaces

The interface for data entry includes default data, and enables the comparison of various cropping systems or the consideration of climatic uncertainties. In order to help users, default input databases propose a description of regional soils (three of the French ones in the prototype) and cropping systems. Each simulation folder describes the cropping system within its context, through a tree structure representation. Syst'N also includes post-processing routines of simulation results, a graphical interface for input and output visualization to facilitate use by non-scientist users (Figure 1).

RESULTS AND DISCUSSION

Syst'N uses and users

About 30 active users are currently using Syst'N in France. We performed an analysis to characterize the users and their use of Syst'N (not published). Environmental managers in water catchments or protection areas and agricultural extension services mainly use Syst'N, to assess nitrate losses towards aquifers in their landscapes and design new cropping systems emitting low N emissions. An emerging use is agricultural training courses, due to the didactic properties of the tool.

A case study

This case study is described in Dupas et al. (2015). Addressing the issue of agricultural pollution in water protection areas (WPA) requires assessing the impact of agricultural activities at regional scales. However, current water quality modeling studies often neglect the agronomic concept of a cropping system and interactions with soils. This study consisted of a participatory assessment framework involving local experts in building a shared diagnosis of nitrate losses from cropping systems in a WPA. It includes a co-designed typology of landscape units and participatory assessment of nitrate losses with the modeling software Syst'N. Results show that characteristics of cropping systems depended on soils and that nitrate losses were highest in shallow soils. Intercrop periods were identified as critical periods for nitrate leaching, which demonstrates the importance of considering pluri-annual crop rotations rather than individual crops. The framework is generic for a modeling approach based on the involvement of local experts, who define their functional system in an agronomically sound way.

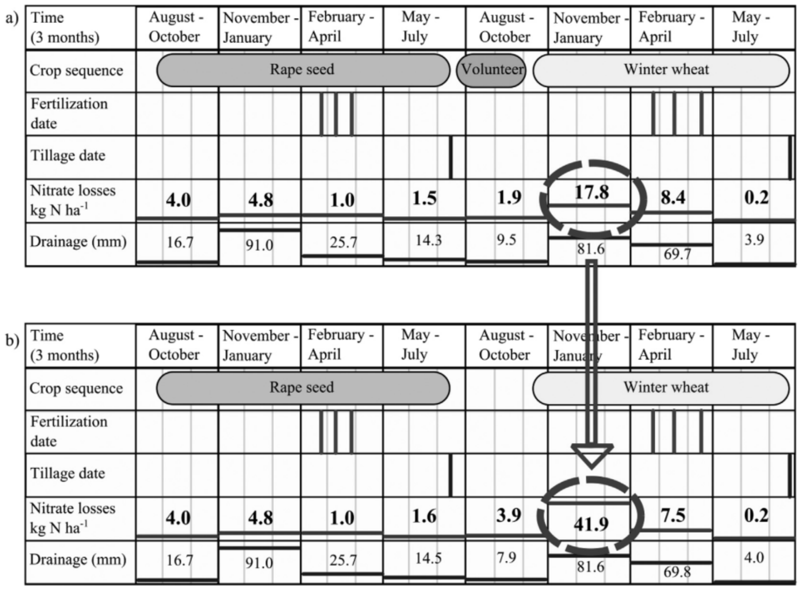

Figure 1. Syst'N output interface (simplified and translated into English) comparing intercrop period (a) with volunteers and (b) without volunteers in rotation "rape seed - winter wheat - winter wheat - winter barley" (Dupas et al, 2015).

CONCLUSION

Syst'N is still evolving to take account of more crop species as legumes (soybean or fababean), and complex systems including intercrops or organic farming practices. These improvements are performed by researchers and agricultural engineers by interacting with Syst'N users who have meetings two days a year.

REFERENCES

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Dupas R., Parnaudeau V., Reau R., Jeuffroy M.H., Durand P., Gascuel-Odoux C. 2015. Integrating local knowledge and biophysical modeling to assess nitrate losses from cropping. Environmental modeling and software, 69:101–110.

Parnaudeau V., Reau R., Dubrulle P. 2012. Un outil d'évaluation des fuites d'azote vers l'environnement à l'échelle du système de culture : le logiciel Syst'N. Innovations Agronomiques, 21:59–70. http://www6.inra.fr/ciag/Revue/Volume-21-Septembre-2012.

FARMSTAR: A COMPLETE AGRICULTURAL DECISION-SUPPORT TOOL BASED ON REMOTE SENSING

Kammoun, B.[1], Closset, M.[1], Bonnard, A.[1] Paganelli, E.[2], Mallavan, B.[2], Veloso, A.[2]

[1] ARVALIS, FRANCE; [2] AIRBUS, FRANCE

INTRODUCTION

Farmers are facing a variety of challenges, ranging from uncertainty of weather, the risk of environmental degradation and production and labor costs increase. Precision agriculture is a farming management concept based on observing, measuring and responding to inter- and intra-field variability in crops. This approach uses information technology to ensure that the crops and soil receive exactly what they need for optimum health and productivity. Precision agriculture is also known as satellite agriculture. Satellite data has become the uppermost data source to monitor large-scale crop condition. Remotely sensed images are used as mapping tools to classify crops and determine the optimum amount of water, fertilizers and pesticides to apply. Farmstar has been a French service dedicated to precision agriculture and crop management since 2002. Through a combination of Airbus Defence and Space's unique expertise in analysing remote sensing images and the agronomic expertise of the Arvalis –Institut du végétal and Terres Inovia technical institutes, Farmstar provides a complete range of recommendations on plant protection, crop condition and input management.

MODEL/TOOL DESCRIPTION

French leader in decision-support tools based on remote-sensing, Farmstar offers recommendations that can be directly implemented on crops. Farmers subscribe to Farmstar through their distributors. In 2018, the service covers an area of 720 000 hectares of cereal and rapeseed crops. At the beginning of agricultural campaign, farmers subscribe and reference each field with agronomic data (soil type, cultivar sowing date and sowing density, preceding crop) and geographical position (outlines)....

A georeferenced database is created every year to produce agronomic advices specified to each subscribed field. Due to its large satellite fleet, Airbus ensures the highest quality of imagery acquisition. Aeroplane or drone images can be used also for precise advice specific to crops requirements. Every image is integrated into the processing chain to produce reliable and comparable biophysical parameters that enable monitoring and quantitative assessment of vegetation status. These biophysical parameters are then associated to the farmer field data and used in agronomic models developed by Arvalis –Institut du végétal and Terres Inovia such as “QN method”. All field specific advices are validated by regional experts from Arvalis and Terres Inovia. Input recommendations or lodging‘s risks are delivered with modulation maps that enable to optimize the fertilizers and pesticides application. This helps the farmer to maximize production while avoiding wasting resources, reducing costs and controlling the farm's environmental impact. Farmers receive their advices through the secure Farmstar web portal, the distributor’s extranet or by postal mail.

RESULTS AND DISCUSSION

Although Farmstar remains by far a nitrogen management service, it offers also other advices such as the lodging risk estimate which reflects the plant nitrogen status. Moreover, Farmstar provides its customers with optional recommendations that do not use remote sensing data such as fungal disease risk on wheat crop. Thus, Farmstar with its various advices cover all the crop growth cycle. In France, the balance sheet method is one of the most popular nitrogen fertilizer management. This method determines the amount of N fertilizer needed to meet the crop requirements for a potential yield objective by estimating soil mineral N variations over the potential rooting depth between mid-winter and crop harvest.

One of the most important components of the balance sheet equation is the nitrogen absorbed by the crop at the end of winter. Farmstar provides a nitrogen crop absorbed value specified to each field instead of using a mean value based on national references. This allows optimizing the calculation of nitrogen fertilizer recommendations by considering the real nitrogen status of each crop on each field. To assess the nitrogen absorbed by the crop, Farmstar estimates at first, the crop biomass between tillering and the beginning of stem elongation stage using the Leaf Area Index (LAI). Several studies have demonstrated the high correlation between this biophysical parameter and the canopy status (Jacquemoud et al., 1999). Considering that at early crop growth stage, wheat plant does not lack nitrogen, it is possible to use directly the nitrogen dilution curve for wheat crops (Justes et *al*., 1994) to calculate the N absorbed by the wheat crop. Since this method gives a prediction over a long period of time (between mid-winter and crop harvest), the estimation of the soil N supply and plant uptake may not be reliable enough. Therefore, Farmstar proposes a late N recommendation based on a reliable nitrogen diagnosis during stem elongation by the “QNmethod” (cf “QN METHOD” abstract). A dynamic approach of nitrogen flows would be the best nitrogen management tool that can help to reduce environmental impacts while sustaining farm economic benefit.

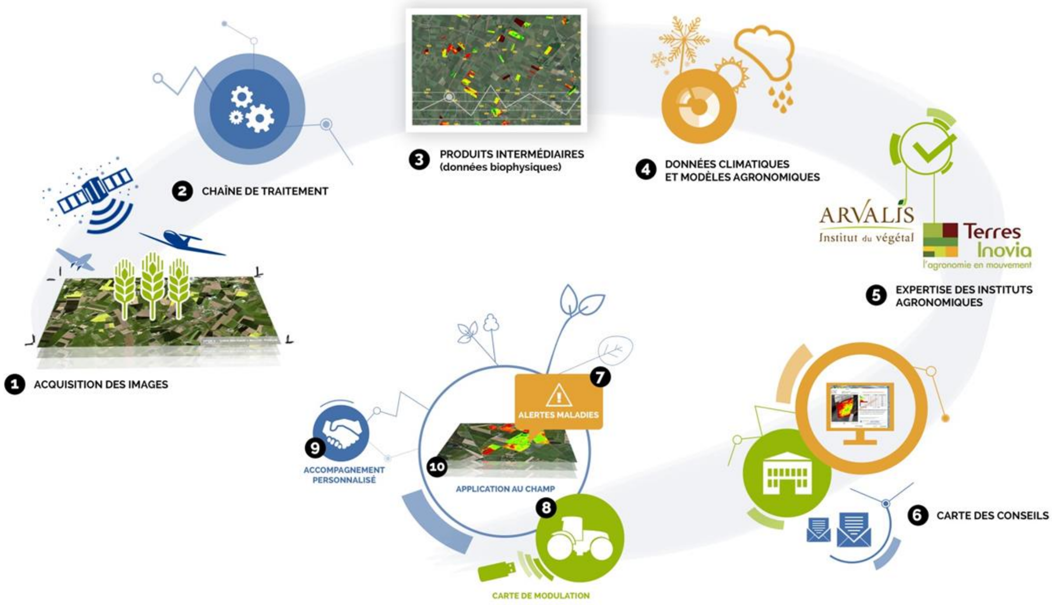

Figure 1. Farmstar operational processing

CONCLUSION

With 20 years of research and development and 16 years of renewed farmer use, Farmstar is the leading decision-support tool combining remote sensing and agronomics. It allows to monitor crop condition without any sampling procedure and to optimize input application rate. Today, Farmstar offers a large range of advices for winter wheat, barley, rapeseed, triticale and going to be extended to maize crop by 2019.

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Justes E., Mary B., Meynard J.M., Machet J.M., Thelier-Huches L. 1994. Determination of a critical nitrogen dilution curve for winter wheat crops. Annals of Botany,74.397-407

MANNER-NPK: ORGANIC MANURE NUTRIENT MANAGEMENT SOFTWARE

Sagoo, E.[1], Nicholson, F.A..[2], Williams, Jr.[3], Thorman, Re.[1], Bhogal, A.[2], Misselbrook, T.H.[4], Chadwick, D.R.[4]

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INTRODUCTION

Organic materials are a valuable source of plant available nutrients. However, farmers do not always make adequate allowance for the contribution of organic materials to crop requirements, potentially resulting in nutrient oversupply which can reduce crop yields and quality and increase the risk of nutrient losses to air (e.g. ammonia and nitrous oxide) and water (e.g. nitrate., ammonium and phosphorus). Increasing the contribution that the nutrients supplied by organic materials make to crop requirements is essential to increase resource use efficiency and minimise agriculture's environmental footprint.

MODEL/TOOL DESCRIPTION

MANNER-*NPK* conceptual model

MANNER-*NPK* (MANure Nutrient Evaluation Routine) is a decision support tool for quantifying crop available nutrient supply from applications of organic materials (i.e. livestock slurries, compost, digesates and biosolids). The MANNER-*NPK* nitrogen (N) model includes modules that estimate ammonia volatilisation, nitrous oxide emissions, nitrate leaching losses and N mineralisation to estimate crop available N supply in the first and second year following application. Each of these modules include algorithms which take into account factors affecting the N mineralisation and loss pathways and are based on a large database of field experimental research.

Validation of crop available N predictions has been undertaken by comparing predicted manure fertiliser N replacement values with independently collected field experimental measurements (>200 site years of data). MANNER-*NPK* predictions of crop available N supply from cattle, pig and poultry manures were in good agreement (P<0.001) with measured values, indicating that MANNER-*NPK* provides a robust estimate of the fertilizer N replacement value of different types of farm manures spread under a range of conditions (Nicholson et al., 2014).

In addition, MANNER-*NPK* estimates organic material phosphate (as P_2O_5), potash (as K_2O), sulphur (as SO_3) and magnesium (as MgO) supply, based on total manure nutrient concentrations and crop availability estimates (where available) as published in the "AHDB Nutrient Management Guide" for England and Wales (AHDB, 2017).

MANNER-*NPK* Decision Support tool

MANNER-*NPK* is a free desk based decision support tool, available either on CD or internet download (www.planet4farmers.co.uk/manner). It has been designed as a practical tool to provide farmers and advisers with a quick estimate of crop available nutrient supply from organic manure applications.

MANNER-*NPK* is presented as five tabs which describe the information required and data presented. The first three tabs – 'Farm and Field Details', 'Application' and 'Manure Analysis' – are input tabs where the user can enter details of the organic manure applications. The last two tabs – 'Results' and '£ value' – display the results of the MANNER-*NPK* software. When the software is opened, default information is shown in all the essential fields apart from area code. The user must enter their area code (which is used to select location specific climate data) and then edit the other default information with more specific information (if available) for the organic manure application. Other input information includes soil type, manure type, application date, application rate and type of application equipment and method and time of soil incorporation. When the user selects the manure type, the 'Manure analysis' tab displays default or 'typical' nutrient values for the manure type selected, which can be edited if laboratory analysis data is available.

The 'Results' tab shows crop available N supply for the current and next crop, total and crop available P_2O_5 and K_2O and total SO_3 and MgO. Estimates of N losses (as nitrate leaching, ammonia volatilisation and denitrification) are also shown. The '£ value' tab calculates the economic nutrient value of the manure application (in £/ha) based on default manufactured fertiliser prices which can be altered to current prices.

MANNER-*NPK* allows farmers and advisers to quickly test the likely impact of changes to organic material management practices on crop N availability and N losses to the environment e.g. the potential increase in crop N supply and reduction in nitrate leaching losses from applying organic materials in the spring rather than autumn, or the increase in crop available N supply and reduction in ammonia emissions from applying slurry using a trailing hose, trailing shoe or shallow injection techniques compared with surface broadcasting.

RESULTS AND DISCUSSION

MANNER-*NPK* was released in 2013 and there are currently *c.*4,000 registered users. The MANNER-*NPK* 'calculation engine' has been integrated into the PLANET Nutrient planning software tool (*c.*18,000 registered users). PLANET (Planning Land Applications of Nutrients for Efficiency and the environmenT) is a free desk based nutrient management decision support tool for use by farmers and advisers in England/Wales and Scotland for field level nutrient planning (www.planet4farmers.co.uk). Furthermore, the PLANET 'calculation engine' has been made available free of charge to commercial software companies as a Dynamic Link Library (DLL) for integration into their products. PLANET has been integrated into the commercial software tools produced by Farmade, Muddyboots and Pear Technology, significantly expanding the use of the MANNER-*NPK* nutrient availability calculations. The 2017 Defra "Farm Practices Survey" showed that more than half of holdings in England with a Nutrient Management Plan used either PLANET or one of the commercial software tools integrating the PLANET 'calculation engine' to produce their Nutrient Management Plan.

Acknowledgements: MANNER-*NPK* has been developed by ADAS and Rothamsted Research North Wyke, with funding and support from AHDB, CSF, DARD, Defra, Environment Agency, Natural England, Scottish Government, Tried and Tested and WRAP for use throughout the UK.

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COWNEX, A TOOL TO ASSESS NITROGEN EFFICIENCY, AUTONOMY AND EXCRETION AT DAIRY HERD LEVEL

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INTRODUCTION

The efficiency of nitrogen (N) use in dairy herds is an important challenge due to the environmental impacts of the N cascade and to the cost of protein resources. The assessment of global N efficiency and N excretion of dairy herds is complex due to the large diversity of feeding management during the year (several diets and several feeding groups). CowNex is designed to estimate the N parameters very simply for each farm situation.

MODEL/TOOL DESCRIPTION

CowNex is a new web application (http://www.cownex-record.inra.fr/) that facilitates the calculation of dry matter and nitrogen use in dairy herd according to the management, with a special attention to feeding management with user-friendly interface (Figure 1). It based on a subpart of the whole farm MELODIE model (Chardon et al. 2012) using the Record modelling platform. The model simulates the daily intake, production and excretion of the different categories of animal in a dairy herd according to the feeding management described by the users (Fig 2). CowNex enables the assessment of existing farms and the simulations of changes in feeding management both on production and excretion.

Cows-Vaches

	Diet 1 (75 Day) Begin : 9/1/2012 End : 11/15/2012 (mm/jj/aaa)		Diet 2 (60 Day) Begin : 11/16/2012 End : 1/15/2013 (mm/jj/aaa)		Diet 3 (88 Day) Begin : 1/16/2013 End : 4/14/2013 (mm/jj/aaa)		Diet 4 (76 Day) Begin : 4/15/2013 End : 6/30/2013 (mm/jj/aaa)		Diet 5 (62 Day) Begin : 7/1/2013 End : 8/31/2013 (mm/jj/aaa)	
	DM (kg/day)	%	DM (kg/day)	%	DM (kg/day)	%	DM (kg/day)	%	DM (kg/day)	%
FreshGrass		100						100		100
MilkP-LaitP										
MaizeS-EMais			7			65				
Straw-Paille										
SMB-Tt_Soja			1			10				
Barley-Orge	4					20	4		4	
Grass Silage										
BRE										
Foin				100		5				
Total	4	100	8	100	0	100	4	100	4	100
Time outdoors (h)		20		0		0		20		20

Figure 1. Example of the description of an annual feed management of a group of cattle with the CowNex web interface.

Applied to a large diversity of dairy systems encountered in France based on the “model farms” of INOSYS, CowNex was used to estimate the actual situation and to test some mitigation options to reduce NH_3 emissions and associated N2O emissions from manure. The estimation of these impacts was calculated using the EMEP-EEA equations with the CowNex results of N excretion (urine and faeces) either indoor of outdoor.

RESULTS AND DISCUSSION

The results of the different simulations are presented in figure 3. The reduction of protein supplementation to reach a crude protein content of 14% with maize silage based diets is a simple and efficient solution to highly reduce ammonia emissions and decrease GHG emissions between 10 and 20%, with a good choice of protein sources, but without changing any manure management options. In many systems, there is both economic and environmental benefit to pay attention to the protein supplementation.

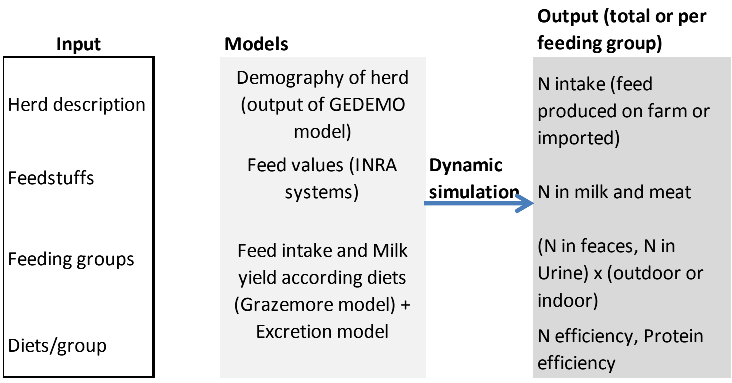

Figure 2. Simplified representation of CowNex tool, inputs outputs and model used.

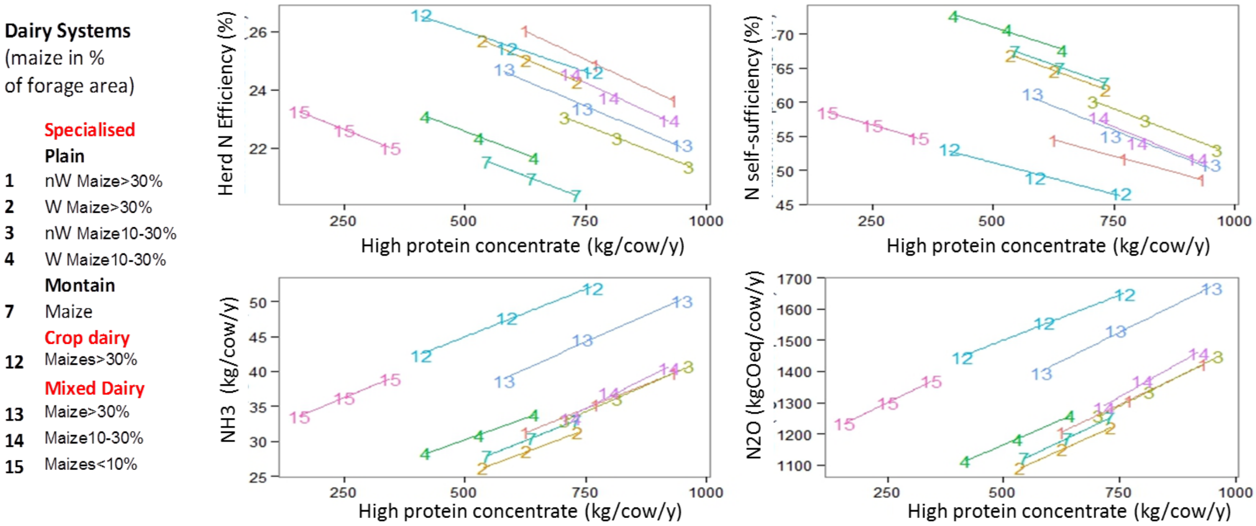

Figure 3. N efficiency ad N emissions for different model dairy systems with different protein supplementation.

CONCLUSION

CowNex is a free application to simply compare N excretion of different dairy systems with different feeding management. The reduction of protein supplementation during the indoor period is an efficient solution to reduce NH3 emissions of dairy cattle, but with different effects according to the farming system.

Acknowledgements: CowNex was funded by the project RedNex UE FP7 KBB-2007-1

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N-PERENNES : NITROGEN FERTILISATION FOR PERENNIAL CROPS

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INTRODUCTION

Currently, nitrogen fertilisation management for perennial crops remains empiric, while this element is very important, relatively to inter-row cover-crop extension. However, fertilisation management is not easy because it is difficult to find a balance between correct vigor and yield, and fruit quality, this last decreasing with yield increase (Champagnol, 1984; Soing, 1999).

MODEL/TOOL DESCRIPTION

The decision-support tool called "N-Pérennes" results from a national project supported by the Fertilisation & Environment joint technological network (RMT Fertilisation et Environnement, http://www.rmt-fertilisationetenvironnement.org/). It is a prototype which calculates the projected dose of nitrogen fertilizer for perennial crops (vine and apple-tree for instance). It has been constructed by adapting an existing and innovative tool used for annual crops, AzoFert® (Machet et al., 2017), and based on a balance sheet method.

The prototype "N-Pérennes" is a computer program that requires internet access. The user has to enter several categories of data: location, soil (type and characteristics if known: % clay, % sand, pH, C, N, lime, depth), crop (cultural route, aimed yield, organic applications). Specific agronomic parameters are included in the model equations.

This tool is eventually intended for technicians, agricultural advisors, and soil analysis laboratories, but it may also be used by skilled farmers.

RESULTS AND DISCUSSION

An operational and user-friendly interface has been developed and an initial assessment of the software has been made during the project (Figure 1).

For vine, 27 trials (nitrogen fertilisation, organic management, soil management) were used to validate the recommendations calculated by the prototype, but only 3 trials were available for the tool-validation for apple-tree. The nitrogen amount recommended by the prototype was compared to the real amount applied on the trials. If the difference was less than 10 kg N/ha, we considered that the recommendation was adequate and relevant.

The validation results of the prototype "N-Pérennes" (table 1) are hopeful for vine growing compared with the empirical recommendations (50 % of matching recommendations). For fruit growing, the ratio of correct recommendations is nearly the same, but with larger average difference.

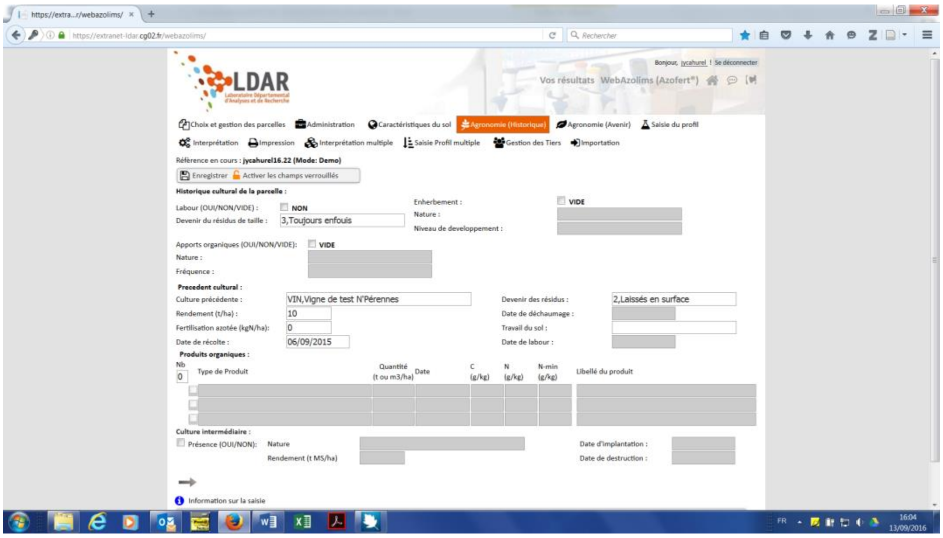

Figure 1. Example of interface screen

Table 1. Results repartition of validation and average difference between tool recommendation and real application

	Vine		Apple-tree	
	Frequency (%)	Average difference (kg N/ha)	Frequency (%)	Average difference (kg N/ha)
Matching recommendations	51	-	46	-
Advised N application but useless in reality	26	30	11	99
No advised N application while necessary	7	42	14	37
Advised N application too important or too low	16	33	29	62

CONCLUSION

Work of programming, configuration and validation in practical use is yet needed to achieve an operational tool. Other perspectives, widening the prototype objectives, are also possible: piloting tool, use in organic farming, for example.

Acknowledgements: Acknowledgements for CASDAR and all the project partners (Acta, BNIC, CEHM, CIVC, Chambres d'Agriculture, INRA, LDAR, Montpellier SupAgro).

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AZOFERT®: A DYNAMIC DECISION SUPPORT TOOL FOR FERTILISER N RECOMMENDATIONS

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INTRODUCTION

A rigorous management of nitrogen (N) for crops is necessary to achieve the following important objectives: i) sustain crop production; ii) promote product quality (protein content of cereals, technological quality of sugar beet, nitrate content of vegetables, etc.); iii) preserve the quality of water and air by minimising nitrate leaching, volatilisation, denitrification and nitrous oxide (N_2O) losses; and iv) improve the energetic performance of farms considering the energy cost of mineral N fertilisers. Calculation of N fertiliser amount is required to adjust the inputs of mineral or organic fertilisers to satisfy the crop N requirements by considering other N sources. Over the past twenty years, research findings have provided a basis for improving fertilisation recommendation tools, particularly when considering on the one hand the dynamics of various N organic sources over time: characteristics of animal and organic waste and crop residues recycled to soils and their potential mineralisation (Lashermes et al., 2010), and on the other hand the dynamics of fertiliser N after application, as well as the determinants of fertiliser N recovery in crops, particularly using nitrogen 15 (^{15}N) measurements (Recous et Machet, 1998). A dynamic approach of soil N supplies in the predictive balance sheet method called AzoFert® was developed by INRA (National Institute of Research and Agronomy), LDAR (Research and Analysis Departmental Laboratory) and ITB (Sugar Beet Technical Institute). In 2005, AzoFert® software replaced Azobil based on a static balance sheet method (Machet et al., 1990) in order to make a more precise decision support tool for N fertiliser recommendation for main crop systems.

MODEL/TOOL DESCRIPTION

AzoFert® is a decision support system for farmers and extension services. It is based on a full inorganic N balance sheet applied at the field scale for main field crops (Machet et al. 2017). This balance sheet is applied to the inorganic N pool in soil considering the rooting zone depth of the crop and the entire growth cycle of that crop. Calculation started at the date of measurement of the inorganic N profile (opening of the balance sheet) from analytical results of the laboratory, and from technical information pertaining to the plots to be fertilised. These latter data are filled up by farmers. Main inputs data are soil characteristics (clay, sand and limestone content, pH, total N and C content, bulk density, depth of rooting zone, thickness of the ploughed layer), crop description (nature, sowing and harvest dates, growing stage for cereals…), cultural history, previous crop (nature, yield, N fertilization level, crop residues management), organic products (type, amount and date of application), establishment of cover crops.

AzoFert® includes the following agronomical characteristics:

- A dynamic simulation, according to climatic conditions, is used to estimate N supplies from the soil, and organic sources (crop residues from the preceding crop, catch crop residues, and organic products). To perform these simulations dynamically, the concept of "normalised time" is introduced, which considers temperature and moisture content change over time. It takes into account processes that affect the fate of N fertiliser applied to a crop: microbial N immobilisation and the volatilisation of ammonia from fertiliser Therefore, it allows assessment of environmental risks (i.e. nitrate leaching).
- It provides N fertiliser advice for main annual field crops (cereals, industrial and vegetable crops) whose N requirements and cycle of vegetation are known (more than 50 annual crops).

RESULTS

To show AzoFert® performance estimation of soil N supply, we performed a comparison between control treatment (0 N) and to plants N uptake measured in the same control plots in several agricultural situations (sugar beet, wheat, winter barley, vegetables, maize and spring barley). Among 133 data points, a significant linear correlation was found (r^2=0.76, $p<0.01$) between the measured and estimated N supply by AzoFert® (Figure 1) with estimated values ranging from 26 to 288 kgN/ha.

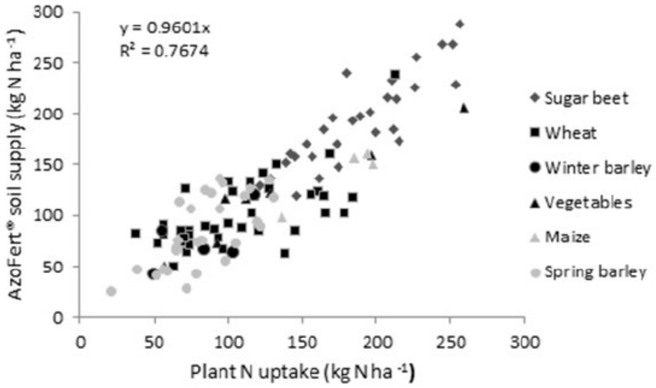

Figure 1. Comparison of the N uptake by plants in the control plots (no fertiliser) and the N supply estimated using AzoFert® software. The 133 data points include several crops. Source: Machet et al. 2017, Agronomy 2017, 7, 73.

CONCLUSION

The recent scientific knowledge of C and N cycles are integrated in several models. However, scientific models need a large amount of inputs which are not easily to find for farmers, that is why, AzoFert® model was created to integrate recently acquired knowledge into a more simplistic tool. The main particularity for AzoFert® is the use of the concept of "normalised days" which integrates past real and future climatic data according to the characteristics of the year and to the location of the field. AzoFert® is a model in constant evolution because setting changes according to needs and knowledge. Recognized for its true value, we wish to extend its use. A promising development for the tool is its ability to evolve towards other cropping systems. The generic formalism and modularity of the software allow such evolution. The current adaptation of AzoFert® for the fertilisation of perennial crops, particularly fruit-growing and vine-growing systems, constitutes the "N Perennes" project. Moreover, AzoFert® has been implemented as a teaching tool in "N'EDU" project.

Acknowledgements: This work was funded by INRA, LDAR and ITB.

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VEGSYST-DSS TO CALCULATE N AND IRRIGATION REQUIREMENTS IN VEGETABLES GROWN WITH FERTIGATION IN MEDITERRANEAN GREENHOUSES

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INTRODUCTION

In south-eastern Spain, excessive nitrogen (N) and irrigation application to fertigated, soil-grown vegetable crops in greenhouses has caused appreciable nitrate (NO_3^-) contamination and over-exploitation of underlying aquifers. To help reduce these problems, the decision support system (DSS) VegSyst-DSS has been developed to prepare site and crop specific plans for optimal management of N and irrigation of seven major vegetable crops grown in Mediterranean greenhouses: tomato, pepper, cucumber, zucchini, supported melon, non-supported melon, watermelon and eggplant. The DSS was designed to require few inputs and to be simple to use for farmers and farm advisors. This work presents the VegSyst-DSS software that calculates daily N fertilizer and irrigation requirements, and the N concentration in nutrient solutions applied by fertigation for the seven main vegetable species grown in this region. For a pepper crop, a comparison of the irrigation and N requirements following the recommendations of the DSS and the local practices is presented.

MATERIAL AND METHODS

The decision support system (DSS) software for Windows VegSyst-DSS, based on the VegSyst version 2 simulation model calculates daily crop requirements for N and irrigation, and the applied N concentration. N fertilizer requirements are calculated using a N balance based on daily crop N uptake and that considers soil mineral N at planting, and N mineralized from manure and soil organic matter. Irrigation requirements are based on calculated ETc and consider irrigation application efficiency and the salinity of irrigation water. The DSS can be used for crops grown in soil or in substrate; it assumes that crops have no water or nutrient limitations. The calculations are made using historical climate data. For detailed descriptions of the VegSyst-DSS see Gallardo et al. (2014).

In this work, a simulation of the irrigation and N fertilizer plans for a theoretical pepper crop grown from 15 August to 15 February in a plastic greenhouse in Almeria is presented. The soil had a root-zone mineral N content of 80 kg N ha^{-1} at planting, and 50 m^3 ha^{-1} of sheep manure was applied 6 months before planting. The EC of the irrigation water was 2.0 dS m^{-1} and the Uniformity Coefficient (UC) was 0.95. The simulated irrigation and N fertilizer recommendations of the DSS were compared with commercial farmers' management practices. The irrigation volume applied by farmers was obtained from a comprehensive survey of irrigation practices on commercial farms, and the N fertilizer used by farmers was obtained considering the irrigation volume and a [N] of 12 mmol N L^{-1}, in the applied nutrient solution, which is representative of grower practice for commercial pepper crops.

RESULTS AND DISCUSSION

The gross irrigation requirement recommended by the DSS was slightly higher than ET_c because an additional 9% of water was applied for the leaching requirement (Fig. 1a). The sharp increase in irrigation and N fertilizer requirements at 63 days after transplanting (DAT), corresponded to the day in which the whitening (previously applied as calcium carbonate suspension) on the greenhouse roof was removed. The soil N supply contributed 60 kg N ha^{-1} to the total crop N requirements of 259 kg N ha^{-1}; the DSS assumes that 0.5 of the soil N supply (root zone mineral N plus mineralized N) of 120 kg N ha^{-1} was available to the crop (Fig. 1b). The average recommended [N] for the duration of the crop was 5.4 mmol N L^{-1} which is considerably lower than the 12 mmol N L^{-1} recommended to farmers for commercial practice.

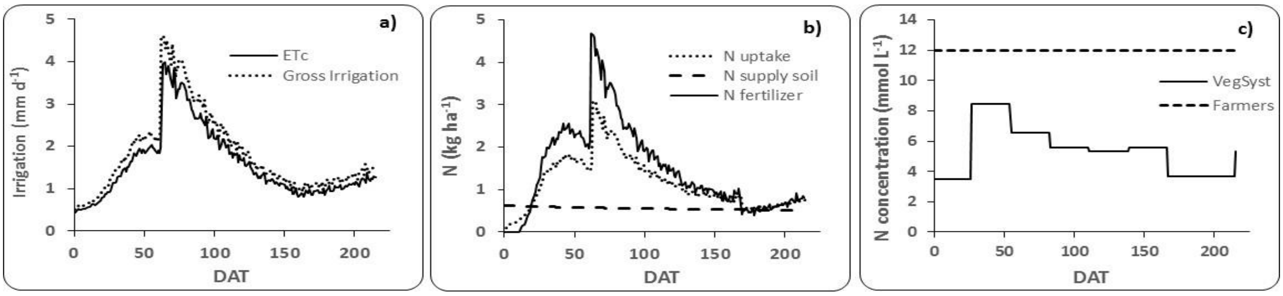

Figure 1. For a greenhouse pepper crop seasonal evolution of (a) daily values of ETc and gross irrigation requirement, (b) daily values of crop N uptake, N supply from the soil and N fertilizer requirements, and (c) the recommended four-weekly [N] of the fertigation nutrient solution compared to the standard [N] used by local growers.

The total irrigation volume that was estimated from growers' practices was 8% more than recommended by VegSyst-DSS (Table 1), while estimated total N for growers' practices was approximately double that recommended by VegSyst-DSS, the relative differences were larger in the early part of the season (Table 1). During the crop establishment period, the VegSyst-DSS suggested that it was not necessary to apply fertilizer N on account of the soil mineral N present in the soil at transplanting and the low N demand of the crop.

Table 1. Irrigation volumes and amounts of N fertilizer recommended by the VegSyst-DSS, and those used by farmers. Values are shown for the periods of 1) establishment, 2) rapid growth, and 3) from the end of rapid growth to maturity, and for the duration of the crop.

Period	Irrigation (mm)		N Fertilizer (kg ha-1)	
	DSS	Farmers	DSS	Farmers
1 (0-17 DDT)	10	23	1	39
2 (18-58 DDT)	60	91	78	152
3 (59-215)	269	252	238	424
Total (0-215 DDT)	339	366	317	615

CONCLUSION

The VegSyst-DSS calculates recommendations of daily volumes of irrigation, daily amounts of N fertilizer, and the N concentration in nutrient solutions applied by fertigation, for the seven major vegetable crops grown in greenhouses in SE Spain. The comparison of the irrigation and N requirements following the recommendations of the DSS and the local practices showed that considering crop N demand and the N supplied by the soil and organic amendments, the VegSyst-DSS software can appreciably reduce application of N fertilizer and consequently notably reduce N losses to the environment.

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FERTIWEB®: A TOOL FOR DIFFERENT TECHNICAL REQUIREMENTS

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[1] ARVALIS ; [2] AUREA

INTRODUCTION

Calculation of fertilizer rate to fit crop demand is not a new issue, but the current approaches often consider the nutrients separately and focus on limited range of stakes (mostly related to technical optimization of fertilization). The multiplicity of issues involving fertilization and the growing need to adjust fertilization on global basis (all the nutrients together) require an evolution of the decision support tools proposed to the farmers. The FERTIWEB® software, created by ARVALIS and AUREA, is an illustration of this evolution.

In the case of nitrogen dose calculation, a large part of the French territory is covered by the Nitrates Directive. This led to the writing of regional reference decrees, describing the methods of calculating the dose in each region, in a simple way readable and applicable by the farmers on paper format. Next to this, the French administration leaves open the possibility of using a N-dose calculation tool referring to the consensual principles of reasoning proposed by the COMIFER (French Comity for Reasoned Fertilization). Then, the use of dynamic models to calculate the nitrogen dose is recommended.

TOOL DESCRIPTION

The FERTIWEB® tools offers three types of nitrogen dose calculation methods which fit to these increasing technical requirements.

FERTIWEB® Basic allows calculation in accordance with the technical specifications of the regional reference decrees.

FERTIWEB® Technic allows a calculation of the N-dose using the forecasted balance sheet method according to the principles recognized within the COMIFER (COMIFER, 2013), but including regional specification. This tool is, for example, fully and faithfully reproduced in GEOFOLIA, a tool of the company ISAGRI.

FERTIWEB® Dynamic carries out an updated calculation over time of the nitrogen dose, based on a model (CHN model of ARVALIS) with formalism consistent with the tools carried by the RMT Fertilization and Environment. This calculation program is connected to the meteorological databases, allowing live updates of nitrogen dose calculation. FERTIWEB® Dynamic is suitable for wheat, maize and barley. More crops will be implemented soon. This tool is currently being tested by customers.

The dose advice modules of S, P, K, Mg, and lime, are identical for these 3 tools. They are carried out on the basis of consensual rules, taking into account supplies from the soil, as well as all inputs from organic waste products of all origins.

The development of those tools on web service base opens wide possibilities of links with upstream or downstream tools.

RESULTS AND DISCUSSION

Although the calculation methods are very different between the 3 tools, calculated results are quite similar on average. However, differences are more pronounced for innovative cropping systems, which use highly diversified sources of nitrogen.

The main difference between the "Technic" tool and the "Basic" tool is the more complete parameterization in “Technic” tool, in particular on the description of soil types and effluent characteristics. The nitrogen calculation dose is then closer to the results of field experimentation, due to the possibility of integrating model functions recently improved (soil nitrogen mineralization (Mh) and organic fertilizer nitrogen mineralization (Mpro/Xpro) models).

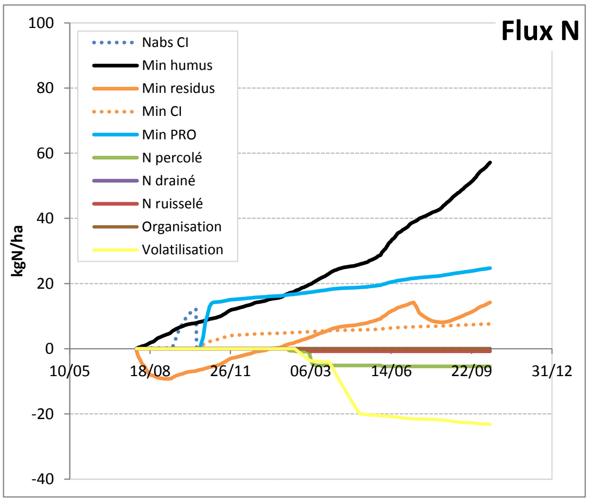

Figure 1: Dynamics of nitrogen flows for a wheat simulation with FERTIWEB Dynamic

The technical gap when switching to FERTIWEB® Dynamic is the possibility to simulate all the nitrogen fluxes of the soil-plant-atmosphere system in the daily time step, and to project the evolution of the states of these compartments on the basis of the climatic forecasts (+ 5 days) supplemented by frequency analyzes (Soenen B. et al., 2017).

CONCLUSION

The relevance of the result is linked without any surprise to the quality of the models and parameterization. Implementation nevertheless requires support to warn on the effects of each input data to the calculated nitrogen dose. Everything is now being done to ensure that this promising tool can be used via distribution networks to serve as many farmers as possible.

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POSTERS

SERDAF, A SOIL-SPECIFIC NUTRIENT MANAGEMENT EXPERT SYSTEM FOR SUGARCANE FERTILIZATION IN REUNION ISLAND

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INTRODUCTION

The sugarcane sector is a major pillar of Réunion Island's economy and covers 54% of arable lands. An expert system was developed since the late 90's to improve nutrient management practices in local sugar industry. The so-called SERDAF (Système expert d'interprétation des analyses chimiques des sols réunionnais) aims at promoting sustainable soil and nutrient management and balanced crop nutrition. The expert system provides local fertilisation guidelines on the basis of soil analysis by mobilizing pedological and agronomic knowledge gained over the last 40 years in Réunion Island.

TOOL DESCRIPTION

Soil fertility diagnosis

The soil fertility diagnosis is established by comparison of the physical-chemical proprieties of soil samples with threshold values. Threshold values were built from agronomic experiments and statistical processing of the laboratory soil database. There are six different packs of threshold values corresponding to the six main types of soil identified in the island: i.e. ferralsols, andosols (two types), vertisols and cambisols (two types). The soil classification was determined from morphopedological studies and chemical distribution of about 10000 soils analysed by the laboratory. The soil sample localisation allows the expert system to identify the type of soil and to use the corresponding threshold values. A basic fertilizer application can be recommended when the soil diagnosis suggests that soil organic matter content, soil acidity, P content and sometimes K content are not able to support crop production.

Crop fertilisation guidelines

Crop nutrient requirements are calculated by the expert system from expected crop yield (informed or spatially deduced). The expert system considers the outputs from the soil diagnosis and annual crop requirements to determine the amount of N, P and K and sometimes micronutrients to supply as maintenance fertilization. The management of crop residues and organic fertilization are also accounted for in this computation. Fertilizer formulations are proposed by SERDAF in accordance with the commercial availability. The soil diagnosis and the fertilization recommendation are hosted on the Web platform Margouill@.

RESULTS, DISCUSSION & PERSPECTIVES

Current usage of SERDAF

About 1000 soil fertility diagnosis are delivered yearly by the CIRAD laboratory thanks to soil sample analyses and the Serdaf application. About 90% of these analyses are performed for sugarcane farmers and are therefore supplied with soil-specific sugarcane fertilization guidelines.

Improving the soil type assignment with an updated soil map

The assignment of a soil sample to a given soil type has a major effect on the soil fertility diagnosis. Feder and Bourgeon (2009) however already highlighted some failure in the definition of soil types and in their localization on the west part of the island. Recent works, done on the east and south parts of the island and based on spectral analyses combined with soil descriptions, confirmed that some soil units of the current soil map were misleading. Soil spectral profile will be thus used to update the soil classification, the spatial soil distribution and the associated soil properties (Ph.D of M. Ramos, 2018-2021).

Questioning N processing by Serdaf

The amount of N fertilizer proposed by the expert system accounts for soil N provisions. Differences in soil N fertility among soil types in La Réunion is considered by Serdaf through the use of a specific coefficient of soil N mineralization for each soil type. A recent study highlighted that the use of soil N availability indices to predict soil N provisions or sugarcane N requirements is still challenging (Mariano *et al*., 2017). A suitable index should thus be determined to establish the soil mineralization rates of the newly defined soil types (Ph.D of M. Ramos, 2018-2021).

Future extension to other crops and areas

The soil diagnosis module of Serdaf, which is based on the rendition of soil physical-chemical analyses, is *per se* generic and consequently applicable to soil grown with any crops of interest. However, to date, crop requirements were referenced only for sugarcane, thereby focusing the fertilization guidelines on sugarcane fertilization. Nevertheless, another tool, Ferti-Run, co-developed by the Agricultural Office of Réunion and Cirad, references the requirements for a substantial list of crops including 20 market-garden crops, 6 fruit-growing crops, and pasture crops in addition to sugarcane. Consequently, the coupling of Serdaf with Ferti-Run[1] is envisaged within the framework of the SolAgriDOM project (submitted in April 2018 to the CasDAR call).

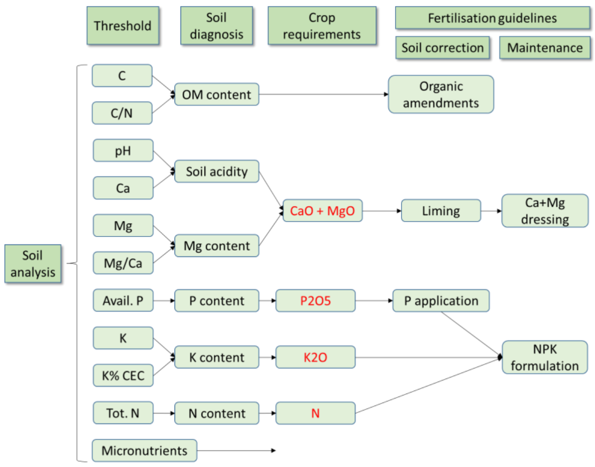

Figure 1. Operating diagram of the expert system SERDAF

Acknowledgements: The authors would like to thank the technicians from the CIRAD "Soil, organic material and plant analyzes" laboratory for their investment and maintenance of SERDAF. They also would like to thank eRcane, the technical institute for sugarcane in Réunion Island, for supporting the third author's Ph.D. thesis (ANRT CIFRE grant).

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DECISION SUPPORT TOOL FOR SPRING N FERTILISATION OF WINTER OILSEED RAPE –ESTIMATION OF N UPTAKE IN LATE AUTUMN USING UAV

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INTRODUCTION

To calculate the optimal spring nitrogen (N) fertilisation rate to winter oil seed rape (WOR), Swedish farmers are recommended to determine the crop N uptake in late autumn, as well as estimating yield and N mineralisation in soil during spring (Swedish Board of Agriculture). N uptake is normally estimated by using the 'fresh weight method (N uptake = fresh aboveground biomass × 56) or by scanning the crop with a tractor-mounted N-sensor. In present study, conducted 2016-2017, we investigated how to use RGB/multispectral cameras mounted on unmanned aerial vehicles (UAV) as a tool for determining the N-uptake and to capture within field variations. The relationships between N-uptake and various wavebands or indices were compared.

MATERIAL AND METHODS

Experimental setup

Seven fields in Southwest Sweden with winter oilseed rape were scanned 13th October 2016 and 2nd November 2017 with an UAV (Pitchup Explorian 8), equipped with two sensors: the 5-band Micasense Rededge sensor (blue (B), green (G), red (R), red edge (RE) and near infrared (NIR)) and an ordinary digital RGB camera (Sony RX100II). In each field, the crop was cut in 1 m^2 plots at five (three fields, n = 15, 2016) and 10 positions (four fields, n= 40, 2017), after measuring normalized difference vegetation index (NDVI) with a hand-held sensor (Trimble GreenSeeker) as a control. The sampling locations were selected to capture the spatial variation in aboveground biomass.

Statistics

The sensor images were georeferenced and mosaicked using the softwares MicasenseAtlas (Lausanne, Switzerland; 2016) and Solvi (Göteborg; Sweden, 2017). Prediction models (univariate linear regression and partial least squares regression; PLS) were made and cross-validated (site-wise) using the software UnscramblerXversion10.5 (CAMO). The response was N-uptake and predictors were the unique wavebands (B, G, R, RE and NIR) or indices (NDVI, MSAVI2, OSAVI, NDRE, ChlI, dI, VARI). For index formula see www.indexdatabase.de/db/i.php. Sites that had high weed biomass or low biomass on white sandy soil were removed from the dataset to be analysed (n= 46), as the soil reflectance affected the optical measurements adversely.

RESULTS AND DISCUSSION

In the total dataset the N uptake ranged between 11 and 216 kg N ha^{-1}. The best prediction of the N-uptake was made from models based on all wavebands or the Chl-index from the 5-band sensor. Root Mean Squared Error of Cross Validation (RMSECV) was 25 kg N ha^{-1} and the coefficient of determination (r^2) 0.70 for both models. When the dataset was limited to include a maximum N uptake of 150 kg N ha^{-1} RMSECV was reduced to 18 and 17 kg N ha^{-1} for all wavebands and Chl-index respectively. If the dataset was limited to a maximum N uptake of 100 kg N ha^{-1}, RMSECV was reduced further to 13 kg N ha^{-1} for both models.

The second best prediction of the N uptake was made with the indices ENDRE, MSAVI2, OSAVI and dI for which RMSECV was 28-29 kg N ha^{-1} and r^2 0.59-0.64. Prediction of N uptake using the indices NDVI or VARI from the 5-band sensor agreed with the results from the handheld NDVI-sensor, RMSECV was 32-34 kg N ha^{-1} and r^2 0.50.

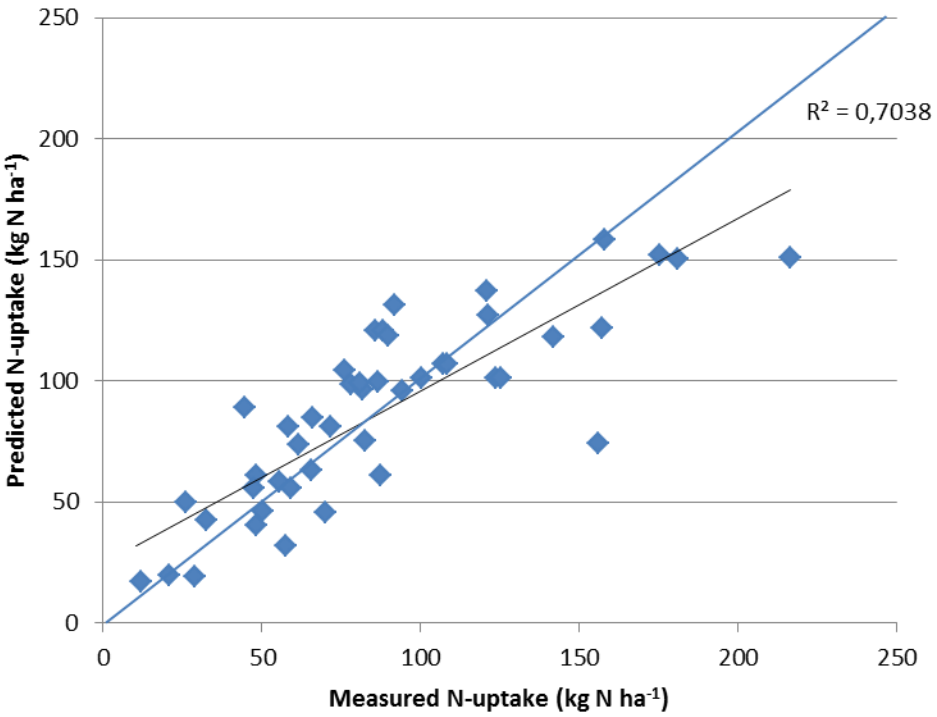

Figure 1. Cross validated (sitewise) model for predicting N uptake of winter oilseed rape in late autumn from Chl-index measured using a 5-band sensor equipped unmanned aerial vehicle (UAV), n= 46, 2016 and 2017.

CONCLUSION

It was possible to determine within-field variations in N uptake of winter oilseed rape in late autumn with a 5-band sensor mounted on an UAV. The best models were based on all wavebands or the index Chl and RMSECV could be improved if limiting the N uptake to 150 or 100 kg N ha^{-1}.

Acknowledgements: This study was financed by Interreg-ÖKS, European Regional Development fund, Innovations for sustainable agriculture and Västra Götalands Regionen (VGR).

A MILK UREA MODEL TO BETTER ASSESS NITROGEN EXCRETION AND FEEDING PRACTICE IN DAIRY SYSTEMS

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INTRODUCTION

Agricultural systems are facing increasing demands to reduce their environmental impacts. In particular, livestock is the main source of ammonia emissions causing damages on air, water and animal and human health. This ammonia comes essentially from the volatilization of the nitrogen (N) excreted in the urine, especially in the form of urea (Monteny and Erisman, 1998). One of the important levers to reduce the amount of N excreted is the feeding of animals. However, fine management of nitrogen nutrition requires working with simple and inexpensive indicators that are robust and reliable enough to estimate excretion and allow rapid correction of diets. In dairy systems, milk urea, nowadays routinely accessible by infra-red spectrophotometry, is undoubtedly the best biological indicator for quantifying N metabolism losses (Burgos et al., 2007). An objective of our research project is to build models and tools, tested in real-life situations, to better interpret this indicator both at the dairy herd level to evaluate the practice of nitrogen rationing and at more aggregated scales to assess the impacts of feeding practices on the environment.

First, a model was built to represent the dynamics of the main N component flows in the dairy cow. Second, simplified meta-models were proposed to predict diet N content and N excretion from a small number of parameters such as milk urea and additional information on the diet. These meta-models will be available to improve current evaluation and decision support tools both for public policies and advisors on farm.

MATERIAL AND METHODS

The model

The mechanistic model of N flows at the individual level was designed to use feed and animal performance information, among those often available in livestock farms, as inputs. It predicts N excretion, especially through urine, both in the form of urea-N and non-urea-N. The analysis of the model was performed by comparison of its outputs with databases derived from experimental tests or simulations and by the use of sensitivity analyses.

Meta-models

Meta-models resulted from the analysis of one million animal-diet combination simulations (SYSTALI model; INRA, 2018) to associate feed input and milk output. They consisted in simplified equations to predict diet N content and N excretion from milk urea and some additional information on the diet, available on farm. These equations were validated by comparison with datasets of experimental measurements and confronted with data from commercial farms in various French contexts.

RESULTS AND DISCUSSION

The model

The inputs of the model describe the animal and its diet including the way it is distributed. The cow is characterized by its milk yield, milk nitrogen content, body weight and body condition. The diet is defined by its components (forage, concentrates), nitrogen content and dry matter intake. The intake dynamics is also simulated regarding diet distribution modalities. Figure 1 describes the simulation of N flows for a cow fed with maize silage. Outputs of the model showed good correlations with experimental data (e.g.: slope of the observed vs. predicted uremia = 0.9, RMSE = 29 mg urea-N/L).

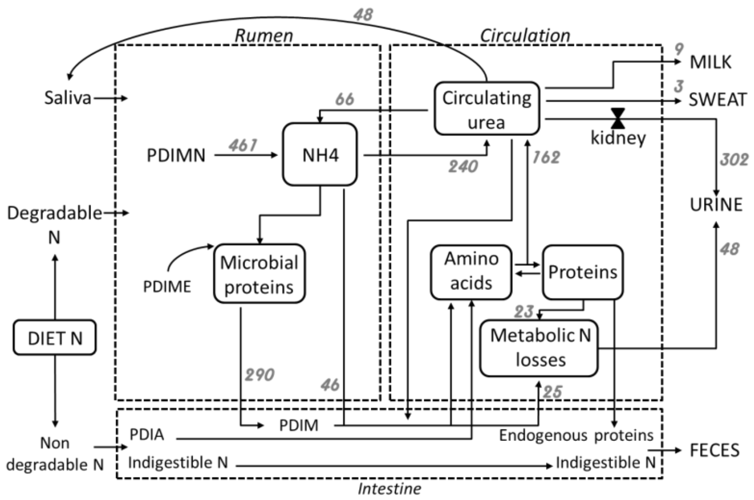

Figure 1. Main nitrogen flows, in g/day, as simulated by the model for a multiparous dairy cow fed with maize silage and producing 40L of milk per day. PDI: protein digestible in the intestine, PDIMN: PDI supplied by microbial protein from rumen-degraded dietary nitrogen, PDIME: PDI supplied by microbial protein from rumen-fermented organic matter, PDIA: PDI supplied by rumen-undegraded dietary protein (Inra, 2007)

Meta-models

Urinary total-N and urea-N were well predicted from simplified equations using milk urea, milk nitrogen content, milk yield and the proportion of concentrates in the diet as predictive variables (R^2 = 0.99, RSME = 10 and 5 gN/d for urinary total-N and urea-N respectively). The same variables were also showed to be good, but less precise, predictors of the N content of the diet when associated with urinary total-N or urea-N excretion (R^2=0.95, RMSE = 6 g/kgMS). However, this last variable is rarely available on farm and has therefore to be estimated from the model (or simplified equations).

CONCLUSION

Confrontation with experimental data showed that the model correctly describes N flows at the animal level. The resulting meta-models still need to be evaluated with real-life data but seem to quite efficiently predict both nitrogen excretion and diet content. It will therefore be possible to mobilize these estimations to better integrate changes in feeding practices for national inventories (collaboration with CITEPA) and to elaborate decision-support tools for farmers and their advisors to better manage nitrogen nutrition.

Acknowledgements: This work was supported by Ademe.

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ADAPTING SYST'N® FOR MODELING ALFALFA GROWTH

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INTRODUCTION

Syst'N® (Parnaudeau et al. 2012) is a pluriannual diagnosis tool of nitrogen emissions at plot scale that enables to assess agri-environmental performance of cropping systems according to the soil-climate context. This tool is intended for a broad range of stakeholders in air and water quality management (agricultural consultant, facilitators in water catchment …). It consists of a dynamic model to simulate daily nitrogen atmosphere-biosphere fluxes and of ergonomic graphical interfaces to describe the cropping system and the soil-climate context of the field but also to visualize N emissions changes (in ammoniacal, nitrate or nitrous oxide form) during the rotation.

The model is based on existing models (STICS, AZODYN, NOE, AZOFERT…), and parameters of some twenty crops have already been integrated in the tool. However the range of parametrized crops is limited compared to the diversity encountered on the field. A new is now to adapt Syst'N to alfalfa, a perennial forage legume emerging in cropping systems.

MATERIAL AND METHODS

The integration of alfalfa in Syst'N was carried out in several steps to adapt the formalism for taking into account alfafa particularities and to test the model with measures from field trials.

Formalism adaptation and parameters

The analysis of existing literature highlighted some particularities of alfalfa growth different from other crops included in Syst'N. The formalism and parameters database architecture were adapted to improve growth and nitrogen uptake modelling for a perennial legume especially after a cut or pasture period. Different growth dynamics after emergence and after a cut (Thiébeau et al, 2011) due to the ability of alfalfa to store and release nitrogen at different stages. Because most of alfalfa varieties are dormant in winter, this aspect was also taken into account, based on CropSyst model (Confalonieri and Bechini 2004).

Most of crop parameters mobilized in model equations were obtained in existing models (STICS, CropSyst and AZOFERT) and scientific papers. In order to complete the database, some missing parameters were calculated from a sample of crop measures in Châlons-en-Champagne, France (root and aerial biomass and nitrogen content, height, root length and development stages) provided for the project.

Comparative analysis of simulated variables and optimization

Seven datasets, that came from experiments carried out in different sites in the Northern half of France, were provided and used for testing Syst'N simulations for alfalfa (aerial biomass, crop nitrogen content, soil nitrogen). The measures were first graphically compared with simulated variables to analyze growth and N uptake dynamics. Statistical indexes (Relative Root Mean Square Error) were then calculated as a synthesis of the comparative analysis. This test step resulted in a fitting of parameters in order to improve comparative results. Another dataset was used to test the residues mineralization after alfalfa destruction. In the absence of measures in obtained datasets, the simulated proportion of nitrogen derived from atmosphere was compared to orders of magnitude from literature and more specifically the variation depending on soil nitrogen content.

RESULTS AND DISCUSSION

The results analysis is still in progress but some observations can already be discussed. The graphical comparisons showed satisfactory dynamics for biomass, crop and soil nitrogen content, confirmed by statistical indicators around 30% of error on nitrogen content for 2 datasets. Considering that some processes like biotic factors, senescence and nitrogen storage-release of phenomenon in roots are not completely taken into account in the model, this level of error is acceptable.

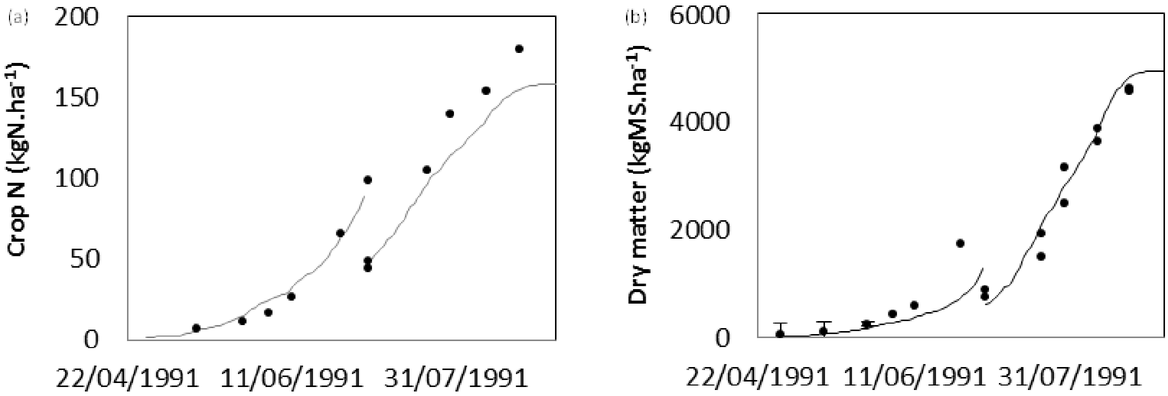

Figure 1. Measured and simulated crop nitrogen (a), dry matter (b) for one plot of Châlons-en-Champagne dataset. (●measured, ‒ simulated)

However overestimation of dry matter and, to a lesser extent, crop nitrogen content (when available) was observed for 4 datasets especially during summer. The most likely hypothesis is that the inhibition formalism under water stress conditions in Syst'N do not enough constrain fixation and growth of alfalfa.

The observed error after dormancy is also higher than other development period but could be expected with the simplified formalism that was included in the model. It nevertheless enables to take into account growth stop during winter period.

The simulated proportion of fixed nitrogen was consistent with the literature. Variations from 70% to 50% nitrogen derived from atmosphere were observed with fertilized alfalfa.

After alfalfa destruction, cumulated N mineralized from residues after two years reached 331 kgN.ha^{-1} and 368 kgN.ha^{-1} (depending on the last cut date), which fits with experimental results (3% and 7% of error).

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“QN METHOD”- FARMSTAR: A NITROGEN MANAGEMENT TOOL ON WINTER WHEAT BASED ON REMOTE SENSING DIAGNOSTIC AND AGRONOMIC PROGNOSIS

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INTRODUCTION

FARMSTAR is a decision support tool dedicated to agriculture since 2002. It was developed in partnership with Arvalis-Institut du végétal and Airbus Defence and Space. This service offers a complete range of information and advice for annual crops such as: winter wheat, barley, rapeseed and triticale at intra-field scale and thus enables modulation of agricultural inputs. FARMSTAR is used particularly for the management of the last nitrogen application on wheat. This tool helps farmers to optimize their crop yield by calculating the crop N requirement at each point in the field during booting stage. The agronomic algorithm used to produce it is named “QN Method”. It was developed by Arvalis-Institut du végétal experts and validated with multi-annual field experiment data.

MODEL/TOOL DESCRIPTION

Diagnosing nitrogen (N) deficiency in crops is used to help insure more effective management of N fertilizer application. The N nutrition index (NNI) offers a reliable measurement (Justes et al., 1997), but it is relatively difficult to determine. This index is based on the relationship between plant tissue N concentration and the biomass of the plant's aerial parts. Many studies had revealed that vegetation biophysical properties could be estimated from remotely sensed data by inverting radiative transfer models (Jacquemoud et al, 2009). Two major indicators are used in “QN Method”: “Chlorophyll content” (Cab) which is closely correlated with the nitrogen status of the plant and “Leaf Area Index” (LAI) which is representative of the aboveground plant biomass. “QN Method” is a mechanistic model, which calculates the crop N requirement during the booting stage. Firstly, crop N uptake is evaluated by converting LAI and Chlorophyll content (LAI*Cab). Then, by using a growing forecast including water stress, crop N requirements at flowering stage is estimated according the crop Nitrogen Nutrition Index (NNI). The final result of the model is the difference between crop N demand and the soil N supply adjusted for the apparent nitrogen fertilizer recovery. An intra-plot recommendation map is delivered to farmers allowing them to modulate their N inputs automatically or manually. Multi-sensor images (satellite, aeroplane or drone) are acquired during the stem elongation stages (BBCH 32 to 39). Airbus Defense and Space has established a unique processing chain to analyse the images in order to produce reliable and comparable biophysical parameters (Poilvé et al., 2016). All FARMSTAR advices for last nitrogen application are validated by experts from the Arvalis-Institut du végétal before delivery to the farmers. Recommendation maps are then delivered to farmers through the secure FARMSTAR web portal, the distributor's extranet or by postal mail. FARMSTAR customers are regrouped by agrometeorological zone to adapt the delivery schedule advice to the variability of wheat development. Crop growth stages are monitored by Arvalis-Institut du végétal using agro-climatic models, according to crop cultivar and sowing date.

RESULTS AND DISCUSSION

“QN Method” is built of 4 submodels; the first one converts LAI in aboveground biomass (QDM_{acq}) while the second one converts chlorophyll content in crop N uptake (QN_{acq}). Combining both models allows calculating the nitrogen nutrition index (NNI) when satellite picture is taken. A third model estimates the crop aboveground biomass at flowering stage (QDM_{flo}) by using a weather forecast; this provides a prognosis of potential biomass at flowering, associated to adequate N content. Finally, the fourth model is used to estimate the soil N supply (QNsoil). Each submodel of “QN Method” has been validated with specific databases: 313 measurements of biomass at acquisition (QDMacq) for model (1); 158 measurements of nitrogen uptake at acquisition (QNacq) for model (2); 944 measurements of biomass at flowering (QDMflo) and soil N supply (QNsoil) for model (3) and (4). The method as a whole has been evaluated with nitrogen response curve field trials during two years (n=27). Each submodel provides satisfactory predictions, but soil nitrogen contribution could be improved according a dynamic approach of nitrogen flows. The evaluation of "QN Method" as a whole provides satisfactory results too. It allows to advice a nitrogen dressing closed to the optimal rate, closer than an approach based on the nitrogen balance method alone, even under water stress or various biomass levels. Furthermore, it has been demonstrated that managing the last N application on wheat using "QN Method" would increase grain protein by +0.4%.

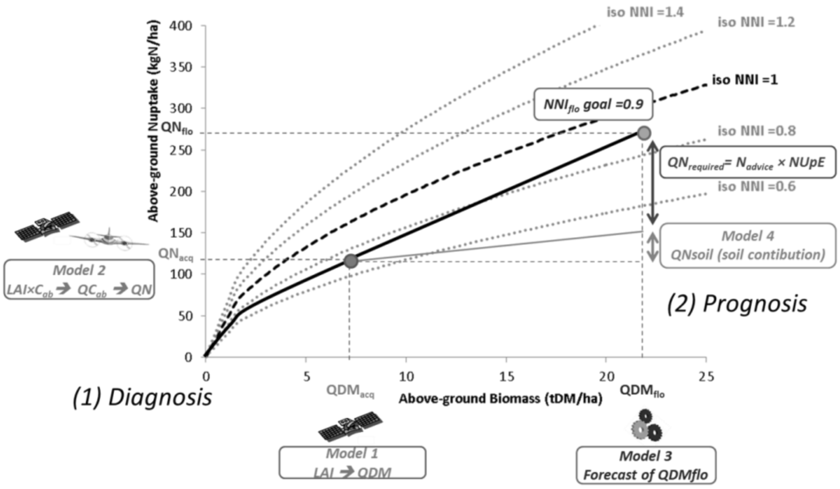

Figure 1. "QN Method" Description

Table 1. Performances of "QN method" submodels

	Model 1 QDMacq	Model 2 QNacq	Model 3 QDMflo	Model 4 QNsoil
N	313	158	944	944
RMSE	0.68 t DM.ha^{-1}	10.53 kg N.ha^{-1}	0.87 t DM.ha^{-1}	28 kg N.ha^{-1}
Biais	-0.02 t DM.ha^{-1}	0.00 kg N.ha^{-1}	0.00 t DM.ha^{-1}	0.00 kg N.ha^{-1}

CONCLUSION

Each "QN Method" submodel has been parametrized in French context and provide satisfactory results. The outputs of the model are controlled and validated by Arvalis experts before delivery to farmers. Consequently "QN Method" shows better results than nitrogen balance method. It represents a perfect combination between agronomics and remote sensing.

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SOL-AID: A WEB APPLICATION TO ESTIMATE SOIL NITROGEN MINERALIZATION AVAILABLE FOR CROPS IN BRITTANY

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INTRODUCTION

In Brittany, 59% of the area is used for agriculture. Optimizing Nitrogen (N) fertilization is then essential to achieve good crop yields and minimize environmental issue such as nitrate leaching. This requires correctly predicting the amount of N resulting from soil organic nitrogen mineralization (*Mh*), usable by the crop, which can vary greatly depending on climatic conditions, soil properties and cropping system.

A recent study made on soil N mineralization in Brittany shows that *Mh* was quite variable (from 50 to more than 250 $kgN.ha^{-1}$ between March and October) (Lambert et al. 2016), and a new predictive model based on the following formalism was parameterized: $Mh = Vp \,.\, tn$ with *Vp*, the potential mineralization rate (which depends of soil properties and land management) and *tn*, the normalized time which is a climate normalization allowing the integration of soil temperature and water content into *Mh* estimation (Brisson et al. 2008). Because this new model is more complex than the current regional recommendations, it seems us essential to develop a web application to help the farmers to use it. Indeed, farmers usually do not have soil analysis results for all their fields and moreover, they do not have an access to the meteorological databases required for the calculation of *tn*. Therefore, UMR SAS INRA-Agrocampus and Regional Chamber of Agriculture of Brittany have decided to develop a web application, Sol-AID. This application should be operational in 2020 and a first version will be available at the end of 2018. In addition, a field experiment aims to evaluate the model (N response curve) on 24 fields during 3 years.

MODEL / TOOL DESCRIPTION

Sol-AID is developed mainly for farmers and fertilization advisers to help them to properly estimate *Mh* at the field scale with the new predictive model. This application is made of different modules.

Soil module

The Brittany soil map (1:250 000), gives cartographic units of soil. In each unit, there is usually more than one soil type which can be quite different (e.g. localization, soil properties, geology). Determining the soil type is therefore essential in agronomy such as for estimating *Mh*. For that, we develop a simple method to help the farmer determining the soil type of their fields. From the cartographic unit of the soil (defined with field position), a decision tree is proposed to the farmer, with simple questions such as the localization in the landscape or the presence of soil crust, to define its soil type. A data base contains the soil properties for *Mh* estimation for all soil types of Brittany.

Cropping system module

Inserting land management in the model is not straightforward. We therefore developed an indicator of the cropping system, *I_Sys*, which estimates the N restitution to soil from crops of the rotation and manure application for the past 15 years. With simple questions on their land management, the farmer will determine the type of cropping system of its fields for which value of *I_Sys* are associated.

Climate module

Because we cannot predict the climate of the next crop year, a provisional *tn* is estimated. It is the average of the *tn* determined for the weather of the 20 past years. STICS crop model is used to automatically calculate this provisional *tn* with (i) weather data base, (ii) the soil properties and (iii) the crop of the field (Brisson et al. 2008). The provisional *tn* is then used in *Mh* calculation. An actualization of *tn* could be done with the weather of the current year, for the period prior to fertilizer inputs.

Mh module

Mh is automatically calculated with data coming from other modules (soil properties, *I_Sys* and *tn*). The values will be directly available on the web interface of Sol-AID.

RESULTS AND DISCUSSION

Figure 1 presents a screen capture of the web application. A user-friendly interface makes it easy to inform and use the application. The results are easily displayed by user and are stored in a data base.

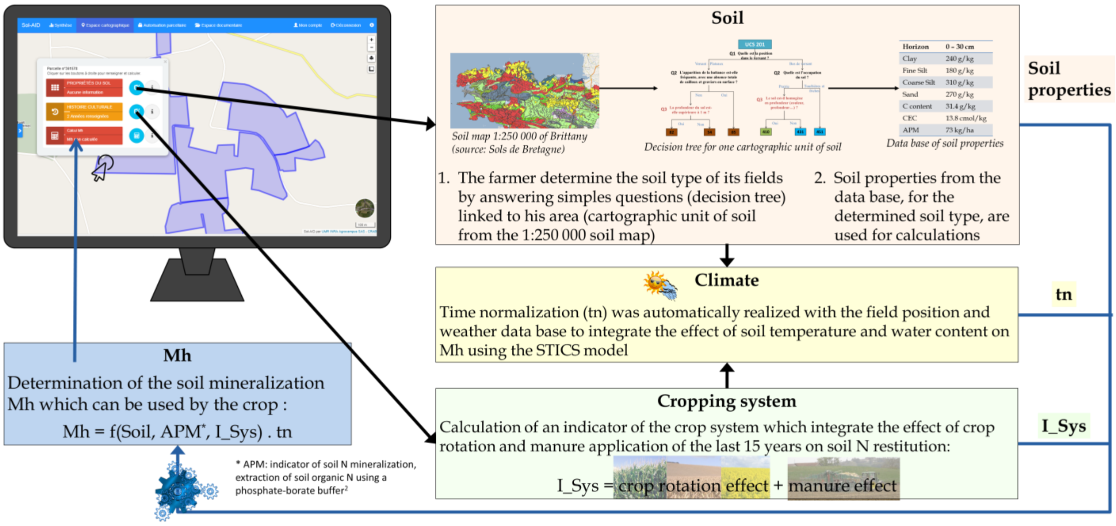

Figure 1: Capture of the Sol-AID interface with the link to the calculation and determination modules (soil, climate, cropping system and Mh). Mh is the mineralization of soil organic nitrogen, tn is the normalized time (climate normalization) and I_Sys is the indicator of the crop system.

CONCLUSION

Sol-AID will be available in 2020 and will be a user friendly web application to easily estimate *Mh* considering soil properties, cropping system and climate.

Acknowledgements

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MANNER-*NPK* NUTRIENT MANAGEMENT SOFTWARE: MAXIMISING IMPACT AND FARMER UPTAKE

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INTRODUCTION

MANNER-*NPK* is a practical software tool for use by farmers to quantify the crop available nutrient supply from organic materials (nitrogen, phosphate and potash). In particular, crop available nitrogen supply can be difficult to estimate because it depends on a number of factors. An extensive national research programme in the UK has improved our understanding of nitrogen transformation and loss processes following the land application of organic materials. The MANNER-*NPK* tool estimates crop available nitrogen supply based on algorithms for each of the main nitrogen pathways (Nicholson *et al*., 2013).

MATERIAL AND METHODS

The MANNER-*NPK* tool addresses the challenge of translating the complex science of nitrogen transformations and losses following applications of organic materials into an accessible format that enables farmers to calculate crop available nutrient supply. Importantly, MANNER-*NPK* was designed to be easy to use and to require only a few simple inputs which should be readily available to all farmers (e.g. location, soil type, crop type, application date, application method, application rate and organic material incorporation details).

The MANNER-*NPK* model was the first decision support tool to combine all the factors and processes affecting crop available nutrient supply from organic materials. The MANNER-*NPK* model was released as a software tool to farmers and was also used as the basis for written guidance, specifically to produce 'look-up' tables of crop available nutrient supply under difference scenarios which are published in UK national fertiliser recommendation systems (AHDB, 2017; SRUC, 2017).

The first MANNER software tool was released to farmers on CD in 2000. The MANNER-*NPK* calculations were updated in 2004 and 2010 to incorporate advances in our understanding of nitrogen transformation and loss processes following the land application of organic materials. The latest version – MANNER-*NPK* includes additional improvements to usability and functionality and was released to farmers in 2013.

RESULTS AND DISCUSSION

MANNER-*NPK* is a free desk-based tool available on CD or to download from the internet (www.planet4farmers.co.uk/manner); there are currently around 4000 registered users of the standalone MANNER-*NPK* tool. Estimating the nutrient supply from organic materials is an important component of nutrient planning, and the MANNER-*NPK* calculation engine (Dynamic Link Library – DLL) has been integrated into the PLANET nutrient management software tool (www.planet4farmers.co.uk, c.18,000 registered users). PLANET provides fertiliser recommendations taking into account crop requirements, soil nutrient supply and the nutrient supply from organic materials (calculated from MANNER-*NPK*). Development of PLANET was funded by Defra and the Scottish Government, and the PLANET 'calculation engine' is available as a Dynamic Link Library (DLL) free of charge to commercial software companies to integrate into their own tools. The PLANET DLL has been integrated into commercial tools produced in the UK by Farmplan, Muddyboots and Pear Agri. The Defra Farm Practice Survey (2017) showed that 54% of farms with a nutrient management plan used a software tool which integrates the MANNER-*NPK* calculations (i.e. PLANET, Muddyboots or Farmplan).

CONCLUSION

The MANNER-*NPK* tool has been successful because it translates the complex science of nitrogen transformations and losses following applications of organic materials into an accessible format that enables farmers to calculate crop available nutrient supply. Importantly, MANNER-*NPK* was designed to be easy to use and to require only a few simple inputs which should be readily available to all farmers (e.g. location, soil type, crop type, application date, application method, application rate and organic material incorporation details).

The impact and success of MANNER-*NPK* has been increased by its availability within a number of other guidance and software tools. This widespread availability of the MANNER-*NPK* calculations has been critical in establishing the tool as the recognized 'industry standard' method for calculating the nutrient supply from organic materials in the UK (see section 'Replicability and upscaling').

Acknowledgements

MANNER-*NPK* has been developed by ADAS and Rothamsted Research North Wyke, with funding and support from AHDB, CSF, DARD, Defra, Environment Agency, Natural England, Scottish Government, Tried and Tested and WRAP for use throughout the UK.

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THE JOINT TECHNOLOGY NETWORK "FERTILISATION & ENVIRONMENT" (RMT F&E): TEAMS, PROJECTS AND TOOLS MOBILIZED AROUND THE MANAGEMENT OF BIOGEOCHEMICAL CYCLES IN AGRICULTURAL SYSTEMS

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A unifying and ambitious general objective

The RMT F&E aims to bring together, develop and synergize existing scientific and technical skills within the agricultural research, training and development area, in order to provide stakeholders (farmers, agricultural advisors, trainers, resource and land managers, public authorities) with references, methods and tools for sustainable management of biogeochemical cycles and soil fertility in the main farming systems present in France (Metropolitan and Overseas).

A dynamic network of numerous and varied partners

Initially created in September 2007, the Joint Technology Network "Fertilisation and Environment" (RMT F&E) was labelled once again in January 2014 for a period of 5 years on the basis of its 2014-2018 work programme. It receives financial support from the Ministry in charge of Agriculture, for the animation of the network, led by eight animators. A solid and long-standing multi-actor centre of expertise, the RMT F&E currently brings together 34 partners implied in agricultural research, development and training. In total, around one hundred people make up this RMT and are belonging to 8 Agricultural Technical Institutes and their network head (Acta), 8 public research or higher education establishments (including 2 Belgian and one Swiss), 5 chambers of agriculture and their network head (APCA), 5 agricultural technical teaching establishments and their national public institution of support, 2 non-profit organisations dealing with applied research, development and transfer, one cooperative group, one soil analysis laboratory and one public administrative establishment.

Three high-stakes agro-ecological themes

The RMT F&E work programme is structured around three thematic priorities which, by combining plant production and environmental conservation, are in line with agro-ecological principles (parsimonious use and equitable distribution of resources, reduction in the use of inputs, recycling of organic products, ecological intensification, preservation of agro- and ecosystems, enhancement and preservation of ecosystem services provided by agriculture and soils) at different spatial and temporal scales:

- crop fertilisation,
- recycling of waste products (mainly organic),
- control of biogeochemical cycles at different scales and organizational levels.

Four lines of work to promote the production of results

To carry out its programme of activities and produce the expected results, the RMT F&E facilitation team organizes the work along four axes, defined by the type of production they generate:

1. Foresight and scientific watch, European strategy

2. Coordination and sharing around the acquisition of scientific and technical references and the appropriation of new paradigms
3. Development and improvement of decision-making tools for stakeholders
4. Transfer and training to education and development; support to public policies.

The themes of the RMT and the projects that contribute to it can therefore fit into one or more of these axes depending on the case.

Diversified collaborative productions

The results of the RMT F&E vary in nature, depending on the type of activity from which there are derived and the composition of the partnership that produced them. We can mention for example:

- States of the art, prospective studies and analyses, formulation of new research questions (for example, a collective prospective work: "*Fertilisation et environnement: Quelles pistes pour l'aide à la décision*? February 2014, Acta-Quae co-publication], result of a forward-looking brainstorming on the evolution of the fertilisation context in the next 5-10 years, and future needs in references, tools and methods for biogeochemical cycle management and fertilisation reasoning;
- Several projects developed by RMT partners, some of which were the direct result of forward thinking conducted within the RMT, and financed within the framework of calls for projects in France (CASDAR, ADEME, ANR...) and Europe (PEI, Horizon 2020), and the results, references and common databases that resulted;
- Decision support and diagnostic tools : Régifert®, diagnostic and prescription software for P, K, Mg, Zn, Mn, B, organic carbon and soil acid-base status; Syst'N®, nitrogen loss estimation and diagnostic tool for nitrogen management, at cropping system level; AzoFert®, software for the prescription of N fertilisation of crops, at plot and annual scales, with two variants, one adapted to the fertilisation of fruit trees and vines (N-Pérennes), the other adapted to an educational use to promote the learning of nitrogen dynamics and the nitrogen balance method (N'EDU);
- Scientific and technical support to public policies via the national technical support of the Regional Nitrate Expertise Groups (GREN), in partnership with the COMIFER association;
- Teaching tools for teaching and development, training;
- Scientific and technical publications (articles, posters, book chapters, Internet pages);
- Scientific seminars and technical days that promote the sharing of results and the setting up of new projects.

The RMT F&E promotes (i) the sharing of financial resources, human resources, knowledge, tools and references, avoiding dispersion and duplication, (ii) the development of scientific and technical consensus among its members and beyond, and (iii) the acquisition of a common vision of the major issues related to the management of biogeochemical cycles of mineral elements in agriculture.

For more information : http://www.rmt-fertilisationetenvironnement.org

Contacts : mathilde.heurtaux@acta.asso.fr ; sylvie.recous@inra.fr

COMIFER LABELING OF CALCULATION TOOLS FOR THE PREDICTIVE DOSE OF NITROGEN: APPROACH AND OUTLOOK

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Context

In the context of the Nitrates Directive, the national action program requires the balance of fertilization be respected and the expected dose of nitrogen be calculated for each cultural island. The regional referential decrees *(arrêtés référentiels régionaux)* give to all farmers the elements necessary for this calculation, in a simple way, for use in paper form.

However dose calculation tools can be used. The existing tools take up the content of the decrees, or propose other modes of expression of the calculation, often for the sake of precision by the valuation of a larger number of input data.

The regional referential decrees specify that "the tool used must comply with the forecast balance sheet method developed by COMIFER".

As a reminder, COMIFER has published a methodological guide establishing the rules for calculating nitrogen fertilization according to the forecast balance sheet method in 1996. This guide was updated in 2013.

In order to specify the status of projected doses calculated by tools compared to that calculated with the regional referential decrees, the Ministries of Agriculture and the Environment launched, in 2015, a procedure for the regulatory recognition of tools. This allowed to:

• Identify a large part of the tools available on the market;

• Know their calculation methods;

• Engage themselves in a cross-comparison of the tools.

To date, 74 tools have been reported by 62 publishers. All follow globally the reasoning principles of the COMIFER method. There is today no tool presenting an alternative method.

Following the abandonment of the regulatory procedure by the Ministries at the beginning of 2016, in order to clarify the status of the tools, COMIFER, in partnership with the RMT Fertilization & Environment, created a label guaranteeing their conformity to the COMIFER method.

This approach to labeling COMIFER nitrogen dose calculation tools has received institutional support from the Ministry of Agriculture and Food.

Approach

The labeling process for the tools responds to the following objectives:

• Clarify the offer of advice to farmers and advisors by identifying tools that comply with the COMIFER method;

• Check that these tools meet a number of requirements, constituting the principles of COMIFER;

• Support publishers to improve the quality and accuracy of their tools by testing them on typical farming situations.

Labeling tools is a voluntary approach.

It is intended for all publishers proposing tools calculating projected doses of nitrogen from the COMIFER method, for annual crops and grasslands, whether for software, web application, and spreadsheet or paper grid.

A tool is defined as the combination of calculation algorithms and parameter data.

The label specifications contain requirements for compliance with the principles of the COMIFER method:

• Use of the complete equation or one of the simplified equations in the COMIFER brochure;

• Locking the setting;

• View the version of the tool and the values taken by the items in the equation on the exit slips.

All requirements are described in the specifications.

Moreover, publishers must engage in a process of inter-comparison and improvement of tools. For this, they must perform dose calculations for 60 typical cases per old administrative region. These typical cases were built with the help of Regional Groups of Expertise Nitrates (GREN).

The label will be issued for a period of 3 years, for a given version and for a region, possibly with restrictions depending on the area of validity of the tool (geographical area, crops, soil types, etc.).

The control and issue of the certificate will be carried out by an independent third party. The audit will consist of two parts, a documentary audit and an on-site audit. An annual monitoring will be set up, with each year a check on a random sample of publishers.

Steps to come

COMIFER, in partnership with the RMT Fertilization & Environment, launched the labeling process in June. All tool publishers are free to submit a folder. All information relating to the labeling application is available on the COMIFER website (www.comifer.asso.fr).

On term, the COMIFER wants to introduce, in the specifications, quantitative criteria to evaluate the doses. For this, COMIFER and RMT Fertilization & Environment are currently conducting a study on dose uncertainty using the balance sheet method.

ELFE, A DATABASE TO DETERMINE GREENHOUSE GASES AND AMMONIA EMISSIONS FACTORS FROM LIVESTOCK

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INTRODUCTION

Livestock sector represents a major source of gaseous emissions contributing to air pollution. In France, 17.8% of greenhouse gas (GHG) and 70% of ammonia (NH_3) originates from this sector. Improving the knowledge on the magnitude and origin of gaseous emissions is, thus, essential to reduce emissions, to meet the societal requirement and to setup regulations at national and European levels. A French consortium involving research and extension services partners was created to draw up an inventory of GHG and NH_3 emissions resulting from livestock systems. The aim of this project was to develop a new methodology to provide emission factors (EF) characterizing the diversity of practices. A database called ELFE (ELevages et Facteurs d'Emission) containing EF from the international literature and related metadata was developed, allowing the calculation of gaseous emission per technical itinerary.

MATERIAL AND METHODS

The first step was to create the structure of the database using Microsoft Excel® 2013. To organize it, five stages of manure management characterizing emission sources were defined: housing; pasture; outdoor manure storage; manure treatment and spreading. The housing database was created for each animal production (cattle, poultry and swine) to take into account production specificities. Technical itineraries were defined for each animal production and manure management stage. A review of the international literature references was performed to collect publications on GHG and NH_3 emissions in cattle, poultry and swine productions for the different stages of manure management: around 1 000 publications were recorded, corresponding to scientific papers, proceedings or study reports. EF and metadata taking into account livestock system practices and metrological information were integrated in the corresponding part of the database. EF were then classified according to two selection criteria: 1/ the level of information about metadata associated to emission values previously defined as determinant - three completeness classes depending on the level of information were defined: > 50%; 30-50%; <30%; 2/ a classification based on the measurement method/technology employed to obtain emissions values will also be proposed. Then, EF were converted into "reference units" to allow their analysis and comparison. The next steps focused on data analysis to determine average EF's per itinerary and EF-variability due to metadata (i.e. climate, housing system, animal type, diet, storage duration, storage type, etc.).

RESULTS AND DISCUSSION

Table 1 presents the number of data integrated in the base (n EF) for housing (by animal production), outdoor manure storage and spreading and the corresponding number of publications.

Table 1. Number of integrated EF in the database and number of corresponding publication

		Housing		Storage	Spreading
Number	Cattle	Pig	Poultry		
Number of EF	545	1 758	313	1 567	860
Number of publications	46	152	28	106	56

According to the objectives, the database ELFE can be used in different ways: *(i)* to calculate an average emission value corresponding to a specific technical itinerary, *(ii)* to calculate an average emission value depending on selection criteria, and *(iii)* to carry out statistical analysis to provide emission references (under development).

(i) Average values were calculated for NH_3 emission from housing for a specific technical itinerary defined as reference system for dairy cattle (cubicle house, producing slurry) and swine production (growing-finishing pigs kept on fully slatted floor with vacuum system to remove the slurry from the pit at the end of the batch). The first results seem consistent with official reference documents values on gaseous emissions reported by Bittman et al. (2014) in UNECE report; in EMEP inventory (2016) and in IRPP BREF (Giner-Santonja et al., 2017): 15.9 ± 13.2 and 3.9 ± 1.7 kg NH_3.animal place^{-1}.year^{-1} for dairy cattle (full-time housing of the animals) and fattening pig respectively.

(ii) At this time, EF were only obtained according to the first selection criterion (level of metadata provided in the publication). Figure 1 presents the distribution of data into the three completeness classes and shows a great variability between the different manure management stages and animal production for housing (more data need to be integrated in the database to calculate an average emission value per completeness classes).

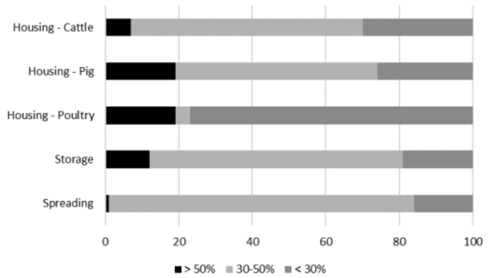

Figure 1. Distribution of EF into the three completeness classes

CONCLUSION

This project proposes a global approach including different tools to provide an inventory and selection criteria of GHG and NH_3 emissions published in the literature. Despite the high variability of emission levels due to the large diversity of livestock systems, practices and measurement methods, this study allows to propose a detailed inventory of gaseous emission. This study also allows to identify the lack of data about the conditions for the acquisition of emission values reported in the literature that make difficult the comparison of EF.

Acknowledgements: This project was funded by the French Environment and Energy Management Agency (ADEME), the French Ministry of Agriculture and the French National Research Agency (ANR).

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THE ONLINE SUPPORT-TOOL "RAX": FERTILIZATION RECOMMENDATION WITH SLURRY IN GRASSES AND FORAGE CROPS

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INTRODUCTION

In Galicia, the first milk production region of Spain, livestock feed in dairy farms is based on concentrates and grasses, winter forages and forage maize and accordingly in these systems, the best use of slurry is as fertilizer in the crops of the farm itself. If recycled of nutrients is improved putting in value the slurries and with a good managing of them, dairy farms will achieve a high degree of self-sufficiency in fertilization, reducing also production cost trough saving in mineral fertilizers (Green Dairy, 2006). All this will improve the economic margin and the sustainability of Galician dairy farms. The INGACAL-CIAM in association with Cooperativa Agraria Provincial de A Coruña, has developed an online support-tools (www.ciam.gal), which present the great advantage that farm organic nutrients are integrated and valued, helping to technicians and farmers to get fertilization recommendations.

MODEL/TOOL DESCRIPTION

The online support-tools RAX (X refers to *xurro*, slurry in Galician language) make grasses or forage crops fertilization recommendation considering that the best nutrient source in dairy farms is in recycling slurry as organic fertilizer, recommendation that if it is necessary can be completed with mineral fertilizers.

Input data

Following data are necessary to get fertilization recommendations with tools RAX:
- Chemical composition of the slurry that is going to be applied. Nutrients content of slurries are different from one farms to another and in the same farm varies with the season. This support tools allow four options to introduce the nutrients content of slurries: a) Directly from a laboratory analysis of slurry (dry matter percentage, nitrogen, phosphorus and potassium percentages on dry matter basis), whether it's dairy or pig slurry, b) Considering a regional mean value of dairy slurry nutrients, c) Estimating dairy slurry nutrients from the density, d) Estimating dairy slurry nutrients from the electrical conductivity and the density
- Dry matter yield (t ha^{-1}).
- Soil analysis: percentage of aluminum saturation (given the acidity of Galician soils), P (ppm) and K (ppm). We will find from high-nutrient soils which will allow to economize on fertilizers, to low-nutrient soils where an extra fertilization will be necessary (Castro *et al*., 2012).
- Grass management and botanical composition.
- Techniques, times and conditions of application of the slurry to calculate the losses by volatilization of the ammonia nitrogen (García *et al.*, 2010, 2014a)
- Mineral fertilizer (you can select from a wide range of fertilizer formulas that are in the market) complementary to the amount of slurry previously selected to be applied. Specific mineral fertilizer is selected considering the specific nutrient (nitrogen, phosphorus and potassium), that we want to be completely fulfilled.

Output data

The tool shows a data output, which can be printed or saved: i) The fertilizer value of 1 m^3 of slurry, expressed as kg of N, P_2O_5 and K_2O; ii) the correction fertilization expressed as m^3 of slurry needed to satisfy the needs of the soil in phosphorus and potassium, with the aim of increasing low-nutrient soils to an optimum level, through successive fertilizer applications; iii) the liming recommendation as t ha^{-1} of limestone ($CaCO_3$) assuming a 100% pure material; iv) the necessary fertilization to satisfy the nutrient needs of the crop in nitrogen, phosphorus and potassium expressed as m^3 of slurry; v) kg of N, P_2O_5 and K_2O required to complement nutrient needs of the crop when a specific dose of slurry was previously selected; vi) the nutrient needs that may stay unfilled for the specific dose of slurry and/or specific mineral fertilizer selected.

RESULTS AND DISCUSSION

Nowadays there are four RAX support-tools, with similar structure:
RAX- Grasslands establishment fertilization; RAX- Grasslands annual fertilization; RAX- Winter forages fertilization; RAX- Forage maize fertilization.
You can access online: www.ciam.gal , with a format that is easy to use through mobile phone.

Soil analysis and habitual yield per plot as well as quick on-site methods for estimating nutrients content of the dairy slurry allow getting recommendations adjusted to the reality of each plot and farm. Slurries doses are provided in an immediate way, with the subsequent environmental and economic benefits. Fertilization recommendations can be saved and consulted online. The support-tools RAX are accompanied by an user guide, but they are very easy to use, so they are proving to be a good tool for increasing and improving the use of slurry as fertilizer on Galician dairy farms. RAX is a tool in continuous review, it is coming soon incorporation of the estimation of chemical composition of pig slurry trough the measurement of density and conductivity, the influence of previous cultivation (legume or not, catch crop or cover crop,...) and the mineralization of organic matter.

CONCLUSION

The support-tools RAX for grasses and forage crops, is helping to technicians and farmers to get fertilization recommendations in Galician dairy farms, considering that the main nutrient source in the dairy farm is in recycling slurries as fertilizers, which can be completed if it is necessary with the use of mineral fertilizers.

Acknowledgements

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VEGSYST-DSS TO CALCULATE N AND IRRIGATION REQUIREMENTS IN VEGETABLES GROWN WITH FERTIGATION IN MEDITERRANEAN GREENHOUSES

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INTRODUCTION

In south-eastern Spain, excessive nitrogen (N) and irrigation application to fertigated, soil-grown vegetable crops in greenhouses has caused appreciable nitrate (NO_3^-) contamination and over-exploitation of underlying aquifers. To help reduce these problems, the decision support system (DSS) VegSyst-DSS has been developed to prepare site and crop specific plans for optimal management of N and irrigation of seven major vegetable crops grown in Mediterranean greenhouses: tomato, pepper, cucumber, zucchini, supported melon, non-supported melon, watermelon and eggplant. The DSS was designed to require few inputs and to be simple to use for farmers and farm advisors. This work presents the VegSyst-DSS software that calculates daily N fertilizer and irrigation requirements, and the N concentration in nutrient solutions applied by fertigation for the seven main vegetable species grown in this region. For a pepper crop, a comparison of the irrigation and N requirements following the recommendations of the DSS and the local practices is presented.

MATERIAL AND METHODS

The decision support system (DSS) software for Windows VegSyst-DSS, based on the VegSyst version 2 simulation model calculates daily crop requirements for N and irrigation, and the applied N concentration. N fertilizer requirements are calculated using a N balance based on daily crop N uptake and that considers soil mineral N at planting, and N mineralized from manure and soil organic matter. Irrigation requirements are based on calculated ETc and consider irrigation application efficiency and the salinity of irrigation water. The DSS can be used for crops grown in soil or in substrate; it assumes that crops have no water or nutrient limitations. The calculations are made using historical climate data. For detailed descriptions of the VegSyst-DSS see Gallardo et al. (2014).

In this work, a simulation of the irrigation and N fertilizer plans for a theoretical pepper crop grown from 15 August to 15 February in a plastic greenhouse in Almeria is presented. The soil had a root-zone mineral N content of 80 kg N ha^{-1} at planting, and 50 m^3 ha^{-1} of sheep manure was applied 6 months before planting. The EC of the irrigation water was 2.0 dS m^{-1} and the Uniformity Coefficient (UC) was 0.95. The simulated irrigation and N fertilizer recommendations of the DSS were compared with commercial farmers' management practices. The irrigation volume applied by farmers was obtained from a comprehensive survey of irrigation practices on commercial farms, and the N fertilizer used by farmers was obtained considering the irrigation volume and a [N] of 12 mmol N L^{-1}, in the applied nutrient solution, which is representative of grower practice for commercial pepper crops.

RESULTS AND DISCUSSION

The gross irrigation requirement recommended by the DSS was slightly higher than ET_c because an additional 9% of water was applied for the leaching requirement (Fig. 1a). The sharp increase in irrigation and N fertilizer requirements at 63 days after transplanting (DAT), corresponded to the day in which the whitening (previously applied as calcium carbonate suspension) on the greenhouse roof was removed. The soil N supply contributed 60 kg N ha^{-1} to the total crop N requirements of 259 kg N ha^{-1}; the DSS assumes that 0.5 of the soil N supply (root zone mineral N plus mineralized N) of 120 kg N ha^{-1} was available to the crop (Fig. 1b). The average recommended [N] for the duration of the crop was 5.4 mmol N L^{-1} which is considerably lower than the 12 mmol N L^{-1} recommended to farmers for commercial practice.

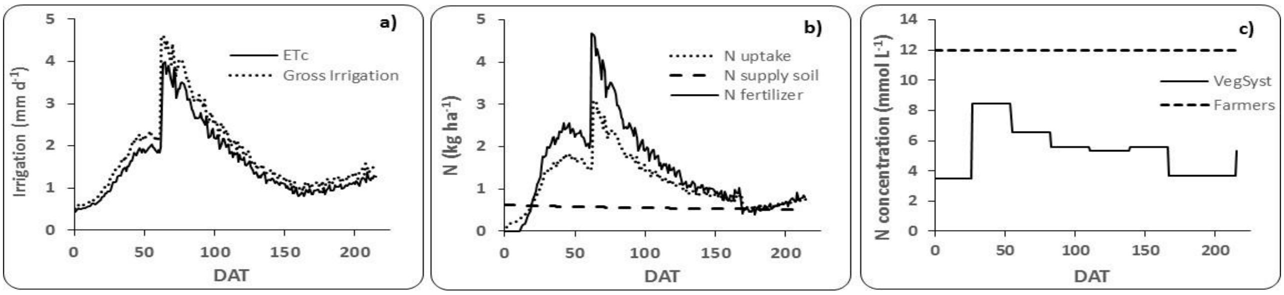

Figure 1. For a greenhouse pepper crop seasonal evolution of (a) daily values of ETc and gross irrigation requirement, (b) daily values of crop N uptake, N supply from the soil and N fertilizer requirements, and (c) the recommended four-weekly [N] of the fertigation nutrient solution compared to the standard [N] used by local growers.

The total irrigation volume that was estimated from growers' practices was 8% more than recommended by VegSyst-DSS (Table 1), while estimated total N for growers' practices was approximately double that recommended by VegSyst-DSS, the relative differences were larger in the early part of the season (Table 1). During the crop establishment period, the VegSyst-DSS suggested that it was not necessary to apply fertilizer N on account of the soil mineral N present in the soil at transplanting and the low N demand of the crop.

Table 1. Irrigation volumes and amounts of N fertilizer recommended by the VegSyst-DSS, and those used by farmers. Values are shown for the periods of 1) establishment, 2) rapid growth, and 3) from the end of rapid growth to maturity, and for the duration of the crop.

Period	Irrigation (mm)		N Fertilizer (kg ha^{-1})	
	DSS	Farmers	DSS	Farmers
1 (0-17 DDT)	10	23	1	39
2 (18-58 DDT)	60	91	78	152
3 (59-215)	269	252	238	424
Total (0-215 DDT)	339	366	317	615

CONCLUSION

The VegSyst-DSS calculates recommendations of daily volumes of irrigation, daily amounts of N fertilizer, and the N concentration in nutrient solutions applied by fertigation, for the seven major vegetable crops grown in greenhouses in SE Spain. The comparison of the irrigation and N requirements following the recommendations of the DSS and the local practices showed that considering crop N demand and the N supplied by the soil and organic amendments, the VegSyst-DSS software can appreciably reduce application of N fertilizer and consequently notably reduce N losses to the environment.

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SMARTAGRI: OPTIMIZATION OF ORGANIC AMENDMENTS APPLICATIONS

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INTRODUCTION

The promotion of more sustainable agricultural practices in France includes the improvement of organic amendment strategies, such as composts. Indeed, it is important to ensure the level of organic matter (OM) in the soil, which is essential for the functioning of its biogeochemical cycles. In addition, it is necessary to rationalize the use of non-renewable resources, such as synthetic fertilizers, for environmental and economic reasons. These concerns might be taken into account by recycling nutrients which will improve the soil quality while reducing the volume of waste and increasing carbon sequestration.

The use of organic waste products (OWP) meets these characteristics, enriching the soil in OM and contributing to crop fertilization. Nevertheless, it is essential to understand the OWPs characteristics and their behavior in soil in order to optimize the amendments while advising potential customers on new soil management strategies. To achieve this goal, an effort has to be done concerning (i) the fitting of simulation models in order to correctly predict carbon (C) and nutrients (N, P and K) dynamics in soil and resulting crop yields; (ii) the optimization of compost doses and spreading schedule to maximize the agricultural benefits (financial and soil sustainability gains).

TOOL DESCRIPTION

The solution is developed as an online decision support tool on a tablet. The decision tool is composed of a simulation model which allows the evaluation of envisaged agricultural practices and an optimization algorithm, that completes the decision-making process, by proposing a land application schedule and product doses which search for the optimal compromise between crop yield, operational cost and nutrient requirements. To initialize the decision-support tool, a soil diagnostic characterizing the initial state has to be performed. Figure 1 shows the steps and the usage of the tool, including its inputs and outputs.

The simulation model

The Century simulation model (Parton et al., 1987) allows the prediction of the atmosphere-plant-soil system while considering the dynamics of nutrients under different pedo-climatic and agricultural scenarios. A modified version of Century simulates, besides C, N and P in soil and plant yields, the input of different types of composts and the dynamics of K.

The optimization tool

The optimization problem addressed by the decision support tool, modeled and solved by LocalSolver (Gardi et al., 2014), aims to define the monthly application schedule of mineral fertilizers and organic amendments, as well as the types and quantities of each product. The solution proposed searches for the optimal calculated profit for the whole time-horizon, composed as follows: i.) the total cost of compost and fertilizer, ii.) the total economical yield-related gains of crops and iii.) the respect of certain constraints, e.g. the target level of C and N in the soil, regulation constraints regarding the maximum land application quantity of certain nutrients and trace elements. The dependence between the objectives and the simulation model leads to a complex optimization problem which has to be solved in relative short time for decision-making purposes.

RESULTS AND DISCUSSION

The tool is developed for the French agricultural context and mainly for field crops. Databases were created for weather and soil departmental characteristics, regulatory aspects, crops requirements, price and characteristics of mineral fertilizers and organic amendments and different levels of soil cultivations. Other information needed to run the decision-support tool is gathered from interviews with the farmers and from the soil initial diagnostic.

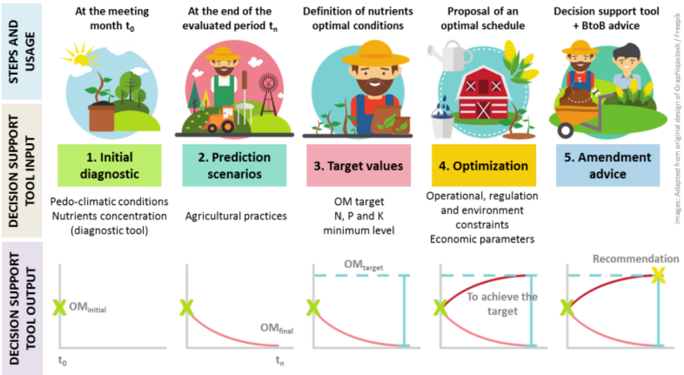

Figure 1. Decision support tool usage, inputs and outputs

In order to adapt the simulation model to French pedoclimates, a calibration was performed and validated with 3 French long-term experiments with different soil and crop managements, comparing measurement data and model predictions. The mean percentage error of the validation step, for C and N predictions, are around 14% and 11% respectively. In order to analyze the accuracy of the optimization tool, two real scenarios of field crops rotation and management were evaluated for 10 years. These scenarios were proposed by agricultural experts and were first simulated with their amendments schedule proposition. The results of the simulations were then compared to the solutions proposed by the optimization tool after 30 minutes of CPU time calculation. In all solutions proposed by the optimization tool the soil OM increases over the evaluated period by at least 1%, regarding the soil initial state. This increase is less significant (0.2%), or even negative (-0.2%), when considering the schedules proposed by the experts. In the same way, the concentration of total N and mineral P are increased by the optimized solution by, at least, 50% and 200%, respectively, whereas in the best case of the experts scenarios these are increased, respectively, by 20% and 180%. Both simulated and optimized results were validated jointly with the experts.

CONCLUSION

Coupling a simulation and an optimization approach in a decision support tool allows to better advise compost users on new management strategies. The development and use of different databases combined with a calibration and validation approach lead to a reliable use of the tool. Future work includes a sensitivity analysis and more powerful calibration of the simulation model to decrease the prediction uncertainty. Also, the coupling between different optimization methods would allow to decrease the computational budget spent during optimization and to increase the solution quality.

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FROM AZOFERT® TO N-PÉRENNES: ADAPTATION OF A DYNAMIC DECISION SUPPORT TOOL FOR ANNUAL CROPS FERTILIZATION TO PERENNIAL SPECIES

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BACKGROUND AND OBJECTIVES

The main way to calculate fertilizer-N rates to be applied to annual crops is the predictive balance sheet method which is the basis of many decision support tools used by advisors, soil laboratories or farmers. Among these tools, AzoFert® is a software package widely used in Northern France since 2005 (Machet et al., 2017; Machet et al., 2007). AzoFert® is based on a complete inorganic nitrogen (N) balance sheet. It integrates from climatic data a dynamic simulation of soil N supplies and takes into account processes affecting the availability of fertilizer-N (immobilization and volatilization of ammonia). For perennial crops, this method had to be adapted because the N management is different. Indeed, unlike annual crops, perennial plants accumulate reserves in different compartments, especially N, during their vegetative cycle, store them during the winter phase in their perennial parts (trunk, roots ...) and remobilize at the start of the plant next cycle (Jordan et al. 2009).
This poster aims to present a new paradigm used for perennial crops based on AzoFert® model.

DESCRIPTION OF AzoFert® CONCEPT TOOL

AzoFert® is based on a complete inorganic N balance sheet. The following equation is used to predict fertiliser-N rates, expressing that the variation of soil inorganic N between opening (usually measured between January and March) and close of balance sheet (plant harvest) equals the difference between N inputs and outputs:

Rf – Ri = (Mn + X + Ap + Fns + Fs + Ir) – (Pf – Pi + Ix + Gx + Lx + Gs + Ls)
With Mn = Mh + Mr + Ma + Mci + Mp

Rf: soil inorganic N at close of balance sheet (at harvest), **Ri**: soil inorganic N at opening of balance sheet (end of winter for winter crops, sowing for spring crops), **Mn**: net mineralization from humus (**Mh**), crop residues (**Mr**), organic products (**Ma**), catch crops (**Mci**) and meadow (**Mp**) residues, **X**: amount of fertilizer N, **Ap**: N wet deposition, **Fns**: non symbiotic fixation, **Fs**: symbiotic fixation, **Ir**: N irrigation contribution, **Pf**: total N uptake by crop at close of balance sheet, **Pi**: N uptake by crop at opening of balance sheet, **Ix**: fertilizer N immobilised, **Gx**: fertilizer N lost as gas, **Lx**: fertilizer N lost by leaching, **Gs**: soil inorganic N lost as gas, **Ls**: soil inorganic N lost by leaching between opening and close of balance sheet

At the opening of the balance sheet (end of winter for winter crops, at sowing for spring crops), the soil inorganic N pool is measured at the rooting depth. Input data include soil type, previous crop, current crop, and farming techniques, easily collected from an information sheet completed by farmers. The annual climate and all necessary data characterizing the different soil types and crops are added into the software settings because AzoFert® integrates a dynamic simulation of soil N supplies. In order to take into account the various contributions of crop residues, catch crops and organic products previously applied to the residual mineral N (varying with climate and characteristics of added organic matter), the decomposition of the different organic sources are simulated (using observed climatic data) from harvest of the previous crop, until the opening of the balance sheet. Decomposition is expressed over time using a "normalized time", based on temperature (T) and soil moisture (W) functions : Normalized time $_{(\text{day } i,\, \text{day } j)} = \Sigma_{ij}\, f(T) * g(W)$
Normalized time takes into account climatic variations and determines a potential decomposition rate. From the opening of the balance sheet to the harvest of the crop, the subsequent net contribution of the organic

residues or wastes and the net mineralisation of the humified organic matter are simulated using normalised days calculated from the past years mean climatic data of the area.

PARAMETERS ADAPTATION TO PERENNIAL CROPS (N-PERENNES PROJECT)

For the constituent compartments of perennial plants, the work has resulted in a distribution based on the yield of the crop with different approaches for the vine-growing and fruit-growing systems. Indeed, for apple tree and peach tree, relations were already established by the Interprofessional Technical Center for Fruits and Vegetables (see **Table 1**). They have also been confirmed by the results acquired by INRA PSH d'Avignon on experiments in apple growing systems conducted at INRA de Gotheron (Drôme) and at the regional experimental station (Bouches-du-Rhône).

Table 1. Main modifications and specificity of perennial crops adapted from AzoFert® concept.

	Vine-growing systems	Fruit-growing systems
Opening balance sheet	Budburst	Flowering
End of balance sheet	Veraison	Start of yellowing leaves
Cover crop management	Hypothesis: cover crop place is an isolated compartment and there is no interaction with the vine or fruit-growing systems	
Estimations of N requirements	Definition of N repartition on different compartments of vine established from literature (see Cahurel et al. 2017)	Apple trees: 80 + 0.6 x yield Peach trees: 90 + 1.3 x yield
Reserves	Hypothesis of equality reserves between the start and the end of the annual cycle	Taken into account in the previous relation
Leaves on soil	Taken into account of the % of leaves returned in the plot	
Vigor	Not considered. We have to take it in the finish recommendation	
Planting density	Integrated indirectly in the calculation on the specific surface area	
Canopy management	Not considered	

For the supply of N by organic products, the work consisted in the acquisition of parameters (composition, N and C mineralization kinetics). These data come from experiments, scientific references and manufacturers. They concern organic products specific to vine-growing and fruit-growing systems: compost of grape marc, hardwood bark, softwood bark and some commercial products.

CONCLUSION

AzoFert® is a decision support tool for fertilizer N advice based on a dynamic version of the predictive balance sheet method. AzoFert® is a model in constant evolution. The introduction of a dynamic simulation of soil N supplies allows its application to a larger range of cultural situations included perennial and annual crops and pedoclimates. The perennial crops adaptation of AzoFert® is a prototype. Improvements are in progress. Moreover, AzoFert® has been implemented as a teaching tool in "N'EDU" project.

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Acknowledgment: We want to thank J.M. Machet and N. Damay for their wise work on AzoFert® development. AzoFert® and N-Pérennes are part of RMT Fertilisation and Environment network. N-Pérennes project received funding from CASDAR (Fertilisation N-Pérennes 2013-2016).

CADASTRE_NH_3: A NEW FRAMEWORK TO ESTIMATE SPATIO-TEMPORAL AMMONIA EMISSIONS AFTER N FERTILIZATION IN FRANCE

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INTRODUCTION

Ammonia emission from crops is a major international environmental and sanitary issue. Above all it represents a major loss of nitrogen use efficiency of mineral and organic fertilisers. This loss needs to be reduced by appropriate agricultural practices. However, ammonia volatilization is a surface process which intensity and duration depend on agricultural and environmental conditions. The variability of the conditions encountered in French agricultural practices makes the quantification of emissions difficult. The lack of reliable tool able to assess the effects of the main environmental and management conditions on ammonia emissions has been stressed out. It prevents to test scenarios of agricultural practices and/or climate changes. The framework CADASTRE_NH_3 aims at producing a realistic representation of French conditions for N-fertilization. Its originality relies on the combined use of two types of resources: the process-based Volt'Air model and geo-referenced and temporally explicit databases (Ramanantenasoa et al., in press).

MATERIAL AND METHODS

Volt'Air is a process-based 1D model predicting NH_3 emissions from N fertilisers on bare soils, from physical, chemical and biological processes. It takes into account the influence of soil, meteorological and agricultural variables and runs at an hourly time step at the field scale for a period of several weeks (Garcia *et al.* 2012). It explicitly accounts for volatilization-related parameters for the type and dose of N-fertiliser applied and the application method and/or abatement technique. Areas of each surveyed crop are derived from the European Land Parcel Identification System built within the framework of the Common Agricultural Policy regulations and delivered by the Observatoire du Développement Rural service unit. Spatial weather conditions, generated by the Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige model are delivered by Météo-France for each year, on 8 km mesh grid. Soil spatial distribution is provided by the European Soil Data Center and soil properties by the Harmonized World Soil Database of the Food and Agriculture Organization. N fertilisation management data come from national survey of cultural practices for arable crops and grassland, conducted by the Department of Statistics and Forecasting of the French Ministry of Agriculture, available every 5 years on average, for 13 main crops and 21 regions (NUTS2). Statistical calculations carried out following Mignolet et al. (2007) allows a realistic representation of the French fertilisation practices for real crop-years at the regional scale. They are expressed as the distribution of the N applications (fragmentation, periods of application and types of mineral fertiliser and organic products) and the N dose for each fertilisation. French expertise allows the specific description of the organic fertiliser applied (Dufosse et al., 2018b). Simulation units (SU) are determined using a Geographical Information System, as the intersection of departments (NUTS3) and homogenous agricultural region (AR), thus creating 713 SU.

RESULTS AND DISCUSSION

Practical applications of this new framework are yet available for France for crop years 2005-06 and 2010-11. A set of about 80 000 situations are available for each crop-year: they can be considered as representing the realistic combinations of the main factors known to influence ammonia volatilization encountered in French agricultural conditions. CADASTRE_NH_3 accounts for both the spatial and temporal variabilities of both N fertiliser use and NH_3 emission rate.

(a) (b)

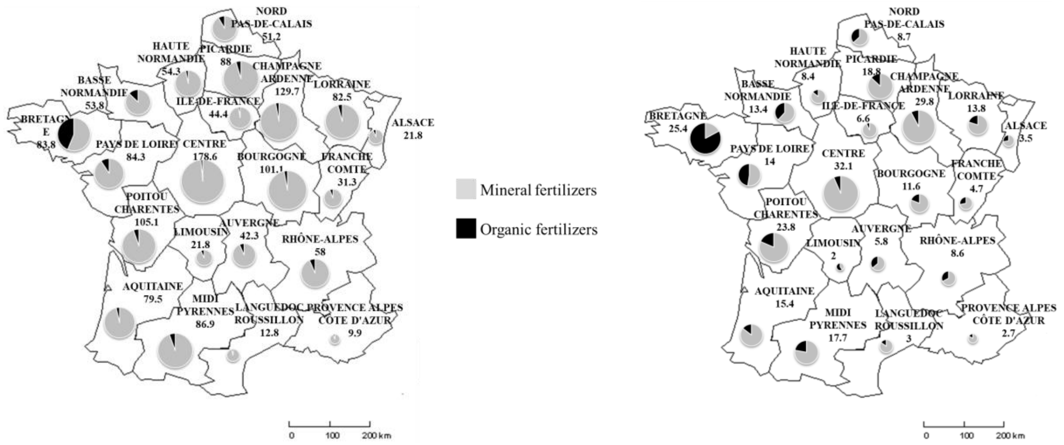

Figure 1. Regional distributions of (a) N fertiliser use (kt ammoniacal-N) and NH_3 emissions (kt NH_3) in France estimated using CADASTRE_NH_3 for the crop-year 2005-06

CONCLUSION

One of the most valuable interests of the CADASTRE_NH_3 framework for decision making relies on the fact that it does not use mean data estimated from a general knowledge of fertilization practices in France. Indeed, real cultural practices data on specific crop years are used: specific fertiliser application practices which are coherent with specific weather conditions encountered during the crop year described. Robust prospective studies can thus be undertaken to evaluate the effect of the implementation of policies aiming at mitigating ammonia emissions (e.g. Gothenburg Protocol, 1999) (Dufosse et al., 2018a). This tool is also being used to generate simple ammonia volatilization response curves for inclusion in N fertilization decision support models.

Acknowledgements: This work was conducted within the CADASTRE_NH_3 (Spatial and temporal high-resolution inventory of ammonia emissions from agricultural soils over France at regional and national scales, agreement n°1081C0031) project, supported by the French Environment and Energy Management Agency (ADEME). It was supported by a public grant overseen by the French National Research Agency (ANR) as part of the «Investissements d'avenir» program (reference: ANR-10-EQPX-17 – Centre d'accès sécurisé aux données – CASD).

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A DECISION SUPPORT FRAMEWORK FOR THE INTEGRATED EVALUATION OF AGRICULTURAL MANAGEMENT IMPACTS ON CROP YIELD, SOIL QUALITY AND ENVIRONMENT

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INTRODUCTION

Current agricultural management practices significantly affect crop growth and environmental quality in varying ways based on local agro-ecosystem properties. Integrated and optimal combinations of farm management are needed for agriculture to intensify sustainably. We develop a decision support system (DSS) to evaluate the overall benefits and trade-offs that management has on crop yield, soil quality and environment, using indicators for soil organic carbon (SOC), phosphorus and nitrogen cycles. The DSS integrates a range of soil, crop, and nutrient management practices along with an assessment of the influence of local agro-ecosystem properties (AEPs).

TOOL DESCRIPTION

At the current stage, an initial model framework is developed into a prototype, consisting of: (1) management and AEP input data, (2) model calculations, and (3) output of changes in response variables (Figure 1). Empirical relationships between management and impacts on crop yield, nitrogen use efficiency (NUE), and SOC changes are assessed using meta-analysis. Process-based modelling estimates changes in nutrient losses to air and water.

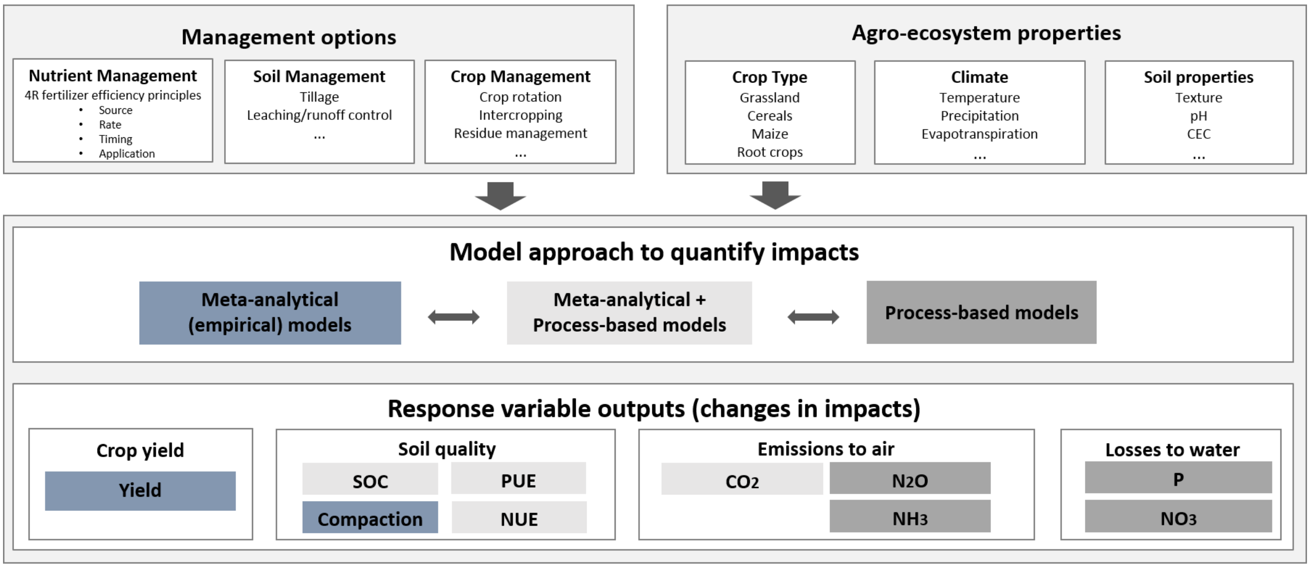

Figure 1. Conceptual overview of DSS (SOC = soil organic carbon; NUE = nitrogen use efficiency; PUE = phosphorus use efficiency)

At a later stage, phosphorous use efficiency (PUE) or soil P status will be integrated, and process-based models can supplement the medium-term meta-analytical models for long-term SOC, N, and P changes. Furthermore, the results of these models will be integrated into a DSS framework by means of multi-criteria analysis (MCA), since the selection of best management options is a multi-objective goal. The aim is to maximize agricultural intensification (e.g., fertilizer use efficiency, crop yield) and minimize negative environmental externalities (e.g., N and P losses to air and water), while relating (multiple) measures to (multiple) outcomes. Using the indicators mentioned as response variables, evaluation and weighting will be based on (1) various user goals (farmer, policy) and (2) the distance that current levels in the system are from target levels (crop yield, soil quality) or critical levels (N and P losses). Other impacts, such as soil compaction (by a meta-analytical approach) or heavy metals (by existing model algorithms), will be integrated as well.

MODELLING APPROACH AND RESULTS

The first set up of the DSS has been focused on (1) assessing the impacts of measures on soil organic carbon (SOC) content and crop yields by meta-analytical approaches and (2) related uptake and losses of N by process-based modelling. Furthermore, site factors such as local AEPs are included in both to assess their influence on each management-impact relationship. As an illustrative example of the meta-regression for yield and SOC, consider the following equation set-up:

ΔYield, SOC = ***a*****MP +* ***b*****soil properties +* ***c*****climate properties +* ***d*****crop type + interactions*

where: *MP = management practices; see Figure 1 for soil, climate, and crop properties. Coefficients are estimated by meta-regression.*

We currently quantify medium-term impacts on SOC (a minimum of 5 years). So far focus has been on the effects of soil management (tillage) practices on soil carbon inputs and SOC changes. Existing meta-analytical approaches in literature will be improved by assessing the influence of AEPs (e.g. initial SOC status) and their interactions, and by extending the model as a function of time. In a second meta-analytical study, we focus on short-term effect sizes of yield changes due to management using yield data for at least one season. From yield changes, changes in N uptake can be estimated based on a fixed N content of crop types, assuming no changes in those contents in response to the management measures. Based on additional data of N added to the soil, this gives an initial idea of NUE changes as a function of management as well as soil status. In later stages of the research, a meta-analytical approach can be taken to improve these estimations. Where relevant, results of similar meta-analytical studies related to SOC and yield changes in response to management practices will be included (e.g. Haddaway et al., 2017; Han et al., 2016; Hijbeek et al., 2017). Based on results of changes in nutrient uptake from the above-mentioned approaches, changes in N (and later P) balance (nutrient input minus nutrient uptake) will be assessed using the MITERRA/INTEGRATOR model approach (Velthof et al., 2009). Related losses to the environment will be estimated in response to predicted changes in N and P surplus. At the conference, results of (1) meta-analytical techniques for modelling SOC, crop yields, and nutrient uptake changes and (2) N losses will be presented.

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ORAL COMMUNICATIONS

THE "N" IN NEW COMMON AGRICULTURAL POLICY

Invited key-note given by:

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The Commission proposal for the Multiannual Financial Framework (MFF) for 2021-2027 (the MFF proposal)[2] sets the budgetary framework and main orientations for the Common Agricultural Policy (CAP). On this basis, the Commission presented on the 1 June 2018 a set of legal proposals for the CAP in the period 2021-2027, together with an impact assessment of alternative scenarios for the evolution of the policy.

The proposal delivers on the Commission's commitment to modernise and simplify the CAP, to provide genuine subsidiarity to Member States to better reflect their particular circumstances, to ensure a more resilient agricultural sector in Europe, and to increase the environmental and climate ambition of the CAP, including its contribution to climate action.

For the 2021-2027 period, the European Commission is proposing an ambitious total CAP budget of €365 billion (in current prices). Out of this amount for the CAP, €265.2 billion is for direct payments, €20 billion for market support measures (EAGF) and €78.8 billion is for rural development (EAFRD). An additional €10 billion will be available through the EU's Horizon Europe research programme to support specific research and innovation in food, agriculture, rural development and the bioeconomy.

Based on nine clear specific objectives, which reflect the economic, environmental and social pillars of the policy, the future CAP will continue to ensure high-quality food and strong support for the European farming model with an increased focus on the environment and climate, supporting the continued transition towards a more sustainable agricultural sector and the development of vibrant rural areas.

The future CAP will deliver more benefits for our citizens while significantly simplifying and modernising the way the policy works, both for farmers and for Member States. Rather than rules and compliance, the focus will shift to results and performance. Moving from a one-size-fits-all to a tailor-made approach means the policy will be closer to those who implement it on the ground. This approach will give far greater freedom to Member States to decide how best to meet the common objectives at the same time as responding to the specific needs of their farmers, rural communities and society at large, setting out how they plan to do so in a comprehensive CAP Strategic Plan.

Ensuring a high level of ambition with regard to climate, environment and biodiversity will be achieved in a variety of ways:

A new system of "conditionality" will link all farmers' income support (and other area- and animal-based payments) to the application of environment- and climate-friendly farming practices. Making support conditional on enhanced standards is an improvement on the existing rules in the current CAP. One of the elements will be the obligatory nutrient management tool.

A new system of so-called "eco-schemes", funded from national direct payment allocations, will be mandatory for Member States, although farmers will not be obliged to join them. These eco-schemes will have to address the CAP environment and climate objectives in ways that complement the other relevant tools available and go beyond what is already requested under the conditionality requirements. However, it will be up to each Member State to design them as they see fit. One example could be an eco-scheme to fund zero use of fertilisers in order to improve water quality. The payments involved could be offered either

[2] MFF proposal 2021-2027, http://ec.europa.eu/budget/mff/index2021-2027_en.cfm

as "top-ups" to farmers' direct payments, or as stand-alone schemes whose payment values are based on the extra costs and income losses involved for farmers.

Member States will be required to dedicate at least 30% of their rural development budget to environment and climate measures. Rural development funding will be used to support climate and environment-friendly actions, in particular so-called ‘agri-environment-climate commitments' which will again be mandatory for Member States to offer but voluntary for farmers. Rural development budgets can also be used to fund a range of other actions such as knowledge transfer, eco-friendly investments, innovation and co-operation. Such support could concern farmers, forest managers and other interested parties in rural areas.

In line with the Union's commitment to implement the Paris Agreement and the United Nations Sustainable Development Goals, actions under the CAP are expected to contribute 40 per cent of the overall CAP budget to climate action.

Knowledge and innovation are essential for a smart, resilient and sustainable agricultural sector. The main instrument supporting innovation under the new CAP will continue to be the European Innovation Partnership (EIP-AGRI), focusing on knowledge exchange and including advisory services, training, rural networks and pilot projects.

MODELLING NITROGEN FLOWS AND LOSSES ON DAIRY LIVESTOCK FARMS

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INTRODUCTION

The FarmAC model simulates the flow of carbon (C) and N on arable and livestock farms, enabling the quantification of GHG emissions, N losses to the environment and C sequestration in the soil. It was constructed as part of the EU project *AnimalChange*. It is intended to be applicable to a wide range of farming systems across the globe. The model is parameterised separately for each agro-climatic zone.

MATERIAL AND METHODS

A static livestock model is used in which the user defines the average annual number of dairy cows, heifers and calves on the farm and the feed ration (including grazed forage). Ruminant livestock production is modelled using a factorial energy accounting system. Protein supply limitations on production are simulated using an animal N balance approach. Losses of C in CO_2 and CH_4 are simulated using apparent feed digestibility and IPCC (2006) Tier 2 methods, respectively. Carbon and N in excreta are partitioned to grazed pasture in the same proportion as grazed DM contributes to total DM intake, with the remainder partitioned to the animal housing. Tier 2 methodologies are used for simulating flows in animal housing (CO_2 and NH_3), manure storage (CO_2, CH_4, N_2O, N_2 and NH_3) and fields (CO_2, CH_4, N_2O, N_2, NH_3 and NO_3^-). A dynamic model is used to simulate crop production and nutrient flows in the field. The dynamics of soil C are described using the C-Tool model (Taghizadeh-Toosi et al., 2014). A simple soil water model is used to simulate soil moisture content and drainage. Soil organic N degradation follows C degradation. Mineral N is not chemically speciated. The pool of mineral N is increased by the net mineralisation of organic N and by inputs of fertiliser and manure. It is depleted by leaching, denitrification and crop uptake. The N_2O emissions associated with the modelled NH_3 volatilisation and NO_3^- leaching were calculated using IPCC (2006). Crop production is determined by a potential production rate, moderated by N and water availability.

The model was used to simulate eight dairy farm scenarios within a factorial design consisting of two climates, and two feeding systems. Two climates (annual means Cool = 9.6 ˚C/757 mm precipitation, Warm = 14.3 ˚C/1268 mm), two soil types (Sandy, Clayey) and two production systems (Grass only, Grass & maize silage). Feed rations were adjusted to balance energy and protein demand and stocking rate was adjusted to match on-farm roughage production.

RESULTS AND DISCUSSION

The farm-scale N flows are shown in Table 1. The input of N in feed and fertiliser was higher for the Grass only than Grass & maize farms, due to the higher capacity of the grass to utilise N and the need to balance grass feed with imported grain products. This led to higher N flows and losses at the farm scale. The only effect of soil type was on NO_3^- leaching, where losses were higher from the Sandy scenarios than for the Clayey scenarios under both climates but the effect was twice as large under the Warm than the Wet climate.

Table 1 Summary of results for the different scenarios

Scenario*	CSG	CSM	CCG	CCM	WSG	WSM	WCG	WCM
Dairy cows (ha^{-1})	1.41	1.16	1.36	1.14	1.42	1.2	1.36	1.24
Maize area (%)	0	26	0	24	0	22	0	20
	N flows (kg N ha^{-1} yr^{-1})							
Imported feed + bedding	54	13	58	12	39	5	41	8
Atmospheric N	15	15	15	15	15	15	15	15
Fertiliser N	192	163	196	182	233	198	229	201
N sold in products	64	53	62	52	64	54	62	56
NH_3 housing	14	8	14	8	9	6	9	6
N_2 manure storage	2	1	2	1	1	1	1	1
N_2O manure storage	1	0	1	0	0	0	0	0
NH_3 manure storage	1	1	1	1	1	0	1	0
N_2 field	25	16	69	43	30	18	79	48
N_2O field	7	4	7	5	9	5	8	5
NH_3 fertiliser	4	3	4	4	5	4	5	4
NH_3 manure application	18	11	17	10	13	9	11	8
NH_3 grazing	3	3	3	3	7	6	6	6
NO_3^- field	85	69	57	56	132	102	80	74
Storage losses	24	19	22	19	12	11	13	11

* Cxx = Cool climate, Wxx = Warm climate, xSx = Sandy soil, xCx = Clayey soil, xxG = Grass only, xxM = Grass and maize.

CONCLUSION

On dairy cattle farms, changes in farm management, climate or soil have complex effects on N flows, due to the interactions between livestock, animal housing, manure storage and fields, and the feedback effects due to internal N cycling.

Acknowledgements: The model was developed using funding from the EU *AnimalChange* project (no 266018).

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SMARTAGRI: OPTIMIZATION OF ORGANIC AMENDMENTS APPLICATIONS

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INTRODUCTION

The promotion of more sustainable agricultural practices in France includes the improvement of organic amendment strategies, such as composts. Indeed, it is important to ensure the level of organic matter (OM) in the soil, which is essential for the functioning of its biogeochemical cycles. In addition, it is necessary to rationalize the use of non-renewable resources, such as synthetic fertilizers, for environmental and economic reasons. These concerns might be taken into account by recycling nutrients which will improve the soil quality while reducing the volume of waste and increasing carbon sequestration.

The use of organic waste products (OWP) meets these characteristics, enriching the soil in OM and contributing to crop fertilization. Nevertheless, it is essential to understand the OWPs characteristics and their behavior in soil in order to optimize the amendments while advising potential customers on new soil management strategies. To achieve this goal, an effort has to be done concerning (i) the fitting of simulation models in order to correctly predict carbon (C) and nutrients (N, P and K) dynamics in soil and resulting crop yields; (ii) the optimization of compost doses and spreading schedule to maximize the agricultural benefits (financial and soil sustainability gains).

MATERIAL AND METHODS

The solution is developed as an online decision support tool on a tablet. The decision tool is composed of a simulation model which allows the evaluation of envisaged agricultural practices and an optimization algorithm, that completes the decision-making process, by proposing a land application schedule and product doses which search for the optimal compromise between crop yield, operational cost and nutrient requirements. To initialize the decision-support tool, a soil diagnostic characterizing the initial state has to be performed.

The simulation model

The Century simulation model (Parton et al., 1987) allows the prediction of the atmosphere-plant-soil system while considering the dynamics of nutrients under different pedo-climatic and agricultural scenarios. A modified version of Century simulates, besides C, N and P in soil and plant yields, the input of different types of composts and the dynamics of K.

The optimization tool

The optimization problem addressed by the decision support tool, modeled and solved by LocalSolver (Gardi et al., 2014), aims to define the monthly application schedule of mineral fertilizers and organic amendments, as well as the types and quantities of each product. The solution proposed searches for the optimal calculated profit for the whole time-horizon, composed as follows: i.) the total cost of compost and fertilizer, ii.) the total economical yield-related gains of crops and iii.) the respect of certain constraints, e.g. the target level of C and N in the soil, regulation constraints regarding the maximum land application quantity of certain nutrients and trace elements. The dependence between the objectives and the simulation model leads to a complex optimization problem which has to be solved in relative short time for decision-making purposes.

RESULTS AND DISCUSSION

The tool is developed for the French agricultural context and mainly for field crops. Databases were created for weather and soil departmental characteristics, regulatory aspects, crops requirements, price and characteristics of mineral fertilizers and organic amendments and different levels of soil cultivations. Other information needed to run the decision-support tool is gathered from interviews with the farmers and from the soil initial diagnostic.

In order to adapt the simulation model to French pedoclimates, a calibration was performed and validated with 3 French long-term experiments with different soil and crop managements, comparing measurement data and model predictions. The mean percentage error of the validation step, for C and N predictions, are around 14% and 11% respectively.

In order to analyze the accuracy of the optimization tool, two real scenarios of field crops rotation and management were evaluated for 10 years. These scenarios were proposed by agricultural experts and were first simulated with their amendments schedule proposition. The results of the simulations were then compared to the solutions proposed by the optimization tool after 10 minutes of CPU time calculation. In all solutions proposed by the optimization tool the soil OM increases over the evaluated period by at least 4%, regarding the soil initial state. This increase is less significant (0.2% in some case), or even inexistent (around -4% as in Figure 1), when considering the schedules proposed by the experts. In the same way, the concentration of total N and mineral P are increased by the optimized solution in some cases by 50% and 200% respectively, whereas in the best case of the experts' scenarios these are increased, respectively, by 20% and 180%. Both simulated and optimized results were validated jointly with the experts.

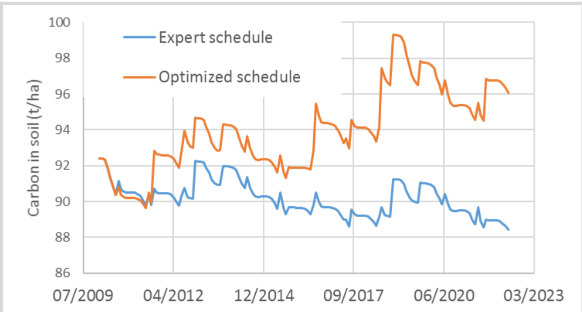

Figure 1. Expert simulation vs. optimization results comparison for a real French scenario.

CONCLUSION

Coupling a simulation and an optimization approach in a decision support tool allows to better advise compost users on new management strategies. The development and use of different databases combined with a calibration and validation approach lead to a reliable use of the tool. Future work includes a sensitivity analysis and more powerful calibration of the simulation model to decrease the prediction uncertainty. Also, the coupling between different optimization methods would allow to decrease the computational budget spent during optimization and to increase the solution quality.

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MANNER-*NPK* NITROGEN MODEL

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INTRODUCTION

MANNER-*NPK* is a software decision support tool for calculating crop available nutrient supply from applications of organic materials to land. The tool addresses factors affecting crop available nitrogen supply from organic materials (i.e. nitrate leaching, ammonia volatilization, denitrification and mineralization). The MANNER-*NPK* outputs are based on algorithms developed from an extensive programme of national research experiments. The outputs have been validated against independently collected field experimental data (Nicholson *et al.,* 2013).

MATERIALS AND METHODS

The MANNER-*NPK* nitrogen model includes algorithms for calculating nitrogen transformation and loss pathways. Each algorithm takes into account the main factors affecting the transformation and loss pathways.

Ammonia volatilisation

Ammonia volatilisation losses are estimated based on the organic manure ammonium-N content (plus uric-acid N for poultry manure) and the following factors:

- *Application technique*: 'precision' slurry application techniques (i.e. bandspreading and shallow injection) reduce ammonia emissions following land spreading.
- *Method of soil incorporation*: soil incorporation reduces ammonia emissions with the greatest reduction from incorporation methods that achieve the greatest degree of mixing with the soil.
- *Delay to soil incorporation*: nitrogen losses via ammonia volatilisation occur rapidly following organic manure application. Standard ammonia emission curves for different organic manure types are used to calculate of ammonia loss up to the time of soil incorporation.
- *Topsoil moisture*: ammonia emissions following slurry application to 'dry' soils in summer are generally higher than from 'moist' soils, due to a combination of the hydrophobic effect of dry soils on slurry infiltration and also higher temperature/lower humidity conditions in the summer.
- *Land use*: ammonia emissions following slurry application to grassland soils are generally higher than from arable soils, as the grass crop provides a greater emitting surface area and grassland commonly has a compacted layer at the soil surface which reduces the slurry infiltration rate.
- *Windspeed at application*: ammonia emissions increase with windspeed at application.
- *Rainfall following application*: rainfall events soon after slurry application reduce ammonia losses as slurry is washed into the soil.

Nitrate leaching

MANNER-*NPK* estimates the amount of nitrogen that is leached below the crop root zone (>90cm), taking into account the readily available organic manure nitrogen remaining following ammonia volatilisation losses and after any autumn manure crop nitrogen uptake. MANNER-*NPK* estimates drainage volumes and nitrate leaching losses based on postcode specific climate data, and takes into account the volumetric moisture content of the soil (based on topsoil and subsoil texture).

Denitrification

MANNER-*NPK* estimates the amount of nitrous oxide (N_2O)-N lost through a combination of nitrification and denitrification processes, using an emission factor of *c*.2% of the readily available N remaining after ammonia volatilisation losses.

Mineralisation of organic nitrogen

The MANNER-*NPK* mineralisation algorithms are based on the results from UK Defra funded research (Bhogal *et al.,* 2016) and take into account soil temperature (thermal time) and nitrogen mineralisation differences between 'fast' (i.e. pig slurry and poultry manures) and 'slow' (i.e. FYM and cattle slurry) organic nitrogen release manure types.

Crop available nitrogen

The crop available nitrogen is the amount of available nitrogen remaining for crop uptake after losses from ammonia volatilisation, nitrate leaching and denitrification, and nitrogen mineralisation have been accounted for. MANNER-*NPK* also estimates the nitrogen available to a subsequent crop from nitrogen mineralisation, using relationships between organic N release and thermal time after application.

RESULTS AND DISCUSSION

Validation of crop available nitrogen predictions was undertaken using data from more than 200 field experimental studies where livestock manure fertiliser nitrogen replacement values had been quantified. Validation showed that relationships between predicted and measured fertiliser nitrogen replacement values were highly significant ($P<0.001$) and the slope of the line was not significantly different from 1.0, indicating that MANNER-*NPK* predictions were robust (Nicholson *et al*. 2013).

The MANNER-*NPK* tool is well known and widely used in the UK. The tool is free to users and there are currently *c.*4000 registered users of the standalone MANNER-*NPK* tool. In addition the MANNER-*NPK* calculations have been integrated into a number of other nutrient management software tools and also form the basis of written guidance on nutrient supply from organic materials

Acknowledgements: MANNER-*NPK* has been developed by ADAS and Rothamsted Research North Wyke, with funding and support from AHDB, CSF, DARD, Defra, Environment Agency, Natural England, Scottish Government, Tried and Tested and WRAP for use throughout the UK.

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CADASTRE_NH_3: A NEW FRAMEWORK TO ESTIMATE SPATIO-TEMPORAL AMMONIA EMISSIONS AFTER N FERTILIZATION IN FRANCE

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INTRODUCTION

Ammonia emission from crops is a major international environmental and sanitary issue. Above all it represents a major loss of nitrogen use efficiency of mineral and organic fertilisers. This loss needs to be reduced by appropriate agricultural practices. However, ammonia volatilization is a surface process which intensity and duration depend on agricultural and environmental conditions. The variability of the conditions encountered in French agricultural practices makes the quantification of emissions difficult and the effectiveness assessment of abatement techniques even more difficult.

The lack of reliable tool able to assess the effects of the main environmental and management conditions on ammonia emissions has been stressed out. It prevents to test scenarios of agricultural practices and/or climate changes. The framework CADASTRE_NH_3 aims at producing a realistic representation of French conditions for N-fertilization. Its originality relies on the combined use of two types of resources: the process-based Volt'Air model and geo-referenced and temporally explicit databases (see details in Ramanantenasoa et al. (in review)).

MATERIAL AND METHODS

Volt'Air is a process-based 1D model predicting NH_3 emissions from N fertilisers on bare soils, from physical, chemical and biological processes. It takes into account the influence of soil, meteorological and agricultural variables and runs at an hourly time step at the field scale for a period of several weeks (Garcia *et al.* 2012). It explicitly accounts for volatilization-related parameters for the type and dose of N-fertiliser applied (physicochemical properties) and the application method and/or abatement technique (continuous or discontinuous surface application, narrow band application, shallow or deep injection, incorporation, etc.). Areas of each surveyed crop are derived from the European Land Parcel Identification System (LPIS) built within the framework of the Common Agricultural Policy (CAP) regulations and delivered by the *Observatoire du Développement Rural* (ODR) service unit. Spatial weather conditions, generated by the *Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige* (SAFRAN) model are delivered by *Météo-France* for each year, on 8 km mesh grid. Soil spatial distribution is provided by the European Soil Data Center (ESDC) and soil properties by the Harmonized World Soil Database (HWSD) of the Food and Agriculture Organization (FAO). N fertilisation management data come from national survey of cultural practices for arable crops and grassland, conducted by the Department of Statistics and Forecasting of the French Ministry of Agriculture, available every 5 years on average, for 13 main crops and 21 regions (NUTS2). Statistical calculations carried out following Mignolet et al. (2007) allows a realistic representation of the French fertilisation practices for real crop-years at the regional scale. They are expressed as the distribution of the N applications (fragmentation, periods of application and types of mineral fertiliser and organic products) and the N dose for each fertilisation. Additional national statistics on deliveries of mineral fertilisers provided by Union des Industries de la Fertilisation (UNIFA) may also be used. French expertise allows the specific description of the physicochemical properties for each type of organic fertiliser applied (see Dufosse et al., this Workshop).

Simulation units (SU) are determined using a Geographical Information System, as the intersection of departments (NUTS3) and homogenous agricultural region (AR), thus creating 713 SU. The local features described above are attributed to each SU.

RESULTS AND DISCUSSION

Practical applications of this new framework are yet available for France for crop years 2005-06 and 2010-11. A set of about 80 000 situations are available for each crop-year (see Dufosse, this workshop): they can be considered as representing the realistic combinations of the main factors known to influence ammonia volatilization encountered in French agricultural conditions. CADASTRE_NH_3 accounts for both the spatial and temporal variabilities of both N fertiliser use and NH_3 emission rate.

(a) (b)

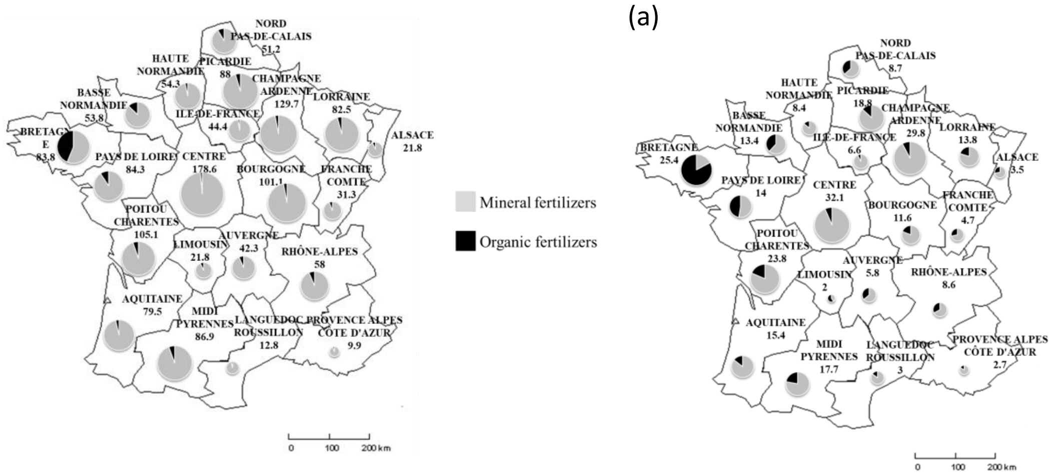

Figure 1. Regional distributions of (a) N fertiliser use (kt ammoniacal-N) and NH_3 emissions (kt NH_3) in France estimated using CADASTRE_NH_3 for the crop-year 2005-06

CONCLUSION

One of the most valuable interests of the CADASTRE_NH_3 framework for decision making relies on the fact that it does not use mean data estimated from a general knowledge of fertilization practices in France. Indeed, real cultural practices data on specific crop years are used: specific fertiliser application practices which are coherent with specific weather conditions encountered during the crop year described. Robust prospective studies can thus be undertaken to evaluate the effect of the implementation of policies aiming at mitigating ammonia emissions (e.g. Gothenburg Protocol, 1999). This tool is also being used to generate simple ammonia volatilization response curves for inclusion in N fertilization decision support models.

Acknowledgements

This work was conducted within the CADASTRE_NH_3 (Spatial and temporal high-resolution inventory of ammonia emissions from agricultural soils over France at regional and national scales, agreement n°1081C0031) project, supported by ADEME. It was supported by a public grant overseen by ANR as part of the «Investissements d'avenir» program (reference: ANR-10-EQPX-17 – Centre d'accès sécurisé aux données – CASD).

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A DECISION SUPPORT FRAMEWORK FOR THE INTEGRATED EVALUATION OF AGRICULTURAL MANAGEMENT IMPACTS ON CROP YIELD, SOIL QUALITY AND ENVIRONMENT

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INTRODUCTION

Current agricultural management practices significantly affect crop growth and environmental quality in varying ways based on local agro-ecosystem properties. Integrated and optimal combinations of farm management are needed for agriculture to intensify sustainably. We develop a decision support system (DSS) to evaluate the overall benefits and trade-offs that management has on crop yield, soil quality and environment, using indicators for soil organic carbon (SOC), phosphorus and nitrogen cycles. The DSS integrates a range of soil, crop, and nutrient management practices along with an assessment of the influence of local agro-ecosystem properties (AEPs).

TOOL DESCRIPTION

At the current stage, an initial model framework is developed into a prototype, consisting of: (1) management and AEP input data, (2) model calculations, and (3) output of changes in response variables (Figure 1). Empirical relationships between management and impacts on crop yield, nitrogen use efficiency (NUE), and SOC changes are assessed using meta-analysis. Process-based modelling estimates changes in nutrient losses to air and water.

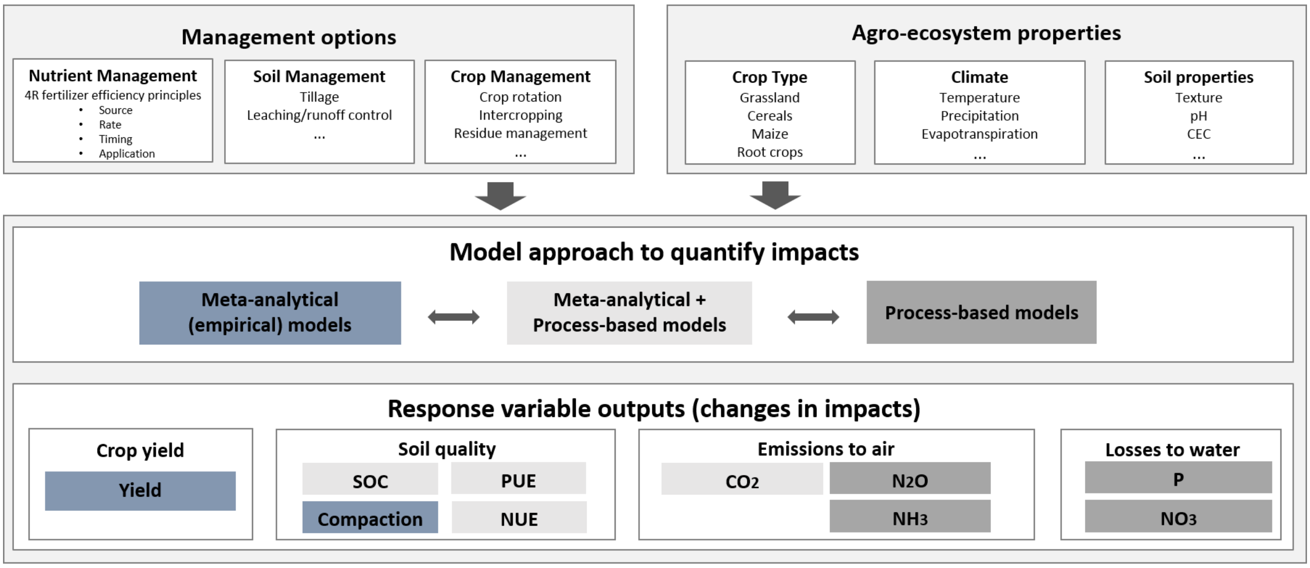

Figure 1. Conceptual overview of DSS (SOC = soil organic carbon; NUE = nitrogen use efficiency; PUE = phosphorus use efficiency)

At a later stage, phosphorous use efficiency (PUE) or soil P status will be integrated, and process-based models can supplement the medium-term meta-analytical models for long-term SOC, N, and P changes. Furthermore, the results of these models will be integrated into a DSS framework by means of multi-criteria analysis (MCA), since the selection of best management options is a multi-objective goal. The aim is to maximize agricultural intensification (e.g., fertilizer use efficiency, crop yield) and minimize negative environmental externalities (e.g., N and P losses to air and water), while relating (multiple) measures to (multiple) outcomes. Using the indicators mentioned as response variables, evaluation and weighting will be based on (1) various user goals (farmer, policy) and (2) the distance that current levels in the system are from target levels (crop yield, soil quality) or critical levels (N and P losses). Other impacts, such as soil compaction (by a meta-analytical approach) or heavy metals (by existing model algorithms), will be integrated as well.

MODELLING APPROACH AND RESULTS

The first set up of the DSS has been focused on (1) assessing the impacts of measures on soil organic carbon (SOC) content and crop yields by meta-analytical approaches and (2) related uptake and losses of N by process-based modelling. Furthermore, site factors such as local AEPs are included in both to assess their influence on each management-impact relationship. As an illustrative example of the meta-regression for yield and SOC, consider the following equation set-up:

ΔYield, SOC = ***a*****MP +* ***b*****soil properties +* ***c*****climate properties +* ***d*****crop type + interactions*

where: MP = management practices; see Figure 1 for soil, climate, and crop properties. Coefficients are estimated by meta-regression.

We currently quantify medium-term impacts on SOC (a minimum of 5 years). So far focus has been on the effects of soil management (tillage) practices on soil carbon inputs and SOC changes. Existing meta-analytical approaches in literature will be improved by assessing the influence of AEPs (e.g. initial SOC status) and their interactions, and by extending the model as a function of time. In a second meta-analytical study, we focus on short-term effect sizes of yield changes due to management using yield data for at least one season. From yield changes, changes in N uptake can be estimated based on a fixed N content of crop types, assuming no changes in those contents in response to the management measures. Based on additional data of N added to the soil, this gives an initial idea of NUE changes as a function of management as well as soil status. In later stages of the research, a meta-analytical approach can be taken to improve these estimations. Where relevant, results of similar meta-analytical studies related to SOC and yield changes in response to management practices will be included (e.g. Haddaway et al., 2017; Han et al., 2016; Hijbeek et al., 2017). Based on results of changes in nutrient uptake from the above-mentioned approaches, changes in N (and later P) balance (nutrient input minus nutrient uptake) will be assessed using the MITERRA/INTEGRATOR model approach (Velthof et al., 2009). Related losses to the environment will be estimated in response to predicted changes in N and P surplus. At the conference, results of (1) meta-analytical techniques for modelling SOC, crop yields, and nutrient uptake changes and (2) N losses will be presented.

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