EIP-AGRI Focus Group - Nutrient recycling

Mini-paper - On Farm Tools for accurate fertilisation

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1. Introduction

Accurate fertilisation, taking into account the crop needs and the environmental aspects (legal limits), is only possible if the farmer has exact information on the composition and nutrient efficiency of the fertiliser, has a site-specific soil analysis, and can apply the fertiliser with the correct application technique to its field.

This mini-paper tries to give an answer on the following questions:

1. How can farmers be supported to obtain improved information on fertilisers composition/efficiency?
2. How can the fertilisers composition/efficiency be linked to the soil characteristics and conditions?
3. How can farmers be supported to improve the management of the nutrients and organic matter available on the farm?
4. Which techniques can be used to obtain a correct and site-specific application of fertilisers on the field, according to the crop needs?

The objective of this mini-paper is to have an overview of available methodologies/protocols/instruments to obtain an accurate fertilisation on the farm, and to identify the research needs and the need for technological innovations, dissemination, or other.

2. Improving information on composition of fertilisers: analysis systems and tools

The composition of animal manure can vary significantly. This variation is influenced by different factors such as type of manure (animal species, feeding i.e. N- and P-adaptation, water management in the stable, storage time, housing system), differences between farms and even within the same storage container. Transportation of the manure products can also cause segregation.

It is still regarded as good agricultural practice (DüV, 2006, 2015) to use standard values (N- and P-excretion), deduced for standard animal categories for standard feeding regimes (DLG, 2014), calculated for a standard dry matter content (Horlacher et al., 2014; DüV, 2015). An example of a web-application to calculate the amount and nutrient concentration of livestock manure, depending on various factors is available under http://daten.ktbl.de/wdrechnerdemo/home.action. This approach may be justified by high costs of laboratory analysis, the waiting time until results from the laboratory are delivered, and above all, high analytical tolerances, as it must be taken into account that the (total) tolerance includes the procedural error margins of the chemical analysis, the previous sampling and the sample preparation. Anyhow, as breeding methods (feeding, shedding) differ and there are increasing requirements to improve the precision of fertilizer application in order to minimise surplus, tools to better quantify slurry nutrient content and to improve the precision of slurry allocation within a nutrient management significantly gain importance. These tools can be distinguished between those, which are used on farm and those applied on field.

Tools to estimate nutrient content of manure

Obtaining a representative sample of slurry without complete agitation of the tank is a problem, due to stratification of slurry in storage and formation of a crust on the surface. Slurry agitation is usually carried out immediately prior to land spreading and this means that laboratory results are usually not available in time for spreading.

Sampling methods

The use of a "tube sampler" (Berry et al., 2012) method to collect a representative sample prior to agitation of slurry was shown to produce a sample which was not significantly different than the use of a bucket and rope method post-agitation. Use of this method is a way for samples to be collected prior to agitation so that laboratory analysis of nutrient content can be conducted in time.

Figure 1: 'tube sampler' method

A brochure (in german) gives detailed information on sampling methods and shows, how to assess slurry quantity in storage (Bohnenkemper und Steffens, 2006).

A different approach to estimate nutrient and volume of manure produced at the farm can be based on the monitoring of the main production parameters and calculating a dynamic nutrient and volume balance. The usual recordkeeping of number of heads, feeding and water consumption integrated with simple modelling about emissions and evaporation can produce a good prediction of the amount of nutrients in the storage tank. The installation of level sensors in the slurry tank helps in reducing the errors.

In Italy a software application has been developed and tested for pig and dairy farm in Italy (see http://www.agricoltura.regione.lombardia.it/shared/ccurl/678/770/969_simazoo_Lisbona_%202010.pdf).

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This tool can be used effectively in commercial farms to assess the actual manure production and thereby improve manure and nutrient management.

On site measurement of fertiliser composition

On site estimation/measurement of the nutrient concentration of manure is possible with a range of different commercial tools.

<u>Slurry hydrometer</u>

With the slurry hydrometer, dry matter concentration of slurry can be determined just before application. Standard table values (Horlacher et al., 2014; DLG, 2014) (example annex I) can be adjusted to this measured dry matter content using the rule of three.

Figure 2: Slurry hydrometer

Dry matter content of slurry in Ireland has been shown to be positively and strongly correlated with N, P and K concentrations in slurries (Martínez-Suller *et al.*, 2010) and with the dry matter content estimated by the slurry hydrometer (Lalor, 2012). In contrast, Kessel and Reeves (2000) reported that the hydrometer did not estimate total N accurately (r^2 = 0.39). So although there is a positive correlation between dry matter content and N content, the accuracy of the relationship can be variable. The advantage is that farmers might actually use it if it can provide some useful information in certain circumstances. Measurements of farmer perceptions also indicated that the slurry hydrometer is a tool they would be likely to purchase (Lalor, 2012).

<u>Ammonium N-meter</u>

Measurements of the readily available ammonium nitrogen levels in slurries, manures or other bio-based fertilisers are important for estimation of readily plant available N applied. These measurements are particularly useful where low ammonia emission spreading techniques are used because much of the variability in the N retained for plant growth following application is removed. For estimation of the fertiliser value, the value can be limited, because the organic N-content is not known, although the ammonium level will already be a good indicator of plant available N. Nevertheless, there is a more or less constant ratio between organic N and ammonium N content for each type of animal slurry.

- Agros Nova meter

  The Agros Nova Mk3 ammonium meter uses hypochlorite to oxidise ammonium; N_2 gas is produced creating pressure which is measured providing an indirect measure of the ammonium in slurry (van Kessel et al., 1999). Kessel et al. (2000) found that the Agros N meter readings from dairy slurries were well correlated with slurry ammonium content (r^2 = 0.92).

- Quatofix N Volumeter

  Like the Agros Nova meter the principle of a reaction between ammonium and hypochlorite is used. The reagent used is a liquid mixture of sodium hypochlorite and sodium hydroxide. The meter is

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calibrated to read off in kg ammonium per cubic meter of slurry. Kessel et al. (2000) found the Quantofix N volumeter readings from dairy slurries were well correlated with slurry ammonium content (r^2 = 0.97).

Analysis of Electrical Conductivity
Electrical conductivity (EC) could be used as an indirect measurement of the nutrient content of slurry. EC has been shown to be correlated to the content of the soluble nutrients (nitrogen and potassium) present in liquid manure (with R^2> 0.6), but not to other elements such as phosphorus, which are mainly linked to the solid fraction and do not affect significantly the electrical properties of manures (Provolo and Martínez-Suller, 2007; Parera et al., 2010a, 2010b).

A correlation (usually linear) between EC and total nitrogen (TN), ammonia nitrogen ($N\text{-}NH_4^+$), and potassium (K_2O) should be performed for each typology of animal, manure management, feed, etc.

EC can be measured manually taking a sample, automatically during the loading of the tank or before spreading when the EC device is installed in the tank. Examples of companies that offer the EC-device (to be installed in the tank):

- Krohne: Optitsys IND 8100
- Endress Hauser: Mod Indumax CLS 50/CLS50D
- Emerson: Mod. 228
- Hamilton: Mod. 4USF Arc 120
- Metler Toledo: InPRo 7250HT PFA

Integrated solutions to optimize the dose of slurry include the following devices that should be installed in the tank: EC sensor, temperature probe, flow meter, automatic valves, level measurer and GPS. Example of company offering the integrated system: 'Dosicontrol' of Gili Group (http://giligroup.com/dosicontrol-innovation-special-prize-in-the-feria-san-jose-san-jose-trade-fair-of-mollerusa-2016/?lang=en).

In Catalonia (North-East of Spain), EC measurement is accepted as a technique to estimate N- and K-content of slurry. The Agricultural Ministry provides default correlation lines (https://www.ruralcat.net/web/guest/oficina-de-fertilitzacio/oficina/eines), but construction of own correlation line is encouraged to better adjust estimates.

NIRS-technology
The NIRS-technology (near infrared spectroscopy) makes it possible to measure 'in real time' quantity and qualitative composition (N, P, K, DM) of liquid or solid manure/digestate by use of a sensor. The system works by the reflection of light. During the loading/unloading of the tank, the manure passes the sensor which sends out light beams. The amount of reflected light is translated into contributions and contents of different components. The reflection is translated in a spectrometer into a useful value, which can be transferred in the PC into a content value.

Measurement can be executed when loading the transporter/spreader (i.e. Zunhammer, Vlastuin-Groep, Veenhuis, Eijkelkamp) or when spreading liquid manure (i.e. John Deere).

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Figure 3: Output manure composition by measurement with NIRS-sensor (source: VCM, 2015)

Today the NIRS-system is applied on liquid manure fertilisers. This system could also be used for mixing of different manure types with different composition, according to the crop needs.

In the Netherlands a project is currently running to see whether this NIRS-system can be used as recognised analysis system. In this way, the NIRS-system could replace the lab-analyses. The cost for the NIR-system on the slurry tank (without RTK-GPS) would be around €25.000-30.000.

Examples of producer of NIRS-analysis-device:

- m-u-t GmbH, https://www.mut-gmbh.de/en/agricultural-industry/nir-analysis

Examples of companies that offer the NIRS-technology:

- Veenhuis, www.veenhuis.com
- John Deere, https://www.deere.com/en_INT/products/equipment/agricultural_management_solutions/precision_farming_solutions/manure_sensing/manure_sensing.page
- Zunhammer, http://www.zunhammer.de/de/produkte/elektronik/van-control

Example of companies/organisations offering calibrations for NIRS-spectrometers and thus contributing to quality assurance:

- VDLUFA Qualitätssicherung NIRS GmbH: http://www.vdlufa-nirs.de/cms/index.php?page=the-company
- Ondalys: http://ondalys.fr/
- AUNIR: http://www.aunir.co.uk/
- CRA-W: http://www.cra.wallonie.be
- IRSTEA: http://www.irstea.fr/

3. Soil scan for site-specific fertilisation

Information on the soil is also needed to perform a site-specific and correct fertilisation. Within one field, differences can occur in f.e. hydraulic conditions, acidity and soil fertility. A soil scan can give a good view on the soil condition in order to adapt the fertilisation site-specific.

Some parameters that can be mapped currently by using a soil scan are the conductivity (EC), pH and the content of organic matter. This is a good basis for estimation of the local texture and cation-exchange capacity

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(CEC). Although, to have information on the amount of available nutrients, this needs to be combined with sampling and laboratory analyses to estimate the fertilisation needs.

The location of every point measurement can be exactly fixed by the RKT-GPS system (see chapter 5) of which the scanner is equipped. The measurements are calibrated by use of soil samples which are analysed in the lab. Eventually a map can be set up for each fixed parameter. This will serve as a basis for site specific advice, which can be read in the form of a task card into GPS-controlled machinery.

Different types of soil scans are available. Today the most used models are the MSP3 (Veris) and the EM38 (Geonics). The first can determine the described parameters, the latter is limited to determination of the conductivity (Dekeyser *et. al.*, 2016).

Figure 4: Soil scanner with 'Verisscanner'

The GeoBas Moisture sensor measures the moisture in the soil and the suction tension on different depths. By using an app or webtool, the farmers can see the results and get a warning if the soil needs irrigation (according to the soil type and crop).

Similar tools as tensiometer or moisture sensor (for example Sentek sensors) are used to monitor the water state in the soil and to manage irrigation.

Figure 5: monitoring of water state in soil (© Jean-Philippe Bernard, Chambre d'agriculture, FR)

Other hand tools can be used on the field to assess the nutritional status of crops: from the plant's sap, it's possible to measure the level of nitrogen content with a reflectometer or with test strips - Jubil® method with Nitracheck or RQflex system. Other examples are SPAD (Minolta), N-tester (Yara), Greenseeker, etc.

In Sweden as well as Denmark (CropSat project) the farmers are offered a free application, where they can get a satellite picture of every field plot. The picture shows spatial variations in the amount of chlorophyll and the amount of plant biomass. The obtained data is equal to the data provided by near-sensing, for example Greenseeker (Geotrim), N-sensor (Yara), OptRx (Agleader) or Isaria (Fritzmeier). For the farmer it is then possible to adjust the use of fertilisers or other inputs using the information. By the use of scanning the soil or near-sensing, larger homogeneous zones could be delineated within one field. Based on these zones, soil samples can be taken, that represent different soil types and growing conditions in the field. Link to the tools:

- http://vegetationsindex.datavaxt.se/
- http://cropsat.dk/

Examples of companies who offer soil scans:

- Agrometius: http://www.agrometius.nl/
- Van Den Borne Aardappelen: http://www.vandenborneaardappelen.com/

4. Tools for nutrient management at the farm

Nutrient management planning

Basing organic and inorganic fertiliser application rates on a calculated nutrient balance (fertilisation advice) can considerably improve nutrient efficiency and therefore reduce their losses. More effective nutrient management plans (considering additional factors in the nutrient balance) can be devised beyond the basic requirements of the Nitrates Action Programme for manure utilisation. Specific tools (e.g. software and advice based on soil analysis) to match the amount of nutrients applied to the conditions of the land (soil type, crop demand, and remaining nutrients) are available and often used by advisory services.

These tools are generally based on crop nutrient requirements for the desired yield under the given environmental circumstances. Some of these tools account for the nutrient content of organic fertilisers and establish the ratio to mineral fertilisers to fully satisfy crop needs, and consider the time lapse between the application and the assimilation of nutrients by crops.

The used approach generally considers soil analysis, but in some cases, when specific data are not available, takes into account only crop requirements.

One key aspect of the nutrient planning is the determination of the nutrient efficiency (especially nitrogen) that can vary according to the soil type, weather condition, application rate, application techniques, characteristics of the organic and mineral fertilisers used.

The reasons of the limited efficiency in the use of fertilisers can vary from situation to situation but some general causes can be highlighted:

- uncertainty of the nutrient content of organic fertilisers;
- limited knowledge of nutrient availability after application;
- limited awareness of the cost-benefit of a better nutrient planning;
- great number of information required for detailed planning at field level;
- lack of technical assistance to farmers.

Relevant projects in practice

- In Flanders, farmers have access to an online tool to recalculate the fertilisation advice, based on their soil analysis, into the amount of fertilisers to be applied. So the fertilisation advice, expressed in units of nutrients, can be translated into amounts of different organic fertiliser products. The farmer can choose from a diverse list of organic fertilisers (also products produced by the manure processing plants in Flanders) and the most current mineral fertilisers; in this way the fertilisation advice can be translated into a combination of different fertilising products that the farmer wants to use.
  Link to the tool: http://rekenmee.bdb.be/pls/apex/f?p=1000:1:1862729657817691

- In Flanders a fertilisation model has been developed within the project ('ECOFERT II') (http://www.proefstation.be/project/iwt-ecofert-ii-just-on-time-n-bemesting-in-vollegrondsgroenteteelt).
  The aim of the project was to convert the static approach of fertiliser advices into a more dynamic approach, where the field specific parameters like the history, growth performance, mineralisation, root spreading, precipitation and temperature are taken into account. This model is applicable for the main vegetable crops (leek, cauliflower, celery, fennel, headed cabbage, lettuce and spinach). This is a well-founded model (web-tool), which can simulate the nitrogen concentration in the soil and crop uptake. This results in a more founded advice, with an increased chance to obtain a lower residual nitrate content. Only, today this is barely used by farmers because it is perceived as too complex.

- In the Netherlands, a tool for independent fertilisation advice is available: http://www.bemestingsadvies.nl/. The tool is specified for fertilisation of grassland, maize, grains for whole-crop-silage, fodder beets and lucerne. Per type of crop, general advice on every different nutrient (macro- and micronutrients, lime) is given. Also information on the fertilisation plan is given: soil sampling, sampling of manure, calculation of lime to be added, average content of different organic fertilisers, etc. All information is frequently updated, so all new advice is readily available for the farmers.

- In Catalonia (Spain) a tool for fertilization advise has been developed and tested in the LIFE project 'Futur Agrari ' (LIFE12 ENV/ES/000647) (http://www.futuragrari.cat/16/). Action B3 'Computer tools' aims to develop and test the FertiNext tool to make fertilization recommendations including organic and mineral fertilizer in extensive crops. The tool is based on the use of the nitrogen balance, and it could work with defect values or include analytical data of the soil, irrigation water, manure, etc. (http://www.futuragrari.cat/16/b3_computer_tools_626996.html).

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- There are also commercial tools available, f.e. 'Bemestingswijzer' of Eurofins Agro (NL): http://blgg.agroxpertus.nl/product/bemesting/bemestingswijzer-bouwland
'Bemestingswijzer' offers a soilscan, measuring the organic matter that needs to be added to the soil, giving insight in the Ca-K-Mg ratio, etc. These results are then compared to the agricultural land in the close region. Based on the soilscan, a fertilisation advice is given.

- Assessment of the nutrient cycles on a specific dairy farm can be carried out with the ANCA model (Annual Nutrient Cycle Assessment). This Dutch tool provides insight in the mineral cycles on the farm, resulting in a score for excretion of N and P, surpluses of N and P, mineral use and ammonia emissions. See: http://webapplicaties.wur.nl/software/kringloopwijzer

  The flow model ANCA was constructed to provide indicator values for the utilisation of feeds and fertilisers, including manures, and for losses of harmful products. Reference and normative values are presented as comparisons. Reference values are the average values, as chieved by a group of farms under more or less similar. conditions. Normative values are limits given by national legislation. With the farm specific values of the performance indicators, dairy farmers can justify their farm management towards authorities and the milk processing industry (Aerts et al., 2015).

- In France, the network of Chambers of agriculture broadcasts a web tool to manage farming registrations - as a logbook: "Mes P@rcelles" - http://www.mesparcelles.fr/. This tool contains a fertilization reasoning module, which uses the regional rule sets for the balance of nitrogen fertilization - example of rule set for the old region Poitou-Charnets: http://www.poitou-charentes.developpement-durable.gouv.fr/referentiel-regional-pour-l-equilibre-de-la-r1285.html.

5. Role of precision farming and remote sensing in nutrient balance

In order to obtain a high yield as well as a low environmental impact, it is necessary to give the crop the exact fertilisation it needs and at the exact time it is needed. This can be obtained by a reasoned organic fertilisation with a fertiliser with known composition, based on a site-specific soil analysis and a correct application technique. This can be obtained by 'precision farming'.

Uniform application of fertilisers by GPS-system

In order to have a correct and uniform dose of organic fertilisers, according to the crop needs, a GPS navigation system can be used.

A slurry injector has a fixed working width, where underlap and overlap needs to be avoided. In the case of muck spreaders, a fixed distance between the tracks, which depends on the product to be spread, is very important to have a homogeneous spreading. For both machinery, a GPS navigation system can offer a solution.

The choice can be made for a steering aid which indicated the track, or an automatic steering system which following the track autonomous.

Next to that, the accuracy of the GPS-system is of importance. For the spreading of organic fertilisers a D-GPS (EGNOS correction signal) with an accuracy of 20 cm is sufficient. This system would still be affordable for the farmer.

A possible extension is the choice for an automatic section closure, to avoid overlap. Because of the very precise positioning of the machine, it is possible to close certain sections of the machine in case of overlap.

Closure of sections by GPS is always more accurate than the human eye. Therefore the GPS system can save up to 10% of fertiliser. This technique is already used on sprayers, and would also be possible for centrifugal spreaders and slurry spreaders.

Correct application of fertilisers by NIRS-system

With the NIRS-system (see chapter 4) the farmer can also choose how much nitrogen (or another nutrient) he wants to apply per hectare, instead of the cubic volumes (=precision farming). The dosage system regulates automatically the dosage on the spreader. Different constructors are working on a system that is ready for practice. In this way, the potential of the nutrients in manure can be used far more.

To conclude, by precision fertilisation, the fertiliser dose is adapted to the needs of the plant. This can be obtained by an accurate steering system (GPS) and the measurement of the nutrient composition (f.e. NIRS), but this is not sufficient. It is also needed to adapt the dose while spreading, based on maps. This can be done by adaption of the dose in the driving direction, or to control the different sections separatly. F.e. today the dosage of liquid nitrogen with a field sprayer is already possible in this way.

Remote sensing

Remote sensing can provide data that help identify and monitor crops. When these data are organised in a Geographical Information System along with other types of data, they become an important tool that helps in making decisions about crops and agricultural strategies.

Remote sensing includes the following elements/tasks:

- Satellite-supported global monitoring of in-field crop status;
- High resolution satellite-image derived field maps of crop biomass, vitality, leaf area, chlorophyll, nitrogen content, water content, level of maturity and productivity;
- Spatial and temporal assessment of plant growth and health.

Remote sensing is employed in France using drones to board the sensors.

Figure 6: Use of drones (© Chamber of agriculture of Charente-Maritime)

The multispectral camera boarded on the drone measures different wavelengths which are considered as significative of the nutritional status or the development level of the crop.

Sources : société Airinov – CA 17

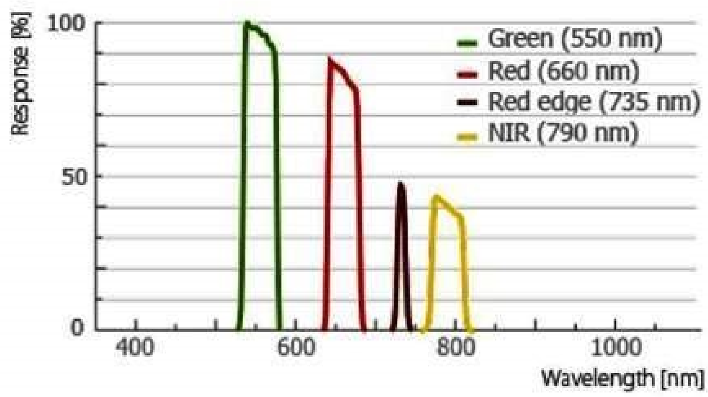

Figure 7: multispectral camera (© Airinov)

For example, the camera „multispec 4" (Figure 7) receives four wavelengths chosen for their agronomic interest : green, red, red edge and near infra-red. (Combinations of) wavelength values are mainly used as vegetation indexes - NDVI is the most known index for biomass.

Examples of vegetation indexes with some of their agronomic usability:

Vegetation indexes

	Name	Formula	Purpose	Crops
DVI	Difference vegetation index	DVI = NIR(890)-RED(670)	N content	wheat
MTCI	MERIS terrestrial chlorophyll index	MTCI = (NIR – REDedge)/ (REDedge – RED)	chlorophyll content	wheat oat corn bean grassland
NDVI	Normalized Difference Vegetation Index	NDVI = (NIR(890)-RED(670)/(NIR(890)+RED(670))	Biomass phenological stage N content chlorophyl content Leaf area	wheat corn rice
SAVI	Soil adjusted vegetation index	SAVI = (NIR-RED)/(NIR+RED+L)*(1+L) L = 0,25 for high vegetation bulk L = 0,5 for medium bulk L = 1 for low bulk	Biomass	corn
MSAVI	Modified Soil adjusted vegetation index	MSAVI = (NIR-RED)/(NIR+RED+L)*(1+L) L = 1-2*a*(NIR-RED)*(NIR-a*RED)/(NIR+RED) MSAVI2 =(2*NIR+ 1 – √ ((2*NIR+1)²-8*(NIR-RED)))/2	N content	corn
NDRE	Normalised Difference Red Edge	NDRE = (NIR (790)- REDedge(720)/ (NIR (790)+ REDedge(720))	Chlorophyll content	wheat

Interest of remote sensing with drones is due to:

- the efficiency of the spatial coverage (Figure 8);
- the convenience in temporal use (Figure 9).

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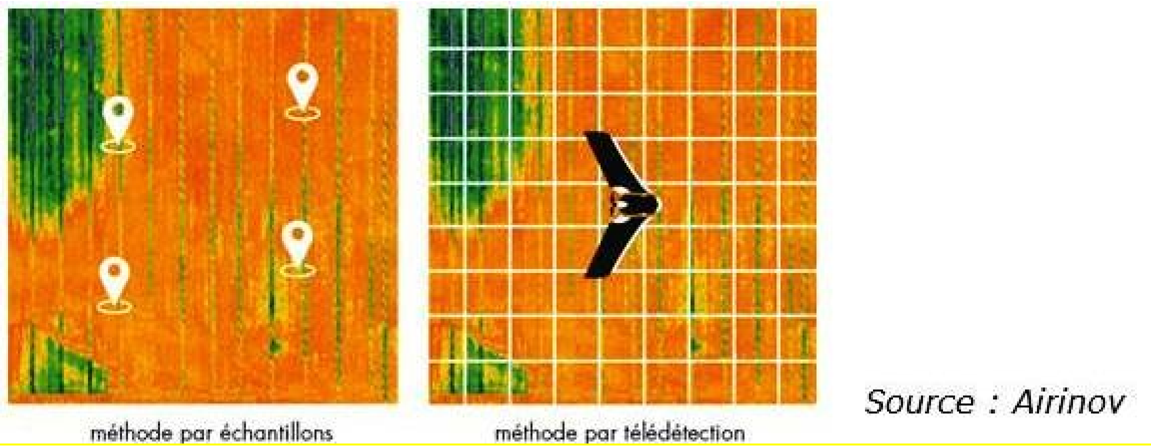

Figure 8: Difference in efficiency between sampling (left) and remote sensing (right) (© Airinov)

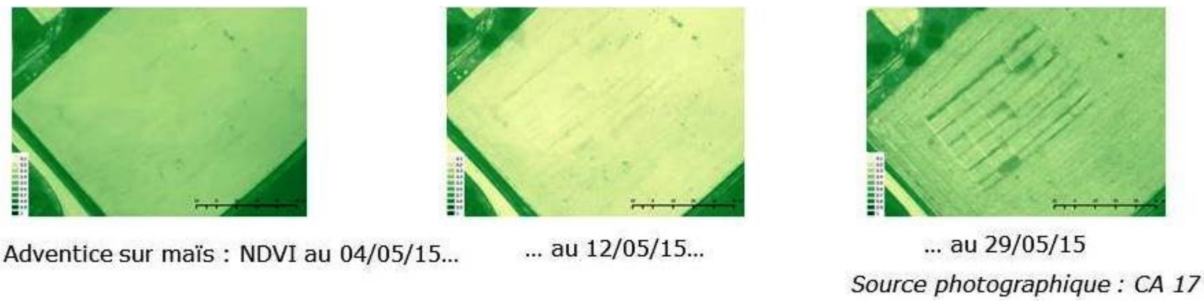

Figure 9: Ease of use over time: followed weeds on corn crop with NDVI pictures from the 4th to the 29th may 2016 (© Chamber of agriculture of Charente-Maritime)

The use development of remote sensing needs now progress in building of models to translate the index value to agronomic values. For a number of crops, like grains, these calculation principles are already in place. There are different companies (f.e. Airinov, Arvalis-Airbus) who offer these advices to apply a 2nd and 3rd fraction of fertilisation. Only the places where a deficit occurs in the crop, extra inputs are applied.

Nowadays in France a nitrogen monitoring tool is offered for rape and wheat crops by some agricultural organisations – "Mes dro'im@ages" in Chambers of agriculture - with remote sensing with help of Airinov company.

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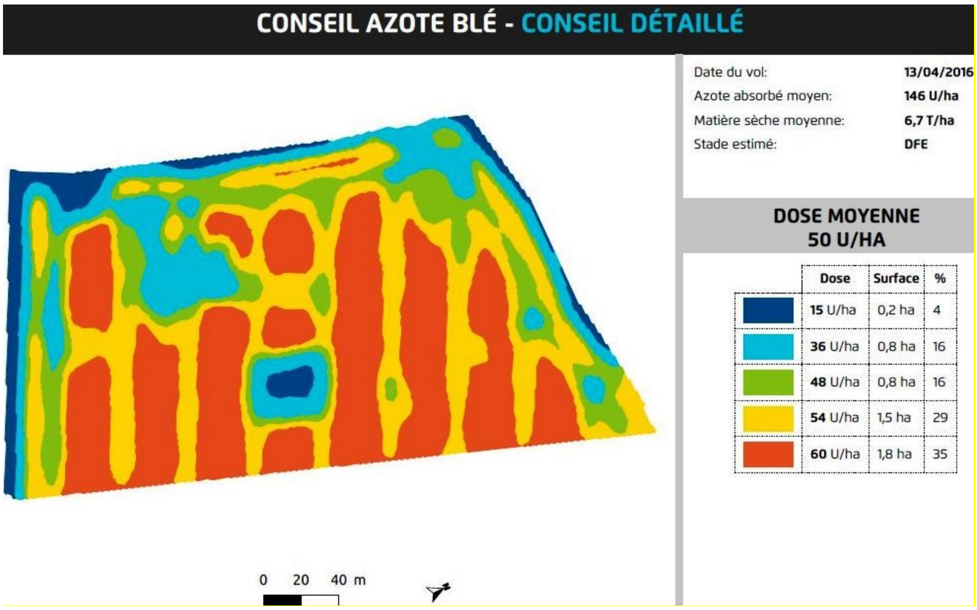

Figure 10: Example of advice of nitrogen monitoring on wheat in april 2016 – nitrogen inputs proposed in kg/ha, average nitrogen input: 50 kg/ha. (© Chamber of agriculture of Charente-Maritime)

Link to basic research and application:

- Spatial Business Integration – Crop Parameter Map: http://www.spatial-business-integration.com/precision-farming/

- Precision agriculture tools/satellite maps:
  - ✓ BayWa – FarmFacts: http://www.farmfacts.de/produkte/talkingfields/tf-biomassekarte.html
  - ✓ Geosys – FarmSat Mapping Application: http://www.geosys.com/products/farmsat/
  - ✓ Bayer CropScience – Zoner: https://zoner.bayer.com/#data
  - ✓ Cropio: https://about.cropio.com/#agro
  - ✓ Monsanto – FieldView: https://www.climate.com/

- 'Connected Nutrient Management' is a user-friendly, optimized nutrient management system enabling the demand-oriented, precise application of organic and chemical N and P fertilizers. The system supports planning and optimisation with a holistic, overall observation of the harvest history and includes technologies for highly precise fertilizer application.
  Partners:
  - John Deere GmbH & Co. KG, Mannheim, German
  - LAND-DATA Eurosoft – a BayWa Company. Pfarrkirchen, Germany
  - Vista Geowissenschaftliche Fernerkundung GmbH, München, Germany
  - RAUCH Landmaschinenfabrik GmbH, Sinzheim, Germany
  - SULKY BUREL, CHATEAUBOURG, France

  Link: http://rauch.de/english/news/agritechnica-2015-gold-medaille.html

- LIFE project '*Futur Agrari*' (LIFE12 ENV/ES/000647) (http://www.futuragrari.cat/16/)
  Action B4 'Remote sensing' of this Life-project aims to test the use of remote sensing techniques to adjust N-inputs in crops at an advanced phenological stage:
  http://www.futuragrari.cat/16/b4_remote_sensing_626997.html

6. Conclusions

In many European areas, the surplus of nutrients is very relevant, especially in areas with high animal loads. Therefore there is the need to increase the practical use of these tools by farmers.

From this mini-paper it is clear that a variety of tools and systems is already available in order to perform a more accurate fertilisation. Although we can still identify gaps in knowledge, dissemination, cooperative arrangements, etc.

Proposal for potential operational groups

- Even if there are different techniques available for the improvement of fertilization, an integrated system that uses jointly the best available techniques in order to maximize the management of organic and mineral fertilizers, minimizing production costs and environmental impact, has not yet been fully developed and used in real conditions (without production losses). The operational group that may be undertaken to fill this gap can aim to establish a management system that: i) meets legal requirements ii) uses information mainly collected automatically (low input by the farmer), iii) can provide information to support the management of fertilisation, iv) works cross-company, i.e. under the organisational framework of machinery rings (see also mini-paper "cooperation and logistics"), v) can enhance the knowledge on fertilizer content of organic and mineral products and vi) can reduce emissions towards the environment.

- It is necessary to make the 'on farm tools' as user friendly as possible as not all farmers are familiar with online tools. The output results should be easily understandable/implementable and further processable. The tools should be widely available (calibration for every region; available in region's language) (see also mini-paper 'nitrogen and water need based on a model' of the focus group 'Fertiliser efficiency in horticulture'). In the operational group different tools could be made user friendly, in close cooperation with farmers who will use them.

- Often the direct benefit of all these tools/new techniques are not clear for farmers. There is a strong need for (field) demonstration of the tools/techniques in use to prove the practical suitability, and balance the possible additional cost (f.e. remote sensing) against these benefits. So these systems need to show financial/environmental benefit of saving on fertiliser application and need to be low cost (see also mini-paper 'fertiliser planning and simple recommendation systems' of the focus group 'fertiliser efficiency in horticulture').

- Survey of farmers concerning their willingness to use certain tools and mapping of the possible resistance for applying these tools, from country to country: f.e. will it only be applied when they are forced to do it by law? Or is there a lack of technical assistance? Or lack of education on the benefit of a better nutrient planning? By this mapping (see proposal for R&D), new operational groups to tackle the specific bottlenecks could be set up.

- An operational group could be established consisting of farmers who have already great interest in soil fertility and/or substitution of mineral fertilisation by organic fertilisation. This can be the base for communication to other farmers, who have still a traditional view on fertilisation. This operational group would also act as demonstration to other farmers.

- Operational groups could also be set up for information and communication purposes. These groups could consist of teachers, pupils, trainers, consultants from enterprises and applied researchers

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working together with the company. Aim is to increase consciousness of farmers, that an accurate and correct fertilisation has an environmental benefit. Test results of the farms on site would give the practical reference.

Proposals for R&D needs from practice

- It is necessary to improve the practicality and statistical reliability of rapid determination methods for the nutrient content of organic fertilisers. For this purpose, a Europe-wide ring test could be set up for organic fertilisers, in particular liquid manure and digestate. Methods shall be compared with traditional laboratory analysis. Procedures should be tested under practical conditions regarding their user friendliness. Links to other technologies shall be evaluated. The test should be announced to public and test results could be published broadly.

- Many techniques and technologies that can be used to improve the fertilization of crops at farm level are available and have already been validated individually, although not all validation results are sufficient to have a real added value in practice. An in-depth assessment of the advantage of these technologies need to be redone, before farmers can be informed/obliged to use them (f.e. this is the aim of the NIRS pilot project in the Netherlands).

- Clarify all elements of the nutrient flow of farms (i.e. biomass-production is overestimated, therefore fertilising is oversized, with the result of emissions in air and water): for accurate fertilisation, on farm tools need to be calibrated and target values need to be introduced. Nutrient management planning involves the establishment of realistic, site-specific parameters. While in arable farming nutrient demand by crops and nutrient export by harvested crops are quite well known, for grassland and pasture planning figures are quite vague and harvested biomass as well as its nutrient concentration are not regularly determined. A regular analysis of the composition of these crops could give an added value for the calculation of the nutrient balance on the farm.

- Further research on remote sensing: by application of remote sensing a good special image of the biomass can be obtained. What is lacking is a good translation of these images to the actual yield and N-content. As already mentioned (page 13), for grains, these calculation principles are already in place. This needs to be expanded to other crops (grassland, maize, vegetables, etc.).

- Most of the tools, described in this mini-paper are focused on the determination of nutrients (N, P, K), but tools for management of organic matter on the farm are also needed.

- Establishment of a common scientific platform which enables all member states to assess the respective strengths and weaknesses in fertilisation management. This can be translated in a software tool, to be used by farmers and advisors to manage crop fertilisation.

- Survey of farmers concerning their willingness to use certain tools. Mapping of the possible resistance for applying these tools, from country to country: f.e. will it only be applied when they are forced to do it by law? Or is there a lack of technical assistance? Or lack of education on the benefit of a better nutrient planning? In a second step, operational groups focussing on closing this gap could be established.

Proposal for need of dissemination and other actions

In this mini paper, different available tools and systems are described, some already widely used by farmers, some only little used or not known. It is up to agricultural advisors to disseminate these tools and systems by demonstration (see 'potential operational group') towards the target public, the farmers, and, particular for the (online) tools, available in other regions, to integrate them in their own region (make the tool available in the region's language/tailored on the specific conditions of the own region).

Proposal for need of other actions

- Recognition of alternative analysis systems, f.e. NIRS; this can foster the investment in those systems (lab-analysis can be replaced by this system). Without this recognition, this could be too costly for the farmer. As in the Netherlands, a national certification of the NIRS-technology for manure-analysis is planned from the German Agricultural Society (DLG). It is needed to bear in mind that variability also occurs in lab analyses, so the accuracy which can be allowed for other alternative systems needs to be clarified.

- Economic return for farmers applying these technologies: the investment cost of most of the techniques (NIR, remote sensing, GPS, etc.) is still too high. It is needed to clarify how these costs can be reduced.

- It is needed to clarify cost sharing: who pays the additional cost for applying these systems, f.e. NIRS-analysis: the arable farmer, the stock breeder, or maybe the government (subsidy if method is mandatory)?

- Education of the people working with these new technologies: often there is only 1 person at the farm who has knowledge on the working of the system. What if this person is not available, and the system breaks down; can the system be maintained automatically? Or how people be better educated on the working of these new technologies?

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ANNEX I

Example: cattle farming liquid manure production rates and characteristics

1) Calculated by method of KTBL-Schrift 502 (2014) using data from DLG (2014)
2) Standardizied to 7,5 % dry matter content
3) Calculated without taking into account of bedding material
4) Calculated without taking into account of NH_3-N storage losses
5) Calculated without taking into account of $C_{org\ decomposition}$ storage losses

pref. = preferential

[1] DLG (2014): Bilanzierung der Nährstoffausscheidungen landwirtschaftlicher Nutztiere. Arbeiten der DLG, Band 199.
[2] Horlacher, D.; Rutzmoser, K.; Schultheiß, U.(2014): Festmist und Jaucheanfall. KTBL-Schrift 502.

Days/rotation: 365
DM content 0.075

Livestock category	Type of manure	Quantity						Content				
		Fresh matter	Dry matter	Organic matter	N	P	K	Dry matter	Organic matter	N	P	K
Dairy cow 8000 kg ECM/a pref. fresh grass & grass silage feeding		Kg/(animal place.a)						g/kg FM				
	Faeces [1,4,5]	8685	1737	1393	43.2	16.7	23.4	200	160	5.0	1.9	2.7
	Urine [1,4,5]	8617	172	-	85.5	2.0	94.7	20	-	9.9	0.2	11.0
	Gross liquid manure [1-5]	25458	1909	1393	128.7	18.7	118.1	75	55	5.1	0.7	4.6

Days/rotation: 365
DM content 0.075

		Quantity	Content

Livestock category	Type of manure	Fresh matter	Dry matter	Organic matter	N	P	K	Dry matter	Organic matter	N	P	K
Dairy cow 8000 kg ECM/a pref. corn silage feeding		Kg/(animal place.a)						g/kg FM				
	Faeces [1,4,5] Urine [1,4,5]	8463 7044	1693 141	1395 -	39.9 76.9	15.4 2.0	20.1 79.6	200 20	165 -	4.7 10.9	1.8 0.3	2.4 11.3
	Gross liquid manure [1-5]	24446	1833	1395	116.8	17.4	99.7	75	57	4.8	0.7	4.1

Days/rotation: 820 DM content 0.075

Livestock category	Type of manure	Quantity						Content				
		Fresh matter	Dry matter	Organic matter	N	P	K	Dry matter	Organic matter	N	P	K
Beef cattle 45-700 kg LM, 19 months, pref. corn silage feeding		Kg/(animal place.a)						g/kg FM				
	Faeces [1,4,5] Urine [1,4,5]	4541 2614	908 52	798 -	19.7 42.3	6.7 1.5	7.7 33.9	200 20	176 -	4.3 16.2	1.5 0.6	1.7 13.0
	Gross liquid manure [1-5]	12805	960	798	62.0	8.2	41.6	75	62	4.8	0.6	3.2

Days/rotation: 820 DM content 0.075

Livestock category	Type of manure	Quantity						Content				
		Fresh matter	Dry matter	Organic matter	N	P	K	Dry matter	Organic matter	N	P	K
Young cattle rearing, 45-650 kg LM, 27 months, pref. fresh grass & grass silage feeding		Kg/(animal place.a)						g/kg FM				
	Faeces [1,4,5] Urine [1,4,5]	8805 10085	1585 202	1255 -	40.7 87.9	14.1 2.0	24.0 108.2	180 20	143 -	4.6 8.7	1.6 0.2	2.7 10.7
	Gross liquid manure [1-5]	23822	1787	1255	128.6	16.1	132.2	75	53	5.4	0.7	5.5