

eip-agri
AGRICULTURE & INNOVATION



EIP-AGRI Focus Group

Nutrient Recycling

FINAL REPORT
November 2017

Table of contents

Table of contents	2
List of abbreviations	2
1. Summary	3
2. Introduction	5
2.1. The importance of nutrient recycling	5
2.2. Reconnecting nutrient flows between livestock and plant production.....	5
2.3. Recycling nutrients into new biobased fertilisers	6
3. Brief description of the Focus Group process	7
4. Results of the Focus Group.....	8
4.1. Technology review.....	8
4.2. Market uptake of novel fertilising products	11
4.3. On-farm needs	12
4.4. Regulatory framework affecting nutrient recycling	16
5. Future perspectives	17
5.1. Identified research needs	17
5.2. Ideas for Operational Groups.....	18
5.3. Raising awareness	19
Annexes.....	20
Annex 1. List of members of the Focus Group (FG).....	20
Annex 2. List of mini-papers.....	21
Annex 3. Complete list of research needs from practice	22
Annex 4. Complete list of ideas for Operational Groups.....	23

List of abbreviations

AD	Anaerobic Digestion
CAP	Common Agricultural Policy
EOM	Effective Organic Matter
FG	Focus Group
LCA	Life Cycle assessment
MFE	Mineral Fertiliser Equivalent
NIRS	Near Infra-Red Spectroscopy
NUE	Nutrient Use Efficiency
N/P ratio	Nitrogen over Phosphorus ratio
OG	Operational Group
PSNT	Pre-sidedress Nitrate Test

1. Summary

Mineral nutrients are vital for producing the food on our plates, as well as for a wide variety of other products and materials which we use every day. Agricultural intensification using mineral fertilisers has allowed the world to sustain population growth and prosperity. However, it is appearing increasingly self-evident that the upward spiral of population growth and dependency on fossil resources needs to be re-thought. More attention must be paid towards closing nutrient loops throughout the entire agro-food chain.

The EIP-AGRI Focus Group (FG) on Nutrient Recycling worked on the following main issue “How to improve the agronomic use of recycled nutrients (N and P) from livestock manure and other organic sources?”

The FG discussed the benefits and constraints of some **emerging technologies** that allow the recovery and re-use of nutrients. Over the last decade, anaerobic digestion has developed considerably throughout Europe, first focusing on the climate change abatement benefits of this renewable energy. But now, it also focuses more and more on the potential it holds for bringing recycled nutrients and organic carbon in the soil. In addition, downstream processing of manure, agro-residues and digestate has received increasing attention. The aim of such processes is to either mitigate environmental emissions (to avoid eutrophication) or to recover nutrients in more plant-available form. The list of existing treatment techniques is ever-expanding: mechanical separation, biological treatment, composting, drying, combustion/gasification/pyrolysis, membrane technology, ammonia stripping/scrubbing among others. This report touches on some of these techniques.

The FG identified **farmer acceptance and appreciation** as one of the key issues to foster the wider use of recycled nutrients in practice. To increase the adoption of organic waste processing technologies and the production of new types of biobased fertilisers on a large scale, a real understanding of the fertilisers market and the end-user (e.g. arable farmers, fruit or vegetable producers, etc.) requirements is needed. This also implies that the cost for new biobased fertilisers must be sufficiently competitive with respect to traditional mineral fertilisers, when considering elements such as: logistics (transport and application), nutrient content and plant availability, physical parameters (compatibility with handling and spreading equipment) and potential nuisances (odour, dust) for neighbours.

The **market uptake** needs to be driven from the demand side, not (or not solely) from pushing technologies that aim to recover nutrients from manure (and other organic sources) for example to resolve regional problems related to nutrient excesses. To expand the use of new products, “trust” is needed all along the value chain: farmers should know the effects and results of the biobased fertiliser and the food industry needs to be sure as well that this can be safe and environmentally friendly. A more open market development is necessary with a level-playing field between products from fossil and biobased resources.

The ambition towards nutrient recycling lies not only in the technologies for producing biobased fertilisers, but also in a better understanding and managing nutrients at the farm which requires **practical tools and practices**. These on-farm tools may involve the assessment of the composition of the fertilisers (e.g. N/P ratio), the release pattern of nitrogen from biobased fertilisers, the emission of ammonia, etc. Also the **contribution of biobased fertilisers to the soil organic matter** must not be ignored. The challenge is that nutrients contained within a biobased fertiliser have more complex dynamics, making their release more difficult to predict and plan than mineral fertilisers. The FG suggests to distinguish ‘organic soil improvers’ and ‘biobased fertilisers’ based on the ratios EOM/mineral N and EOM/P₂O₅. (EOM= Effective Organic Matter)

Regulatory frameworks at EU and regional/national level play a vital role as drivers or restraints on developing more optimal nutrient recycling strategies. It is expected that the new EU fertiliser regulations included in the Circular Economy package¹ will improve the utilisation of biobased fertilisers. In addition to a concise overview of the most relevant legal frameworks at the EU level, the Focus Group

¹ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614>

identified possible policy measures for further discussion and debate, such as financial incentives, environmental taxation schemes, labelling obligations and possible incentives under the CAP.

The FG identified **gaps in existing knowledge** which require further attention:

- develop and adopt specific LCA and environmental risk assessment methodologies for agricultural systems as the current methods were designed particularly for industrial processes;
- devise a standard way of assessing nutrient use efficiency of fertilising products, including meta-analysis of existing data and reports;
- focus on organic contaminants in some of the recovery pathways, like impacts of organic components on soil ecology and on food safety and how to improve the processing to treat these contaminants;
- better understand the perception and acceptance of recycled nutrients throughout the food production value chain through social sciences;
- use remote sensing tools and practices to get a better understanding and matching of fertilisation with crop requirements;
- explore practical tools that can be applied on-farm (farm-scale recovery, measurements, application equipment,...);
- study the transition from raw bulk products containing nutrients in variable concentrations and ratios towards tailor-made fertilisers with desired and well-known formulated compositions.

Finally, the FG also made some suggestions for EIP-AGRI **Operational Group projects** that address some of these research needs yet also go further towards demonstrating concrete solutions:

- test nutrient circular economy technologies such as low ammonia (NH₃) emission techniques while involving the whole value chain to highlight the improvements in terms of sustainability;
- demonstrate how tailor-made biobased fertilisers match plant requirements;
- integration of nutrient management in certifying schemes to create transparency and trust;
- development or adaptation of cooperation business models to improve the production and marketing of tailor-made fertilisers;
- exchange of information between farms on the use of biobased fertilisers, including nutrient and carbon behaviour in the soil.

In all such proposals the involvement of as many farmers as possible is considered key.

2. Introduction

2.1. The importance of nutrient recycling

Crops require more than sunlight or water alone in order to flourish – they also require a good and balanced supply of essential minerals. In the past, the production of mineral fertilisers from rock deposits (Phosphorus: P) and based on fossil energy (Nitrogen: N) have enabled food security and access to sufficient food for the World's growing global population. Nonetheless, in the future we need to progressively focus on recycling resources instead of consuming non-renewable ones.

The production and transport of mineral fertilisers require significant amounts of fossil energy. Worldwide the production of reactive ammonium (NH_4) through the extraction of unreactive atmospheric nitrogen gas (N_2) uses more or less 2% of world's total energy consumption, and this is not sustainable.

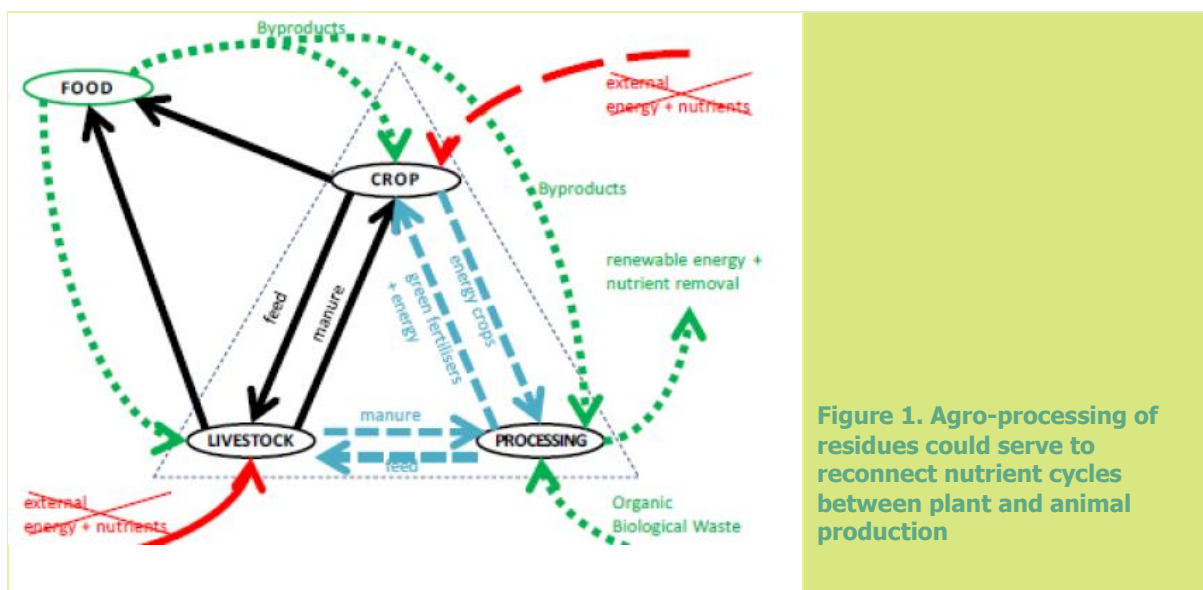
The dependency of agriculture on fossil-based mineral fertilisers (especially N, P, and Potassium: K) must be regarded as a very serious threat to future food security. Furthermore, estimates of remaining phosphorus reserves are highly uncertain. Based on population growth and future demand for nutrients, the scarcity of phosphorus at a global level and the absence of geological reserves on the European continent mean that this a future threat requires much attention. For these reasons, the European Commission (EC) has placed phosphate rock on the list of Critical Raw Materials (CRMs). These CRMs are materials with a high economic importance to the European Union (EU) which also have a high risk associated with their supply. European agriculture therefore needs to progress towards more closed loops concerning the provision of nutrients. This can be envisaged both within the agricultural sector and the mineral fertiliser industry where recycled nutrients can be used as input. It must not be forgotten that nutrient recycling can allow farmers to be less dependent on imported and purchased fertilisers - and so less exposed to price variations or supply issues. Nutrient recycling can also create rural jobs in processing, marketing and distribution of recycled nutrient products.

2.2. Reconnecting nutrient flows between livestock and plant production

Throughout the last century, the two conventional pillars of agriculture - plant production and livestock production - each intensified independently from one another. To obtain the highest possible productivity and economic efficiency, plant production increasingly required nutrients in directly available mineral form whereas animal production increased in concentrated areas.

From a nutrient perspective, this division implied an increasing need for chemical fertilisers even though substantial local surpluses in animal manure were being produced at the same time.

In recent years, the idea has taken root that in order to reconnect nutrient flows between plant production and livestock production there is a need to invest in agro-industrial processes. These processes can contribute to the recycling of nutrients from organic flows as biobased fertilisers which leads to higher nutrient use efficiency (NUE). Increased efficiency within an individual agricultural system will also result in reduced dependency on external energy and nutrients. This approach calls for agro-processing as a third pillar, agro-residue processing and upcycling in particular (see Figure 1).



2.3. Recycling nutrients into new biobased fertilisers

“Biobased fertilisers” are defined as organic or organo-mineral fertiliser products derived from renewable biomass-related resources rather than synthetic products which require fossil resources for their production. There is a rapidly growing interest in recycling nutrients from organic sources in order to achieve a higher economic and practical value. Nonetheless, there are technical issues that need to be addressed:

- Biological systems and resulting organic streams are prone to **variability** and potentially also **instability**. To move forward, biobased fertilisers will need to be reliable and predictable.
- **Field scale experience** of new biobased fertilisers to amend or replace mineral fertilisers based on fossil resources is widespread yet scattered and fragmented. There is a need at regional and European level to obtain a clearer overview of emerging (yet-to-be-proven) as well as validated practices in recycled nutrients.
- **Independent analytical assessment and quality assurances** are required for end-users (e.g. arable farmers, fruit or vegetable producers, etc.) to switch with confidence to such new products. For this, end-users must be reassured on the two following elements in equal measure: (i) nutrient use efficiency (NUE) of recycled nutrients, as these are often derived from organic sources and are generally still perceived to have lower plant availability than their mineral fertiliser counterparts; (ii) the absence of undesired compounds or agents (weed seeds, pathogens, heavy metals, organic contaminants such as pharmaceuticals, etc.).
- **Awareness and confidence** in recycled products needs direct communication and interaction with end-users, as well as consumers or rural residents to explain the new fertilisation policy. Fertilisation advice given by agricultural advisors will need to be adapted to take into consideration new products if and when they meet quality and stability standards.

3. Brief description of the Focus Group process

To investigate the possibilities of closing nutrient loops within European agriculture, the European Commission (DG AGRI) initiated a dedicated EIP-AGRI Focus Group (FG) on Nutrient Recycling. The FG aimed at answering the following question: "*How to improve the agronomic use of recycled nutrients (N and P) from livestock manure and other organic sources?*". This central question has both an agronomic and an environmental side to it; inefficient use of nutrients can lead to reduced yield as well as nutrient loss to the environment, leading to eutrophication.

The FG on nutrient recycling had the following specific tasks:

- Identify relevant techniques (e.g. composting, bio-digestion, etc.) to process livestock manure and other organic sources and assess the agronomic and environmental value of the derived products (e.g. nutrient availability, quality, impact on soils, contaminants, etc.).
- Contextually, identify tools and instruments to help farmers to measure the nutrient content (and availability for crops) and recommendations for the application of these products.
- Analyse economic and technical factors (e.g. livestock management practices, sanitary aspects, etc.) that stimulate or limit the use of these products in agriculture and indicate how to address them exploring the role of innovation and knowledge transfer.
- Illustrate possible strategies to adapt derived products to market demands (e.g. development of quality standards) and successful business cases that exist at farm level, local and regional scale.
- Identify research needs from practice, possible gaps in technical knowledge, and further research work to address them.
- Suggest innovative solutions and provide ideas for EIP-AGRI Operational Groups and other innovative projects.

This report is a compilation of insights gained from the two meetings of the FG experts which took place in 2016 (in Stockholm, Sweden and Leuven, Belgium). Starting from an initial discussion, 8 mini-papers ([see annex 2](#)) were drafted on subjects covering: (i) product assessment of recovered nutrients including environmental aspects concerned with recovery processes and recovered products; (ii) techniques and (management) strategies which can be adopted at farm-scale; and (iii) regulatory aspects which, to a large extent, shape and determine the drive forwards. The mini-papers also include recommendations for research needs and suggestions for EIP-AGRI Operational Groups (OGs). OGs are innovative projects receiving financial and organisational support via the EU rural development policy to develop and implement new agricultural strategies, processes and products.

The published mini-papers, a factsheet, a presentation and other documents produced by this FG can be found at: <https://ec.europa.eu/eip/agriculture/en/content/nutrient-recycling>

4. Results of the Focus Group

4.1. Technology review

There are many marketable or near-to-marketable techniques in Europe for nutrient recycling. The main techniques and their advantages and disadvantages are listed below. A more complete overview can be found in mini-paper 1 (Fangueiro et al.). This technology overview describes the context as well as some of the main issues related with the potential and possible drawbacks of these techniques.

Anaerobic digestion (AD)

The production of biogas from biomass as a renewable alternative to natural gas is achieved via anaerobic digestion. The AD process not only produces renewable energy, the processed biomass can also help soil fertility e.g. conversion of the organic carbon to a stable form which will persist in the soil. It also has other advantages, such as increasing soil organic carbon in the soil, being a carbon sink, as mentioned in the abatement of climate change objectives by the COP-21 Paris Agreement. For example, the '4 pour mille' initiative launched by France promotes the annual increase of soil organic carbon by 0.4% per year as a means to stock and sequester CO₂ capture by plant biomass (www.4p1000.org).

Manures are often anaerobically digested, mixed with other organic waste with a higher biomethane potential and more optimal C/N ratio: green waste, food industry by-products, household separated organic waste. Co-digestion of manure with other substrates enables better biogas production and more stable reactor operations as well as more optimal economics. AD can now be considered as a key technology in the nutrient recovery value chain. This is due to its ability to mineralise organic substrates so that the nutrients (N, P and others) contained within them can be more easily taken up by plants. This implies that digestate and derived products can be more suitable as fertilisers than the raw resources from which they originated (such as sludges, slurries, biowastes, etc.). Nonetheless, varying input sources can lead to large differences in digestate composition between biogas installations as well as digestate outputs with different and unpredictable composition at each single biogas plant. However, farmers require homogeneous and "predictable" mineral nutrients, as is commonly the case in synthetic mineral fertilisers, so biogas plant owners may need to address this constraint.

Biological treatment (e.g. nitrification/denitrification)

In European regions which have an excess of manure, the removal of excess nitrogen is considered a cost-efficient technique to tackle the environmental problems related to this regional surplus. The process used is first converting the manure to nitrate-nitrogen (NO₃) via 'nitrifying bacteria' and then subsequently converted this to inert nitrogen gas (N₂) via 'denitrifying bacteria'. This allows industrialised livestock farms to be more sustainable by avoiding eutrophication caused by regional concentration of livestock production. Nonetheless, the current trend is to consider 'destruction' of mineral nutrients into inert nitrogen gas. However this is seen more as a transition-technology where Europe should tentatively move towards more recovery.


Mechanical separation into solid and liquid fractions

This consists in the separation of manure or digestate in a solid fraction with a higher organic matter and P content and a liquid fraction with a higher mineral N and K content. The liquid fraction usually has a higher ratio of mineral N over total N which implies a higher direct plant availability compared to raw unseparated digestate or animal slurries. On the other hand, as P is less soluble, it tends to end up predominantly in the solid fraction. This results in different N/P ratios in the two fractions compared to the unseparated digestate or slurry. Considering crop requirements and fertilisation management, the liquid fractions that have a high mineral N over total N as well as high N over P are considered better fertilising products than manure or digestate in their raw unprocessed form. However, the separation efficiency and subsequent division of P and N, depends on the ingoing raw manure or digestate which are subject to variability. This means that here as well, product homogeneity may become a key issue to address in future research.

Drying


Drying of manure or digestate, then simple mechanical processing such as granulation and blending with other products can meet specific crop needs because of a more optimal micro and macro nutrient


composition. It enables manure to be converted into recycled nutrient products whilst conserving the organic carbon so it can be returned to the soil. The disadvantage is the energy cost of drying, which is often prohibitive. The business case around manure/digestate drying therefore only makes sense if there is access to sufficient renewable heat. For example, the **French pig farm cooperative COOPERL** recycles around 400 000 tonnes of pig manure by anaerobic digestion (often combined with on-farm biological treatment) followed by centralised drying and granulation of the digestate at their meat processing factory which has waste heat energy available for drying from incineration of animal by products.

 In Flanders (Belgium), most biogas plants have a drier running on the cogenerated heat from CHP power production from the biogas. The dried and hygienised* product (*legally: at least 70°C for at least 1h) are then exported from Flanders, a surplus region, to regions in Northern-France and Western-Germany which are in demand for nutrients. In addition to hygienisation, the drying process also has the advantage of reducing the mass requiring transport.

Combustion /gasification of chicken litter


Unlike most manures, chicken litter has a high calorific value. Hundreds of thousands of tonnes are currently combusted for renewable energy production with the resulting ash being sold as a quality P-K fertiliser.

 The gasification plant in Moerdijk (Netherlands) processes one third of all poultry manure produced in the Netherlands, generating 285 000 MWh of renewable electricity each year. The ashes are used as a secondary resource for the production of P-fertilisers. The Moerdijk facility was an initiative of 600 poultry farmers and has been in operation since 2008, processing 430 000 tons of poultry manure each year.

 Similarly, the Fibrophos plant in the UK processes 800 000 tonnes per year of poultry manure into renewable energy. Although this is advantages for the circular economy, certain regions and countries have banned the combustion of manure (e.g. Flanders, Belgium). Their argument is that through the process, valuable nitrogen is destroyed or lost whereas poultry manure can already be sold on the international market in its crude form in which then NPK and organic carbon are preserved for agricultural use.

Pyrolysis and the production of biochar

The word "biochar" is a combination of "bio-" as in "biomass" and "char" as in "charcoal". It is obtained by charring/pyrolysing plant or animal biomass, via a process of heating it in the absence of oxygen. There are currently processes on the market which enable energy-neutral processing of pig manure or other manure to biochar. This is a stable recycled nutrient which is beneficial for the soil, containing P, K, micronutrients and stable carbon which can be applied to the soil.

 Cases are also being advocated for so-called 'animal bone char' which uses slaughterhouse animal by-products as an input. The resulting bone char is rich in P and was promoted in the EU project Refertil (www.refertil.info).

Other experts argue however that certain environmental problems in soil chemistry related to the use of charred products have been underestimated in the past and need to be further studied.

Membrane and ultrafiltration techniques

Membrane cascades, ending in ultrafiltration or reversed osmosis allow for suspended particles to be filtered out and for mineral nutrients in the form of dissolved salts (mostly N and/or K) to be further concentrated. Reversed osmosis as a final step in the membrane cascade also results in ultra-pure water which could be recycled and re-used. This type of technology allows the production of mineral concentrates, although the concentrations are not as high as in synthetic mineral fertilisers. Also, the use of membranes in the farm environment has encountered operational issues related to (bio-) fouling and clogging of membrane pores leading to loss of performance and (in such cases) excessive

operational costs. New developments are underway to tackle these negative effects, nonetheless it has proven to be challenging to introduce membrane technology in farming environments.

Ammonia stripping & scrubbing

The chemical equilibrium between water soluble ammonium (NH_4^+) and its volatile counterpart ammonia (NH_3) is determined almost entirely by temperature and pH. Concretely, by increasing pH and temperature, ammonium can be driven out in the form of gaseous ammonia. Passing the air saturated with ammonia through an acidic scrubber system then recaptures the nitrogen as soluble ammonium. Depending on which counter acid is used in the scrubber (e.g. sulphuric acid, nitric acid) a pure ammonium sulphate (NH_4SO_4) or ammonium nitrate (NH_4NO_3) mineral fertiliser product can be obtained. The resulting products consist entirely out of mineral nitrogen and therefore have 100% nitrogen use efficiency (NUE), similar to synthetic fertilisers. Both nitrogen and sulphur (S) are plant essential nutrients, so the scrubber water in the form of NH_4SO_4 also provides the farmer with a good source of mineral S. Nonetheless, the ratio N/S found in the scrubber fluid can differ from the actual N/S ratio required for the crop which could therefore lead to S over-fertilisation. This constraint is not encountered when working with NH_4NO_3 scrubber waters.

Acidification

Acidification of slurries and digestate is not a nutrient recovery technique as such but is promoted in some EU member states as a mitigating measure to reduce ammonia emissions related to manure/digestate management. Those in favour of acidification argue that it improves manure storage and stabilisation and enables a better return of nitrogen to crops when manure is spread, so improving nutrient use efficiency of the manure. A point of attention when using acidification is the type of acid used: when using sulphuric acid, it is important to avoid anaerobic microbial formation of hydrogen sulfide (H_2S) in storage afterwards. Hydrogen sulphide is not only odorous (smell of rotten eggs) and can cause nuisance as a result, but this product is also very toxic and even lethal at low concentrations when inhaled. Therefore, strict operational guidelines must be followed. The disadvantage of the acidification of manure is the loss of buffering capacity which is present in the raw manure and digestate in the form of free carbonates. Acidification will decrease the liming capacity of such products and convert the carbonates to CO_2 , releasing them to the atmosphere.

Composting

Composting is one of the oldest techniques in the book to create a more stable and hygienic product. Stability and hygienisation are essential for recycling minerals from complex and variable organic products such as biowastes. These organic products tend to function more as soil enhancers, containing higher organic carbon load as well as P which can be considered more slow-release. Product quality when working from biowastes is of major concern for the end-user, which implies that sound quality assessment protocols need to be in place, preferably audited and controlled by independent auditing and certifying entities. The natural heat released during composting also results in "biothermal drying" reducing the water content and so making the product more transportable.

Algae cultivation

Algal technology has been receiving increasing attention. The process is to biologically accumulate and retrieve nutrients from complex liquid waste water-streams. Algal biomass can subsequently serve different purposes – both in bulk as in fine chemical applications. This can be for example for animal feed or renewable energy but also for example for the recovery of colorants (e.g. fycocyanin via *Spirulina*).

Phosphorus precipitation

P in liquid streams (such as wastewaters or liquid fractions) can be retrieved in purified form by selective precipitation processes. Most known target precipitates are struvite (MgNH_4PO_4) and calcium-phosphate (CaPO_4). In the potato processing industry, struvite reactors have found progressive market uptake whereas in other sectors (such as manure processing) development of recovery techniques for calcium phosphate have seemed to gain momentum in recent years.

4.2. Market uptake of novel fertilising products

The recycling of nutrients is a very important element within the move towards a circular economy. However, to increase the adoption of organic waste processing technologies and the production of new types of biobased fertilisers on a large scale, a good understanding of the fertiliser market is needed as well as how end-users' behaviour, technological readiness and the wider legislative framework contribute to shape it.. These elements are addressed in this and the following sections.

4.2.1. End-user profile and technological readiness

Despite many available or emerging techniques, market uptake by farmers remains rather limited and marginal in comparison to common fertilisation practices. The FG experts identified reasons for limited market uptake by category of farmer:

1. For farmers owning sufficient land to apply all the raw slurry produced on their own farm, the advantages of slurry processing are less obvious and are either economically or practically less interesting than direct application of raw products on their land. On the other hand, farmers that do face regulatory challenges or constraints regarding nutrient management on their farm, represent a primary group for adopting new nutrient recycling technology. For example, farmers facing manure processing quotas, insufficient arable land in the vicinity to spread manure on, requirements relating to ammonia emissions and so on.
2. Large poultry or pig farms are required to use the Best Available Technology (BAT) defined under the Industrial Emissions Directive (IED BAT; www.eippcb.jrc.ec.europa.eu/reference). BAT lists have the intrinsic risk that they can delay or even block emerging techniques that are not yet included in them. This implies that the BATs need a rather regular update and that on the other hand, local authorities and policy makers should consider emerging techniques even if not yet listed in BAT documentation.

More generally, European regulatory frameworks, with their implementation in national and regional policies will determine the direction and speed of the development of a circular economy. Constraints imposed to safeguard the environment may encourage European agriculture to move towards more sustainable practices, yet it will only do so if emerging and market-ready techniques can fulfil these requirements. To stimulate technological progress, research institutes have released calls for end-of-manure/end-of-waste protocols as well as optimal procedures allowing new innovative technologies to be added to BAT lists. Scientific and practical research will need to address identified research requirements whereas policy and (farming) business will need to embrace and adopt the emerging technical possibilities.

4.2.2. End-user acceptance

Apart from technical readiness, the human factor also plays a crucial role: farmer awareness and acceptance to use recycled nutrients are of paramount importance. Mini-paper 4 (Forestal et al.) provides interesting insights based on a recent survey by Case et al. (2017)² on the constraints and bottlenecks of recycled nutrients as seen by end-users. These included:

- Odour
- Uncertainty towards nutrient content combined with time for lab analysis
- Difficulty in planning use and application of recycled nutrients
- Cost of adapted equipment
- Slower speed of application and increased horse-power requirements for low-emission spreaders
- Practicalities for applying bulk materials during the growing season, as opposed to application of more condensed mineral fertilisers (with higher nutrient concentration)

² Case S., Oelofse M., Hou Y., Oenema O., Jensen L.S. (2017) Farmer perceptions and use of organic waste products as fertilisers – a survey study of potential benefits and barriers. *Agricultural Systems* 151, 84–95, <http://dx.doi.org/10.1016/j.agsy.2016.11.012>

- Risk for soil compaction when applying slurries onto the seedbed near the roots as opposed to applying before ploughing

4.2.3. End-user requirements

From various surveys discussed and analysed in mini-paper 6 (Jensen et al.), **the primary requirement/driver for the conventional arable farmer (as being end-users of recycled nutrients) is low cost.**

"The ambition towards nutrient recycling is not only about technologies for producing biobased fertilisers, but also about better understanding the behaviour of nutrients and their management at the farm using practical tools." - Emilie Snauwaert expert in the FG.

This implies that the cost for new biobased fertilisers must be sufficiently low to compete with traditional mineral fertilisers. However, the former tend to have higher logistics costs (transport and application), they also have a less predictable nutrient content and plant availability and other physical parameters which may not fit with existing handling and spreading equipment or can cause potential nuisance (odour, dust) for neighbours. The only exception being organic farming where no mineral fertiliser application is allowed. In organic farming, the willingness to pay for alternatives is higher but concern for the integrity of the production chain and extra stringency towards the absence of contaminants and traceability are also paramount.

From these surveys, it is also apparent that **organic matter content and contribution to soil quality is perceived as an extra advantage.** Nonetheless, translating this to a monetary value is difficult. The authors of the mini-paper begin with a socio-economic analysis in which an interest-influence diagram is provided for all potential stakeholders across the entire food production and consumption value chain. Producing the right tailor-made product will remain a challenge in the coming years as production and marketing is dependent on the upstream availability of waste/residue surpluses which need to be processed.

"It is vital to understand the end-user acceptance and requirements of recycled nutrients - so the opinion of farmers, retailers and consumers. The market uptake needs to be driven from the demand side, not solely from pushing technologies that aim to recover nutrients from manure and other waste to resolve regional problems related to nutrient excesses." - Lars Stoumann Jensen expert in the FG.

4.3. On-farm needs

Recycling nutrients and their subsequent utilisation needs to be possible at farm-level. The following section looks into tools and practices available at the farm, followed by a farmer's opinion of biobased fertilisers.


4.3.1. Tools and practices aimed at nutrient management and recycling

Within the scope of the FG, two mini-papers were developed on the topic of on-farm applications: mini-paper 2 (Snauwaert et al.) which provided a description of applicable tools, and mini-paper 3 (Riiko et al.) which provided an overview of farm-level practices.

Several **low-tech and easy-to-use tools** exist to monitor the fertilisers or the soil.

For example, a “tube sampler” can provide an accurate averaged **sample of manure slurries from storage** without agitation of the manure (i.e. mixing the manure). The results are comparable to sampling at the surface after agitation of the storage. The advantage of non-agitation is that the sample can be taken without making the slurries homogeneous at the moment of sampling or when the livestock is present above the storage.

Slurry hydrometers allow a crude **estimation of dry matter content**. Several methods exist for assessing slurry quantity in manure storage: e.g. this can be achieved by installing level sensors in the slurry tank, or software tools can be used to estimate animal manure production based on animal production quantifiers.

 In Italy, such a tool has been developed and tested for pig and dairy farms. This tool can be used effectively in commercial farms to assess actual manure production and thereby improve manure and nutrient management.

To **estimate the nitrogen content of fertilisers** a variety of metres exist, ranging from the rudimentary electrical conductivity electrode, to more specific ammonium N-metres, and then to more advanced systems operating on the principles of Near Infra-Red Spectroscopy (NIRS).

Electrical conductivity electrodes, in essence, measure ionic strength of a solution and thereby give a measure of total dissolved salts. Applying this to manure gives a crude estimate of ammonia but not the exact composition as all ions (Na, K, Cl,...) contribute to the electrical conductivity, and so this creates uncertainty.

Ammonium N metres measure then ammonia nitrogen but do not measure organic nitrogen. So in order to convert ammonium content to total nitrogen content, certain assumptions need to be taken on the ratio of organic N/ammonium N in the manure or digestate. Nevertheless, considering that ammonium N provides insights on the directly available nitrogen that is present, this type of sensor can be helpful regardless of the unknown (variable) organic nitrogen content.

Near Infra-Red Spectroscopy is a relatively new development that makes it possible to have ‘real-time’ measurement of NPK and dry matter content of manure and digestate. Several constructors of agro-equipment have started to integrate these sensors. However, validation research is still going on in the Netherlands and Belgium (amongst others) to study the level deviation between on-line measurements and the slower wet-chemical lab analysis. All on-line sensors (ranging from electrical conductivity to NIRS) have the obvious advantage that the farmer receives estimations in real-time and not after days or week(s). Moreover, on-line metrology allows multiple measurements to be taken of the same tank/tractor load which itself is prone to variation because of the non-homogeneous nature of slurries.


To **predict crop nitrogen requirements** via soil analysis, mini-paper 4 (Forrestal et al.) describe the use of the Pre-sidedress Nitrate Test (PSNT). This is an in-season soil nitrate test that can be used to determine if additional nitrogen fertiliser is needed for corn. This test should be conducted on soil samples taken just prior to side dressing (just before the period of major N demand by corn). The test can be done for fields with a history of manure and/or sod incorporation. The PSNT is designed to: (1) estimate the soil’s nitrate supplying potential, and (2) decide if there is enough N to meet crop needs.



Figure 2. A quick test is used to measure soil nitrate; in the future, the development of smart sensors may make real-time monitoring of soil nitrate levels easier.

The overview on practices on-farm in mini-paper 3 (Riiko et al.) begins with the general notion that nutrients in organic fertilising products (sewage, digestate, products derived from manure, etc.) differ from actual crop requirement in terms of nutrient ratios and when these nutrients become available for plant uptake. The mini-paper makes a comprehensive overview of: (i) case studies in which mineral and biobased fertilisers are optimally combined; (ii) examples of cooperatives (including web links) working on optimising nutrient recycling and its use in plant production and; (iii) some examples of research projects which have tackled this topic.



 Acqua & Sole is a biobased fertiliser producer that recovers nutrients from municipal waste and municipal waste water sludge by advanced anaerobic digestion systems. The digestate, in form of a gel, is directly injected in the soil at depth of 15cm in order to reduce any possible loss of nutrients. The uniformity of distribution is achieved thanks to a distribution system based on the use of volumetric pumps and GPS systems with the distribution of the material proportional to the speed of the tractor. In addition, the company is field-testing NIR technology for real-time

measurement of the nutrient content while spreading on land. Acqua & Sole, together with the Milano University are partners in the [H2020-project SYSTEMIC](#) (2017-2021), which aims at advanced nutrient recovery from large scale biogas plants. [Read the article on Acqua & Sole on the EIP-AGRI website.](#)

4.3.2. Value of biobased fertilising products for farmers

End-user acceptance and appreciation was identified by the FG as one of the key focus points when wanting to achieve closed loops in practice. The first objective of nutrient recycling is to retrieve nutrients in a chemical form that makes them susceptible for plant uptake, thereby having the **ability to substitute fossil based mineral fertilisers**.

Anaerobic digestion breaks down biomass into biogas, a methane rich gas. The microbial degradation of the biomass entering the biogas plant also implies effective mineralisation of this biomass and thereby results in an increased ratio of mineral nitrogen compared to total nitrogen content. The ratio of mineral over total nitrogen is important as it is equivalent to the plant-available fraction of nitrogen in the product. This ratio can be further increased by mechanical separation of the digestate: undissolved organic matter will have a tendency to move to the solid fraction after separation, leaving the liquid fraction with a higher mineral N over total N ratio. The ratio can be even further enhanced by membrane filtration on the liquid fraction. In the Netherlands large scale investigations have been conducted demonstrating biobased fertiliser effectiveness when compared to commercial mineral fertiliser as a bench-mark (CAN: calcium-ammonium fertiliser), also known as the **Mineral Fertiliser Equivalent (MFE)**.

It is important to also take the impact of '**ineffective nutrients**' into account. For example, in the case of nitrogen, we should consider whether ineffective N is prone to (ammonia) volatilisation, (nitrate) leaching or if it can contribute to soil organic stock as non-mineralised organic N. The selected strategy for spreading the manure or digestate (splash plate, band spreader, trailing shoe, shallow injection) will affect ammonia emission during and shortly after fertilisation. One way for assessing 'ineffective nutrients' is analysing the presence of free nitrate in the top soil after harvest. These "nitrate residues" form the basis for monitoring the environmental compliance of farmers by regulating authorities in Flanders (Belgium) and Brittany (France).

To predict the **release pattern of nitrogen from biobased fertilisers**, soil incubation tests can be used as an analytical tool. The experimental design in such tests is simple but effective: under

standardised laboratory conditions, soils fertilised with biobased fertilisers are compared to soils fertilised with mineral fertiliser as a reference. Conversion into mineral nitrogen is monitored over time to simulate in-field performance of such products. Predictions and easy-to-use validating tests may be the way forward for market implementation of biobased fertilisers. In addition, such testing and prediction mechanisms are also aligned with regulatory frameworks in various European regions where post-harvest nitrate residues are regulated and monitored. In the United States, the presence of free nitrate in corn stalks post-harvest have been considered as a reliable indication of excess N application. Other tools which have been developed and are being used at market scale include satellite imaging for specific fields and crop follow-up (Cropsat) in Sweden and Denmark.

In addition to mineralisation behaviour and possible nitrate leaching, it is also important to understand **ammonia emissions**. In normal upland soil conditions, ammonium is readily converted to nitrate by endogenous bacteria in a matter of days and weeks thereby preventing further ammonia emissions. However, up to that point, ambient temperature, pH of product and soil as well as the means of application (e.g. injection vs. spreading) will affect ammonia emissions. Mini-paper 4 (Forestal et al.) provides an overview of the prediction of ammonia volatilisation.

Scientific and agronomic communities alike increasingly stress the **importance of organic matter in the soil** as an indicator for overall soil fertility. But paradoxically, legal frameworks and fertilisation advice take this very little into consideration and focus solely on nutrient limits. This can lead to soil degradation (i.e. reduced soil organic carbon content). Soil organic carbon can therefore rightly be considered as the 'forgotten nutrient'. The challenge is that nutrients contained within an organic fertiliser or soil improver have more complex dynamics, making their release more difficult to predict and plan than mineral fertilisers. But, scientific and agronomic literature have clearly demonstrated that crop yield, nutrient and water holding capacity are all mechanistically and statistically correlated with 'effective organic matter' (EOM) in the soil (i.e. organic matter which is recalcitrant to break-down in the short-term).

Mini paper 5 (Veeken et al.) highlights the importance of **recalcitrant organic matter** which can contribute to the soil carbon stock for prolonged periods of time. The mini-paper refers to the importance of the Fertiliser Regulation (European Commission COM (2016) 157 final) revision, which recognises biobased fertilisers as mineral fertilisers under a given set of conditions. The regulation makes a distinction between solid organic fertilisers and organic soil improvers based on certain criteria. The mini-paper 5 makes an alternative proposal regarding the classification of the biobased fertilisers which need further attention. It subdivides products originating from nutrient recovery techniques into 'organic soil improvers' and 'biobased fertilisers'/'organic fertilisers' based on the ratios EOM/mineral N and EOM/P₂O₅. The motivation for this is:


- The EOM gives good indication of the part of the organic matter that contributes to soil organic matter and soil quality. EOM can be determined by measuring the organic matter content and multiplying by the Humification Coefficient (the HC of most organic sources are well documented).
- The N-mineral gives good indication of nitrogen that is directly available to plant. N-mineral (ammonia and nitrate) determination is a standard routine analysis.
- P₂O₅ gives a good approximation of the P availability. Determination of total P₂O₅ is a standard routine analysis.


4.4. Regulatory framework affecting nutrient recycling


Although the EIP-AGRI FGs aim to focus on scientific and agronomic content, in this particular case of nutrient recycling, regulatory frameworks at the European and national/regional level represent an important driver (or obstacle) for making progress. There are many pieces of legislation concerned and mini-paper 7 (Kabbe et al.) highlights and briefly discusses the most relevant policy initiatives which have been undertaken at EU and member states level, including:

- Water Framework Directive (WFD) – 2000/60/EC
- Urban Waste Directive – 91/271/EEC
- Sewage Sludge Directive – 86/278/EEC
- Waste Framework Directive – 2008/98/EC
- Nitrates Directive (ND) – 91/676/EEC
- Industrial Emissions Directive (IED) – 2010/75/EU
- Fertiliser Regulation – 2003/2003/EC
- Animal by-products regulation – 2009/1069/EC
- Registration, evaluation, authorisation and restriction of chemicals (REACH) – 2006/1907/EC

The list is non-exhaustive and does not presume to be all-encompassing considering that this topic is continuously evolving. Nonetheless it illustrates the common strive towards nutrient recycling throughout Europe. See some examples of policy initiatives below:

 In its Resource Strategy of 2013, Denmark's government announced the target of 80% P from sewage to be recycled by 2018, either as sewage sludge applied on agricultural soil or P recovered from incineration ash.

 In France, the government has called for an increase in nutrient recycling through its recent report "Agriculture and innovation 2025": the purpose is to increase the carbon content of soil to improve soil fertility and to tackle climate change.

 In Switzerland (non-EU), a new waste regulation entered into force on 1 January 2016 making phosphorus recovery compulsory for sewage sludge and meat and bone meal, with a 10 year transition phase.

In addition to making a concise overview of the importance of each of the legal frameworks on nutrient recycling stated above, the mini-paper debates potential policy measures for further discussion, such as:

- Financial incentives such as taxation of fossil-based nutrient resources or reduced taxation of renewable nutrients.
- Quantification and charging of real costs including environmental impact not yet included in any environmental taxation scheme.
- Linking CAP (Common Agricultural Policy) subsidies to sustainability/recycling criteria.
- Labelling obligations to include the share of recovered nutrients or carbon foot print per unit of product.
- Phasing out of non-renewable biological materials (e.g. peat) (Scottish Government, 2016)³

³ Scottish Government (2016) Making things last - Consultation on creating a more circular economy in Scotland. URL: <http://www.gov.scot/Publications/2015/08/2820/downloads> (the link "Making things last: Consultation on Creating a More Circular Economy in Scotland [PDF, 825.1 kb: 25 Aug 2015]")

5. Future perspectives

The Focus Group identified, discussed and prioritised seven research needs from practice and five ideas for topics for EIP Operational Groups. The complete list of topics raised by the experts can be found in [Annex 3](#) and [Annex 4](#).

5.1. Identified research needs

Standardisation of LCA methodologies/risk assessment

Life Cycle Analysis and risk assessment often use information from theoretical databases which themselves were derived from other fields of (industrial) application for which they are more adapted. However, dedicated data and modelling methodologies are required for agricultural processes. In the pursuit of more dedicated assessment methodologies, great care is required for appropriate standardisation.

Assessment of the Nutrient Use Efficiency

When fostering the recycling of nutrients, both agronomic yield assurances and sufficient environmental safeguards need to be considered. Specific nutrient use efficiency, as well as nutrient losses, need to be quantified. Significant amounts of work have already been carried out on this issue and therefore the compilation and meta-analysis of existing and reported data is also required. Finally, unfortunately, different countries and research institutes use different approaches in defining nutrient use efficiency which raises the need for standardisation and model calibration.

Organic contaminants

The list of potential organic substances is long and non-exhaustive as opposed to the list of potential inorganic elements which is well-delineated and exhaustive. Organics can enter the agro-food chain through various pathways, of which agro-pharmaceuticals is only one such example. Whenever organic biological wastes or sludge are processed and recycled for their nutrients, these can expose agro-systems to additional risk concerning xenobiotic compounds. Specific research needs in this area identified by the FG include: collating existing data on organic contaminants from different sources (member states, industries, research) and filling data gaps; information on what happens to organic contaminants during manure processing and how to improve processing to treat these contaminants; impacts of organic contaminants on soil ecology and on food safety.

Acceptance of the use of biobased fertilisers

Social sciences use 'choice experiments' to identify the willingness to accept & pay for novel types of biobased fertilisers. In addition, social acceptance studies should investigate the entire value chain – for example the food industry and distribution/retail have an overwhelming impact on the acceptability of biobased fertilisers. Interests and views on sustainability can cause conflict between stakeholders – for example, the application of renewable nutrient resources can be emphasised against the perceived risks of unknown impact on the environment or (real or imaginative) risks associated with recycled products. The terms 'renewable' or 'recycled' therefore do not necessarily imply a higher acceptance level.

Use of remote sensing

The future in fertilisation lies largely in developing and applying smart systems based on (remote) sensing and integration of various nutrients as well as organic matter in such intelligent systems. Precision farming combines environmental with agronomic benefits. Achieving these combined goals will prove more challenging when dealing with biobased fertilisers whose nutrient use efficiency is not as exactly defined as is the case for pure chemically formulated mineral fertilisers. Technologies exist for optic sensing of crop nitrogen needs (based on colour), on-tractor metre-by-metre measurement of crop yield. However further research and development is needed on how to bring real-time analysis into precision farming e.g. for phosphorus management for which to date, only non-instant sample soil tests exist.

Development of farm tools

Some of the major hurdles of implementing nutrient recycling schemes can be found in the uncertainties at farm level regarding composition (variability) and speciation of nutrients and organic carbon in manure, materials such as digestates or composts and in soil. Development of easy-to-use and affordable tools which can be applied at the farm therefore require further attention: e.g. to maintain an overview of composition, speciation and ratios of nutrients and organic carbon in manure storage or storage of derived products.

Development of tailor-made products

Composition of biobased fertilisers are determined by the original streams from which they are produced. Rarely to never the composition of such products will represent an optimal concentration and ratio between N-P-K and other nutrients in relation of the targeted crop requirements. Because of this, there will always be a 'limiting element' which determines how much you can supply as based on fertiliser regulations. This in turn will required the other nutrients to be additionally amended. If biobased fertilisers could be adaptable to serve variable crop requirements more directly at the source, being able to supply several nutrients at once in desired ratio, they would become more valuable to end-users who would otherwise need to blend and amend products to meet their specific crop requirements.

5.2. Ideas for Operational Groups

When discussing and prioritising concepts for EIP-AGRI Operational Groups, some common points were raised for all of the suggestions:

- The need to involve farmers as much as possible in Operational Groups since they bring practical experience in the use of biobased fertilisers and they themselves can act as advisors/promoters for the use of these new technologies.
- No need to reinvent standards or new business models. Operational Groups can mainly focus on how to adapt the existing ones to nutrient recycling.
- The need to increase the trust in the use of new biobased products all along the value chain: farmers should know the effects and results of organic fertilisers and the food industry need to be sure that it can be safe and/or environmentally friendly.
- Operational Groups should look at agronomical and environmental assessment to show the advantages in using this kind of recycled products.

The top-rated ideas for Operational Groups as proposed by the FG were the following:

Process demonstration (general)

There is a need to demonstrate nutrient recycling technologies that can be replicated, including technologies for the reduction of ammonia emissions. Implementation of systems with higher environmental performance due to e.g. recycling of non-renewable resources, reduced ammonia emissions, return of carbon to soil, and creation of environmentally friendly food products. Involvement of actors throughout the value chain, including the food industry and retailers, to highlight sustainability and value gain. The whole system assessment of agricultural production should include stable to manure storage, further treatment and final application. For example, there is a particular need for demonstration of available low NH₃ emission technologies that can be replicated across Europe.

Product demonstration (focusing on the products and the farmer)

There is a need to explore tailor-made fertilisers from agro-residues and other organic secondary materials which match plant requirements, in optimal concentrations and nutrient ratios. These should take account of site/crop specificity and also reflect market and user requirements concerning marketing, distribution, compatibility with farmers' storage and spreading equipment etc. This could be achieved through technology demonstration in practice, by illustrative success stories like the ability to substitute fossil-based synthetic fertilisers with recycled nutrients. Such demonstrations should include agronomic assessments to validate that the recycled nutrient product performs as required based on crop yield and soil quality data.

Integration of nutrient management in certifying schemes

Standards need to be defined both by farmers and consumers. A whole-chain approach is advised in which producers, farmers but also food-industry/retail and consumers get involved and engaged in making the entire agro-food production and supply chain more sustainable. It is also apparent that quality requirements can induce opposite demands throughout the chain: e.g. some food-industry sectors tend to demand standardised production using synthetic mineral whereas ecolabels towards carbon footprint may want to move in the opposite direction towards more biobased/organic fertiliser products. The proposal is to work as much as possible from existing labelling and certification schemes and to include traceability and a high level of transparency. Examples already exist for sludge and composts (+ digestate in some countries and regions) in respect to recycled nutrients. The aim of installing additional certification is to create trust as well as extra value.

Cooperative business models

There is a need for setting up cooperation between different types of stakeholders to improve tailor-made production of fertiliser products as well as enhance marketing of such novel products. Intermediary facilitators can include technology suppliers, product blenders and marketers. This does not necessarily imply doing new things, rather looking at transfer of experiences and cooperating locally. Think out of the box and explore new markets for recycled nutrients (e.g. organic farming, landscape management, public domains etc.) and work on acceptance by tackling existing legal barriers. Develop business models while looking at the environment and integrate environmental protection and sustainability in procurement and marketing.

From the farmer for the farmer

In order to achieve market uptake of recycled nutrients in the form of biobased fertilisers, field experience and exchange of information between farmers is required on the pros and cons of using such products, like nutrient behaviour in soil and crops and impact on the C content in the soil. Trust in biobased fertilisers by farmers should be created. The effects on what happens in the soil should be made clear for the farmers and examples of good performance should be highlighted. Farmer decision tools and auto-control systems can be developed and tested in order to stimulate use and foster trust and control.

5.3. Raising awareness

The transition towards more nutrient recycling will not be achieved by technological innovation alone. There is a clear and present need to interlink the many actors and stakeholders along the agro-food value chain. Farmers, fertiliser industry, food industry, consumers and other actors involved in logistics, distribution and retail need to be made aware that recycling our nutrients is in the best interest for all involved.

Annexes

Annex 1. List of members of the Focus Group (FG)

First name	Family name	Country	Professional background
Fabrizio	Adani	Italy	Scientist
Jean-Philippe	Bernard	France	Expert from agricultural organisation
August	Bonmatí	Spain	Scientist
Jeanet	Brandsma	Netherlands	Farmer
Susanne	Klages	Germany	Expert from agricultural organisation
Vera	Eory	United Kingdom	Scientist
David	Fangueiro	Portugal	Scientist
Patrick	Forrestal	Ireland	Scientist
Zoltán	Hajdu	Hungary	Farm advisor
Dolores	Hidalgo	Spain	Scientist
Lars	Stoumann-Jensen	Denmark	Scientist
Christian	Kabbe, PhD	Germany	Other
Airi	Külvvet	Estonia	Farmer
Erik	Meers	Belgium	Scientist
Giorgio	Provolo	Italy	Scientist
Filip	Raymaekers	Belgium	Other type of advisor
Kaisa	Riiko	Finland	Expert from NGO
Emilie	Snauwaert	Belgium	Other type of advisor
Edward	Someus	Hungary	Expert from agricultural organisation, industry or manufacturing
Christopher	Thornton	France	Expert from agricultural organisation, industry or manufacturing
Adrie	Veeken	Netherlands	Expert from agricultural organisation, industry or manufacturing

Annex 2. List of mini-papers

Mini-paper 1

Available technologies for nutrients recovery from animal manure and digestates

David Fanguero, Emilie Snauwaert, Giorgio Provolo, Dolores Hidalgo, Fabrizio Adani, Christian Kabbe, Augustus Bonmati, Jeanet Brandsma

Mini-paper 2

On Farm Tools for accurate fertilisation

Emilie Snauwaert, Patrick Forrestal, August Bonmati, Kaisa Riiko, Susanne Klages, Jeanet Brandsma, Giorgio Provolo, Jean-Philippe Bernard

Mini-paper 3

On Farm Practices

Kaisa Riiko, Patrick Forrestal, Emilie Snauwaert, Zoltán Hajdu, Susanne Klages, Airi Külvet

Mini-paper 4

Towards increasing the mineral fertiliser replacement value of biobased fertilisers

Patrick J. Forrestal, Fabrizio Adani, Emilie Snauwaert, Adrie Veeken Jean-Philippe Bernard, Lars Stoumann Jensen

Mini-paper 5

The value of recycling organic matter to soils: Classification as organic fertiliser or organic soil improver

Adrie Veeken, Fabrizio Adani, David Fanguero, Lars Stoumann Jensen

Mini-paper 6

End-user requirements for recycled and biobased fertiliser products

Lars Stoumann Jensen, Chris Thornton, Patrick J. Forrestal, Jeanet Brandsma, Airi Külvet, Kaisa Riiko, Christian Kabbe

Mini-paper 7

Regulatory environment effecting nutrient recycling

Christian Kabbe, Vera Eory, Emilie Snauwaert, Edward Someus, Jean-Philippe Bernard

Mini-paper 8

Assessing the environmental effects of nutrient recycling from organic materials used as fertilisers

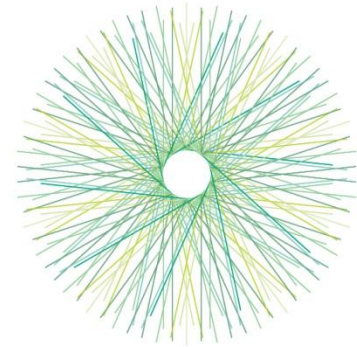
Vera Eory, Christian Kabbe, Zoltán Hajdú, Dolores Hidalgo

Annex 3. Complete list of research needs from practice

Nr	Research need from practice
1	LCA methodologies particularly adapted for nutrient recycling in agro ecosystems as current LCA approaches appear to be more suitable for industrial processes
2	Long term effect of recycled organic sourced fertilisers
3	Data collection of technologies bat (Best Available Techniques)/BAU (Business as usual) on nutrient flows in different regions Data collection of results from different project - not to lose information and to avoid repeating the same type of research
4	Trade-offs in environmental indicators: e.g. GHG emission vs. nutrient losses; reducing environmental impact for one indicator may (and will often) result in an increase for another (feed/fertilisers/energy)
5	Risk assessment from a quality perspective (e.g. (organic) contaminants such as pharmaceuticals coming from intensive animal husbandry OR compounds in recycled municipal sludges
6	Acceptance of the use of fertilisers by different groups of stakeholders : (i) farmers; (ii) general public; (iii) food industry/retailers
7	Agronomic and environmental impact of fertilization using new types of products (e.g. derived from biogas activities, manure treatment, composting,...) on the organic carbon content in soils
8	The use of organic fertilisers on grassland
9	Monitoring and evaluating nutrient flows on farm: calibration of on-line tools (e.g. instantaneous NIR vs. longer wet chemistry determinations in the lab), nutrient accountancy systems
10	Remote sensing translation to actual yield and N content
11	Economic efficiency on ICT tools
12	Developing smart loops between cities (waste and sludge) and farms
13	Nutrient content determination through fast and cheap on-farm tools
14	Practical aspects of (new) form of organic fertilisers: implications for storage, handling and spreading
15	Functional classification of organo-mineral fertilisers, biobased mineral fertilisers, organic fertilisers and soil improvers
16	Environmental behaviour of new developed products applied to soil (e.g. N and P leaching)
17	Develop 'tailor-made' products to better match crop and soil requirements e.g. low N/P high carbon in some animal husbandry intensive regions
18	Sustainable logistic solutions

Annex 4. Complete list of ideas for Operational Groups

Nr.	Topic	Operational Groups
1	Nutrient use efficiency, available techniques, environment and end-user requirements	Focus on products: to explore tailor-made fertilisers from waste which match with plant requirements (product optimisation) +consider site specificity, end-user and market requirements.
2	Environment	Data collection for environmental assessment, using pilot assessment which results in marketing/environmental labelling.
3	Standards	Field testing of standards for recycled nutrients products
4	Standards	Integration of nutrient management into certification schemes
5	End-user requirements, organic matter content, on-farm practices	How farmers can deal with pros and cons of different organic fertilisers. To identify examples of good performances. Including impact on C content of the products and the soil. To test decision tools.
6	Farm tools	To test or develop integrated system that uses jointly the best available techniques
7	Farm tools	Demonstration of techniques in use to prove practical sustainability.
8	Farm tools	Development of end-user friendly and widely applicable tools.
9	Farm tools	Mapping of possible resistance to apply/use existing tools.
10	On farm practice	On farm trials to see effects with respect to mineral fertiliser (e.g. liquid separated manure)
11	Technologies	Prototype demonstration of >TRL 7 technologies
12	NUE	Utilisation of low emission technologies (NH ₃ emission). Many techniques are already available.
13	Legal aspects standards	Explore cooperative quality assurance schemes (self-certification)
14	Organic matter	Decision tools for farmers to choose products in terms of organic matter
15	Technologies	Looking to downscale or upscale technologies to have the most efficient scale in terms of logistics, economics, ...
16	Logistics	Work in group of farmers to set up business models for marketing (e.g. export excess of manure) e.g. mixing and stabilisation of the manure



eip-agri
AGRICULTURE & INNOVATION

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

An EIP AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

The concrete objectives of a Focus Group are:

- ✓ to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:

http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf



funded by



Join the EIP-AGRI Network & Register via www.eip-agri.eu