ESPP SCOPE Newsletter n°155 – April 2025

Phosphorus sustainability in livestock

*This Newsletter summarises the workshop on **phosphorus sustainability in livestock**, with TIMAC AGRO (the leading activity of the Groupe Roullier) and Cooperl at Saint Malo, Brittany, France, and online, 5-7 March 2025, as part of the United Nations UNEP GEF uPcycle project, organised by BETA (Vic Spain), CEH UK and ESPP.*

Over one hundred participants took part in the workshop including UNEP, FAO and the European Commission.

Participants visited TIMAC AGRO's production installations, research centre and quality control laboratories, the Roullier Endowment Fund Minerallium (an immersive exhibition explaining the origin of minerals, their roles in life and their processing), Cooperl's processing of manure digestate and animal by-products to organo-mineral fertilisers and energy, and a low emission, high-performance pig farm.

Workshop recordings, slides, documents: https://phosphorusplatform.eu/LivestockBrittany.

The workshop was organised with the following partners:

TIMAC AGRO International and Roullier Group

Participants visited one of TIMAC AGRO's 120 production facilities (organic and organo-mineral fertilisers, biostimulants) and the company's international research centre and production control laboratories.

Roullier Group

TIMAC AGRO is part of the **Roullier Group**, a family-owned company established in 1959, with today a total of over 100 production sites and 10 000 staff in 135 countries worldwide. TIMAC was established around agronomic valorisation of local materials from Brittany: TIMAC = Société de Traitement Industriel du Maërl en Amendement Calcaire. Maerl (rhodolith) is a red algal seaweed, abundant on Brittany's coasts.

The Roullier Group's activities are today fertilisers and biostimulants (TIMAC AGRO), animal nutrition (including Phosphea) and related sectors including magnesium minerals (magnesite mine in Spain), bakery products and plastics (spin-off from fertiliser packaging and transport).

TIMAC AGRO, the plant and soil nutrition branch of Roullier Group, has 7 400 staff worldwide and some 120 production facilities at 83 different sites. More than half of the company's staff are technical farm advisory, meeting around 20 000 farmers per year.

TIMAC AGRO's success is based on a unique model: valorisation of local and secondary organic resources, innovation and farmer dialogue.

Roullier CMI - Global Research Centre

The **Roullier Global Research Centre (CMI)** in Saint Malo was inaugurated in 2015, regrouping some 70 researchers in a new building and facilities. Installations include state-of-the-art chemical and biological laboratories supporting research, controlled greenhouses for pot testing (including a unique, fully-robotised greenhouse system enabling randomised and plant-by-plant non-destructive plant and root monitoring). The site also includes a library of past production batch samples, enabling quality verification as needed.

Research includes **cooperation with over 80 universities and research centres** and generates 5 – 10 patents and 10 – 20 scientific publications each year. The centres laboratories carry out over 120 000 analyses per year to accompany research, support production process development, or verify conformity to regulatory, product label or individual customer specifications.

The company produces **biostimulants from bio-sourced materials, in particular regional marine resources**. These can improve crop nutrient use by e.g. stimulating root fungi (mycorrhiza), solubilisation of phosphorus, nitrification, or breakdown of cellulose or lignin (releasing nutrients fixed in organic materials, or organic molecules which can improve nutrient availability). Biostimulant action can be direct (e.g. P solubilisation in soil) or indirect (e.g. stimulating plants or soil organisms to release sugar exudates which attract root fungi).

The CMI and TIMAC AGRO's priority is to ensure **robustness of response, that is a positive effect on production for farmers, whatever crop, soil and weather conditions**.

The product research aim is to understand which active molecules are present in a biological extract, which are having the intended biostimulant effect or crops, what is the mechanism in the soil, plant and symbiotic organisms and what effects other molecules present might have. This requires both chemical and biological analyses, as well as a range of pot tests with different plants and conditions, before field tests and then commercialisation.

A challenge is to balance the effects of soluble mineral fertilisers. These can cause plants to become 'lazy' about nutrient uptake, for example to release low-affinity P transporters.

Holistic plant and animal nutrition

Tristan Chalvon-Demersay, CMI - Groupe Roullier, discussed challenges and opportunities in mineral use efficiency in livestock.

Nutrients in animal feeds show varying bioavailability, between different types of feedstuff, different minerals and in different livestock species. But generally, **less than 50% of minerals in animal feed are taken up by the animal**, the remainder going to manure. Gut uptake of phosphorus and other oligo-elements is limited by compounds naturally present in fodder: oxalates, tannins, interactions with other minerals, and by the non-digestibility of phosphorus in minerals bound to phytate for monogastric animals (phytate is the P-rich molecule in which plants store phosphorus, in particular in seeds). See Bryne et al. 2022

LCA (Monteiro & Dourmad 2022) indicates that trace minerals have a high environmental impact on water pollution (part not taken up, going to manure) and on resource depletion, while phosphorus contributes to eutrophication.

Nutrients are generally supplied to livestock in excess to cover the requirements of most animals. Levers exists to improve the efficiency of use of feed minerals:

- **Phase feeding**: diets adapted to animal weight range and development stage.
- **Precision feeding**: diets adapted to each individual animal in real time using sensors and automatic feeders,
- **Feed processing to optimise digestion while reducing nutrition interaction** (liquid feeding, micronisation),
- **Phytase enzyme supplementation** for monogastrics (enables breakdown of phytate, so uptake of its phosphorus content). This is now generalised practice.
- **Organo-mineral compounds**, facilitating mineral nutrient uptake such as glycinates or proteinates.

Roullier Group through its animal feed subsidiaries offers its own innovative feed solutions:

- **HumiPHORA (PHOSPHEA)**: organo-mineral solution which promotes phytic phosphorus digestibility by limiting calcium-phytate interaction and facilitating phytase activity
- **Capmag Zinc (TIMAB)**: zinc protected in a magnesium matrix enabling a slow release of zinc and reducing its complexation with phytate.

Sylvain Pluchon, CMI - TIMAC AGRO, Groupe Roullier, presented the holistic **soil biome approach to plant nutrition**. The nutrient biome is the holistic set of nutritional factors which enable plant growth and health (see Posma et al. 2000)

The approach is feed the soil fauna, to feed the plant, to feed livestock.

An example is to stimulate earthworms, whose excrement then stimulates microbes which produce enzymes which mineralise nutrients and stimulate plant root development. Such approaches can both increase plant nutrient uptake, and improve plant nutrient and micronutrient content, for example increasing selenium, sodium and nitrogen content in fodder or grazing.

A problem is that it is unclear whether products with such holistic approaches correspond to the EU Fertilising Products Regulation definition "PFC 6: Plant Biostimulants … the function of which is to stimulate plant nutrition processes … with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere …".

Site visit: TIMAC AGRO production

The site visit started with an overview of the production plant to be visited, explaining the various raw materials, both organic and inorganic, and the final products produced.

This helped the participants understand the TIMAC model (B2C = sales directly to the customer), which is based not only on technological products but also on **daily agronomic support to farmers**, helping to optimise their time, quantities applied agronomic performance.

After taking all the necessary health and safety measures for such a visit, particip followed the **site process chain**, starting with the reception of raw materials, in a covered area with separated compartments to manage different raw materials efficiently. This management aligns with the ISO and other standards followed on-site and also with the EU Fertilising Products Regulation 2019/1009.

Depending on the production schedule, different quantities of raw materials from the reception area are weighed and conveyed by mechanical belts to undergo fine grinding, ensuring an optimal particle size and then to pre-granulation. Participants visited the pre-granulator, a large cylinder measuring 4 metres long by 1.5 metres diameter. This phase allows for the adjustment of the mixture's humidity, which can vary from one formula to another. The granulator is similar to the pre-granulator, but applies a centrifugal force on the mixture to break it into granules. Visitors also saw micro-granulation installations which can be used for different products, the plant's central control room and an exposition of the different generations of control rooms that have been used on the plant since its start-up.

Site visit: The Minerallium

Participants also visited the Minerallium, Saint Malo, the first corporate philanthropic initiative of the Roullier Endowment Fund. An interactive exhibition, opened in 2020, with the support of the Paris Natural History Museum, explains the vital role of natural minerals from Earth's origins to modern agriculture. Visitors explore four immersive spaces that reveal how minerals geologically originate and transform, how they are extracted and processed, and how they contribute to plant, animal, and human nutrition. This is illustrated by many different mineral samples from across the world. For example, the Fugui site, Spain, exploited by Roullier for magnesite, is illustrated and explained with samples. Among its highlights is the Couëron, a remarkable 6 500-year-old oak trunk.

The public can visit the Minerallium on request *https://www.fondsdedotationroullier.org/fr/le-minerallium/*

Cooperl

Bertrand Convers, Cooperl. This is a farmers' cooperative: Coopérative des Eleveurs de la Région de Lamballe, (established 1966). Its shareholders are **its 4 600 Brittany pig farmer members**, and its governing body is farmers elected by these members. Cooperl's member farmers have some 5 million pigs, around 27% of Britanny's pig production (Brittany has around 10% of EU pigs).

Cooperl has over 7 000 staff and activities both exporting and producing pork products and pig farming technologies in various countries worldwide. Sustainability and innovation are key objectives, and Cooperl has 120 research staff two full-scale research farms (> 1000 pigs, in Brittany and in China) and production is today 50% no-antibiotic and 100% no-castration.

Cooperl is specialised in the whole pig production chain, including farm advisory services to members, supply of intrants, meat processing and distribution, technologies – equipment and digital solutions.

Examples relevant to phosphorus stewardship include:

Feed optimisation:

- **Replacing soya** by agri-food by-products
- **Additives to improve diet phosphorus uptake**, including phytase and amino acids. Mineral phosphate feed additives are no longer needed for growing pigs > 50 kg.
- **Intelligent feeding**: automatised adaptation of feed provision for each individual pig, with monitoring of weight, feed and water intake. This enables rapid identification of health issues pig-by-pig.
- **Genetic selection** and pig breeding.

Manure nutrient recycling:

- Cooperl's farmer members operate some 70 **manure treatment plants** across Brittany, treating 500 000 t/y ww of pig manure.
- Design and delivery of **low nutrient loss stable buildings** (TRAC, see ESPP SCOPE Newsletter n°114) and now V-Scraper, with slatted floor and scraper systems, ensuring separation of urine from solids, so reducing ammonia emissions, improving animal welfare and increasing biogas potential.
- **Vacuum systems for ammonia removal** from stable offgas in existing buildings.
- **Production of organo-mineral fertilisers** from manure biogas digestate, after drying using waste heat (abattoir non-reusable waste incineration).
- **Non-food valorisation of pigs**: 80% by weight of the pig goes to human food products. The remaining 20% (bones, skin, hair, guts …) is valorised as aquaculture feed, heparin production, biostimulant extraction, etc, with the non-valorisable materials used to produce industrial fuel or for onsite energy.

Cooperl site visit: anaerobic digesters

Cooperl's nutrient recycling is based on:

- Nearly 40 000 t/w (wet weight, c. 28% DM) **solid fraction of pig manure is collected from low-loss stabless** (V-scraper). Average transport distance to Lamballe is c. 60 km. Farmers are paid 15 – 25 €/t-ww, depending on the % dry matter. Storage on farm before transport is up to one month, but because it is stored as separated solid fraction, there is little loss of biogas potential.
- **Anaerobic digestion**: this collected solid fraction of manure is transported to Cooperl's anaerobic digester in Lamballe, where it is mixed with c. 65 000 t/y (6-8 % DM) pig abattoir (Cat2 – Cat3) sludges. The digester is certified ABP Regulation sanitisation. The biogas produced is injected into the natural gas network after membrane purification and H_2S removal (nearly 80 GWh/y), providing ¾ of the gas needs of Lamballe city (15 000 population).
- Animal meals, Cat1 and other ABP materials from the pig abattoir are incinerated generating **energy** (steam).
- This steam energy is used to process the digestate by **evapo-concentration** (steam compressor with energy recovery).
- After solid-liquid separation and blending with mineral nutrients, the solid fraction is dried and nutrients are dosed to produce **organo-mineral fertilisers tailor-made for different crops: sunflower, colza, grapes**, etc.
- Nitrogen is recovered from the digestate by **ammonia stripping to ammonia sulphate solution** (5 000 m^3/y at 8% N/ww and 15% S/ww),
- **Bio-CO_2 recovery** is starting in 2025. The recovered carbon dioxide will be used for food packaging and pig killing.

Current production at Cooperl Lamballe of solid organo-mineral fertilisers at is around 50 000 t/y only in granular form. 150 different formulas are manufactured according to customers' requests. Around two thirds of these are sold to farmers in nearby regions of France for vegetable, wine, or fruit production, and around one third is exported worldwide.

Cooperl site visit: digestate processing, organo-mineral fertiliser production from manure and animal by-products.

Site visit: Cooperl's Bulle Environnement

At the site visit to Cooperl's activities in Lamballe, workshop participants visited the "Bulle Environnement", an interactive showroom located at the heart of the Cooperl's Environmental and recycling processes.

Participants also visited operating installations, including the biogas plant, the organo-mineral fertilisers granulation units, water treatment (reverse osmosis), and R&D pilots including experimental spirulina production (to extract phytocyanin for food industry) and the tests of biodiesel production from animal by-products.

Site visit: Couiclang pig farm

Workshop participants also visited the Couiclang pig farm, located in Plene Jugon and operated by Bernard Rouxel, the chairman of Cooperl, with 4 employees. The farm houses 500 sows in a breeder-finisher model and employs an **advanced manure management system, including V-shaped slatted floor scraping**, for half of the production. The liquid part is treated with the slurry on site. From this system, the solid part is transported from the farm for biogas production.

The raw slurry from the rest of the site is initially stored in tanks equipped for biogas collection from manure storage (**Nenuphar** system), then separated into solid and liquid fractions. The solid fraction is transported to Lamballe to produce organo-mineral fertilisers, while the liquid part undergoes a biological treatment, where N content is decreased by 95% (to air as N_2). The resulting liquid is stored in a pond and then discharged with <500 mg/l N and some K. This solution is currently being substituted by a new one, to recover nitrogen rather than losing it to air.

Couiclang pig farm site visit:
covered manure storage with biogas collection

Livestock and phosphorus

In Europe, the quantity of phosphorus in livestock feed (including grazing input) – which is nearly the same as the amount of phosphorus in raw livestock manure - is somewhat **more than phosphorus used in mineral fertilisers**.

60 – 85 % of the phosphorus eaten in feed by livestock is found in manure[i].

Worldwide, phosphorus in livestock manure is estimated to be over 27 MtP/y[ii], compared to maybe around 24 MT/y in mined phosphate rock[iii].

Phosphorus is accumulating in soils in much of Europe, in particular in Southern Europe and in regions with high livestock production (see Panagos et al., JRC, 2002, fig. 9 below, and ESPP eNews n°73 and n°83).

Agricultural nutrient pollution contributes importantly to the fact that less than 30% of EU surface waters are achieving good chemical status (as specified by the EU Water Framework Directive, see ESPP eNews n°95).

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[i] 60- 90% of the phosphorus eaten in feed by livestock is found in manure. Jondreville & Dourmad (2006 DOI) estimate that for pigs 30-35% of digested P is retained (but that only 45% of P in a cereal-based diet is digested). Rothwell et al. 2020 (DOI) estimate that 35%, 42% and 16% of P in diet of Northern Ireland poultry, pigs and cattle is converted to in meat + milk + eggs (the remainder ending up in manure). Poulsen et al. 1999 (DOI) and Dourmad et al. 1999 (DOI) estimate that 30 -50% of P diet intake in pigs is retained, the remainder going to manure.
As a reality check, ESPP estimates that the slaughtered broiler chicken contains around 10% of available phosphorus in feed eaten (maybe around 5% of total phosphorus in feed) over its lifetime is based on the following: P_{av} content of broiler diet = 4gP_{av}/day (source) - final broiler weight = 2.8 kg (source) so estimate average weight over lifetime = 1.5 kg - broiler life time to slaughter = 45 days (source) - P-content of final broiler = 1% (source) - 60% of diet P is available (source)

[ii] Worldwide, phosphorus in livestock manure is estimated to be over 27 MtP/y:17 Mt/y in 2000 (Bouwmann et al. 2013 DOI, cited in Panagos et al. 2022 in ESPP SCOPE Newsletter n°142. Extrapolated to 2023 based on increase in global meat production (source). For comparison, total worldwide P in manure estimated at 23 MtP/y in 2011 by Liu et al 2017 (DOI).

[iii] See sources cited in ESPP Phosphorus Fact Sheet http://www.phosphorusplatform.eu/factsheet

Robert Van Spingelen, ESPP President (Ostara), opened the workshop, underlining the challenges posed in many regions of the world by **regional concentration of livestock production**. To avoid this generating local nutrient pollution in livestock concentration hotspots, **manure processing is necessary to generate storable, transportable products which can be moved to regions with fertiliser demand**. Processing also avoids ammonia N loss, ensures stabilisation, and allows application according to crop needs (appropriate form, during the growth period).

Guillaume Jouslin de Noray, CEO of TIMAC AGRO, Roullier Group's historic and leading activity, underlined that **livestock is a major part of world food production, essential for a healthy diet, but contributes 15% of global greenhouse emissions**. Livestock manures are both a nutrient-rich fertilising material, but also a potential pollution if not appropriately managed.

TIMAC AGRO is specialised in valorising both organic and inorganic nutrients and bio-based biostimulants, with a strong commitment to sustainability and to cooperation. This workshop aims to further these commitments.

See further information on TIMAC AGRO and the Roullier Group above.

Laurence Loyon, INRAE, France, explained that Brittany has around 18 000 livestock farms (of which 1 500 are 'permitted' pig and poultry farms under the current Industrial Emissions Directive – IED). **In 2018, Brittany generated over 42 000 tN/y and 13 000 tP/y in excess, beyond regional crop needs** (official data not updated since 2018).

Regulatory policies have focused on limiting nitrogen losses to water (in particular, EU Nitrates Directive implementation), but this has led to improved manure management, so also impacting phosphorus. Nutrient balance excesses were reduced by -52% for N and -72% for P from 2000 to 2018.

In some water basins in Brittany, local rules (EU Water Framework Directive implementation) also limit phosphorus application to 80 – 95 kg P_2O_5/h/y.

In Brittany, nutrients in cattle manure are in total c. 2x in pig manure, however, only half of cattle manure is emitted in stables (the remainder on pasture) whereas nearly all pigs are in stables.

The level of knowledge and the manure management approach are very different between cattle and pig manure in France.

A key challenge is to **improve understanding of agricultural nutrient flows in Water Framework Directive targeted and Natura 2000 catchments**, to reduce negative impacts.

Livestock and manure across the world

Kimo van Dijk, Wageningen University & Research, outlined the context for sustainable agricultural phosphorus management. Soil acts like a sponge for phosphorus: phosphorus added to soil is rapidly adsorbed (to minerals, clays) but is then held and difficult to extract (by crops), but can then leach out over time. Phosphorus-enriched water bodies often remain eutrophic for decades after P inputs are stopped, as stored P is released from sediments over time.

Much of Europe's agriculture have N and P levels below agronomic optimum, with crops needing P inputs, whereas regions where livestock is concentrated have excess phosphorus in manures (e.g. The Netherlands, Flanders, Brittany). In The Netherlands, which has Europe's biggest concentration of livestock, application of legislation has reduced excess manure application to land, but manure produced remains higher than legal land spreading capacity. This means that manure should be treated and exported to other regions of Europe.

There is more phosphorus in manure in the EU than is used annually in mineral fertilisers. Manures are also a major input of organic carbon to soil.

If manure is appropriately recycled as fertiliser, intensive livestock production can be one-and-a-half half times more phosphorus efficient than extensive livestock (40% vs. 25% P efficiency).

To avoid nitrogen losses (ammonia) and enable appropriate recycling of manure P as fertiliser in intensive livestock production, **manure processing is essential**, in particular solid-liquid separation, anaerobic digestion, nitrogen recovery or stabilisation, and processing of the solid fraction to a fertiliser product.

Also new **stable collection systems** are needed where emissions in stable are reduced and manure can be better recycled. A new innovation is the cow toilet, which separates urine from faeces during milking time of cows.

Nutrient recycling potential in manures

Total nutrients in manures and the 'poorly utilised' part of these were estimated by country, worldwide, by comparing livestock numbers to local agronomic nutrient needs.

Nutrients in livestock manure and human sewage were estimated based on 10x10 km grid square livestock density data and human population numbers, combined with literature values for manure / excrement / urine quantities and nutrient concentrations. These estimates of manure + sewage nutrients potentially available for reuse/recycling were then compared to estimates of local agronomic nutrient requirements, based on crop types in each 10 km square multiplied by agronomic fertilisation recommendations (including grasslands).

For nitrogen, biologically fixed N was estimated per 10 km square (based on local crop types) and nitrogen losses in manure storage and application were estimated (supplementary data, table 9). The study estimates (for 146 countries) that more than 45% of N in manure is lost to air and water, and 37% is lost on cropland. Losses (leaching) of phosphorus and potassium are not estimated.

Conclusions are that total nutrients in livestock manures and human excreta worldwide are as follows (see fig. 1b in the paper):

- c. 120 MtN/ in manures (plus c. 20 MtN/y in human excreta), compared to c. 100 MtN/y use in mineral fertilisers and to 225 MtN/y fertilisation needs of crops and grassland (of which around half for grasslands)
- nearly 20 MtP/y (plus c. 34 MtP/y in human excreta), compared to c. 20 MtP/y use in mineral fertilisers, and to over 50 MtP/y fertilisation needs of crops and grassland (of which around one quarter for grasslands)
- nearly 140 MtK/y (plus c. 6 MtK/y in human excreta), more than 5x use in mineral fertilisers, and to around 200 MtK/y needs of crops and grassland (of which around half for grasslands)

Most nutrients in manure worldwide are from cattle manure (73% of phosphorus) with 15% of P from chickens and only 2% from pigs.

The authors conclude that 14% of global livestock manure is "poorly utilized" (local excess based on a distance of 13 km). They assume that 100% of human sewage nutrients are "poorly utilised".On this basis, "poorly utilized" livestock manure (without sewage) represents 16% of global mineral fertiliser use for N, 7% for P and 101% for K.

Overall, the authors highlight that local mismatches between nutrients content in manure and crop + grassland requirements can represent substantial amounts at the subnational scale, which poses challenges for nutrient management and opportunities for recycling nationally but also globally.

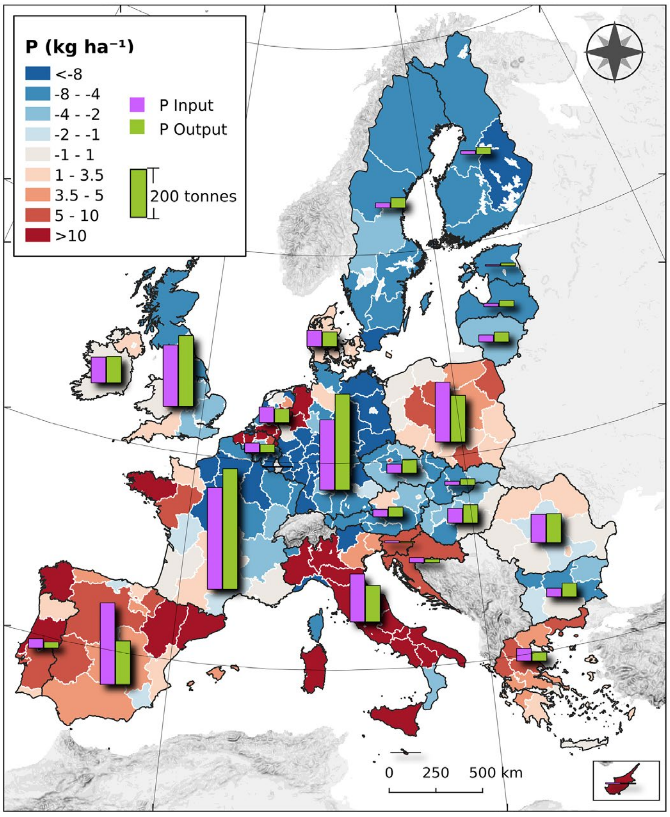
"Nutrient recycling potential of excreta for global crop and grassland production", M. Devault et al., Nature Sustainability 2024 DOI.

ESPP notes *that the above estimates require significant adjustment for Europe where most sewage is collected/treated and around 50% of sludge today is used on farmland, and where manures are in some cases processed locally then transported to crop-growing regions enabling nutrient recycling (see example of Cooperl above).*

Also, for phosphorus, the study assumes that if there is crop or grassland nutrient requirement nearby to manure production, then the manure nutrients are recycled (not 'poorly utilised'). This ignores:

- *phosphorus losses in cases of local over-application, application at the wrong time of the year;*
- *Phosphorus losses in extensive grazing because livestock concentrate manure in one place (see case of Swiss Alpine altitude pastures, M. Kreuzer, ETH Zurich in SCOPE Newsletter n°131) or around e.g. drinking or stable areas, or defecate in a stream where they drink (case seen by the author of this Newsletter in France recently).*

Below: Phosphorus is accumulating in soils in much of Europe, in particular in Southern Europe and in regions with high livestock production (see Panagos et al., JRC, 2002, fig. 9 below, and ESPP eNews n°73 and n°83).



Renjie Dong, Research Centre for Carbon Neutrality in Agriculture and Rural Areas, China, indicated that **livestock is regionally concentrated in China**: 60% of dairy in Inner Mongolia, 70% of beef cattle, poultry and pigs in South East China. 50% of manure in China is from pigs. China is continuing to move towards more intensive livestock production, so increasing regional nutrient excesses.

Open lagoon storage of manure leads to considerable ammonia releases (up to 50% N loss) and there is a trend to cover storage in China. However, composting of manure is widespread and leads to >30% N loss. Anaerobic digestion of manure (with carbon capture) offers considerable greenhouse gas emission reductions, and also (processed) manure digestates are more effective fertilisers than composts (3x higher nitrogen use efficiency) in some field trials.

Greenhouse gas emissions from livestock in China vary considerably, from 0.8 to >5 kgCO_2e/kg/y fat and protein corrected milk (FPCM). The main emissions are from feed and fodder production (32%), enteric fermentation (30%) and manure management (21%).

Pedro Federico Rizzo, Argentina National Institute of Agricultural Technology, indicated that the country's pork, poultry, meat, and dairy production is concentrated in the central-northeast region.

Argentina lacks legislation limiting nutrient losses from livestock production or the excessive application of manure. Some producers are testing manure management processes, such as anaerobic digestion or composting, but lack legal or financial incentives.

There is evidence of contamination of the environment (rivers, lagoons, soil, among others) with excess nutrients from manure from livestock farms, whereas much of the country experiences nutrient deficiencies due to intensive agriculture, resulting in dependency on imported fertilisers. So overall, the nutrient and organic matter supply from manure is not used appropriately in agriculture and instead impacts natural resources. The need for regulations and financial resources to promote the sustainable use and exploitation of nutrients from livestock manure in Argentina's vast agricultural area is highlighted.

Vinicius de Melo Benites, Embrapa Solos, Brazil, indicated that, **two decades ago, pig and poultry production in Brazil were concentrated in the Southern tip of the country**, where small farms and mountains predominate. Today, pig and poultry production are moving towards the centre of the country to regions with high crop nutrient demand, with P-fixing soils (high in iron oxides), so requiring high P inputs. Manure from pig and poultry contains around 1/4 of total Brazil mineral N and P fertiliser use.

The Brazil national fertiliser plan aims to develop the use of organo-mineral fertilisers based on manures after drying, granulation and blending with mineral nutrients and biostimulants, with the aim of reusing these residues and alleviating pressure for nutrient imports.

Mercedes Gelós, Uruguay Ministry of Environment, indicated that **the country has significant eutrophication issues**, causing important value losses to tourism, human and animal health and to wildlife.

Uruguay has a strong tradition of extensive beef cattle production, with one of the highest cattle-to-human population ratios in the world. In 2023, it was the third-largest meat exporter in South America. Extensive livestock production spans the entire national territory, but the number of cattle in intensive livestock farms (IFOs) has doubled in the last 10 years. Dairy farming is concentrated in the centre and centre-south of the country.

While **Uruguay still needs to develop specific national regulations addressing nutrient and manure management**, the country has developed projects, guidelines and strategies to promote sustainable farm nutrient management practices, particularly in drinking water supply basins. These efforts aim to balance agricultural productivity with environmental sustainability.

Uruguay's **National Circular Economy Strategy** includes efficient use of resources, minimising waste and farm nutrient circularity. This strategy incorporates previous national experiences, such as the Biovalor project on agro-industrial waste valorisation (supported by the United Nations Industrial Development Organization UNIDO). More efforts are needed regarding extensive beef production and nutrient sustainability.

Policy – United Nations

Monica Kobayashi, UN Convention on Biological Diversity (UNEP), emphasised that nutrients (including phosphorus) are essential for humans, animals and plants, but excess nutrients lost to the environment can damage biodiversity and ecosystems, with impacts on society including water use and tourism.

The **United Nations (United Nations Environment Assembly, UNEA) has adopted two resolutions on nitrogen management** in 2019 and 2022 (see ESPP eNews n°67) and a resolution on sustainable lake management (2022).

The United Nations has also included in the Kunming-Montreal Global Biodiversity Framework (KMGBF 2022, see ESPP eNews n°74) the aim, by 2030, to reduce all pollution to levels not harmful to biodiversity and ecosystems including (KMBGF Target 7) "***reducing excess nutrients lost to the environment by at least half, including through more efficient nutrient cycling and use***".

The Convention on Biological Diversity is now working with its Parties (countries) to implement the KMGBF and its Monitoring Framework. Early March 2025 in Rome, Parties reached agreements on the Mechanism for Monitoring, Reporting and Review (PMRR), as well as on the full set of headline indicators that will be used to measure global and national progress towards the implementation of the KMGBF. **The headline indicators include 7.1 "Index of coastal eutrophication", as a mandatory data input for all Parties**. This headline indicator can have optional disaggregation, such as reporting by type of nutrient (for instance, nitrogen and phosphorus) and by sub-basin. Countries can also include other voluntary component and complementary indicators, for instance, trends in loss of reactive nitrogen to the environment or trends in nitrogen deposition. This headline indicator is a continuity of the existing indicators for Sustainable Development Goals SDG6 (Clean Water and Sanitation). Sustainable manure management and recycling may be considered under actions to reduce nitrogen and phosphorus losses.

Aimable Uwizeye, FAO (UN Food and Agriculture Organisation), discussed nutrient use efficiency, in particular for phosphorus. **A tendency towards concentrated livestock production worldwide means an increasing dependency on synthetic nitrogen and phosphorus fertilisers for production of animal feed crops, grown far away from the animal farms.**

This situation leads to poor management of manure, which results in nutrient losses into the environment, as shown in the global assessment of nitrogen emissions along the global livestock supply chains using the FAO Global Livestock Environmental Assessment Model (GLEAM). This analysis will be extended to cover phosphorus flows and losses in future.

FAO's recent report "Sustainable nitrogen management in agrifood systems", https://doi.org/10.4060/cd3388en, shows that **<10% of nitrogen input to livestock systems ends up in animal products,** with also some N recycled within the system and the remainder lost into the environment. Considering the entire livestock supply chain, nitrogen emissions represent around one third of total anthropogenic N emissions.

This report recommends:

- **animal feed nutrient use efficiency**: reduce protein content of feed,
- **improve manure management**,
- **use of waste food and leftover feed streams in animal feed**,
- **relocate livestock** close to cropland,
- **support farmers** for better livestock production practices,
- **include livestock N emissions** in climate policies,
- **capacity building** and knowledge.

Policy – European Union

Stephanos Kirkagaslis, European Commission, DG AGRI, summarised the Commission's recently published "Vision for Agriculture and Food" (19th February 2025). This includes the aim of **reducing dependency on mineral fertilisers** by improving **on-farm nutrient use** and **nutrient circularity.** It prioritises **addressing nutrient pollution hotspots and promoting integrated territorial approaches with better management of nutrients from livestock farming** and **supporting extensification of intensive livestock regions**.

The EU generates some 1.4 billion t/y (wet weight) of manure. 90% goes to land with possible excess use beyond the land's capacity or inappropriate application leading, in certain areas, to significant nitrogen loss (mainly as nitrates and ammonia). **Only 40% of livestock farms have manure storage, thus not ensuring its optimised use** (when needed by crops or facilitating its recycling). The number of farms with **open liquid manure storage (lagoons) is less than 5% (2020, reduced by half since 2010), but a significant number of farms have other solid or liquid manure storage which may**

not be covered or manure stored below confined animals etc (Eurostat). This maintains concerns over ammonia losses.

The **Common Agricultural Policy (CAP)** can support farm manure management with EcoSchemes, Agri-Environmental and Climate Commitments and with investment support, including for renewable energy, with an aim of promoting circular use of manure. Manure storage, nutrient recycling and reducing nutrient losses can also be supported. Some Member States also support livestock extensification, either using CAP funding or through national funding programmes.

Future EU agriculture policy developments are expected to include:

- **Nitrates Directive**: evaluation underway, while the draft 'Renure' proposal is being discussed with Member States,
- **New CAP programme post-2027**,
- **Benchmarking** system of farm performance: development starting.

There is room for further emissions reduction in agriculture with effective policies that reward good practices while addressing nutrient pollution hotspots, aligning with regional needs and promoting upscaling of solutions.

Diogo Botelho Moniz and Francesco Presicce, European Commission, Joint Research Centre (JRC), provided an overview of **Best Available Techniques (BAT) for emission prevention and control in pig and poultry farms** under the EU Industrial and Livestock Rearing Emissions Directive (IED 2.0).

This Directive was revised in 2024 to cover a larger number of pig and poultry farms (see ESPP eNews n°89) under a more flexible regime (compared to other industries). The updated environmental norms for this sector will be defined in the **'UCOL' (Uniform Conditions for Operating Rules for Livestock)**, to be published by September 2026. To inform this process, an exchange of information is taking place with relevant stakeholders. This will include the techniques used in pig and poultry farms (BAT and emerging techniques), their associated monitoring, as well the emissions and environmental performance levels in the sector (e.g. for ammonia, nitrogen, phosphorus).

BAT (Best Available Techniques) are defined as those techniques that are most effective in achieving a high general protection of the environment as a whole, including human health and climate protection. The JRC steers the so-called 'Sevilla process', a participatory, data-driven process for the definition of BAT-based environmental norms in large industrial installations in the EU (see https://eippcb.jrc.ec.europa.eu/reference). The process results in the publication of BAT reference documents (BREFs) for more than 30 large industrial sectors. These documents include the 'BAT conclusions', which are **published as Commission Implementing Decisions and are the basis for the obligatory environmental norms** in those sectors in EU Member States.

The revised Directive has also established the 'Innovation Centre for Industrial Transformation and Emissions' (**INCITE**, see ESPP eNews n°91), to identify and evaluate the environmental performance of innovative techniques, to inform policy developments and investments (see https://innovation-centre-for-industrial-transformation.ec.europa.eu/).

Adrian Leip, European Commission, DG Research & Innovation (Bioeconomy), underlined the current linearity and nutrient inefficiency of the food system in Europe: of 20 million tonnes/year of reactive nitrogen fixed annually (by industry, by crops) only around 2.5 Mt/y end up in food. This **nutrient inefficiency is largely due to livestock**. 60% of biomass produced by agriculture goes to animal feed, but animal products provide only 40 – 60% of protein and calories in food (see European Nitrogen Assessment, 2nd Report on "Appetite for Change: Food system options for nitrogen, environment & health", 2023, submitted to the UN Working Group on Strategies and Review (WGSR) for the Convention on Long-range Transboundary Air Pollution, DOI.

Animal production can contribute to nutrition security and serve as an asset for smallholder famers (as argued e.g. by the Dublin Declaration, see below). However, while this is correct, **most meat production is in developed countries in intensive production which does not contribute to biodiversity protection**. Also, most meat consumption is in developed countries where nutrients are consumed in excess (Bryant et al. 2024, DOI).

The "Appetite for Change" report (reference above) suggests that a **"demitarian" diet** (see SCOPE Newsletter n°111, ESPC2) brings health and nitrogen balance benefits similar to a vegetarian diet. Meat consumption is in any case today slowly decreasing in Europe. This report concludes that **a 50% reduction in food system nitrogen losses is achievable** by a coherent combination of measures at farm level, reducing food and nitrogen waste in the food chain, and a demitarian diet. This will require a coherent policy package, including targeted fiscality (with accompanying trade policies and social compensation), regulatory actions towards the food sector, consumer diet communication and information and technical actions to improve nutrient use efficiency and reduce nutrient losses. Health benefits resulting from dietary changes reduce the socio-economic cost of achieving such ambitious nitrogen reduction targets.

Environmental benefits may also be possible by replacement of meat by plant-based analogues (already widely available on supermarket shelves), precision fermentation or cultivated protein (both producing protein directly from biomass).

Food system scenarios

Wolfram Simon, Wageningen University & Research, presented modelling of impacts on greenhouse emissions, land use and nutrient cycles of differing dietary scenarios. **The current largely linear agri-food system has significant environmental impacts and is contributing to both widespread obesity and malnutrition**. Around one-third of the world's food production is lost.

The **Circular Food System Model (CiFoS)** enables the modelling of the impacts of change scenarios in diet and in organisation of the agri-food system. The model suggests that the current inefficiency of the food system is largely due to linearity, too much livestock production (too many animals), and land use for animal feed production instead of human food. See Global Nutrition Report 2021.

Modelling results suggest (see ESPP eNews n°93) that a circular food system in the EU could reduce both farmed land surface and per capita greenhouse emissions by around 70%. Total livestock production would be reduced, with **diets shifting** from 60:40 animal:plant protein currently, to 40:60, and total diet protein intake would decrease from 83 to 55-65 g/person/day, close to the recommended minimum of 46 g protein/person/day (derived from 0.66 g total protein – plant plus animal – per day per kg body weight EFSA 2008 DOI). **Nitrogen Use Efficiency** would increase from currently <20% to around 50%, and mineral fertiliser use would be reduced by over 90%. The total number of livestock animals would decrease by around 50%. Particularly, beef production would be reduced strongly, while dairy numbers would be halved.

With a dietary animal:plant protein ratio below around 40:60, more land is needed for food production. This is because **livestock efficiently use biomass that humans do not want or cannot eat (grazing, recycled materials) and generate manure,** which is used as fertiliser. Below approximately 20g of animal protein per person per day, dietary micronutrient deficiencies would occur unless dietary supplements and fortification were used.

The **widespread replacement of mineral fertilisers by manure risks leading to increased ammonia emissions from an increase in manure quantities in the food system**. The model suggests that some synthetic nitrogen fertiliser is always needed in the system for balanced crop fertilisation and to minimise overall greenhouse gas emissions.

The CiFoS model considers all grassland in the calculation of 'land use' and estimates biodiversity impacts based on the quantification of land use. This approach follows a "land-SPARING" logic, ultimately leading to a significant decrease in grassland areas used for agricultural production. It should be noted that, from a "land-SHARING" point of view, **permanent grassland (not ploughed and replanted) can have high biodiversity and landscape value**, and extensive livestock grazing is often the socio-economically optimal way to maintain these.

See "Circularity in Europe strengthens the sustainability of the global food system", H. Van Zanten et al., Nature Food, 2023 in ESPP eNews n°93

The Dublin Declaration

The ***"Dublin Declaration** of Scientists on the Societal Role of Livestock"* *was developed at the "International Summit on the Societal Role of Meat", hosted by the Irish state agency for agriculture Teagasc, Dublin, 19/20 October 2022. It is today signed by over 1 200 scientists.*

The Declaration states that livestock systems are precious to society and must progress on the basis of good science. It notes the challenges to livestock systems today:

- *societal demand to increase availability of meat, dairy and eggs to satisfy* ***unmet nutritional needs of c. 3 billion people*** *worldwide*
- ***impacts on biodiversity, climate change, nutrient flows and animal health****.*

The Declaration states that evidence shows that "the regular consumption of meat, dairy and eggs, as part of a well-balanced diet is advantageous for human beings".

Livestock are stated to be "irreplaceable for maintaining a circular flow of materials in agriculture, by recycling in various ways the large amounts of inedible biomass that are generated as by-products during the production of foods for the human diet" and that "well-managed livestock systems applying agro-ecological principles can generate many other benefits, including carbon sequestration, improved soil health, biodiversity, watershed protection and the provision of important ecosystem services" as well as contributing to social structures (livestock ownership and livelihoods, rural communities, gender equality …).

The Declaration concludes that "Sustainable livestock will also provide solutions for the additional challenge of today, to stay within the safe operating zone of planet Earth's boundaries".

Criticisms *of the Declaration suggest that it:*

- *neglects the negative health impacts of overconsumption of meat in part of the world,*
- *relies on technological progress to "fix" the sector's identified challenges,*
- *overestimates the beneficial effects of livestock, whereas this is limited to only a minor share of production and consumption worldwide.*

Criticisms also suggest that the authors, many of whom are meat and livestock scientists, the publishing journal (Animal Frontiers) and Teagasc all have indirect vested interest in the livestock industry.

Industry circularity

Anton van den Brink. FEFAC (European Feed Manufacturers' Federation) represents for over 65 years compound animal feed and premix manufacturers, and is part of **IFIF, the International Feed Industry Federation**. He presented the industry's sustainability objectives, which include safe recycling of organic materials and nutrients into animal feeds. See **FEFAC "Circular Feed"** 2022.

In Europe, industrial compound feed represents around 22% of total feed consumption by farm animals, alongside 16% on-farm feed mixing and 60% fodder (feed crops and grazing).

Important circularity routes in animal feed include:

- **co- and by-products** from the primary (food) processing, from industrial bio-refineries (e.g. from production of ethanol, starch),
- **former foodstuffs** (food products which cannot be used as human food for reasons of quality, date, logistics …),
- **grass bio-refining**.

Feed circularity can reduce livestock demand for imported soybean meal, which is a critical food security and environmental impact pressure point for livestock production sustainability.

FEFAC has developed a **four-point key to evaluate sustainability of feed circularity**:

- **reduce food/feed resource competition**,
- **proximity** (essential for economic feasibility and for overall LCA),
- **nutrient digestibility**, to ensure effective nutrient valorisation,
- **land use**, based on Product Environment Footprint and economic-value allocation.

Land use is assumed to correlate to the market price of a material (so-called economic allocation), which in many cases could be considered 'zero'. Inspiration can be taken from the renewable energy sector, where "wastes" and "residues" are de facto considered to not carry any upstream carbon emissions.

Challenges to circularity include:

- **competition for organic residues with subsidised energy valorisation** (e.g. biogas production),
- **lack of demand 'pull' from downstream customers** (food industry, supermarkets), and in some cases explicit refusals or restrictive standards,
- **continuity of supply** for secondary materials,
- **regulatory obstacles**, including inappropriate wording of exclusions which are not justified (as written) for safety reasons, in particular in the Animal Feed Regulation 767/2009, the EU Animal By-Products Regulations and in Waste/End-of-Waste regulations.

FEFAC is coordinating a **Circular Feed Platform**, bringing together a number of EU federations and organisations, to develop proposals for increased feed circularity, encouraging the European Commission to develop a Circular Feed Roadmap/Action Plan, including requests towards EFSA (European Food Safety Agency) for risk assessments of significant potential feed recycling opportunities.

The upcoming EU Circular Economy Act should include a **clarification of the 'Waste Hierarchy':** animal feed valorisation > fertiliser use > energy use.

Manure processing innovation and practice

Philipp Theuring, EasyMining (Ragn Sells Group), presented the company's mineral nutrient recovery processes: **Ash2Salt** (potassium), **Ash2N** (nitrogen) and **Ash2Phos** (phosphorus).

The Ash2Phos process recovers a **high-purity calcium phosphate (apatite, branded RevoCaP)** from ashes. This calcium phosphate respects animal feed and EU Fertilising Products Regulation quality requirements (purity significantly better than animal feed requirements), is free of organic contaminants or health risks (because post-incineration), and has been shown in trials to be safe and to be effective in animal trials with pigs and poultry (see ESPP eNews n°82).

Photos: EasyMining Ash2Phos Helsingborg pilot

A first full scale plant is under construction at Schkopau, Germany (with the regional waste and water utility company Gelsenwasser, see ESPP Technology Catalogue) to recover c. 15 000 t/y of calcium phosphate from 30 000 t/y of sewage sludge incineration ash (commissioning planned end 2026).

However, use of this recycled phosphate in animal feed in the EU is currently prevented by the wording of EU Regulation 767/2009 (see ESPP eNews n°92).

An LCA is underway, and provisional data suggests that this recovered calcium phosphate has greenhouse gas emissions slightly lower than for mineral phosphate fertilisers, but considerably lower than for mineral phosphate animal feed.

Karleigh Lewis, Livestock Water Recycling (LWR), presented the company's manure or manure digestate processing technology. This involves: coarse grid coarse solids removal, flocculant-assisted solid-liquid separation, then polishing filters and reverse osmosis.

Outputs are:

- **solid organic fertiliser:** c. 3%P/DM, c. 25% dry weight,
- **liquid 'concentrate'**: c. 0.2%N/wet weight, c 0.2%K/ww,
- **Clean water** (discharge quality).

The system includes a 2h/day automatic cleaning cycle for the membranes and the focus is on reliability and longevity. LWR systems are today installed at a total of around 40 dairy farms in North America and worldwide, with some systems now operating for more than ten years.

Operating cost and revenue benefits depend on solids separation costs, influent manure and manure disposal costs, NPK breakdown of output products.

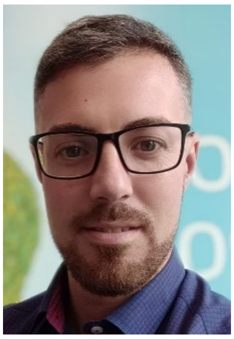
Carbon credits can be possible. Examples include:

- LWR now has three states with carbon credit projects: Washington State, Wisconsin and Idaho,
- Washington State: carbon credits for methane emission avoidance compared to open lagoon manure storage,
- Some US consumer food companies: carbon credits for Scope3 emissions reductions / carbon 'inset' credits,
- California: environmental and carbon credits for farmers.

ESPP comment: for independent analysis by dairy farmers see the US Newtrient dairy manure processing catalogue www.newtrient.com entry for LWR (may not be up-to-date).

Alex Bayo, Bioproductors d'Alcarras (a cooperative of 150 pig and cattle family farmers in Catalunya, photo below). The cooperative collects nearly 130 000 t/y (15% DM) organic wastes, mainly farm manures but also crop and agri-food residues. This is digested, then solid-liquid separated. Ammonia is stripped from the liquid digestate and it is recovered as ammonium salt, the leftover liquid part is used in fertigation. Nearly 60 000 t/y (50% DM, c. 2 mS/cm conductivity, 2% P content) compost are produced from the solid digestate and from cow manure. The cooperative is currently working on pelletisation of the compost, to improve useability by farmers. Projects also include covering the open-air composting installations to capture the atmospheric methane losses*, possible recovery of bio-CO_2, and investigation of e.g. biochar.

** ESPP note: Composting generates considerable greenhouse emissions (unless covered with off-gas treatment), in particular methane and N_2O, in addition to local air pollution (ammonia, volatile organic carbons, particulates). Typical greenhouse gas emissions from composting of manure are: 5 g methane/kg and 0.3g N_2O/kg manure (ww) composted. See Nordahl et al. 2023, review of data from 46 studies "Greenhouse Gas and Air Pollutant Emissions from Composting" DOI.*



Mikel Zubicaray Prol, Mecàniques Segalés, a manure treatment technology provider from Catalunya, presented several technologies for manure management:

- **Sucker**: mobile, autonomous robot manure vacuum cleaner, for collection of mixed solid-liquid slurry from animal housing, adaptable to different types of stable building. This reduces the emissions inside the stable and preserves the nitrogen content (agronomic value) and the methane production potential of the slurry. The collection should be followed directly by solid-liquid separation or introduction into anaerobic digesters.
- **Manure acidification**, recognised BAT technology for stabilising nitrogen in manure, reducing ammonia losses and so N, improving recycling rate. Also facilitates continuous slurry pit emptying.
- **Anaerobic digester** equipment, for biogas production and manure stabilisation, e.g. agitators and enrichment systems for a higher methane production.
- **Hygienisation**, focused on the recovery of the separated solid fraction for safe use in stabled cow bedding.
- **Solid-liquid separation**, with patented ramp filter, technologies (low cost, low maintenance, down to 250 µm) and microfilters (down to 80 µm, allowing use of the liquid fraction in drip irrigation).
- **Nitrification-denitrification (to remove nitrogen as N_2)**, focused on farms without land availability, allowing for the application of a larger volume of treated slurry on a smaller number of hectares.
- **Nitrogen recovery** (ammonia stripping/scrubbing).

He underlined the need to for technologies to treat slurry as quickly as possible on farms, so preventing decomposition, favouring the maintenance of nitrogen content and of methanogenic value, while reducing emissions.

Research

Laia Llenas, BETA Tech Center, University of Vic, Spain, presented a research overview of manure processing for nutrient recycling, developed by the Biorefine ESNI R&D project cluster. The main technologies identified are:

- Combustion and pyrolysis
- Anaerobic digestion
- Ammonia stripping/scrubbing
- Membrane-based systems
- Algae systems.

For each of these, **the process was summarised, output materials identified and technology and cost challenges summarised**. Overall challenges include: on-farm reliability, investment and operating costs, energy consumption and the need to produce a quality product with a regulatory and demand market.

Outcomes of the **Fertimanure R&D project** were summarised (see ESPP Scope Newsletter n°152).

The Catalunya region biogas development strategy was presented, noting that this will lead to a significant increase in manure digestate production, and so a potential for processing to organic fertilisers.

Reindert Devlamynck, Inagro, agricultural research, Belgium, presented **case studies of anaerobic digestion of manure** to produce renewable energy (biogas) and processed digestate fertilising products.

A 165 dairy cow farm uses biogas to generate 44 KW electricity. Residual heat is used for hygienisation (required for export to France), before solid-liquid separation (decanter centrifuge) and drying the solid fraction, to produce a phosphorus-rich organic fertiliser. Ammonia is stripped then acid-scrubbed to produce ammonia sulphate, which is evaporated to give a solid material, which is used locally by farmers.

A 700 sow pig farm uses biogas to produce 150 KW electricity. Digestate is solid-liquid separated (DAF plus paper filter) then membrane treated to give clean water for discharge and a mineral concentrate which is returned to the anaerobic digester.

Challenges identified are permitting for anaerobic digestion, and costs, which depend on farm size, on land availability for manure spreading and on the overlap between the farm and process energy consumption and production profiles.

Rosa Fibla Matamoros, BETA Tech Center, University of Vic, Spain, presented the **Pigpef Environmental Footprint of Pig Production** modelling tool. This is aligned with EU Product Environmental Footprint methods. Pigpef models livestock processes to calculate the Environmental Footprint, including impact categories such as climate change emissions, based on farm production type, composition of animal feeds used with feed data, manure management installed and livestock destination.

This shows the **importance of animal feed composition and manure processing** in livestock farm greenhouse emissions and overall environmental impact.

Francisco Salazar, INIA, Instituto de Investigaciones Agropecuarias, Chile, presented **research into manure management in dairy grazing systems in Chile**, in close collaboration with farmers. Research includes manure farm management tools, in particular an easy-to-use and simple hydrometer for slurry (dry matter enables estimation of nutrient content), evaluation of emissions comparing slurry application to urea fertiliser and development of a farmer manual for slurry application. A challenge is that although farmers are aware of the theoretical economic value of nutrients in manures, best management practices are not implemented on farms to reduce manure nutrient losses (e.g. low emission equipment, manure acidification or stabilisation). He noted that Chile has general regulations for the protection of air, water and soil that apply to all activities, including e.g. dairy farms and dairy processing. Currently there are plans to develop anaerobic digestion of manure for biogas production and to optimise cattle feed. There are also initiatives for dairy livestock sustainability. For example, Nestlé offers financial incentives to dairy farmers for sustainability (LINK).

Workshop key messages

This workshop inputs to the white paper on phosphorus sustainability in livestock production to be produced by CEH UK as part of the UNEP GEF project uPcycle.

The following key messages for this white paper were proposed by the Saint Malo workshop participants:

- **Livestock production worldwide is inefficient and environmentally damaging**: 15-40 % of phosphorus[iv] and of nitrogen[v] eaten in feed ends up in livestock products. Livestock nitrogen emissions (mainly from manure) represent one third of total anthropogenic N emissions[vi].
- Most[vii] **phosphorus in livestock diet ends up in manure**, with potential for recycling or for water pollution, depending on management.
- The international **objective to reduce nutrient losses by 50% is signed in the United Nations** Kunming-Montreal convention Global Biodiversity Framework 2022. **For nitrogen, this objective can be achieved** by a combination of dietary change and technical measures across the food chain[viii]. **Plant-based diets** have generally show higher Nitrogen Use Efficiency and have lower greenhouse gas emissions than animal-based diets. These calculation may not be fully applicable for phosphorus, which is not lost to air and which is conservative in manure, so can be recycled.
- **EU livestock production is dependent on imported nutrients**. Around 1/5th of phosphorus fed to animals in the EU is currently imported[ix]. Additionally, fodder production in Europe is partly dependent on imported fertilisers.
- **Phosphorus in manure in the EU is around 1.3 MtP/y[x] so somewhat more than used in mineral fertilisers**. The potential for recycling is therefore significant. However, most manure is already returned to land, but possibly with low levels of real nutrient recycling[xi].
- **Slurry, manure and digestate should be transformed into products with higher nutrient use efficiency that can be stored and transported**, allowing transfer from livestock production areas to crop-growing regions and from carbon- and nutrient-rich soils to poor ones.
- The development of manure anaerobic digestion for **renewable energy (biogas) objectives[xii],** opens opportunities for digestate processing to products with better nutrient use efficiency.
- **Food- feed hierarchy**: Organic residues should be used for animal feed where possible (preferable to energy use).
- Need to **engage with downstream agri-food industry (food companies, dairy industry, meat companies)** who were invited to this workshop but were absent.
- If manure cannot be economically processed to fertiliser products with a regional market (as achieved by Cooperl), then **regional concentration of livestock should be avoided or reduced** (manure hotspots, soil nutrient saturation) and livestock production should be developed in regions where crop production needs fertilisers, so can use (stabilised) manure. However, in much of the world, the current trend is contrary, with increasing regional concentration and intensification of livestock production.
- **Nutrient stewardship needs to be locally and holistically managed at the water basin and catchment level,** integrating land, crop, livestock, water and nutrient management.
- **Importance of permanent pasture (not ploughed and replanted)** for biodiversity, landscape, soil carbon: role of extensive livestock production (grazing) in maintaining and restoring permanent grassland ecosystems.
- **Considerable greenhouse and ammonia emissions from manure storage in open lagoons** (without cover, offgas treatment) and from livestock farms without manure storage (manure application at the wrong time of year)[xiii].
- **Manure composting can generate considerable greenhouse and ammonia emissions, if not covered and with offgas treatment**.
- **Need to move to low-emission stable systems** (in-stable solid liquid separation by e.g. slatted floors and scrapers, stable offgas treatment).
- **Importance of manure and digestate stabilisation** (manure acidification, on-farm plasma treatment) and improved application (injection not surface spreading) to reduce ammonia emissions and nitrogen losses and improve P use efficiency.
- **Animal feed can be the highest LCA / nutrient and GHG factor in livestock production**, as well as a factor of food security dependency on imports (e.g. in Europe).
- **A sustainable livestock system would use as animal feed:**
  - biomass not suitable for human food (e.g. extensive permanent pasture grass**),**
  - fodder crops produced by **inter-cropping**
  - secondary materials unsuitable for human food
  - and recycled nutrients
  That is, avoiding feed crops competing for land which could be used to produce human food or for biodiversity[xiv].
- **Investments are needed** for the clean and efficient transformation of slurry and digestate to ensure economic, environmental, and industrial efficiency.
- **Public policies**, including regulatory, economic and information and communication, are essential to drive and accompany livestock sustainability and dietary choices.
- **Farmers should be supported** for livestock sustainability and nutrient recycling, financially and with technical support.
- **Certified carbon and biodiversity credits** should be developed to support reduction of nutrient losses and nutrient recycling.
- **Innovation** is necessary to develop new technologies that increase Nutrient Use Efficiency (NUE) and to improve their on-farm adaption.
- **Better system-understanding and data are needed on nutrient flows**, including Nutrient Use Efficiency and nutrient losses in extensive livestock systems.
- **Collaboration and partnerships** are key to reach this transformation, as underlined at the workshop by the CEO of Roullier Group. Partnership is the 17th UN SDG (Sustainable Development Goal).

[iv] References footnote (i) page 6 of this SCOPE Newsletter n°155.

[v] Nitrogen conversion from animal feed to meat and carcass, dairy, eggs, wool etc: animal
- 29%: Cetraal Bureau voor de Statistiek The Netherlands https://longreads.cbs.nl/the-netherlands-in-numbers-2020/how-much-nitrogen-is-emitted-at-livestock-farms/
- 21 -38%: US Livestock and Poultry Environmental Learning Community (LPELC) https://lpelc.org/strategies-to-reduce-the-crude-protein-nitrogen-intake-of-dairy-cows-for-economic-and-environmental-goals/
- 15%: Yuan, China DOI https://doi.org/10.1016/j.jenvman.2019.04.028
- 15%: New Jersey Agricultural Experimental Station: https://www.sciencedirect.com/science/article/abs/pii/S0301479719304852

[vi] Uwizeye A. (FAO) et al., Nitrogen emissions along global livestock supply chains. Nat Food 1, 437–446 (2020). https://doi.org/10.1038/s43016-020-0113-y

[vii] 60 – 85 % of P in eaten feed ends up in the animal, see above, plus P in uneaten food, bedding, etc..

[viii] European Nitrogen Assessment, 2nd Report on "Appetite for Change: Food system options for nitrogen, environment & health", 2023, DOI.

[ix] Comparing imports in feed crops and feed phosphates to phosphorus in manure in Van Dijk et al. 2016 DOI, SCOPE Newsletter n°117

[x] Phosphorus budget in topsoils, JRC online data

[xi] Nutrient Use Efficiency of manure applied as a fertiliser will depend on processing, application methods, etc. Also, manure may in some cases by disposed of by spreading above crop needs or at the wrong time of the year for crop uptake, or under inappropriate weather conditions (rain resulting in runoff). Animals in fields will not spread manure evenly and livestock may excrete on areas without vegetation (in farmyard, on trodden areas around stables or feeding areas, when drinking in streams …).

[xii] EU REPowerEU Plan fixes the objective of 35 billion m^3 biomethane (purified biogas) production by 2030, that is a 10x increase (see Giulia Laura Cancian, EBA, in ESPP SCOPE Newsletter n°146)

[xiii] Open lagoon manure storage has been largely abolished in the EU (Botelho & Presicce in SCOPE Newsletter n°154) but is prevalent in the USA and elsewhere.

[xiv] FAO 2018 estimate, that on average globally, only 13% of livestock diets are cereals plus an additional 1% of other human-edible crops. Nonetheless, livestock consumer one third of cereals produced worldwide, and use around 40% of arable (ploughed) land, and occupy a further 2 billion ha of grassland. Around 3 kg of grain are consumed by livestock to produce 1 kg of meat. FAP "Shaping the future of livestock. Sustainably, responsibly, efficiently", 10th Global Forum for Food and Agriculture (GFFA) https://openknowledge.fao.org/server/api/core/bitstreams/4d7eff6c-2846-410d-aa37-5a4fa8b1a0f0/content

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