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Efficient Carbon, Nitrogen and Phosphorus cycling in the European Agri-food System and related up- and down-stream processes to mitigate emissions

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D6.7 Policy Note

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POLICY NOTE

TOWARDS A CIRCULAR EU AGRI-FOOD SYSTEM

Summary

Agriculture, and in particular livestock, uses nutrients inefficiently, contributing to water and air pollution and global warming. One of the objectives of the Green Deal of the European Commission (EC), through the Farm to Fork strategy, is the reduction of nutrient losses by at least 50% while ensuring the soil fertility. The EC expects that this will reduce the use of fertilisers by at least 20% by 2030. Integrated nutrient management plans will be developed by Member States with the objective of reducing and preventing further pollution from excessive use of fertilisers, while encouraging nutrient recycling from organic waste as fertilisers. At the same time, the EC encourages increasing information to consumers through harmonised labelling and establishes targets to reduce food waste.

Circular Agronomics aims to convert agriculture into a more circular and sustainable sector through short- and long-term measures from practical innovations to costumer awareness and facilitating legislation. With many of the developed innovative solutions a significant reduction of nitrogen emissions, in particular ammonia (NH_3), was achieved. Besides, the harmful greenhouse gas (GHG) nitrous oxide (N_2O, almost 300 times the Global Warming Potential as carbon dioxide over 100 years) was reduced significantly (e.g. >75 % due to fertiliser reduction in the trials with N efficient genotypes of winter wheat). Results are very promising for a transition to an environment- and climate-friendly agriculture, when farmers are able to invest in such innovations and build up the necessary knowledge. At the same time, consumers need transparent product labelling to make the right decision based on their norms.

Introduction

Nutrients and carbon maintain fertile and healthy soils, and allow adequate plant growth. Both nutrients and carbon are crucial in agriculture, but poorly managed so far. While most of the nitrogen and phosphorus entering our agricultural system comes from non-renewable sources, only one ton of every five tons of nitrogen entering the European Union´s (EU) agri-food chain is actually converted into food for human consumption.
The story is similar for phosphorus and potassium[1]. Agricultural soils suffer carbon depletion and valuable nutrients are lost, leading to environmental pollution and contributing to GHG emissions. Globally, surpluses of nitrogen and phosphorus exceed safe limits for the environment. In Europe, livestock production is responsible for 81% of the contribution of agricultural nitrogen to aquatic systems.

According to the European Environment Agency (EEA), the EU exceeds the nitrogen leak limit by 3.3 times and the phosphorus leak limit by twice (Directive 91/676/CEE, 2021). Animal based emissions represent half of the GHG emissions from agriculture. Feed digestion accounts for 78% of the GHG emissions in livestock[2].
Low nutrient use efficiency (NUE), poor soil management and exploitative agricultural practices reduces agricultural productivity on a long term. In addition, diets rich in animal products and high amounts of food waste put our food security and sustainability of the European agri-food chain at further risk. Hence, improved nutrient management needs to be coupled with measures at the consumer end to build sustainable nutrient cycles guaranteeing high NUE and nutrient recovery.

[1] Buckwell, A. Nadeu, E. 2016. Nutrient Recovery and Reuse (NRR) in European agriculture. A review of the issues,opportunities, and actions. RISE Foundation, Brussels.

[2] European Court of Auditors, Common agricultural policy and climate: half of EU climate spending but farm emissions are not decreasing. Special report No 16, 2021, Publications Office, 2021, https://data.europa.eu/doi/10.2865/285879

The solutions of Circular Agronomics

The solutions of Circular Agronomics addresse the challenge of sustainable circular management of Carbon (C), Nitrogen (N) and Phosphorus (P) by analysing flows, stocks, and emissions from different European agricultural, livestock and food processing practices. The proposed innovations aim to mitigate emissions and eutrophication by increasing circularity and NUE while reducing mineral fertiliser use. Some of the solutions focus on the producer end while others focus on the consumer end. Sustainable and circular use of nutrients and carbon can be achieved only by addressing both.

Innovations to reduce environmental impact

Table 1: The unique selling points of the Circular Agronomic innovations up to TRL 7-8 (still further development needed, more information e.g. on market readiness available on our website: www.circularagronomics.eu)

Circular Agronomics innovations	unique selling points (incl. potential reduction of N emissions compared to conventional scenarios)	
N efficient genotypes of winter wheat	significant reduction of N fertilization rates & of N emissions per kg wheat **(up to 50% NO_x, up to 78% N_2O (GHG), up to 99% NH_3)**	GHG emission reduction, Eutrophication reduction, Mineral fertiliser saving, High Nutrient Use Efficiency
N efficient slurry application techniques	flexible application possible to reduce climate/weather impacts & reduction of emissions **(up to 22% N_2O, up to 44% NO_3)**	GHG emission reduction, Eutrophication reduction, Mineral fertiliser saving, High Nutrient Use Efficiency
Conservation tillage	comparable yields with lower energy (fuel) consumption & reduced emission **(>10% NH_3 and NO_x)**	Eutrophication reduction, Mineral fertiliser saving
Solar-dried digestate in crop rotations	combined calorific and solar power, production of organic biofertiliser with NPK (according to European legislation), no residual streams & significant emission reductions **(up to 46% N_2O, up to 89% NH_3)**	GHG emission reduction, Eutrophication reduction, Mineral fertiliser saving, Bio-based fertiliser production
Fertigation with microfiltered digestate	Increased Nutrient Use Efficiency, replacing mineral fertiliser, low maintenance, reduced water and energy consumption, significant emission reduction **(up to: 79% NH_3, 24% N_2O)**	GHG emission reduction, Eutrophication reduction, Mineral fertiliser saving, High Nutrient Use Efficiency
Precision feeding & fertilization strategies	optimized use of dietary N and reduced emission **(up to 33% NH_3, 33% N20 and 33% NO_x)**	GHG emission reduction, Eutrophication reduction
extensive management in less favourable area	closed production cycle, farms produce food and provide environmental services **(up to 65% NH_3 & 64% NO_3)**	Eutrophication reduction, Mineral fertiliser saving
N recovery through digestate degasification	> 80 % removal of inorganic N achievable, production of mineral fertiliser & N depleted manure/digestate (decoupling N and manure facilitates compliance with EU Nitrates Directive)	Eutrophication reduction, Mineral fertiliser saving, Bio-based fertiliser production, High Nutrient Use Efficiency
P and K recovery in the form of struvite	80-90 % P recovery possible, production of precision fertiliser with, high Nutrient Use Efficiency	Bio-based fertiliser production, High Nutrient Use Efficiency
Acid whey treatment with novel membranes	high potential of valorisation because of high amounts in Europe (further research needed)	Mineral fertiliser saving, Bio-based fertiliser production

Bio-based fertiliser production · Mineral fertiliser saving · GHG emission reduction · Eutrophication reduction · High Nutrient Use Efficiency

Farmer willingness to adopt our innovations

Circular Agronomics also aimed to understand farmers objectives and motivations. A large-scale survey showed that farmers are more willing to adopt these technologies if they are professional farmers with university training, if they are aware of environmental problems, or if they are located in a nitrate vulnerable area. However, the biggest challenges to implement technologies are economic. 84% of the farmers responded that government and public institutions should encourage the implementation of new technologies in agriculture through direct payments that support investments in emission reducing solutions and tax reduction schemes.

Understanding consumers preferences

According to the consumer survey of more than 5000 participants, the willingness to pay for specific products depends significantly on the variations of the country, the production system and the origin. Consumers are willing to pay an average of 120% more for a circular product than for a conventional one. The organic attribute is more preferred than the local one. Furthermore, many consumers across the EU have reported wasting food with fruit and veg the most commonly wasted.

POLICY RECOMMENDATIONS - Closing the circle

Based on the findings, Circular Agronomics proposes the following recommendations:

Recommendation 1 :

EU support through the Common Agricultural Policy (CAP) to invest in emission mitigation practices and adoption of technologies

The CAP has been criticised for its low climate ambition (ECA 2021), in particular its first pillar. However, the current CAP framework allows for further uptake of measures through a more ambitious implementation and **greater use of the Agri-environment-climate Measures (AECM)** of the second pillar, water protection by reducing fertiliser or climate stewardship by reducing greenhouse gas emissions, among others.

According to the results from the farmer survey, the implementation of new technologies in agriculture should be significantly facilitated through **direct payments.** The intervention scheme should be designed to support farmers in their decision to adopt innovations through one-time structural grants for investments in sustainable innovations/technologies. Depending on the innovation, various measures might be also subsidised annually to compensate higher operating costs temporary. **Lower tax schemes** corresponding to lower GHG and nutrient emissions and an **expansion of the European Trade System (ETS)** covering also the agricultural sector is the future for a circular agri-food chain. In addition, **further development and research** for the very complex agricultural systems and their environmental and climate impacts are necessary to build up a more robust data base. This policy recommendation fits in with the current EU scheme on agri-environmental commitments towards manure management and investments in physical assets regarding manure storage and installation of anaerobic digesters.

Recommendation 2 :

Strengthen the processes of dissemination of innovations and capacity building for farmers.

To ensure effective policies that reduce GHG emissions and improve NUE at EU farms, the factors have to be considered that motivate farmers to adopt circular farming' innovations like farmers' characteristics, environmental attitudes and preferences for agribusiness. **The access to information and knowledge** promotes a greater willingness and capacity to adopt technological solutions of circular agriculture as has been evidenced by the research. **Experience and high level of training** increase the likelihood of adoption which is why that should be established readily accessible for all farmers. Furthermore, a **better dissemination of innovations** to national agricultural chambers and ministries is crucial. **Knowledge-sharing platforms and periodical sessions** with farmers and regulators to inform about project results should enhance a better understanding of policy-makers about a circular sustainable agriculture and about a facilitating regulatory framework.

The adoption of climate and environmental-friendly technologies and solutions is higher in Nitrate Vulnerable Zones (NVZ) within the EU. Therefore, the advisory systems and the access to information for farmers operating there, as well as the business cases and motivations should be also considered **best practice** elsewhere.

Recommendation 3

Rising awareness for the value of food and establish sustainable consumer choices based on transparent product labelling

Marketing campaigns to increase consumer demand and uptake of organic (and circular produced) food purchasing should consider attitudes, social norms and behavioural control rather than focus on the traditional demographic segmentation categories of age, gender etc. Changing norms using opinion leaders, role models, and community social marketing to assist in establishing new social and cultural norms may have the biggest impact on changing food purchase behaviour. Increasing sustainable purchasing behaviour in turn will help to form positive attitudes to sustainable foods. Attitudes could be targeted via **advertising campaigns** promoting the availability of sustainable products and education-oriented interventions. In any case, consumers need to have a sense of control over their purchasing behaviour. Hence, the availability of sustainable products in-store or at food markets should be promoted so that the products are readily available and recognizable to consumers. Developing a **sustainable food label** for lower environmental and climate impacts using a Circular Agronomics symbol, would enhance consumer usage and reward farmers for adopting technology. There is a need for **awareness campaigns and strategies for purchasing, using and storing** without food waste. Campaigns should focus on simple measures like meal planning and shopping lists, along with positive behaviours among peer groups and education on how to minimise food waste. The true cost of food including all resources (not just price) would highlight the full impact of food waste.

Conclusion

The most important measures identified in Circular Agronomics are financial support of sustainable agricultural solutions for farmers, transparent information and awareness-raising campaigns for both farmers and consumers. Circular economy, high nutrient efficiency and emission reduction in agriculture aim to improve the agri-food chain at the beginning. Sustainable behaviour and responsible diets of consumers without wasting food are at the end of the chain. Both ensures food security and environmental health on a long term.

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Annex: Information regarding the innovations promoted by Circular Agronomics

Innovations	Current TRL	Unique Selling Points	Main competitors and competitive advantage
SOLAR DRYING OF MANURE AND DIGESTATES	7	Combined calorific and solar power Simple handling and storage of digestate because of 85% dry matter content Recovery rate of about 60% TN, 77% P_2O_5 and 32% K_2O of the input nutrient Holistic technology without waste streams Production of organic bio-fertilisers according to European legislation	• N recovery in the form of Struvite • N recovery by stripping using steam or air • Composting • Biodrying and drying None of these technologies is as simple and as robust as solar drying.
VACUUM DEGASIFICATION OF AGRICULTURAL DIGESTATE	8	>80% removal of total ammonia nitrogen (TAN) achievable + carbon capture storage Heat can be recovered and reused, pH-adaption can be realised by CO_2-stripping (minimalization of external heat and aggressive chemicals) N depleted digestate can be used as soil conditioner Decoupling N from digestate helps comply the EU Nitrates Directive Production of mineral fertiliser or its base material according to the EU Fertiliser Product Regulation	Main competitors are digestate centrifugation or filtration (by membranes) and the use of clarified fractions by means of irrigation systems other than drip lines (e.g. sprinklers pivot). The MDF system reduces CAPEX due to the cost-effectiveness of the solution and OPEX due to reduced energy consumption and optimal integration into a biogas plant.
MICROFILTRATION OF DIGESTATE FOR FERTIGATION	6	Moderate cost and low maintenance equipment Reduction of greenhouse gases (up to 46% N_2O), ammonia emissions (up to 89%) and nitrate leaching/run-off on the field Minimize water and energy consumption A complete pilot plant at farm scale developed and validated (TRL 7-8) Replacing mineral fertiliser according to the EU Green Deal	Main competition is expected to be with providers of stripping units. The PONDUS-N process has reduced CAPEX due to flexibility (no dewatering, only simple fibres removal) and OPEX with an optimal integration into a biogas-plant by more than 50 %.
K-STRUVITE RECOVERY	6	80-90% P recovery possible 60-65% conversion of phytic acid to soluble PO_4-P with phytase enzymes possible K-struvite formation can be added within an existing treatment process as an add-on Production of economically valuable non-soluble K-/N-salts (slow release fertiliser) Production of bio-based fertiliser according to the EU Fertiliser Product Regulation	Main competition is by other companies selling struvite reactor systems (mainly operating in municipal wastewater). NRS is a leading technology provider in terms of struvite recovery from industrial/food-industry wastewater; ambitions of other companies extend their technologies towards food-industry waste or food waste is unknown as well as expanding the recovered nutrients portfolio.
NOVEL MEMBRANES FOR ACID WHEY TREATMENT	6	Valorisation of acid whey (waste product) as soil conditioner Low energy consumption of ENM of 0.6 kWh/m3 ENM also applicable for a more energy efficient digestate thickening compared to a centrifuge (up-scaling under research) High amounts of acid whey in the EU milk industry presents a big market	Competitors in the field of acid whey management are companies dealing with membrane separation in dairy industry, e.g. GE, Novasep, Mega. A competitive advantage could be the application of nanofibrous membranes that have lower production costs.

Additional details are available in D6.9 Exploitation Brochure as well as in the project website (https://www.circularagronomics.eu/).