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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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D6.10. Compilation of EIP-Agri practice abstracts developed No 1

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10.	WUR

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1. INTRODUCTION. MULTI-ACTOR APPROACH

As part of their communication activities, multi-actor approach projects are required to produce short "practice abstracts" (PAs) which outline their plans and main findings. The information should be easy understandable and provided throughout the project's life-cycle. This information must therefore be shared in a specific format (the "EIP Common format") which is specially made so that project info and results can be shared with those who can apply the findings. The format includes: a short and understandable title, a succinct summary of the issue tackled and the main outcomes and recommendations produced, and contact details to find further information. The content of the submitted practice abstracts can be updated at any moment according to new findings.

The practice abstracts produced by H2020 multi-actor approach projects will be made available on the EIP-AGRI website. This will form a unique EU collection of practical knowledge. Anyone will be able to search through the information by theme, sector or region. These practical project outcomes will be easily visible for any reader and contribute to the knowledge exchange and networking activities of the EIP-AGRI, encouraging contacts and interaction across Europe. This unique EU database will also enable researchers to highlight the work they have carried out in a multi-actor environment. Such work is more likely to be taken up in practice, and this can help research institutions to show and measure the impact of their research, which is becoming ever more relevant to justify public funding.

As a multi-actor project, Circular Agronomics is aimed to produce at least 100 PAs during the course of the project, which have been splitted into 3 deliverables to be submitted on M18, M36 and M48, and containing 35, 35 and 30 PAs, respectively.

The first 35 PAs prepared by those partners involved in technological work packages, WP1, WP2 and WP3, are listed task by task in Table 2. If possible, it is foreseen to generate PAs also from WP4 and WP5, focused on socio-economic and environmental evaluation, respectively. A summary of the tasks to be performed within each WP that are liable to generate PAs, is shown in Table 1.

Table 1. Tasks to be performed within each work package

WP	Task
1. Plant-Soil-Interactions	Task 1.1: Comprehensive analysis of C, N and P stocks, flows and emissions in crop farming
	Task 1.2: Increase internal C, N and P cycling in the soil-plant interface
	Task 1.3: Fertilizer application strategies
2. Livestock emissions and residues treatment	Task 2.1: Feeding strategies, gaseous emissions and manure characteristics
	Task 2.2: Demonstration of innovative treatment technologies increasing efficiencies in valorisation and recycling of livestock/agricultural residues and minimizing emissions
3. Carbon and Nutrient valorisation from food-waste and food-processing-waste(water)	Task 3.1: Classification of food waste and wastewater streams in food industry and their recycling potential for C, N and P
	Task 3.2: Pilot Demonstration of innovative treatment technologies for recovery/recycling of C, N and P from food waste and wastewater
4. Social and Economic Evaluation	Task 4.1: Farmers dialogue
	Task 4.2: Consumer Acceptance Evaluation
	Task 4.3: Cost assessment for demonstrated technologies and business models for implementation
	Task 4.4: Effects by international trade
5. Environmental Evaluation	Task 5.1: Methodological framework for the environmental assessment
	Task 5.2: Application of environmental assessments
	Task 5.3: Governance in the field of environmental issues
	Task 5.4: Policy Impact Assessment

The Excel EIP common format, including project information, partners contact information, keywords, related websites and full PAs has been sent to the EIP-Agri for its publication. A non-editable version of the Excel file can also be downloaded from: PAs_EIP common format_773649_Circular Agronomics (note that the order of the PAs differs between the Excel file and Table 2)

2. LIST OF PRACTICE ABSTRACTS UNTIL MONTH 18

Table 2. List of practice abstracts per task included in Deliverable 6.10

WP	Task	Practice abstract
WP1	**Task 1.2**	• Effects of conservation tillage on crop production and soil quality • Smart grass species combinations for improving phosphorus uptake in pastures • N- and P-cycles in grassland-based farms • Suitability of different manure and derived products as fertilizers on arable crops
	Task 1.3	• Effect of nitrification inhibitors on crop growth and yields • Effect of slurry application method on nutrient uptake and yield • Effect of wheat genotype selection on N nutrient efficiency under conditions of reduced N supply • Effect of wheat genotype on bread-making quality under conditions of reduced N supply • Using the dried digestate from an agro-industrial biogas plant as a fertilizer • Advantages of crop rotation • Ammonia volatilization from agriculture • Reducing ammonia volatilization from crop fertilization practices
WP2	**Task 2.1**	• Precision feeding systems in dairy farms • Direct emissions modelling • Influence of feeding strategies on methane emissions of dairy cows • "Farmlife" as management tool to reduce emissions on farms • Dymanic chambers for gaseous emissions monitoring • Effect of genotype and diet composition on efficiency in milk production
	Task 2.2	• Solid-liquid separation of manure • Solar drying of manure • Microfiltration of slurry/digestate • Ammonium sulfate solution from manure • Ammonium hydrogen carbonate • Vacuum degasification of ammonia from manure
WP3	**Task 3.1**	• Recycling potential of food waste and wastewater from the food industry focusing on carbon • Recycling potential of food waste and wastewater focusing on nitrogen • Recycling potential of food waste and wastewater focusing on phosphorus • Nutrient and C recovery from food waste and wastewater • Nitrogen recovery from food waste digestate • Phosphorus recovery from soybean waste/wastewater
	Task 3.2	• Electrospun-nanofibrous membrane for the treatment of whey • Vacuum degasification of ammonia from food waste • Phytase treatment for an enhanced phosphate release • NH4-Struvite • K-Struvite

3. COMPILATION OF 35 EIP-AGRI PRACTICE ABSTRACTS (English version)

PA1. Effects of conservation tillage on crop production and soil quality

Conservation agriculture is based on three pillars: 1) minimum soil disturbance (from minimum tillage to direct seeding) 2) crop rotation 3) continuous soil coverage, with crops or their residues. The assumption is that the soil structure and porosity develop and maintain thanks to the action of the roots and organisms living in the soil, especially earthworms.

Generally speaking, the transition from conventional to conservation tillage requires the so-called "transition period" during which the soil (and the farmer!) adapt to the new system. It has been proven that crop productivity in conservation tillage systems can reach (and exceed) the level as in conventional farming and is generally more stable after a few years of adoption, benefiting from the increased resilience of the agricultural system.

Among the parameters that contribute to quantify soil quality, in conservation tillage regimes there is generally an increase in the organic matter stock, especially in the shallow layers of the soil, as well as the soil aggregate stability, which represents resistance to degradation by water.

In the Circular Agronomics project, the effects of some conservation tillage techniques, both on crop production and soil quality, are studied within the case study of the Emilia-Romagna Region (Italy), with and without the application of exogenous organic matter (digestate).

PA2. Effect of nitrification inhibitors on crop growth and yields

Agricultural plants mainly take up nitrogen in the form of nitrate. On-farm produced fertilizers like farmyard manure, slurry, or biogas digestate do not contain any nitrate but nitrogen in form of ammonia. After soil application, bacteria transform ammonia into nitrate which then can be taken up by plants. However, nitrate is also susceptible to leaching into ground water while ammonia is not. Best growth and highest yields are reached when the needed amount of nitrate is available to the crops at every point of time. In most cases, the transfer from ammonia to nitrate takes about only two weeks. Depending on the crop and time in the year, plant nitrate uptake needs much more time. A nitrification inhibitor (NI) downregulates the bacterial activity during the conversion of ammonium into nitrate in the soil. As a result, the plant nutrient nitrate is available at a later time. Thus, it can help to better match nutrient supply and demand. But NIs do not automatically improve crop development: When not nitrogen but water is limiting pant growth, the delay in nutrient supply means no advantage. From a crop nutritional point of view NIs should be used only, when there is a clear need for delaying and slowing down the nitrate supply. This can be the case when limited slurry storage capacity requires an early application time, weeks before maize planting or applications at a more optimum time during crop growth are technically unfeasible. The use of NIs has positive side effects: It can potentially reduce the amount of $N2O$ emitted to the atmosphere. $N2O$ is a very active greenhouse gas. However, because commercially available NIs consist of complex formulations, they may leave trace residues in the environment.

PA3. Effect of slurry application method on nutrient uptake and yield

Slurry consists of animal excreta and residues of straw and feed as well as water. Because it contains nitrogen, phosphorus and potassium, it is used as a valuable fertilizer. Returning the nutrients to agricultural fields and grassland means closing loops and using an almost perfect recycling system. However, losses from this system can occur, that do harm the environment. The plant nutrient nitrogen is contained in slurry in the form of ammonium. It has the tendency to volatize into its gaseous form: Ammonia. In order to make good use of the nutrient, these gaseous emissions have to be minimized. Following some simple guidelines when applying slurry may result in drastic reduction of emissions: 1. Only apply when there are growth conditions and plants can take up the nutrient. 2. Avoid high temperatures 3. Use an application method that minimizes the contact of slurry with air. Traditionally, broad spread technologies (splash plate) was used for the distribution of slurries. They cause a maximum of slurry-air contact and therefore a maximum of ammonia emissions. A band spreader means a significant improvement because it applies the liquid fertiliser in narrow bands (reducing the slurry surface on land) and the use of distributing pipes ensures reduced air contact. Even better are slurry "injectors" or "under-feet" application systems which pump the slurry directly into the soil and ideally near to the root zone. Their use, however, may harm the existing plant canopy. Any loss of nitrogen in form of ammonia means the nutrient cannot be used by the crops anymore. A reduced nutrient efficiency and reduced yields are the result. Usually more than 30 % of the ammonia is lost when using a traditional splash plate spreader at warm weather.

PA4. Effect of wheat genotype selection on N nutrient efficiency under conditions of reduced N supply

Wheat varieties (genotypes) differ in a number of ways: Climatic conditions they prefer to grow in, potential yields, and internal qualities related to the use of the grain. Differences also exist in the way how flexible the plant reacts to changing growth conditions. Generally, this means the presence of water, enough temperature, sunlight, and nutrients. While the number of grains per area is a result of good growing conditions at the start, the size and weight of single grains is formed later in the growing season. Closer to harvest, fertilization strongly influences the quality of the grain - mainly the protein content. Genotypes differ in their sensitivity to nitrogen supply at different growing stages. A good nutrient efficiency means getting back all the nutrients applied during fertilization in the harvested materials. Bad nutrient efficiencies are mostly a result of difficult growing conditions other than the nutrient supply (low temperatures, drought, diseases) or over-supply of nutrients. Current unbalances in European agriculture strongly suggest reducing the amount of nitrogen applied. This, however, can result in grain qualities insufficient for the intended use, especially for bread-making. In order to reach a nitrogen balance without excess, the choice of wheat genotype must fit to the expected growing conditions. If nitrogen supply is reduced (e.g. in order to minimize overbalances), the effect on the internal quality of the grain is much greater than the effect on the yield. If animal feed is the production goal, a high yielding variety with low protein content should be chosen. If bread for human consumption is the goal, a high protein genotype with good internal quality but lower yield is best.

PA5. Effect of wheat genotype on bread-making quality under conditions of reduced N supply

Wheat is the main ingredient of bread for human consumption. But not all wheat is in the same way suitable to be used for baking bread. In order to reach a certain quality of bread, easily measurable criteria were defined. These criteria are used when trading wheat. Farmers get payed according to these criteria. One of the most important criteria that was historically established for assessing the wheat quality is the total protein content of the grain. The protein content is widely influenced by nitrogen fertilization at a late growth stage. Because this is typically in the summer season, there is a high risk of plants not being able to make use of the nutrient because of drought. Additionally, the protein content quickly drops when cereals ripe for harvest receive rainfall. However, the protein content is just one quality measure when it comes to how good wheat flour is suitable for baking bread. According to recent research, a suitable protein composition is more important to baking qualities than the total protein content. With a modern variety it is possible to generate bread-making quality of wheat even while reducing the total amount of nitrogen fertilizer. But reducing fertilization is risky for the farmer because the international marked price of wheat is still related to its total protein content. Wheat with a lower protein content gets payed less. Selling wheat of modern varieties to local mills and bakeries who are interested in actual bread-making quality and not just in high protein contents may allow to reduce nitrogen fertilization. In this way, choosing wheat genotypes with a good protein composition helps reducing nitrogen overbalances.

PA6. Using the dried digestate from an agro-industrial biogas plant as a fertilizer

From an economic point of view, intensive livestock is a very important activity in our country. However, it produces a large amount of organic waste for which recovery as fertilizers is sought. At present, the use of raw slurries in the fields near pig farms is common, but the excess of its use has led to contamination by nitrates and even phosphorus, with the consequent degradation of soils and water tables in aquifers. European regulations are therefore increasingly restrictive in terms of the type of product, form, dose and times of application of all fertilizer products including organic products. Circular Agronomics is studying the usefulness of a new dry pig digestate, obtained in anaerobic digestion plants, to be used as fertilizer in field crops. The slurry is digested after which a liquid digestate is obtained, being later acidified and dried. Half of the nitrogen in the dry digestate is in ammoniacal form and the other half in the form of organic nitrogen. Its slightly acidic pH, and its easy transport are among its advantages, since most of the water from the slurry or the digestate has been eliminated during the process. The effectiveness of its distribution is improved due to the higher concentration in N. At the end of Circular Agronomics, the application of dry digestate as a fertilizer product in the field is expected to be cheaper and easier than the current liquid products. The acidified and dried digestate is a product to be used within a rational planning in the fertilization plan of any exploitation, depending on the needs of the crop and always within the frame of current legislation.

PA7. Advantages of crop rotation

In Europe, cereal crops have a good adaptation to the environment, where a total crop failure is very rare, so cereals are the only cultivated species in some areas. Some farmers have traditionally opted to grow one or two cereal species (especially barley and wheat), with simple requirements for cultivation and a low technological complication. The current European regulation (CAP) has a requirement for crop diversification (known as Greening) that requires farms to include different species in their fields. Some farmers have chosen to add an additional species of cereal to the rotation, mainly triticale or oats, or even fallow. However, crop diversification can be more beneficial by using crops from other families, such as legumes or crucifers, with biological characteristics different from those of cereals. Complementing a cereal rotation with a year of rapeseed (cruciferous) can help in the control of grasses, diseases and some pests. If we also add a legume species, such as the protein pea, we can save a certain amount of nitrogen fertilizer, along with its application expense, due to the nitrogen fixing capacity associated with legumes. Circular Agronomics aims to analyse the advantages of this crop diversification through its effect on yield and on the dynamics of essential nutrients such as N and P. Although considering the crop obtained only one year it is possible that a cereal is the most profitable crop, a biodiverse rotation can bring certain advantages that can lead to greater sustainability of long-term exploitation.

PA8. Ammonia volatilization from agriculture

Catalonia is one of Europe's hot spots on Ammonia emissions (together with Britany, Po valley and the area of N-W Germany, Belgium and the Netherlands). On average, 57 kg NH3 are emitted for each hectare devoted to agriculture, coming from agriculture and livestock farming, mainly from manure management. Ammonia emissions may produce high concentration of ammonia on atmosphere and, thus, directly affect agricultural land, natural ecosystems and human health. Ammonia on atmosphere may come from the transformation of nitrogen (N) on ammonia or urea form. Once volatilization has occurred, ammonia may interact with other elements in atmosphere and enhance its pollution effects.

The loss of N through ammonia volatilization reduces nutrient use efficiency on agriculture and produces a significant economic loss on farms. It also produces environmental pollution, mainly on atmosphere (reacting with other pollutants increases the abundance of fine particles, PM10), water bodies, soils and natural ecosystems – through eutrophication and acidification.

Since 2010 different norms are limiting que level of ammonia emissions allowed, although the objectives have not been achieved in many cases.

Circular Agronomics works on different agricultural practices devoted to improve manure management and its nutrient use efficiency, including the study of techniques and types of management able to minimize ammonia volatilization from the fertilization of crops with manure and its derived products.

PA9. Reducing ammonia volatilization from crop fertilization practices

In Catalonia, 96 % of ammonia emissions come from farming. The main part (71 %) is caused by manure management in a broad sense: from animal excretion to manure incorporation to land. There are circumstances that may enhance volatilization from crop fertilization: calcareous soils, top application, wind, temperature, type of fertilizer, ... On the other hand, several fertilization practices may reduce volatilization when applying fertilizers to agricultural land. Circular agronomics works on several of these practices and at the end of the project several solutions will be handed out for enhancing nutrient use efficiency on crop fertilization.

In general, several advices may be provided. To reduce ammonia volatilization, use products with N in organic form (i.e.: compost) rather than in ammonia form (i.e.: pig slurry). For slurries and liquid fractions: avoid broad application equipment; when application on top of the soil, incorporate it short after; do not apply when wind is forecasted; and apply when rainfall is forecasted for the following days. For solid manure, incorporate it into the soil short after application, especially when high content of N on ammonia form (i.e.: chicken manure). For mineral fertilizers: use those containing N in nitrate form, especially on wet-hot periods; incorporate fertilizers into the soil always when possible; and do not apply N fertilizers all rate at once, split the rate along the crop cycle.

PA10. Suitability of different manure and derived products as fertilizers on arable crops

Crops have different nutrient needs in diverse moments of their cycle. Nutrients in fertilizers, namely manure, may be found on different forms and levels of availability for crops. For the fertilization of arable crops, different types of manure (farmyard manure, slurry,…) may be applied, some of them at different moments, either before sowing or at early side-dressing. The form in which nutrients are present in each type of manure may make them more suitable for applications in different moments of the crop cycle or the crop rotation. Nitrogen (N) in pig slurry is mainly (65-75 %) in ammonium form, quickly available for crop absorption and, thus, to be applied when crop needs are high -i.e.: side-dressing in winter cereals- or are about to be. In dairy farm-yard manure N is mainly organic. It will be available for crop nutrition on the mid-long run, often several years after application. It must be better applied before the sowing period, when crop needs are low. Circular Agronomics promotes treatment of raw manure and slurry. These processes end up with other kinds of organic by-products that will be also used for crop fertilization. It will be important to characterize these new products, to field test its behaviour when applied at soil in different environments and agricultural systems and to establish its suitability to be applied in certain moments within each crop cycle.

PA11. Smart grass species combinations for improving phosphorus uptake in pastures

Phosphorus (P) is one of the main nutrients for plants. Although most soils contain more than enough P to feed plants in principle, most of this P is chemically bound to soil particles and cannot be used by plants. For this reason, farmers need to apply relatively large amounts of P fertilizer. However, P fertilizer is expensive and the source of P fertilizer (rock phosphate) is limited, which means that we will need to be much more efficient with our P in the future. From studies conducted in nature, we know that combinations of plants can take up more P from the soil than single species. We are attempting to apply this principle in pastures: in a field experiment with a soil with a very low P status, we are testing whether smart combinations of grassland species can lead to a higher P use efficiency. We use four commonly used commercial grassland species (two types of Ryegrass; Timothy grass and Tall Fescue) that are very different in routing patterns to study which combinations take up most P and why this is. The field experiment will be running for two full years. We hope that at the end of the experiment we can give concrete advice to farmers on what combination of species to seed for a more P-efficient pasture system

PA12. N- and P-cycles in grassland-based farms

The nitrogen and phosphorus cycle are complex systems which are subject to various influencing variables and can be divided into several sub-systems. If one looks at the nitrogen and phosphorus cycle of agricultural farms, it can be seen that these usually have a low degree of closure. Through the sale of agricultural products such as milk or grain, nitrogen and phosphorus constantly leave the cycle. On the other hand, nitrogen and phosphorus are continuously introduced into the cycle through the purchase of seeds, fertilisers, feed stuff etc.

In order to close the nitrogen and phosphorus cycle on grassland-based farms to a higher degree, a voluntary programme for farmers was launched in the Lungau region in Austria. Within this programme, participating farms commit themselves to the exclusive use of their own fertilisers and feed stuff. Should it nevertheless be necessary to purchase inputs such as concentrated feed, for example, this must also be purchased from the region. In return, the farms receive a higher milk price from the dairy factory.

In Case Study 3, we assess the nitrogen and phosphorus cycles of these farms. First results show that especially the nitrogen cycle can be closed to a large extent. The phosphorus cycle cannot be closed as well, because the removal of phosphorus cannot be compensated by natural phosphorus sources on the farms.

PA13. Precision feeding systems in dairy farms

Feed cost are the highest costs in a dairy farm, and either overfeeding or underfeeding a dairy cow can have negative consequences. Precision feeding techniques allow to integrate data sensor information to accurately feed dairy cows. Circular Agronomics aims to evaluate a precision feeding system using feed intake, milk yield and composition, and body weight data to feed a concentrate supplemental feed in the milking parlour based on three different ingredients (soybean, corn, and wheat middlings) that provide different source of nutrients (crude protein, energy and fibre, respectively). We speculate that this feeding management can improve economic returns by feeding more accurately cows adjusting their daily requirements using a concentrate feed supplementation in the milking parlour. Furthermore, a reduction in the N excretion is expected since crude protein requirements will be daily adjusted. To evaluate the expected benefits of this precision feeding system a group of 28 dairy cows will be fed following a conventional or a precision feeding system and their diet digestibility will be assessed using faecal and urine spot sampling at different day intervals through a period of three days, and indigestible neutral fibre as internal marker.

PA14. Direct emissions modelling

A large number of emissions are generated by agricultural activities. Depending on the orientation of a farm, some emissions are more abundant and others less. Accordingly, a cattle farm will always produce higher methane emissions than an arable farm without livestock does. At the same time, the arable farm will be responsible for more nitrous oxide emissions than the cattle farm.

Within the framework of life cycle assessment, a distinction is made between direct and indirect emissions. Direct emissions are those that arise directly on the farm as a result of livestock farming, manure management and land management. Indirect emissions are the emissions from inputs. For example, the purchase of one kilogram of soy from Brazil has already caused certain emissions there due to the production of soy. Another example is the construction of buildings. Steel must be produced to build a cattle shed. The prerequisite for this in turn is the mining of ores. This ore mining also causes certain emissions.

In FarmLife, direct emissions from farms are modelled based on various models. These include emissions of phosphorus, heavy metals, nitrate, nitrous oxide, nitrogen oxides, ammonia and methane. As a result, FarmLife can be used to point out possible optimization potentials with regard to emission reduction. Results from cattle farms have shown that the greatest potential for reducing emissions lies in the areas of feeding/concentrate use and in the adaptation of the livestock density to the farm's own area.

PA15. Influence of feeding strategies on methane emissions of dairy cows

Methane is a greenhouse gas which is produced in the digestion process of ruminants amongst others. In times of global warming, it is an aim to find strategies how to reduce methane emissions of ruminants. Thus, gaseous emissions of dairy cows (methane, carbon dioxide and ammonia) are measured in two respiration chambers at AREC Raumberg-Gumpenstein (Austria). Methane is produced in the course of fibre degradation in the rumen. Thus, altering the fibre content of dairy cows' rations by changing the forage: concentrates ratio may be a strategy to reduce methane emissions. However, high proportions of concentrates in the rations might have negative side-effects on the health of the cows (e.g. higher risk of metabolic diseases). Thus, the aim of this project is to evaluate the effect of the forage: concentrates ratio of the ration on the gaseous emissions of dairy cows. Besides the determination of the daily amounts of gaseous emissions, it is also aimed to test the efficiency of gaseous emissions (e.g. g CH4/kg milk production). The results of this study will show which feeding strategy would be the most efficient with respect to both feed intake, milk production and methane emissions of dairy cows. In the next years and decades, prevention of (greenhouse gas) emissions will become more and more a topic in agriculture and especially in animal husbandry. The final results of this study should help dairy farmers to find their optimal way to achieve an economically and ecologically efficient milk production.

PA16. "Farmlife" as management tool to reduce emissions on farms

Emissions on farms can be comprehensively calculated in FarmLife through the combination of nutrient-flow-models with Life Cycle Analysis (LCA)-data. The result, however, not only shows the overall environmental impacts but also their origin from different product or input groups. As the effects of the infrastructure are very clearly splitted from the use of feed, fertilisers and pesticides, very precise recommendations for farm development can be given to the farm managers. These recommendations are also linked to economic aspects in the assessment of eco-efficiency. Within the framework of the Lungau case study, FarmLife was used on 22 farms in 2018 and on 17 farms in 2019, where it now has a major impact on the planning of farm objectives. On over 100 other reference farms in Austria, the effect of FarmLife in reducing emissions by changing the intensity in the direction of site-adapted agriculture is already evident. Circular Agronomics benefits from using the tool in several work packages.

PA17. Dynamic chambers for gaseous emissions monitoring

Livestock emissions represent more than 10% of the total GHG emissions and more than 85% of the total NH3 emissions. Among other sources, manure storage and its field application are the most contributing to these emissions. The European Commission is strongly betting on this aspect and will promote measures to reduce emissions in the coming years, such as storage systems sealing. The first step to reduce emissions would be to determine the hot spots and the amount of emissions generated in each one. However, the determination of these emissions is not an easy task. For this purpose, there are several sampling devices such as the dynamic chambers (Lindvall hood and wind tunnels). These devices can be used in both liquid and solid substrates, they are movable, allow to take samples accurately under controlled conditions, at constant flows, and a subsequent characterisation of these samples. Within the Circular Agronomics project dynamic chambers are being used to determine emissions on pig and cow manure storage, after manure application in agronomic fields and on the treatment processes that are being developed in the framework of the project, with the aim of making nutrient balances in an appropriate manner and to apply minimisation strategies.

PA18. Solid-liquid separation of manure

Manure management represents an important part of the total cost of a livestock farm due to the manure high water content (more than 90%), which makes difficult its transport to other zones. The use of solid-liquid separators is an effective tool that allows a nutrient redistribution, improving the management capability. By using these systems, a solid fraction (SF), with high solids content, and a liquid fraction (LF), aqueous solution with dissolved and suspended material, can de obtained. In the SF more phosphorus (P) than nitrogen (N) is concentred thus increasing the N/P ration in the LF. Therefore, when fertilising using the LF, higher N amount is incorporated without exceeding the P needs of the crop. The solid-liquid separators can be classified in gravity, pressure and centrifugation systems (the most efficient). Separation yield to the SF ranges between 15-45% for N and 20-80% for P, and it depends on the technology and/or the use of additives, manure composition and age, flow stability, etc. Operating costs range between 1.96-2.34 euros per kg of N and 4.96-4.43 euros per kg of P, and they are highly dependents on the kind of separator and the working flow, among other factors. Within the Circular Agronomics project, screw press and centrifuges are being used, followed by post-treatments of the resulting fractions for their valorisation as organic and inorganic fertilizers.

PA19. Solar drying of manure

Livestock manure is a semi-liquid faecal product with about 3-8% of dry matter content, and it is usually spread on agricultural fields in order to use the naturally present nutrients. Its high-water content and the difficulty of applying it when needed led to nutrient losses, mainly in the form of leaching and gaseous emissions. These losses can be up to 50% in some cases. By means of fixing ammonium salts and reducing water content it is possible to obtain a dried product that remains stable for a long time, thus allowing to spread it according to crops needs and avoiding leaching of soluble compounds and gases volatilisation. Solar drying brings together calorific power and solar irradiation to dry manure and, by using a mixing and stirring system, it is possible to obtain a stabilised solid fraction similar to compost. The final product has a dry matter content higher than 65%. This is a renewable technology and it does not produce residual streams, with losses less than 1%. It is estimated an operational cost of about 4€/m3, considering 10 years of depreciation. The results obtained so far are very positive, with high solar irradiation only 10 days were needed to dry manure up to 65% of dry matter.

PA20. Microfiltration of slurry/digestate

Why is it useful to microfilter livestock slurry and digestates?
Microfiltration is carried out downstream of conventional solid-liquid separation, on the clarified fraction, using a new simple equipment such as the microfilter specially developed by Saveco WAMgroup.
A microfiltered phase is obtained from which particles with a diameter greater than 50 microns (equivalent to three white blood cells) are almost completely excluded. The microfiltered fraction, which generally represents the largest portion of slurry or digestate entering the treatment, is pumped easily and does not clog up nozzles or drippers. Moreover, it contains most of the nitrogen in ammoniacal form, which is ready-to-use for plant nutrition.
The optimal agronomic use of the microfiltered fraction is then the distribution on growing crops, in order to increase the nutrient use efficiency as much as possible and saving mineral fertilisers. In the Circular Agronomics project microfiltration tests and the use of microfiltered digestate in fertigation, by means of Netafim drip lines buried 25 cm deep (SDI – subsurface drip irrigation) are being conducted at CAT Correggio biogas farm (Emilia-Romagna region, Italy).
The first year of experimentation was successful both in terms of the technical feasibility of the proposed innovative solution and for the excellent silage maize yields, obtained in combination with high nutrient use efficiency. In 2020 the trials will be repeated on sorghum.

PA21. Vacuum degasification of ammonia from manure

Manure is frequently used as an organic fertilizer in agriculture, delivering organic material for the soil and nitrogen which is an important nutrient for plants. However, the seasonal application time of manure is often not in line with the actual nitrogen demand of the plants. Consequently, an undesired loss of nitrogen for the plants due to emissions to the groundwater (nitrate) or to the atmosphere (ammonia and/or nitrous oxide) occurs and poses serious environmental problems in regions with high rate manure application.
In order to decouple the supply of organics and nitrogen contained in the manure, Circular Agronomics designs and constructs a pilot plant for vacuum degasification to recover nitrogen as ammonia. The pilot plant will produce a "nitrogen depleted manure" ready to serve as a soil conditioner. Circular Agronomics aims to achieve a nitrogen recovery rate between 80% and 90% of the nitrogen which was originally present as ammonium in the manure. The process will be optimized by varying vacuum pressure, chemical dosing for raising pH, and temperature conditions. In a subsequent process step of the pilot plant, the recovered ammonia gas will be used to produce a ready-to-use nitrogen fertilizer.

PA22. Effect of genotype and diet composition on efficiency in milk production

Each agricultural production system should aim to produce food with highest efficiency. In this context, efficiency can have different meanings: optimal utilization of nutrients (nutritional efficiency), realization of high incomes (economic efficiency) or minimization of environmental impacts (ecological efficiency). A project at AREC Raumberg-Gumpenstein aims to study each of these three aspects of efficiency. In this study, effect of genotype (Holstein Friesian_conventional breeding, Holstein Friesian_NewZealand, Holstein Friesian_lifetime performance breeding and Simmental) and diet composition (indoor feeding with 0, 20 and 40% concentrates proportion in whole diet) on feed intake, milk yield and efficiency of milk production is examined. This project will lead to valuable results on nutritional and economic efficiency. Furthermore, within the Circular Agronomics project, ecological efficiency is analysed by measuring methane emissions of dairy cows in respiration chambers. The results will allow conclusions, which genotype, which diet composition and which combination of genotype and diet composition will lead to highest efficiency both from an economic and an ecological point of view in a certain geographic region. Because, besides a high efficiency, it is also important that production strategy is appropriate for a certain geographic region to avoid indirect agricultural emissions (e.g. caused by transport of feeds).

PA23. Ammonium sulfate solution from manure

Ammonium-sulfate is a product from the process of Ammonia recovery from exhaust gas. Sources of the Ammonia gas can be Ammonia removal from manure, from biogas digestate, sewage sludge or the exhaust gas of biological waste treatment or animal husbandry. Ammonia is scrubbed with a sulphuric acid solution. Ammonium-sulfate can be used as liquid mineral fertilizer. N concentrations should match fertilizer recommendations, e.g. 5% N according to the German fertilizer law. Prices that can be generated by selling the Ammonium-sulfate fertilizer depend on the N-concentration, the impurities (such as dust or other particles) and the pH (>5). As the fertilizer contains a lot of water (around 75% when N is around 5%), its handling is rather costly because transport and storage require a big volume. For farmers, ammonium-sulfate is of interest because they can cover both, the N and S demand. Both operators and farmers benefit, when N concentrations are as high as possible. Especially operators of Ammonia scrubbers should demand high N concentrations from scrubber suppliers in their ammonium-sulfate. In addition, many plants operate 365 days per year. Consequently, storage capacity for Ammonium-sulfate during the non-fertilizer season must be considered.

PA24. Ammonium hydrogen carbonate

Ammonium-hydrogencarbonate could be produced from Ammonia recovery from liquids that contain also a high carbonate concentration, such as manure and biogas digestate. Ammonia is evaporated by vacuum or stripping. Ammonium-hydrogencarbonate can be used as liquid mineral fertilizer. N concentrations should match fertilizer recommendations. Prices that can be generated by selling the Ammonium-hydrogencarbonate fertilizer depend on the N-concentration, the impurities (such as dust or other particles) and the pH. As the fertilizer contains a lot of water, its handling is rather costly because transport and storage require a big volume. For farmers, Ammonium-hydrogencarbonate must be incorporated into the soil immediately after field application to avoid Ammonia emissions. Both operators and farmers benefit, when N concentrations are as high as possible. Especially operators of Ammonia evaporation by vacuum should demand high N concentrations from degasifier suppliers. In addition, many plants operate 365 days per year. Consequently, gas tight storage capacity for Ammonium-hydrogencarbonate during the non-fertilizer season must be considered.

PA25. Recycling potential of food waste and wastewater from the food industry focusing on carbon

Especially in food waste and wastewater from the food industry, the organic carbon content is usually quite high compared to municipal wastewater. Thus, recycling or further use of those waste and wastewater streams might be profitable. As long as the waste cannot be reused or processed further to food or fodder additives, there are two options for carbon utilization: (1) the biomass is digestated to biogas for energy production and (2) the biomass is reused as soil conditioner. It might be even favorable to combine both reuse purposes. In doing so, easly degradable organic compounds will be utilized in anaerobic digestion for biogas production and the remaining, more difficult to degrade, organic compounds contained in the digestate can enhance the organic fraction of the soil.

In Circular Agronomics, different organic waste and wastewater streams from food and agricultural industry are screened. Therefore, the updated BREF document (2019) "Best available techniques (BAT) reference document for the food, drink and milk industries" serves as a basis. In this document, a variety of organic wastewater streams are characterized. In addition, publications and results from other research projects as well as data bases available in the internet are evaluated.

PA26. Recycling potential of food waste and wastewater focusing on nitrogen

In Circular Agronomics, different organic waste and wastewater streams from food and agricultural industry are screened in terms of their recycling potential. Therefore, the BREF document (2019) "Best available techniques (BAT) reference document for the food, drink and milk industries" serves as a basis. In this document, a variety of organic wastewater streams are characterized. In addition, publications and results from other research projects as well as databases available in the internet are evaluated.

Especially protein rich food waste and wastewaters from the food industry contain quite high nitrogen contents compared to other food waste and wastewaters. The preparative screening revealed for nitrogen, that in particular, wastewaters from sugar manufacturing, animal feed production, dairies and meat processing contain relatively high nitrogen contents. Furthermore, compared to municipal wastewater, the carbon content is quite high as well. Thus, recycling or further use of those waste and wastewater streams might be profitable.

Circular Agronomics aims to classify the waste(water) streams and to determine the availability and regional distribution of the most interesting streams. In doing so, the small and medium enterprises (SME) might use this information to further extend their business models.

PA27. Recycling potential of food waste and wastewater focusing on phosphorus

In Circular Agronomics, different organic waste and wastewater streams from food and agricultural industry are screened. Therefore, the BREF document (2019) "Best available techniques (BAT) reference document for the food, drink and milk industries" serves as a basis. In this document, a variety of organic wastewater streams are characterized. In addition, publications and results from other research projects as well as databases available in the internet are evaluated.

The preparative screening revealed for phosphorus, that in particular, wastewaters resulting from oilseed processing, soybean processing, meat processing and animal feed production contain relatively high phosphorus contents. Furthermore, compared to municipal wastewater, the carbon content is quite high as well. Thus, recycling or further use of those waste and wastewater streams might be profitable.

Circular Agronomics aims to classify the waste(water) streams and to determine the availability and regional distribution of the most interesting streams. In doing so, the SME partners might use this information to further extend their business models.

PA28. Nutrient and C recovery from food waste and wastewater

The activity creates new business potential of valorisation food waste via its processing into agricultural field. Acid whey, i.e. waste product from cottage cheese and cream cheese production is processed (mechanical pre-treatment, thickening and conservation) before it is placed into the soil to increase missing level of carbon there. Farmers could use acid whey to enrich their soil not only by carbon, but also by nutrients (nitrogen, phosphorus and potassium). It can create win-win scenario between dairy industry producers and farmers to create market with this commodity. Different dosage of acid whey is going to be tested during project duration (until 2022) to ensure necessary carbon level together with calculation nitrogen and phosphorus balances to give guidance and recommendations for practitioners about proper use of acid whey into the agricultural field. The guidance will contain proper dosage in the view of C, N, P and K, necessary acid whey pre-treatment, transport and storage issues together with some basic economic analysis about acid whey application.

PA29. Nitrogen recovery from food waste digestate

In Circular Agronomics, different organic waste and wastewater streams from food and agricultural industry are screened. The preparative screening revealed for nitrogen, that especially wastewaters from sugar manufacturing, animal feed production, dairies and meat processing contain relatively high nitrogen contents. However, the ratio of ammonium-nitrogen to total nitrogen in the raw wastewater is usually equal to 50% and less. For a higher and economically more favourable recovery rate in terms of nitrogen, the fraction of ammonium referring to the total nitrogen content needs to be increased. Therefore, anaerobic digestion of those wastewater streams can increase that fraction from 50% and less to a range between 60% and 80%. Due to that reason, Circular Agronomics will recover nitrogen from food waste digestates. Therefore, Circular Agronomics designs and constructs a pilot plant. This pilot plant will produce a "nitrogen depleted digestate" ready to serve as a soil conditioner. Furthermore, in the pilot plant, the nitrogen is recovered via ammonia degasification at vacuum conditions. In the subsequent gas scrubber, the degassed ammonia will react with sulfuric acid to ammonium sulfate solution. Ammonium sulfate solution is a typical mineral nitrogen fertilizer.

PA30. Phosphorus recovery from soybean waste/wastewater

Phosphorus is a life essential nutrient present in our daily food. So, the initial use of phosphorus is the application as fertilizer for food production. However, phosphorus is a mined resource with limited reserves, so to ensure food supply it will be needed to recover and reuse phosphorus. One the possibilities to do so is the recovery from used waters originated in feed/food processing containing phosphorus. The treatment of this used water in a traditional way results in phosphorus losses. The alternative approach in Circular Agronomics project is to recover the phosphorus by producing a well-defined crystalline product known as struvite. By implementing the correct process conditions, a selective process occurs resulting in the struvite product, which once produced can be readily separated from the used water. In addition, the struvite product has already fertilizer properties and contains next to the phosphorus also nitrogen and magnesium – two other essential elements needed for good plant growth. Starting with wastewater form food or feed processing also has the advantage of making a product that will be readily accredited the End-Off-Waste status. This is as important as the technology that the obtained product can be reintroduced in the circular economy under correct and certified conditions.

PA31. Electrospun-nanofibrous membrane for the treatment of whey

Electrospun nanofibrous membranes are proper alternative of recently used flat-sheet, tubular or ceramic membranes in the area of separation processes, e.g. filtration, mechanical pre-treatment, thickening, etc. Unique technology of electrospinning production of nanofibrous membranes produces membranes with holes up to 100 – 150 nanometers to ensure efficient separation or thickening of media. Electrospun nanofibrous membranes could serve in acid whey management in two different roles, either for pre-treatment before nanofiltration unit (replacement of centrifuge) for removal of fats and casein or for thickening of acid whey. Both hypotheses are going to be tested in lab-scale and pilot-scale during project duration (till 2022) to evaluate those applications. Project output will be feasibility study on electrospun-nanofibrous membrane application in the acid whey management before its further use (animal fodder, lyophilisation, soil conditioning). The study will contain all obtained results, considerations onto full-scale applications, return of investment analyses and market replication analysis.

PA32. Vacuum degasification of ammonia from food waste

Circular Agronomics aims to recover nitrogen from food waste in the form of ammonia via vacuum degasification. Therefore, especially protein-rich food waste is suitable due to its relatively high nitrogen content compared to other food waste streams. The higher the ammonium content is, the more nitrogen can be recovered. Therefore, prior to the degasification process, anaerobic digestion of those waste streams can increase the ammonium-nitrogen fraction referred to the total nitrogen content for example from 50% and less to a range between 60% and 80%.

In order to investigate and optimize the ammonia degasification process, Circular Agronomics designs and constructs a pilot plant. Circular Agronomics aims to degas and recover between 80% and 90% of the nitrogen that was originally present as ammonium in the manure. Thereby, the pressure conditions will be close to vacuum conditions between -700 and -900 mbar. The application of a pH between 8 and 10 as well as an elevated temperature of up to 70 °C will increase the ammonia content due to a shift of the equilibrium between ammonium and ammonia towards the side of ammonia. The process will be optimized within the course of the project by varying the pressure, the pH and the temperature conditions with regard to an energy efficient plant operation.

PA33. Phytase treatment for an enhanced phosphate release

To be able to recover the phosphorus as struvite it needs to be present as ortho-phosphate. The main phosphorus compound in soybean is however phytic acid, a cyclic P-containing compound. Phytic acid has a negative impact on food digestion by reducing protein degradation and uptake of micro-nutrients. Therefore, the addition of phythase enzymes to feed is a common practice and this open an opportunity to use phythases to convert the phytc acid in order to render struvite formation possible. The process under investigation is to condition the phosphorus present in the soybean wastewater in such a way it becomes available for struvite formation. This conditioning process uses the readily available enzymes (used as feed additive) to convert the bound phosphorus into free phosphate. Once the phosphate is present it can be transformed into the struvite compound. There are two types of struvite possible, the ammonia-struvite and potassium-struvite. These two different types of struvite can be produced at different stages of the used water treatment. The most important is NH4-struvite after the anaerobic stage. It should also be mentioned that one the specific features of soybean wastewater is that it contains more magnesium as phosphorus. This a rare case where thus not Mg but PO4-P is the limiting parameter. This does actually would make it possible to recover the struvite with no extra chemicals added but by sampling controlling pH by air sparging. The second possible outcome product is K-struvite. This can only be produced after the aerobic stage when all ammonia has been eliminated. The value of the K-struvite is higher compared to NH4-struvite since it is a rare non-soluble K-salt and K-reserves are also under stress.

PA34. NH4-Struvite

One possible source of phosphorus in the agri-food chain is soybean wastewater. phosphorus present in soybean wastewater is a cyclic phytic acid. Phytic acid also has a negative impact on digestibility and uptake of some essential micro-elements such as iron and zinc. To counter act these negative effects the addition of phythase enzymes to feed is a well-known practice. The phythase enzyme degrades the phytic acid and liberates free ortho-phosphate. Ortho-phosphate is the phosphorus needed for struvite formation. In nature phythase enzyme production in anaerobic conditions is limited. Therefore, during anaerobic treatment of used water little or no phytic acid is degraded, as similar in the gut environment. Added phythase enzymes prior to anaerobic stage treatment of the used water the phytic acid is degraded and struvite formation as ammonium struvite becomes possible after the anaerobic used water treatment. The Circular Agronomics project develops the approach in detail to optimize the phythase assisted phytic acid conversion into orthophosphate to render struvite formation possible. At this stage of the used water treatment this will be as ammonium-struvite. A number of lab scale tests have been done to elaborate the boundary conditions which serve also as basic data to build a pilot unit to implement this approach at m3/h level. The value of NH4-struvite is in relation with the commodity value of the nutrients included, currently 1 ton of NH4-struvite sells between € 80 - € 120 as a dry granulated product. Important is that the product can be handled with existing equipment in the existing fertilizer plants. The real benefits are efficient control of phosphate with reduced chemical use (ic. Fe or Al-salts) and reduced sludge production.

PA35. K-Struvite

During aerobic treatment of the used water the phytic acid is degraded readily. However also the ammonium is removed. This opens the opportunity to produce the second type of struvite where the ammonium has been replaced by potassium. This type of struvite actually has a higher added value since it will not only recover phosphate but is one of the very few non water-soluble potassium compounds. Also, potassium is a limited raw resource which is stressed in terms of availability. In case the struvite formation is done as a tertiary phosphate removal after the aerobic stage treatment on the final effluent prior to discharge in surface water. Given the fact that the water at this stage is already relatively clear, a limited effort is needed. The addition of a magnesium salt will be required to induce the potassium-struvite formation. The benefit of using soybean wastewater is that it contains fairly high levels of potassium, making the phosphorus again the limiting parameter to be focussed upon. This approach does not require the use of phythase enzyme addition. The work done in the Circular Agronomics project is similar as to the ammonium-struvite: laboratory trials to determine boundary conditions a pilot unit to scale up. The pilot unit will have the flexibility to run in different operational modes. The obtained value of the K-struvite is in direct relation with the commodity value of the nutrients included, currently 1 ton of K-struvite sells between € 120 to € 150 as a dried granulated product. Important is that the product can be handled with existing equipment in the existing fertilizer plants. The real benefits are more efficient control of phosphate with reduced chemical use (ic. Fe or Al-salts) and reduced waste sludge production.