# Recovery and Use of Nutrients, Energy and Organic Matter from Animal Waste – Rethinking Manure Recycling

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**Abstract (10 lines)**

Global livestock production is increasing rapidly and becoming intensified, due to increasing demand for animal protein by a growing and wealthier world population. Without changes or adaptation of agricultural production systems, this development is unsustainable and will be a threat to human health, animal welfare and the environment. The agricultural livestock industry will have to develop new technologies to meet the global challenges related to environmental impact and sustainability. Our objective is therefore to rethink manure recycling to manage it more intelligently, with focus on high energy recovery, increasing recycling of plant nutrients and using the most recalcitrant organic matter for soil carbon sequestration, thereby limiting negative impacts on soil, air and water quality. In this presentation we give some examples of the research and development we conduct to address this challenge.

## Introduction

Livestock production is developing dramatically on a global scale, with trends towards increasing concentration on large specialised production units to improve profitability [1]. These changes in production systems have resulted in increased pollution of air, aquifers, surface waters and soil. A major concern is also the uncoupling of the sites of animal feed production and animal production, through the (economic) driving forces specialization, intensification and up-scaling. This leads to surplus amounts of animal manure in areas where livestock are produced. As a consequence, an increasing number of livestock farms have insufficient land for efficient use of manure nutrients, as illustrated in Fig. 1a, where the manure N input density in many regions of Europe exceed 120 kg manure N $ha^{-1}$. There is a strong relationship between the livestock density and N surplus with great risk of loss to the environment [2, 3] and in the European Union, the maximum amount of manure to be applied to agricultural land is regulated, through the Nitrates Directive and the IPPC Directive.

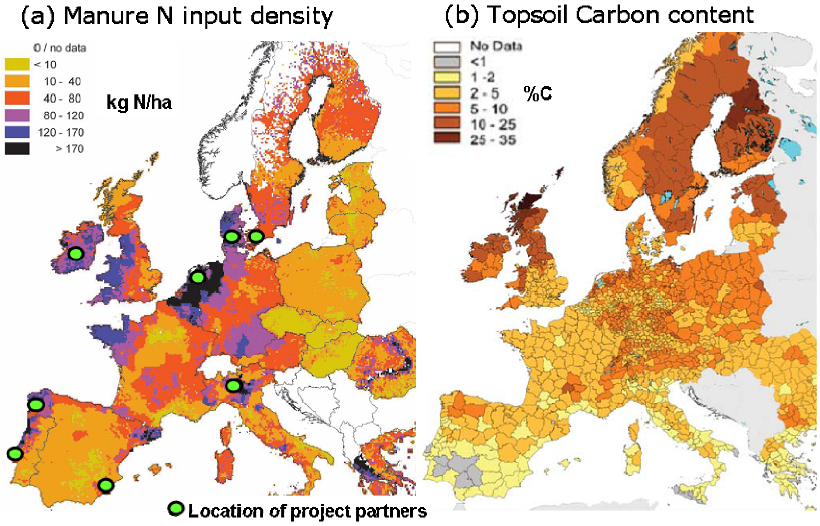


**Figure 1 (a)** Intensity of animal production in Europe (expressed as kg manure N/ha agricult. land. JRC: EUR-22334, 2006) **(b)** Soil organic matter levels in Europe (% carbon in topsoil, JRC: Soil Atlas of Europe, 2008).

Livestock production also contributes 70-80% of the anthropogenic ammonia emissions in Europe [4, 5] and is estimated to contribute 18% of the global GHG emissions [1]. If all indirect emissions are included in a life cycle approach, it has even been estimated that livestock production contributes up to 51% of the global GHG emission [6]. In addition, livestock production contributes with about 80% of the N and 45% of the P lost to the aquatic environment and is also a significant source of malodours.

However, if used appropriately, manure can replace large amounts of mineral fertilisers, indicating the high economic value of manure as a raw material for bio-fertiliser production. In addition manure will contribute to maintain or improve soil organic C stocks. On the other hand, improper management and utilisation of manure will result in wasting plant nutrients which are a limited resource and there will be a risk to the global feed and food supply. For example, phosphorus is a limited resource, with the mineable phosphate-rich rocks used for P fertiliser production projected to be exhausted within the next few centuries. In addition, manure contains large amounts of organic material that, with the right technologies, can be used for energy production. At the same time, European soil organic matter levels are generally decreasing and especially in southern Europe soils are greatly depleted in soil C, as depicted in Fig. 1b. This is threatening soil fertility to the point of desertification. Removing manure organic matter for energy recovery may therefore jeopardize the maintenance of soil organic matter and fertility.

As a consequence, there is increasing need for manure processing in the most livestock intensive regions, and for the recovery and utilization of valuable compounds from the manure. We need new bio-energy technologies capable of recovering energy from manures, while at the same time recycling nutrients and supplying the more recalcitrant fraction of organic matter to the soil. New technologies for reducing emissions to the atmospheric and aquatic environment are also needed. Therefore we set up a training network, '*ReUseWaste*', with the objectives to i) rethink the current, established animal manure management systems to produce both bioenergy and ”green” bio-fertilisers, leading to improved soil, water and air quality, ii) train a group of young researchers from both biological, agronomic and engineering disciplines in developing the needed new technologies and solutions for improved and sustainable utilisation of valuable organic matter and plant nutrient resources in animal manure. Here we summarise the first results from this network of research projects.

**Conceptual and methodologial approach**

Livestock manure is a heterogeneous and complex substrate composed of organic matter and plant nutrients, consequently positive effects of manure recycling and management are multiple and often interwoven. In order to address these challenges, we focus on a number of different aspects and approaches (see Fig.2).

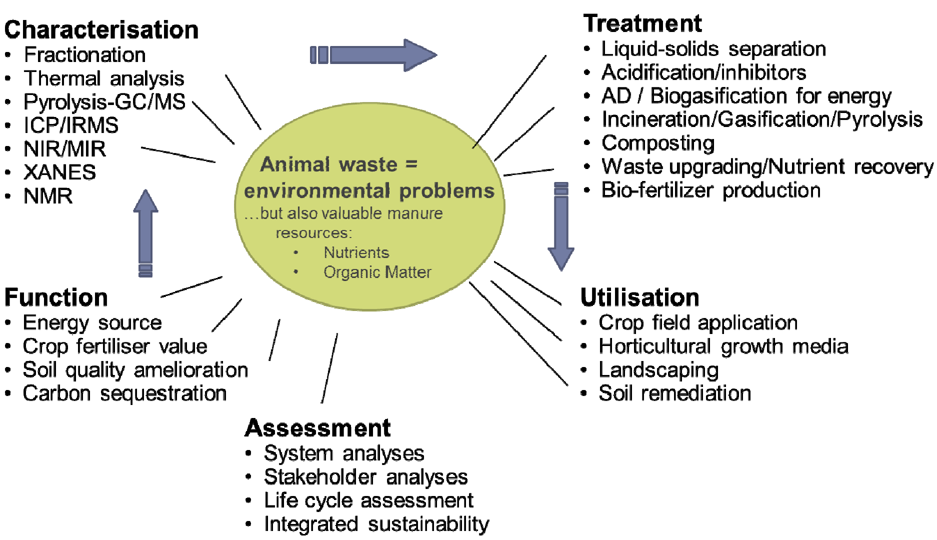


**Fig. 2.** Conceptual and methodological approach

These include the <u>functions</u> that manure organic matter and nutrients may fulfil and the <u>characterisation</u> of manure organic matter and nutrients with new analytical techniques. This is the basis for development of sustainable manure <u>treatments</u> options and <u>utilisation</u> opportunities. Finally, the overall performance and sustainability of the developed solutions is <u>assessed</u> with systems and life cycle analyses.

**Results and discussion**

Separation of animal manure or slurry may improve manure management, as it produces a solid and a liquid fraction, which makes field spreading more feasible, and a nutrient content in better balance with the plant/crop requirements than the raw manure. Separation technology, e.g. simple mechanical screw press or a decanting centrifuge, can be greatly improved by introducing a flocculation step prior to the mechanical separation, but these technologies have not been optimized economically, energetically or considering the end use of the products i.e. as plant nutrient and energy resources [7]. There is a pressing need for research and development on improved separation technology, and [8, this proceed.] have shown that synthetic polymers commonly used for flocculation to improve separation may be replaced by natural flocculants like chitosan and biochar.

Ammonium and other nutrients can be recovered from the liquid phase with membranes, and the development of new membrane technologies for separated liquid fractions has a large market potential. Camilleri-Rumbau et al. [9, this proceed.] made a techno-economic comparison of membrane technologies (microfiltration, nanofiltration and reverse osmosis) and physico-chemical operations (struvite precipitation and ammonia stripping) for obtaining nutrient-rich fractions from biogas digestates, in combination with different mechanical separations (decanter centrifuge or screw press). They showed that although the combinations with decanting centrifuge were most effective, the screw press followed by membrane technologies is the most economical.

Raw slurries or liquid fraction from separation have a significant ammonia volatilisation potential, which may lead to large atmospheric emissions of ammonia during storage or field application. Regueiro et al. [10, this proceed.] demonstrated how acidification can be used to reduce the risk of ammonia loss, and found the acidification process and effects on ammonia loss to depend on the slurry type, acid agent used and the pH to which the slurry was acidified.

More efficient separation facilitates transportation of the much smaller solid fraction, containing a major proportion of the dry matter, organic N and P, over longer distance. This may be the case between farms and biogas plants, where addition of the solid fraction as co-substrate in biogas plants offer both an operational and economic advantage over digestion of non-separated manure alone. Use of the solid fraction for biogas will reduce transportation cost, increase methane yield per volume of substrate and give new opportunities for optimisation of separation and pretreatment of the dry matter rich biomass for downstream energy production. However, as shown by [11] the type of pre-treatment can influence the nature and composition of the separated solid fraction and consequently energy production potentials.

Combustion, gasification or pyrolysis of the solid fraction has also been proposed as a technology to utilise the energy content of the solid fraction. However, the solid fraction often contains 60-80% water, and hence its net calorific value is negative, i.e. it will require more energy to evaporate the water, than the dry matter produces upon combustion [11]. Combustion will also mean that solid fraction N is lost to the atmosphere as $N_2$ or $NO_x$, depending on temperature, while P will remains concentrated in the ash. Although pyrolysis may not be the most energy efficient option for the treatment of separated pig manure, biochar from pig manure with combustion of the pyrolysis gas may be a viable option for nutrient recycling and carbon storage. Methodologies for using the ash or biochar as a slowly available bio-ash P fertiliser or for recovering the P from the ash in an industrial extraction process are now being developed, and results from Christel et al [12, this proceed.] illustrate how process type and temperature influence P availability.

Separation, anaerobic digestion and combustion may also result in reduced C input to the soil, and may hence deplete soil humus, reduce microbial activity and formation of stable soil organic matter, essential for soil fertility and soil filtering functions. Reducing carbon sequestration in soil will transform arable soils into a net source of $CO_2$ rather than a sink, affecting the overall agricultural GHG balance. However, technologies for returning the most recalcitrant components of the manure as bio-fertiliser, e.g. the solids after anaerobic digestion by carbonisation (e.g. by pyrolysis) or composting, could considerably enhance soil C sequestration and quality and may reduce gas emissions from soil. Subedi et al. [13, this proceed.] found little effect of biochar addition on $NH_3$ emissions, while Zhu et al [14, this proceed.] showed a marked reduction in $N_2O$ emissions after soil application of manure biochar.

## Conclusion and perspectives

The results we present on manure organic matter and nutrients characterization, treatment and management technologies, energy and P recovery, land recycling and utilisation of carbon and nutrients indicate that there are great perspectives, but also major obstacles on the track to optimal manure recycling with complete recovery and use of nutrients, energy and organic matter.

See more info at [www.reusewaste.eu](http://www.reusewaste.eu)

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