RiSE
RURAL INVESTMENT SUPPORT FOR EUROPE

Nutrient Recovery and Reuse (NRR) in European agriculture

A review of the issues, opportunities, and actions

EXECUTIVE SUMMARY

agroittica acqua & sole

fertilizers europe

About the RISE Foundation

The Rural Investment Support for Europe (RISE) Foundation is an independent foundation which strives to support a sustainable and internationally competitive rural economy across Europe, looking for ways to preserve the European countryside, its environment and biodiversity, and its cultural heritage and traditions. It works as a think tank, bringing together experts to address key environmental/ agricultural challenges in Europe and develops high quality accessible research reports with clear recommendations for policy makers. It draws on its extensive network of rural stakeholders to highlight innovative practises developed at the farm level and provides a platform for debate on issues that affect rural communities.

Authors

Emeritus Professor Allan Buckwell
Dr Elisabet Nadeu, RISE Foundation

Contributors

Dr Laetitia Six, Fertilizers Europe
Dr Koen Van Keer, Yara International
Annabelle Williams, RISE Foundation

The Report Advisory Group

Professor Mark A. Sutton, Centre for Ecology & Hydrology (CEH), Natural Environment Research Council (NERC)
Chris Thornton, European Sustainable Phosphorus Platform
Dr Luca Montanarella, European Commission - DG Joint Research Centre

This report has been financially supported by

Aqua e Sole
Carlsen Lange Foundation
Fertilizers Europe

Recommended Citation

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

FOR ORDERS AND DOWNLOAD

The RISE Foundation, Rue de Treves 67, Brussels 1040, Belgium
www.risefoundation.eu

The RISE Foundation

Nutrient Recovery and Reuse (NRR) in European agriculture

A review of the issues, opportunities, and actions

EXECUTIVE SUMMARY

2016

Authors:

Emeritus Professor Allan Buckwell

Dr Elisabet Nadeu[1]

With contributions from:

Dr Laetitia Six[2], Dr Koen Van Keer[3] and Annabelle Williams[1]

[1] The RISE Foundation
[2] Fertilizers Europe
[3] Yara International

PREFACE

As concern grows over the looming nexus of climate change, population growth and resource depletion, the agricultural sector has inevitably come under the spotlight. Whilst advances in technology over the last century have enabled a rapid increase in agricultural productivity in line with expanding demands, it is becoming clear that this growth can no longer be sustained in its current form. The impacts on the environment have been huge, causing wide scale water and air pollution, loss of biodiversity and soil erosion.

Inappropriate management of nutrients is a critical part of this story. It is now recognised that the growing leakage of nutrients from agriculture into the environment is affecting Europe's environmental security and clear steps must be taken for improved nutrient stewardship. Nutrient recovery and reuse from waste streams, such as animal manure, human sewage sludge, and food chain waste, can offer an important contribution to improve the efficiency of nutrient management and support Europe in its transformation to a more circular economy.

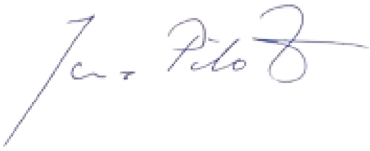
The RISE Foundation has launched this study to build on the previous report on the Sustainable Intensification of European agriculture: a review[4], in which nutrient management featured as a case study. The Foundation saw that nutrient recovery and reuse had great potential to address some of the key issues surrounding nutrient use in the food chain, namely pollution, waste management and dealing with finite resource depletion. The intention is to bring together the key challenges to nutrient management and the potential offered by Nutrient Recovery and Reuse (NRR) to engage policy makers and stakeholders who are working in this field. The NRR sector is still in its infancy and therefore collective actions will have to be taken if it is to grow.

The study engages a multi-disciplinary approach to bring together in a more integrated way, knowledge and expertise which is found in the separate worlds of agricultural science and farming, the food industry, water and sewage treatment industries and environmental and waste regulation. Specifically it aims to provide greater clarity on the following questions:

- What is the scope for nutrient recovery and reuse in Europe?
- What are the issues and opportunities that this involves?
- What are the actions that could support the development of nutrient recovery and reuse in Europe?

This report has been developed at a particularly relevant time following the release of the European Commission's Communication on the Circular Economy and we hope that through its conclusions and recommendations, it will support the thinking and development of the Communication's roll out in the coming years.

Dr Janez Potocnik
Chairman, RISE Foundation



Dr Corrado Pirzio-Biroli
CEO, Rise Foundation

[4] *Buckwell, A. et al 2014. The sustainable intensification of European agriculture. The RISE Foundation, Brussels*

Executive summary

Key Messages

1. Exponential growth in the flow of nutrients (nitrogen N, and phosphorus P) through the global agricultural and food system to feed the longer-living, wealthier more numerous population is causing serious environmental and public health impacts because the processes involved have serious leakage.
2. International studies have quantified the flow of nitrogen and phosphorus through the food chain (from farm to fork) and show that a large proportion of the unwanted side effects from nutrient flows have resulted from expansion of the livestock sector which, is inherently biologically inefficient and leaky.
3. The three main levers available to try and contain the growing damage are to change dietary goals towards lower consumption of livestock products, to improve crop and animal nutrient use efficiency through more knowledge intensive, precision agriculture and to reduce all waste. Nutrient Recovery and Reuse (NRR) contributes to the second and third of these.
4. In coming decades it is not any shortage, and thus high prices, of the raw materials used in mineral fertiliser manufacture which threatens global or European food and environmental security. Rather, it is the growing leakage of nutrients into the environment which poses the greatest threat.
5. Nutrient recovery and reuse in the EU would represent an intelligent diversification of sources of nutrient supply, which would add resilience in the event of supply disruption of phosphorus from N Africa, USA and Russia, or natural gas from Russia.
6. Every tonne of nutrient which is intercepted from a waste flow and processed into a form suitable to be used to fertilise crops represents a tonne less which would have leaked into water, the air, or the atmosphere, or ended up in land fill.
7. There is substantial scope to recover and reuse nitrogen and phosphorus from the European food chain. The most promising three substrates to work on are: animal manures, sewage waste and food chain waste, especially slaughterhouse waste.
8. Between 2 and 5 Mt of N and 0.6 Mt of P are currently not being recovered for agricultural use from these three major waste streams. These quantities represent 18-46% of the 11 Mt of mineral nitrogen currently applied to EU crops, and 43% of the 1.4 Mt of mineral based phosphorus applied to crops.
9. Significant challenges are posed by the characteristics of the waste flows from which nutrients are to be recovered, and the nature of the recovered products. The issue is complex, many actors are involved, it difficult to draw up simple lines of action.
10. As nutrient recovery and reuse is being promoted to rectify significant environmental market failures, NRR activity will not spontaneously, swiftly and significantly increase in scale without further collective actions – many of which are signalled in the Circular Economy action plan of the European Commission. This report offers sixteen suggestions of specific actions to take Nutrient Recovery and Reuse to the next level.

General conclusions

Current global mega-trends, climate change and population growth, are stimulating a rethink of the way all sectors of the economy are operating, and not just how food is produced and consumed. Change is already happening. In some areas these are already quite visible, for example in mobility, while in other areas, including food production, the transition is lagging and the resistance to change is somehow stronger. The way nutrient flows are managed should be a core part of this rethink. The challenges are global, so this requires international efforts to find solutions. This was clearly recognised by important decisions reached at the global level during 2015. Adoption of Sustainable Development Goals (SDG's) in September and the Climate Change agreement reached in Paris in December are showing the way to a more sustainable future. As a highly developed region, with a highly intensive agriculture, Europe can perform a leadership role in improved nutrient management. Since the transition is unavoidable this would also create first mover advantage and economic opportunities.

The primary task of agricultural systems is to provide essential nutrients and other natural products for the human population. Human beings are omnivores and have always consumed, in varying proportions, a diet of vegetable and animal products. As the human population has risen, it has also greatly increased material living standards, these have resulted in diet change towards the consumption of more livestock products, and human life expectancy has also significantly increased. The combined effect of these developments has seen an exponential growth in the flow of nutrients through the global agricultural and food system especially in the last six decades. It turns out that this is causing serious environmental and public health impacts because the processes involved have serious leakage.

It is only comparatively recently that gross flows of the two most important macro-nutrients, nitrogen (N) and phosphorus (P), have been rigorously studied, quantified and brought to the attention of scientists, policy makers and the public. This work has been done by large international teams of biological, environmental and agricultural scientists with substantial European input. The European Nitrogen Assessment, the German Council on the Environment (SRU) and the work of the Global Partnership on Nutrient Management provide accessible descriptions of this work[5]. Most of these large international projects have concentrated on nitrogen while the phosphorus work has been more *ad hoc*. A key message from these studies is that a large proportion of the unwanted side effects from nutrient flows has arisen because of the expansion of the livestock sector which, unfortunately, is inherently biologically inefficient and leaky.

The surge in these two nutrient flows is overwhelming the absorptive capacity of natural nutrient cycles. The processes through the whole food chain are associated with large leakages into the environment. This applies to all four major stages: fertilising crops, with either organic or inorganic nutrients; it especially applies to feeding farm animals and managing their waste; it applies to processing food and feeding the human population; and then managing human waste. The four principal signs of the damage of this over-extended system are: the eutrophication of water courses, lakes, inland seas and oceans; pollution of the air breathed by citizens with damaging health impacts; greenhouse gas (GHG) emissions which are changing the climate in harmful ways; and damage to terrestrial and aquatic biodiversity.

The growth in nutrient flows shows every sign of continuing in coming decades, and therefore the scale of the associated damage can be expected to grow. Human population is expected to rise another 30% by mid Century. It is policy everywhere to drive income growth and to further increase human life expectancy. There is no possibility that these three factors will change. Therefore, the three main levers available to try and contain the growing damage are to change dietary goals towards lower consumption of livestock products, to drive hard to improve nutrient use efficiency at each stage in the food chain, and to reduce all waste. Without strong corrective actions there is every prospect that the damage resulting from nutrient leakage will continue. This damage, through water and air pollution, biodiversity loss and harmful climate change, threatens the very sustainability of the agricultural system itself and thus global food security.

The origins of this report came from a rather different aspect of food security. This concerned fears about the security of relying for our food production on non-renewable mineral phosphorus and the manufacturing of nitrogenous fertiliser using the fossil fuel natural gas which should be curtailed for climate protection reasons. An obvious way to reduce such risks would be to recover nutrients not taken up by plants, animals and humans, and reuse them. This would reduce reliance on mined, and mostly imported, phosphorus and manufactured nitrogenous fertilisers based on imported natural gas and it would be a practical demonstration of the circular economy in action.

The critical point about nutrient recovery and reuse is that each tonne of recovered and reused N and P offers the following benefits:

- Less water and atmospheric pollution, because the N and P in some waste streams has been captured and is thus prevented from leaking.
- Less depletion of finite reserves (P) and use of fossil fuel natural gas (N) contributing to GHG emissions.
- Reduction in environmental pollution associated with the mining, processing and transport of phosphorus and the manufacture of nitrogenous fertilisers.
- Diversification of nutrient supply thereby reducing reliance on imported phosphate rock and natural gas.

[5] *Sutton M and Van Grinsven et al (2011) Summary for Policy Makers, European Nitrogen Assessment, SRU (2015) Nitrogen: strategies for resolving an urgent environmental problem, and GPNM (2013) Our Nutrient World.*

The report therefore assesses the relative role that nutrient recovery and reuse can play in addressing 5 goals and concerns related to current nutrient use:

1. **Food production** to feed a growing population.
2. **Farm viability**.
3. **Pollution of water, air and soil and impact on the climate.**
4. Reduction and recycling of **food chain waste.**
5. Confront the dependence of the food system on **finite, insecure, non-renewable resources**.

The geographical focus of this report is the European Union. A conclusion of this study is that over the next few decades it is not any shortage, and thus high prices, of the raw materials used in mineral fertiliser manufacture which threatens global or European food and environmental security. Rather it is the growing leakage of nutrients into the environment which poses the greatest threat. Nutrient Recovery and Reuse (NRR) in the EU would represent an intelligent diversification of sources of nutrient supply, which would add resilience in the event of supply disruption of phosphorus from N Africa, USA and Russia, or natural gas from Russia. However, the larger and more important contribution of NRR to food security is to improve European nutrient use efficiency. Every tonne of nutrient which is intercepted from a waste flow and processed into a form suitable to be used to fertilise crops represents one tonne less which would otherwise have directly leaked into water, the air, or the atmosphere or ended-up in land fill. To the extent that recovered nutrient displaces some manufactured mineral fertiliser, its use may also reduce pollution associated with the mining and manufacture of phosphorus fertilisers and the manufacture of nitrogenous fertiliser[6]. There is an important proviso that life cycle assessments of recovered nutrients are needed to determine their energy and resource efficiency relative to that of conventional mineral fertilisers. Nutrient recovery and reuse therefore offers an important contribution to improve the efficiency of nutrient management.

It is emphasised that NRR is not the whole answer to the disruptive environmental effects of inflated nutrient flows, it is just the chosen focus of this report. This in no way diminishes the importance of constantly seeking to improve nutrient stewardship in crop and livestock production. This can be done in many other ways. The current moves to more knowledge-intensive precision crop and livestock farming indicate the direction of travel. There is considerable scope to do this. For example, increasing soil carbon stocks by increasing the return to soil of recovered organic material will improve soil quality. This would contribute to a higher nutrient use efficiency and a reduction in losses to the environment. There is large scope to improve the efficiency of nutrient use in crop production by balanced nutrition and precision fertilisation of crops. There is similarly large scope to improve the nutrition of farm livestock by better breeding and more precise data-led livestock feeding. These aspects are not the main focus of this report, and neither is the need to, nor methods of, inducing better diets and thus nutrition of the human population. These are inescapably part of the larger agenda to achieve sustainable nutrient flows but they take us outside the prime focus on Nutrient Recovery and Reuse.

Specific conclusions on the use of nutrients in the EU and the scope for recovery and reuse

Nitrogen and phosphorus are essential nutrients that play key roles in the development and functioning of plants, animals and humans. In order to feed the expanded population, agriculture heavily relies on the inputs of mineral nitrogen and phosphorus. It is estimated that around 16.7 Mt of N enter the EU agricultural system annually, 10.9 Mt of which in the form of mineral fertilisers and 2.7 Mt N as feed, while external inputs of phosphorus include 1.4 Mt P of mineral fertiliser and 0.4 Mt P of feed.

Mineral fertiliser inputs in the EU have fallen over the last twenty-five years and P fertiliser inputs are back to levels of the 1950s. Nitrogen fertilisers now account for 70% of all mineral fertiliser inputs. Despite the significant falls in use of mineral fertilisers the efficiency of nutrient use through the whole food chain unfortunately remains low. For every five tonnes of nitrogen entering the EU agricultural system, only one tonne is converted to finished products for human consumption, that is a 20% Nutrient Use Efficiency (NUE). For phosphorus, the corresponding figure is 30%. While crop production shows a relatively high NUE due to advances in crop genetics and management and fertiliser application techniques (53% for N and 70% for P), livestock makes a particularly inefficient use of nutrients (18% NUE_N and 29% NUE_P).

These low efficiencies result in large leakage of nutrients into the environment with negative impacts on soils, water and air, and are associated with unacceptable health and environmental costs. In soils excess P build-up can lead to increased phosphorus losses through runoff and soil erosion, while atmospheric nitrogen deposition is reducing biodiversity. P and N in waters contribute to eutrophication, reducing water quality, aquatic biodiversity and increasing greenhouse gas emissions. In the atmosphere, nitrogen oxides and ammonia reduce air quality, contribute to atmospheric deposition and have a strong impact on human health. Nitrous oxide, derived from the application of synthetic fertilisers and manure to soils, and methane, from ruminant digestive fermentation, are the main agricultural contributors to climate change while ammonia, resulting mainly from livestock and manure management contributes to air pollution.

[6] *Strictly this latter benefit should be measured as the net saving of energy and pollution associated with the collection and processing of the recovered nutrient compared to the corresponding effects involved in the manufacture of the equivalent amount of N and P in the form of mineral fertiliser. One tonne of recovered nutrient may not necessarily equal one tonne of mineral fertiliser.*

Increased nutrient recovery and reuse can contribute to reducing these losses and increasing nutrient use efficiency. This study suggests the key waste streams on which to focus. A large number of nutrient recovery techniques are currently available or under development to perform this function. In short, increasing the potential of nutrient recovery and reuse requires that three parallel tasks be undertaken: (i) to increase the **total amount of recovered nutrients** from waste streams; (ii) to increase the **fertiliser equivalence value** of recovered nutrients (as formulated by Sutton *et al* 2011); and (iii) to create recovered products that are safe, easy to store, handle and use by farmers and which reduce current N and P leakage associated to nutrient recycling.

The two prime questions posed in this report are:

Is there scope and are there workable processes to recover and reuse nitrogen and phosphorus in the European food system? In what quantities and from which substrates can this be done?

Yes, there is substantial scope to recover and reuse Nitrogen and Phosphorus from the European food chain. The following figures are based on the summary Tables 4 and 5 in Chapter 4. It is emphasised that these figures are the best available estimates based on the nutrient assessments conducted in recent years for the EU. The sources of these figures and details are explained in Chapter 4. The figures are orders of magnitude, they show estimates of nutrients in material flows which are not currently being recovered and reused in agriculture but potentially might be. Because some of this may not be easily recovered these figures should be taken as upper limits considering current waste collection rates.

With current technology and incentives for implementing the circular economy for nutrients, the most promising three categories of substrate to work on are: animal manures, sewage waste and food chain waste especially slaughterhouse waste. The potential volumes of recoverable nutrient from these three waste streams are estimated to be in total, approximately, 12 Mt N and 2.5 Mt P annually. About 60% of N and 75% of P in these waste streams are already being recovered and reused – a large part of this is in the form of animal manure and after very little processing.

It is suggested that between 2 and 5 Mt of N and 0.6 Mt of P are currently not being recovered for agricultural use from these three major waste streams and these therefore constitute the prime targets for further nutrient recovery and reuse. To put these quantities in perspective, they represent 18-46% of the 11 Mt of mineral nitrogen currently applied to EU crops, and 43% of the 1.4 Mt of mineral based phosphorus applied to crops. Technologies for such recovery are available. Some are already in commercial operation in several Member States, but much of this development is at the pilot plant stage and its commercial viability is yet to be proven.

Returning animal manure to land is almost as old as agriculture itself, it must be the longest-established example of the circular economy in action. It is estimated that a little under 8 Mt and N and 2 Mt of P are returned to land in the form of animal manure. These seem impressive

Shutterstock

figures in comparison to the scope for further recovery. However, much of this existing recycling of nutrients back to land is imprecisely applied resulting in unbalanced fertilisation and by no means all of these quantities are available for up-take by crop plants and therefore much is lost to the environment.

Manure is the single largest waste flow of nutrients and provides over 70% of the current total recovered N and P from all sources. However, manure handling and application results in large amounts of nutrient losses (calculated to exceed 6 Mt N per annum) through gas emissions, leaching and runoff. Some of the gaseous nitrogen emissions could be reduced by improving manure field application and ammonia could be recovered by sealing manure storage facilities. There is also scope to reduce ammonia emissions and facilitate nutrient collection by better design and management of animal housing. Such actions often require large farm level investment which can be difficult in small scale operations, although imaginative farmer cooperatives are finding ways to surmount these challenges. In addition, there is scope to further process manure to make it a more targeted fertiliser by providing nutrients in combinations best suited to crop needs and presenting it in a form that is easy to handle and apply by farmers while contributing to reduce nutrient leakage into the environment. Solutions will have to be tailored to suit the differing conditions in the regions of the EU.

In the case of **sewage**, about 10 Mt of dry sludge is produced annually in the EU, representing 3.3 Mt N and 0.3 Mt P. 42% of this sewage sludge is already being returned to agricultural soils after stabilisation, but often with application rates not well matched to nutrient requirements. There is often a high P content which leads to P accumulation in soils. There may be spatial constraints on the extent to which this material can be spread on land because of transport costs. There is also some reticence in some Member States to reuse sludge. There is sometimes insufficient knowledge and specification of the plant-available nutrients present in the sludge to be applied to land. Second there are concerns about possible presence of pathogens, pharmaceuticals and complex organic compounds which could threaten plant, human and long-term soil health. Technological improvements in recovery techniques can address these concerns and increase societal confidence.

Strategies for N and P recovery from sewage differ. One of the main issues for nitrogen recovery is that between a third and a half of the N is lost through nitrification/denitrification processes but could be recovered by implementing appropriate technologies (e.g. ammonia stripping). Therefore, avoiding denitrification in wastewater treatment plants and shifting to nutrient recovery technologies to remove N could significantly increase its recovery from sewage. In the case of phosphorus, many recovery techniques have appeared over recent years. However, only a few are operating at full-scale or even as pilot plants. Most of the processes recover P from sludge dewatering reject streams or sludge liquor with recovery rates ranging between 15-30%. However, higher recovery rates (70-90%) can be obtained from sewage sludge ash from mono-incineration, but this is currently a minor treatment route still being tested at pilot plants. The majority of the systems currently in operation recover P in the form of struvite with maximum potential recovery of 30%. Further investment in technical improvement is needed.

Some of the challenges for nutrient recovery from sludge are therefore to (i) increase central collection of sewage; (ii) switch from nitrification/denitrification to ammonia stripping in order to recover N; (iii) encourage anaerobic digestion to obtain a stable sludge, produce biogas and allow for further nitrogen stripping, and (iv) support research on technologies to separate P in sludge and sludge ashes from pollutants.

Municipal and food chain waste pose their own unique challenges. The total potential quantities appear to be large but the sources are numerous and heterogeneous. Also there is considerable uncertainty about the quantities available because food waste definitions are not agreed. This results in many different estimates of the quantities available. There are long-established recovery and reuse channels in some areas, for example, municipal green waste for composting, and more recently anaerobic digestion. Meat, blood and bone meal have a long history of use as fertilisers. Recovery of phosphorus is technically not difficult, but nowadays this use is subject to animal by-product regulation. The use of offal in pig swill for animal feed ran into difficulty with the discovery of BSE (Bovine Spongiform Encephalopathy) in the mid-1990s. But other food chain waste such as brewers grains have a long history of recycling in their use as cattle feed. For Municipal waste one of the major challenges is to encourage the separation and collection of the organic fraction in laggard counties to catch up on those where this is now routine. A particular feature of the development of nutrient recovery and reuse based on municipal and food chain waste is the policy goal to significantly reduce this waste. The highest priority in the well-accepted waste hierarchy is to prevent waste appearing in the first place. This consideration has therefore to be factored into planning and investment in nutrient recovery from this substrate stream.

The encouraging conclusion is that there is substantial scope for more NRR. The more sobering conclusion is that there is no single new source of nutrients nor single new process which is going to revolutionise NRR and drive it to a new level. What is required is a new determination to push many activities to reach their potential. This is precisely the purpose of the Circular Economy initiative. It is a vehicle to inject energy and enthusiasm to focus attention on sustainable consumption and production, and to ensure the regulatory landscape encourages and does not inhibit the transformation of waste into secondary raw materials. It is a way to stimulate innovation, and in the process to create jobs and growth especially in the rural economy as many of these recovery processes will be decentralised activity.

What is impeding the rapid development of NRR, and what actions could be taken to propel it?

Significant challenges are posed by the very nature of the waste flows from which nutrients are to be recovered. These flows are comprised of very large volumes and masses of materials, many of which are highly dilute and heterogeneous especially the 'outputs' from livestock and humans. They arise in continuous daily flows, widely spatially dispersed in multiple sources over all human-occupied territory; and whilst nutrients *per se* are welcome, many of the output flows are considered wastes and distasteful. They are associated with substantial soil, water and air pollution risks some of which also risk harm to human health; and they are destined to be added to the soil where there is potential for long-run accumulation of any undesirable contaminants present, even if in very low concentration.

These characteristics, particularly the use of human sewage in food production, can bring with them some fairly deep negative attitudes towards this aspect of NRR. Fears about contamination of food by heavy metals, pathogens or pharmaceuticals, and about odour and troublesome traffic in rural areas associated with storage, transport and spreading of recovered nutrients, have to be, and can be, allayed by appropriate technologies and practices. This demands sound monitoring and good communication. In addition the very structure of the nutrient recovery industry, its dispersed, relatively small scale operation compared to mineral fertilizer manufacture, and the heterogeneity of its inputs and products, create a further challenge to the development of the sector. It cannot be taken for granted that the products from nutrient recovery processes are perfect substitutes for existing fertilisers. Farmers will judge them primarily on their price, nutrient composition, consistency, ease of handling and storage, and their crop production performance. They will choose to purchase, or use them if provided free, accordingly.

For these reasons, and the very fact that establishing nutrient recovery and reuse is being promoted to rectify significant environmental market failures, it is suggested that the take-off for this sector will not happen spontaneously but will require a variety of collective actions.

Many of these actions are already well acknowledged and are underway in the EU. There is recognition that nutrient management is a heavily regulated area. It has to be, public safety and confidence are paramount. However, a process of review of some of this regulation is underway. Revision of the fertiliser regulation to more clearly define 'end of waste', and provide for certification of recovered nutrients is work in progress. Raising the ambition of waste separation and collection, establishing a common EU definition of food waste and encouraging nutrient recovery and reuse are amongst the many actions proposed in the European Commission's Circular Economy package of December 2015. The EU research programmes have certainly identified the importance of establishing a sound scientific basis for NRR. In parallel, the private sector has been imaginative and active in creating stakeholder platforms for the sharing of knowledge, ideas and experience in sustainable nutrient use. However, such is the complexity of the legislation affecting the fertiliser industry, farms, food industry and the water treatment sector at both the EU and national levels that it is not possible to assess the coherence of this legislation and whether it is optimally structured to stimulate NRR to realise its potential. This could be a priority for a further research project.

A large remaining question is whether more active steps should be taken to stimulate more recovery of nutrients and their use in agriculture or to incentivise this by restricting, or taxing, non-recovered nutrients? The qualitative arguments assembled and discussed lead to the conclusion that, even with the favourable assistance currently underway through regulatory reform, research and information provision, NRR activity will not spontaneously, swiftly and significantly increase in scale. Therefore, further collective action is justified. It should start with an appraisal of suitability of the current legislative landscape to test if it is most appropriate to stimulate the next stage of development of NRR. Then it should examine in detail the benefits and costs of each of the ways that could be undertaken to provide this stimulus.

The report reviews eight kinds of further collective actions. It looks at five ways of providing positive stimulus (obligations, targets, investment grants, subsidies, fiscal reliefs) and three ways of giving advantage to recovered nutrients by penalising the alternatives (fertiliser tax, land fill and incineration fees or restrictions, nutrient surplus tax). This overview cannot provide the basis on which conclusions can be drawn on the overall or specific costs and benefits of such measures. Policy in this area therefore requires rigorous research to answer two questions:

(1) Do the potential environmental, human health and economic benefits in the EU merit the deployment of a combination of active positive and negative actions to stimulate a step up in Nutrient Recovery and Reuse?

(2) If so, what is the best such combination of measures?

In short, this study has identified that there is substantial scope to increase NRR in the EU. It suggests that NRR could be an important contributor to better nutrient management. The NRR sector is growing, there are suitable technologies being developed, and the regulatory environment is improving. But it concludes that because of the intrinsic character of the materials involved, the processes, products and businesses likely to be engaged, without purposive further incentives and actions NRR activity is unlikely to expand rapidly. However, before such incentives are given, rigorous cost benefit, including life cycle, analyses are required.

Recommendations

Nutrient recovery and reuse has the potential to contribute to better nutrient stewardship and provide some degree of diversification of nutrient supply to help nutrient security. What is also evident is that the lack of uniform data makes it hard to estimate precise potential for recovering nutrients in Europe. Although there is apparently a large recovery of nitrogen through the use of animal manure, the effective reuse of this nitrogen is low because current manure storage and distribution are themselves inefficient. There seem obvious benefits to be gained from nutrient recovery and reuse if done properly. But the path to increase NRR uptake is complex, requiring multiple actions. Unless the many obstacles that block its way are addressed, the industry will remain in its infancy. Some of the actions to do this are summarised here.

1. **Better data**. To assess more accurately the scope for the recovery of nutrients from various waste streams, policy makers, entrepreneurs, and investors in Europe require better data than currently are available. This calls for clearer standardised definitions, measurements, monitoring and analysis of the flows of the relevant waste materials in Europe.

   Recommendation 1: *Develop a common methodology and define indicators to monitor nutrient flows and organic carbon in waste streams as suggested by the DONUTTS project*[7].

   Recommendation 2: *Apply this new methodology in the EU, and at Member State level to provide regular updates on progress towards the goal of increasing nutrient recovery and reuse and meeting the targets set for the Circular Economy.*

2. **Regulatory coherence**. There are a large number of directives and regulations already in place concerning the use of nutrients at the EU level. However, there is a great variety of corresponding regulation at national and regional level which can hinder entrepreneurial impetus, investment and knowledge transfer. If there is to be a greater development and uptake of nutrient recovery and reuse, the regulations that govern the sector require some coherence across the Member States, whilst recognising diversity of conditions and priorities. Do the EU level regulations hinder nutrient recovery in Europe, and are they adequate? What needs to be changed at the national level to better develop this sector?

   Recommendation 3: *Conduct a full review of the legislation affecting all aspects of nutrient management in Europe and changes in European and National legislation that could help stimulate more NRR.*

3. **Appropriate policies for NRR**. There are very important revision processes underway for specific legislation concerning recovered nutrients for use in agriculture (End of Waste Criteria and the Fertiliser Regulation) and it is hoped that these will go a considerable way to support the development of the NRR market in Europe. However, the characteristics of the NRR market structure make it unlikely that this sector will flourish without some form of further policy support: either positively through inducements, or through penalties on polluting activities. Experience has shown that the correct mix of these policy tools cannot be identified without careful and detailed analysis and impact assessment.

   Recommendation 4*: Analyse the impact that nutrient recovery and reuse could have on the environment, and on resource security, and its potential to create jobs, income and growth in rural areas to help establish the case for collective action to drive a step up in NRR.*

   Recommendation 5*: Analyse the feasibility and costs and benefits of the deployment of specific measures, including subsidies and taxes, to directly stimulate NRR, or to restrict or penalise alternative nutrients.*

   Recommendation 6*: Provide public funding to help take technologies for NRR being developed in the laboratory to the pilot project phase and the development of pilot projects towards full scale commercial enterprises.*

   Recommendation 7: *Ensure that NRR projects are flagged as eligible for consideration for EU funds for Rural Development, and activities undertaken by the European Investment Bank.*

   Recommendation 8: *Encourage coordination of R&D activities on NRR across Europe, through more clustering of science centres for the different recycling areas, including the European Commission's Joint Research Centre.*

[7] *See: http://www.phosphorusplatform.eu/platform/news/698-data-on-nutrients-to-support-stewardship-donutss*

4. **Circular Economy Package**. This is a highly welcome development given its comprehensive review of the actions that should be taken to address nutrient recovery and reuse in Europe. Particularly helpful to drive NRR would be the following:

   Recommendation 9: *High priority should be given to make rapid progress with the clear delineation, and establishment of standards and certification procedures for recovered nutrient products, and traceability protocols for recycled nutrient products which could contain organic contaminants. These should cover the nutrient content, the maximum level of impurities which could be a threat to health, safety and environment, and product quality and application techniques.*

   Recommendation 10: *Establish an EU level analytical framework for nutrients as well as a practical check list of potential actions to develop NRR further in Europe.*

   Recommendation 11*: Establish Best Available Technologies and the Best Practices Exchange for nutrient recovery and reuse and their promotion through current Information exchange platforms.*

5. **Consumer acceptance and land managers mobilisation**. It is clear that this can be a significant impediment to further NRR. Some consumers may be anxious about products fertilised with nutrients derived from sewage sludge. In some cases food processing and retailing companies are choosing to pre-empt their customers' views by refusing to buy products if they are fertilised in this way. There can also be resistance from land managers if they are not convinced of the nutrient value, consistency and performance of recovered nutrient products. Remedying this aspect is mostly the responsibility of the enterprises conducting the nutrient recovery, but research and development assistance may also be justified. Even without their own concerns about the quality and efficacy of recovered nutrients, farmers may be nervous about the willingness of their purchasers to buy their products. To overcome these attitude and cultural barriers there has to be in place the appropriate quality and safety standards for recovered nutrients, monitoring of the operation of these standards and their correct use by farmers notably through appropriate extension services. It is also advisable to devote resources to create an awareness raising campaign explaining the rationale and environmental benefits of NRR. This in turn should raise awareness of the consequences of the leakage of nutrients into the environment, and the ill health effects of nutrient mismanagement as well as creating greater clarity regarding concerns over the public health impacts of using recovered nutrients on land. This narrative can explain how waste separation and collection and NRR can reduce reliance on imported non-renewable resources, increase security of EU food, and the recovery processes can contribute to local jobs and growth and ensure productivity and sustainability of managed land in the long term.

   Recommendation 12: *Develop an awareness raising campaign to inform consumers about the impact of current nutrient use and the benefits of nutrient recovery and reuse.*

   Recommendation 13*: Provide research funding for analysis, understanding and risk-assessment of organic contaminants in nutrient recycling, including both processed sewage sludge and manures and recovered nutrient products.*

   Recommendation 14: *Inform, educate and motivate food processors/retailers to engage with the need for the application of circular economy concepts in food production to help create consumer and retailer 'pull' for products that are produced with recovered nutrients.*

   Recommendation 15*: Integrate NRR and soil carbon benefits into EU policies for renewable energy as well its contribution to adaptation and mitigation for climate change.*

6. **Optimal level of livestock product production and consumption**. The detailed research on nutrient flows through the highly sophisticated and complex EU food system which has been reviewed in this report has drawn attention to the worryingly large magnitude of the negative impacts on human health and on the environment and climate of the leakages associated with these flows. In particular it has become clear that a major contributor to this damage is the inherent inefficiency of producing human nutrition though livestock products. This is far from a simple matter. Livestock and its manure have an enormous, positive role in balanced agricultural systems – they currently provide over 50% of all EU crop nutrients and, of course, a high proportion of crop nutrients for organic farming. Livestock products provide valuable nutrients for human development and functioning, and there is a long-established cultural attachment to consuming these products. People enjoy them. But it is hard to avoid the conclusion that, over and above the need for a review to assess more active policy to stimulate nutrient recovery, there is a need for a thorough review of the optimal place of livestock in EU agriculture and livestock product consumption of citizens.

   Recommendation 16: *Conduct a high-level, wide-ranging, review of the optimal place of livestock in the EU, embracing both the health and environmental impacts of meat and dairy products in the human diet, and the spatial distribution and concentration of livestock production and its contribution to cultural landscape.*

NOTES

NOTES

THANK YOU

In addition to the invaluable comments and advice given to RISE on this report by the Report Advisory Group, named below, we would also like to thank the following people for their commentary during the projects evolution, and presentations and engagement in the RISE workshops on Nutrient Recovery and Reuse which helped shape the development of this piece of work.

1. Report Advisory Group

- Professor Mark A. Sutton, Centre for Ecology & Hydrology (CEH), Natural Environment Research Council (NERC)
- Chris Thornton, European Sustainable Phosphorus Platform
- Dr Luca Montanarella, European Commission - DG Joint Research Centre

2. Baltic Sea Action Group

3. Cecilia BERTHOLDS, Käppala Association, Sweden

4. Emeritus Professor Winfried BLUM, University of Natural Resources and Life Sciences (BOKU), Vienna

5. Reinhard BUESCHER, Head of Unit, DG Internal Market, Industry, Entrepreneurship and SMEs, European Commission

6. Paolo DE CASTRO, MEP and RISE Board Member

7. Carl DEWAELE, NuReSys- Belgium

8. Pierre-Olivier DREGE, Chief Executive Officer AGPB (French Wheat Growers Association)

9. The European Landowners' Organisation (ELO)

10. Mella FREWEN, General Director FoodDrinkEurope

11. Aki HEINONEN, Project Officer, Municipality of Punkalaidun- Finland

12. Ludwig HERMANN, Outotec

13. Sébastien HOMO, Responsible for Research & Development, COOPERL- France

14. Tore K. JENSSEN, Jenssen Consulting, Norway

15. Giovanni LA VIA, MEP and Chair of the Committee on the Environment, Public Health and Food Safety

16. Dr Ladislav MIKO, Deputy Director General for Food Safety, DG Health and Food Safety

17. Morten ROSSÉ, Expert Associate Principal, McKinsey and Company Centre for Business & Environment

18. Ruben SAKRABANI, Senior Lecturer, Cranfield Soil and Agrifood Institute, Cranfield University

19. Dr Nina SWEET, Special Advisor of WRAP UK

20. Kimo VAN DIJK, Researcher, Wageningen University

RiSE
RURAL INVESTMENT SUPPORT FOR EUROPE

CONTACT:

The RISE Foundation

67 Rue de Trèves - BE - 1040 Brussels

Tel: + 32 (0) 2 234 30 00

Fax: +32 (0) 2 234 30 09

Email: rise@risefoundation.eu

Website: www.risefoundation.eu