Key challenges for future research on Phosphorus in Europe

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These fertilisers are of course the same ones we rely on to produce enough food to feed the people on our planet, credibly **creating competition between global food and energy systems**.

Food prices and fertilisers

We have previously seen a drastic spike in food prices after the widespread adoption of corn based ethanol. This spike was based on a sudden demand increase for a single crop. The shock would be even worse and more widespread if the item in demand was the P in fertiliser needed for production of every food item.

Clearly**, a sustainable future cannot create conflicting interests between food and energy production**. Use of low P demand crops and P recycling are two practices that growing biofuel production can undertake to help meet this goal.

Crop choices

First, **utilizing low P demand crops** can significantly reduce the amount of P required to produce the necessary biostocks. Genetically modified crops can require only half the P to produce the same yield. However they have faced fierce public backlash when used for food, from labelling requirements to outright bans. This presents **an opportunity to instead use these low P demand crops for biofuel production**. As widespread production of biostocks for fuel are produced, these should be selected from the most nutrient efficient crop strains science has to offer.

Phosphorus recycling

Second, **P recycling can easily be introduced to biostock production.** While biostock crops and algae require P to grow, the extracted ethanol and fatty acid chains fuel is refined from do not. That means all of the consumed P is left in the organic byproducts. It is a critical opportunity to recognize the nutrients embodied in these residuals can be recaptured and reapplied to subsequent crops.

The residuals should be broken down through chemical or physical means, then the P recaptured and concentrated into a reusable fertiliser. P recovery technologies have been developed, but full scale application and widespread adoption are vital opportunities to reduce the P demand of biofuel production. **A sustainable future for biofuel production incorporates P recycling from biostock residuals.**

Use of low P demand GMOs for biostock production, and recycling of the P in the residuals after biofuel refining are critical visions for future P stewardship. **The biofuel industry has an opportunity today to incorporate these technologies so that they are standard as biofuel becomes more widespread** over the coming decades. This will avoid future competition between food and fuel, allowing us to drive *and* eat when we go out to dinner.

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More than 164,000 scientific papers have been published worldwide about phosphorus (P) since the early 70s.

A brief overview of the literature shows that **P was first studied as a nutrient** by agronomists. P fertilisation recommendation systems have been improved, which has led to lower mineral P fertiliser rates in most western European countries. Later **P was studied as a pollutant triggering eutrophication** of water bodies and mitigation options have been proposed. **More recently, phosphorus as an essential non-renewable resource** has received attention from the scientific community (fig. 1).

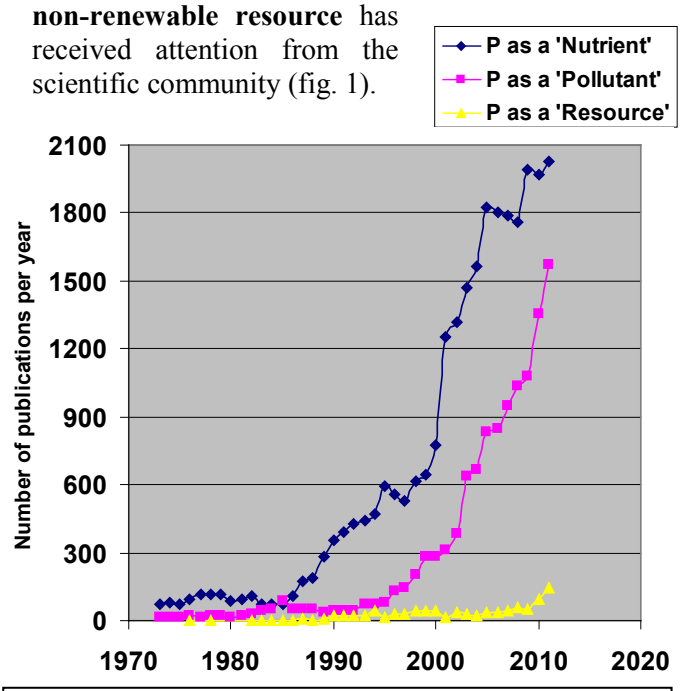

Figure 1: Number of scientific publications per year on Phosphorus (Web of Sciences)

Coordinated P management is needed

In Europe, these three issues are now closely interconnected, but **not addressed in a coordinated way at the EU level**. The European Union has negligible natural P resources. Soil fertility and agricultural production in Europe rely on P imports (1500 Gg P per year of mineral P fertilisers). Phosphorus circulates within and between different industry sectors: agriculture, food/feed and detergent processing industry, households and waste. Calculated P budgets at European and national levels show that only a small fraction (ca. 20%) of the P entering the food chain via fertilisers ends up in food on the plate of consumers (Figure 2).

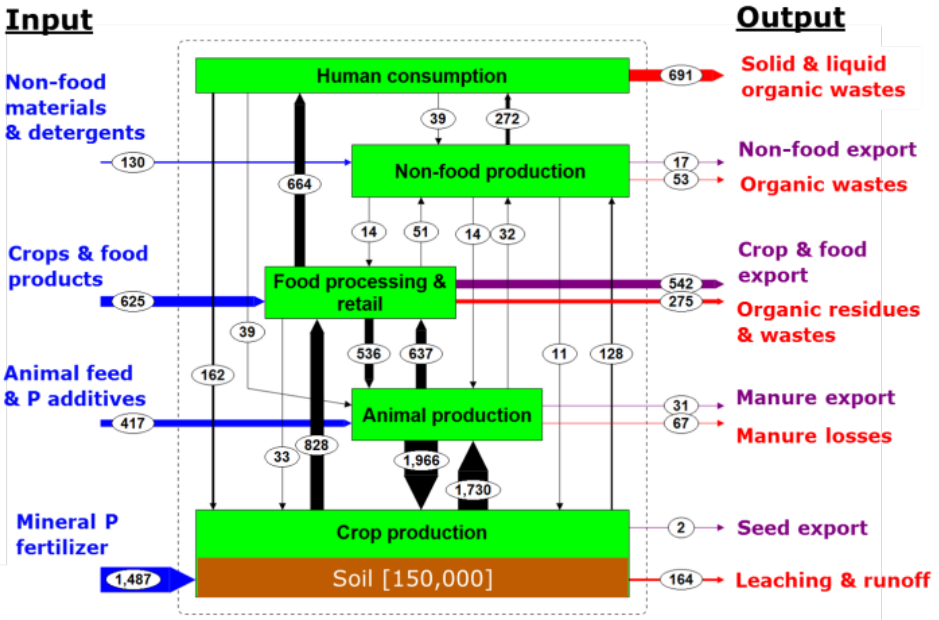

Figure 2: Phosphorus flows in the food production – consumption chain of the European Union (EU-27) in 2005. Inputs are shown on the left-hand side, output and losses on the right-hand side. Flows are indicated by arrows, pools and stocks are indicated by boxes. The size of flows and pools are presented in Gg = Mkg = kton P per year (from van Dijk K, 2013)

The P cycle is characterized by limited recycling, low P use efficiency, accumulation in agricultural soils in some areas and losses to water bodies and landfill. Sustainable P management is urgently needed to ensure agricultural productivity, to secure food production and to protect our environment.

Innovation

Innovations can make Europe less dependent on P imports by: re-aligning P use to more precisely match crop and animal requirements, reducing P losses, reusing P from manures and residues more effectively, recycling P from wastes and redefining the food chain where needed.

A wide range of such innovations has been suggested in different segments of the P cycle, including more P efficient cropping systems, direct use of P-rich by-products as fertilisers, improvement of fertiliser and manure recommendations and application techniques, P-recovery from wastes and wastewater, etc.

Questions

Many on-going research projects in Europe aim at preparing these innovations, **but questions remain as to where and at which points in the food production-processing-consumption-waste recycling chain should recovery and recycling occur and with which technology?**

Possible options and burgeoning innovations are **rarely assessed in an integrated way**. This is limited by a lack of appropriate and harmonized approaches and tools for this, and a tendency of disciplines and sectors to work in isolation.

We argue that future research on P in Europe should increasingly **span multiple disciplines, including social and natural sciences** and featuring multi-disciplinary projects.

Beside efforts to understand P dynamics at micro and meso-scales, there is an increasing need to identify drivers of P flows in the society and model the P cycle at large scales (regional, national, continental and global level).

Framework and indicators

A common conceptual framework and accepted indicators (e.g. P footprint) are needed for a quantitative understanding of the P flows and cycling in the food production-consumption-waste management chain, harmonized calculations of P use efficiency, monitoring of progress, dynamic modelling and scenario analyses.

This integrated approach will **provide the appropriate framework to determine the critical flows, processes and factors** and to assess how individual and combined innovative strategies can improve P recycling and P use efficiency in the society. Moreover, it will enable **interactions with other issues to be assessed such as food safety and C and N cycles**.

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The governance gap surrounding phosphorus

How could phosphorus (P), an essential dietary element, that limits the productivity of ecosystems, and that exists as fossil rock reserves in mainly one country in the world remain a low global governance priority?

That the UNEP Global Partnership on Nutrient Management deals essentially only with nitrogen, that the EU has a Nitrogen Directive but nothing for phosphorus and that the entire UN has no structure in place to monitor and regulate the extraction of phosphate rock all say that a serious gap exists.

Question of concern ?

That phosphorus prices rose 800% in 2008 is common knowledge. Yet, neither P nor fertilisers were mentioned as issues of concern during the ensuing three UN Food Security Summits. In fact the Food Security Summits only discussed expanding the World Food Program. **They did not address the need for fertiliser and self-sufficiency**.

The problem of P governance is complex, exists at multi-level scale and strengthens regional and global disparities. Whereas deprived smallholder farmers in most African countries cannot afford today's chemical fertilisers to improve the quality of their soils, heavy subsidies to the agricultural sector in **the North has ingrained a common perception that P is limitless and hence food should remain cheap**.

When we subsidize agriculture in the EU with 1 billion Euros per week, should this be a surprise?

Governance ?

The extraction of nitrogen from the atmosphere (Haber-Bosch process) has been the most important factor in the provision of fertiliser that has fuelled the first green revolution and makes it possible to feed 6 of the 7 billion people. P extraction from fossil deposits has very quietly kept pace. **But who is managing this finite resource?** Are the geopolitics of dependency on 4-5 countries being adequately addressed?

That the EU's sole source is from one mine in Finland that has about 30 years of commercial life left is apparently a non-issue. Path-dependent ways of managing P around the world leaves little room for improving efficiency and optimizing reuse. As Duncan Brown coined it, the present way we use phosphorus is more like driving a car at top speed down the highway with no fuel indicator on the dashboard, and we will do nothing until we first run out of gas. This calls for a **concerted effort to develop the global and regional governance of this finite resource**.

Action plan

An action plan with several stages is required:

- **global conference** including stocktaking and suggestions for sustainable practices
- **non-partisan monitoring and regulatory program** on extraction of phosphorus rock set up by the UN
- **global convention** erected whereby milestones in sustainable practice are set up including limits to extraction and minimum levels of reuse
- new generation of **best practices** that optimize the quality of waste systems (liquid and solid) be set up in order to promote reuse
- **economic instruments** developed whereby wasteful practices are taxed and reuse promoted.
- **communications** strategies initiated to help make the P question more household and better understood.

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