The James Hutton Institute

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European Commission Consultation on Natural resources – Phosphorus

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The document is generally comprehensive and the facts seem to be accurate. There is a strong emphasis on improving and securing mining and production of phosphate fertilizers and efficiency of waste management. There is little consideration of improving the efficiencies of the agricultural production and the human consumption system. There is little consideration of improving agronomy, soil management and plant genotypes which should have a greater emphasis.

There are also some obvious omissions and misconceptions which are catalogued below

1) There is no consideration of the low N:P ratio of animal manures which means that if they are used to fertilise for N they cause P pollution and if they are used to fertilise for P they cause N deficiency.

2) There is no consideration of Non-Responsive soils in Africa. There are many soils in SSA that are so degraded that even when fertiliser is available no response in crop growth is seen. Theses soils require an Integrated Fertility Management approach to rectify where OM depletion is reversed along with nutrient imbalances and inappropriate pH.

3) There is an omission of the link between P cost and oil price.

4) There is no consideration of the impact of the availability of Sulphur for producing TSP from rock phosphate.

5) The list of plant species that accumulate Cd is not at all exhaustive.

6) There seems a bit of a misconception about what enzyme-based techniques are for improving the P acquisition of plants. Expressing phytase in root exudates (i.e. an enzyme technique) is one option of at least a dozen including root architecture, mycorrhizal symbiosis, root hair production, organic acid exudation, root gravitropism etc. This should be considered in a much more comprehensive manner.

In addition to this critique our responses to the questions laid out in the consultation document are as follows:

Q1: Do you consider that the security of supply issues for the EU in relation to the distribution of phosphate rock is a matter of concern? If so, what should be done to engage with producing countries in order to tackle these issues?

Yes. The issues for supply security relate to international governance so there is a need to target economic and political instability in North Africa. Whilst China and USA may be big producers, the exporting countries relevant to the EU are in North Africa. Development aid would smooth long term relationships for supply security. We agree that we are currently a long way off being able to introduce sufficient recycling measures (in terms of research, practical design and implementation and overcoming socio-economic barriers) to reduce a dominant need for raw product imports. If we predominantly source rock P from North Africa as a sedimentary source there are implications for rock P quality, i.e. Cd contamination which a research agenda needs to address in advance.

Q2: Is the supply and demand picture presented here accurate? What could the EU do to encourage the mitigation of supply risks through i.e. the promotion of sustainable mining or the use of new mining technologies?

Yes. But the story in relation to P reserves of rock phosphate has changed recently. Knowledge of the mining technologies and specific sedimentary basins for reserves are outside our area of expertise. However, we consider that some effort should be made to evaluate the possibility that some, albeit minor and expensive to recover reserves exist on EU land (or coastal waters), and that these could act as a buffer in extreme circumstances. We would also argue that 'sustainable mining' could include 'mining' via eco-technologies to recover diffuse reserves in highly P enriched environmental pools like P-rich soils and sediments. We believe that there are easy gains to be made by making P accumulated in organic and inorganic forms in soils more available.

Q3: Do you consider that the information on the worldwide supply and demand of phosphate rock and fertiliser is sufficiently available, transparent and reliable? If not, what would be the best way to obtain more transparent and reliable information at EU and global level?

No. We question whether the information is reliable at least to wider audiences who cannot appreciate the technological limitations of recovery. The reserve estimations have been increased by a large factor in the last couple of years. There are different organisations USGS and IFDC who give estimates and these may have national, or industry bias to their estimates. Market forces will dictate the size of the 'recoverable resource'. But there is no doubt of the associated benefits for efficient and sustainable P use that will extend the lifespan of reserves and make key associated benefits for environmental pollution, energy and resource efficiency with associated components of fertilizer processing (e.g. sulphur).

Q4: How should we handle the risk of soil contamination linked to phosphorus use in the EU?

There are multiple aspects of soil contamination not only by the Cd from declining grades of available raw reserves of rock phosphate, but also by other contaminants (metals, organics and pathogens) that accompany reuse of recycled materials from waste streams. In the possible actions below we note that Cd (and to a lesser extent U) are associated with sedimentary P reserves but there are likely to be a large number of associated trace elements and this potential contamination presents a considerable research need in future years, e.g.

- Avoid food chain crops for high contaminant risk additions, building instead a risk matrix of contaminant inputs *vs.* grades of crop use (most risk biofuel crops to least risk edible crops). But this avoidance should be balanced by the soil accumulation Cd legacy issues under future land use change.
- Improve the extraction of Cd within the fertilizer production process.
- Improve crop genotypes to avoid Cd accumulation in edible parts.
- Explore soil-Cd interactions where certain soils may be more susceptible to metal release to crops.
- Map trace elements in terms of usable trace nutrients (Cu, Zn etc.) to match fertilizer input to deficiencies. For example in New Zealand phosphate rocks are sources of the trace element molybdenum.
- Explore biological components of the system (possibly mycorhizza) that can provide a Cd barrier to roots.
- Explore potential risks of Cd to soil microbial diversity (building on other long term trial work like the UK sewage sludge network which looked at Zn contamination on rhizobia). At present the issues are around human health. We need to know what 'safe' levels are under a risk based system of different factors to understand the Cd issue properly.

Q5: Which technologies have the greatest overall potential to improve the sustainable use of phosphorus? What are the costs and benefits?

The focus of the consultation document is at the source end of the pipeline of P usage (i.e. security and efficiency in the mining sources) and at the end of the pipe (i.e. solutions of P recovery from waste streams). There are many agronomic system approaches that are only basically covered in the consultation text in comparison. The costs and benefits are a key aspect that needs future inter-disciplinary work. However key target areas would be mining resources, agronomic efficiency of the soil-crop system, cutting wastage, precision agriculture, overcoming socio-economic barriers to development and uptake of technologies needed to realize benefits (particularly from recovered resources).

Q6: What should the EU promote in terms of further research and innovation into the sustainable use of phosphorus?

- Recycling technologies intervening in waste streams, e.g. human wastes and farm/food/abattoir waste without and with energy recovery (e.g. anaerobic digestion). Looking at the use of raw products (e.g. sewage) or processed products (e.g. struvite and sewage ash), also compost use from food/garden waste. There are then many research needs for setting appropriate P loading based on P mineralization/uptake specifics for different soil-crop systems and co-contamination issues. There are major issues of waste separation, distribution and processing nearer sources that are needed to be considered to reduce contamination, dilution of resource and improve recovery potential (for example the current inherited sewage system mixes P rich domestic 'black' water with metal contaminated but large volume waters from industry and street runoff).

- Animal diets (phytate in pig feed), also the composition of foods consumed by humans and novel human dietary supplements (e.g. phytase).

- Efficiency in crop varieties for better internal and external P use efficiency (see Stutter et al 2012; http://pubs.acs.org/doi/full/10.1021/es2044745#). Together these act to use system inputs more efficiently and mine existing legacy soil P, namely:

    - Internal efficiency: maximizing yield efficiency (improvement of P input:crop yield ratio), favouring genotypes of crops able to produce maximum carbohydrate per P uptake.

    - External efficiency: (i) exploring the soil volume more effectively via enhanced root architecture and (ii) utilizing the exploratory volume better via enhanced exudation of enzymes and/or organic acid complexes that solubilize soil bound P.

    - These soil-crop management actions need to be targeted not only to the needs for efficient yield conversion from chemical fertilisers, but also specific needs in relation to recovered P materials (that may be of organically-complexed P or bound to Fe compounds from water treatment residuals).

- Precision agriculture to target placement of fertilizer both spatially and temporally. This includes decision support tools and technology for soil testing/sensing and fertilizer application.

- Complimentary mixed farming/diversification approaches to make farming systems more efficient. This diversification crosses different spatial scales from (i) in-field via mixed cropping to exploit different resources simultaneously or in rotation, or (ii) at larger scales mixed livestock and arable operations to ensure maximum reuse of organic fertilizer targeting onto crops.

- Socio-economic approaches to understand where to intervene with research and innovation resources in terms of P/energy/resource efficiency measures. For example on a chain of P recovery processes where are the key losses occurring and what can be recovered? How do the stocks of recoverable reserves match the agricultural demand (in terms of import needs)? This question involves quantitative life cycle approaches as well as qualitative farmer, consumer-product buyer and householder barriers to uptake research and elements of nations' planning systems.

Q7: Do you consider that the available information on the efficiency of phosphorus use and the use of recycled phosphorus in agriculture is adequate? If not, what further statistical information might be necessary?

No. Whilst fertilizer requirements of crop-soil systems are understood for chemical fertilizers under confounding factors of soil type etc. (under fertiliser recommendation decision support systems such as published in RB209, Defra, UK) this is not the case for all organic wastes and less so for recovered products (e.g. struvite). Research is needed to bring proper guidance as to the P availability indices for such products, both for crop availability and for environmental side-effects such as P leaching. At present assumptions from other organic materials (e.g. manure) are applied to 'newer' considered materials (e.g. composts) in terms of N and P mineralization/bioavailability. Therefore adequate advice and soil testing procedures on which to base this do not exist. Information is required on the interactions of crop × soil × nutrient source to optimise the P efficiency.

Q8: How could the European Innovation Partnership on "agricultural productivity and sustainability" help to take forward the sustainable use of phosphorus?

There is a need for an improved agronomic 'systems' encompassing many of the aspects we have raised earlier, especially under Q6. This requirement needs to be done in partnerships across research - industry (innovation technology providers, farming and product buyers) - regulation – funding/markets. This 'innovation value chain approach' seems embedded in the EU EIP system and in the R&D opportunities under Horizon 2020. Such a chain of activities should be truly inter-disciplinary to encompass the technical science as well as socio-economic aspects that are basically why we are not performing efficiently today. The important thing is to bring into this demonstration sites and knowledge sharing networks under the EIP node and network system.

Q9: What could be done to ensure better management and increased processing of manure in areas of over-supply and to encourage greater use of processed manure outside of these areas?

- We have already stated diversification of production systems under Q6 as a key requirement and diversification of livestock and cropping enterprises would ensure the optimization of spatial-temporal aspects of manure generation and use, without excessive storage and/or transport.

- Promotion of integrated fertility management looking at manure application with other balancing components of crop fertility inputs (e.g. balancing N:P ratios, manure + trace elements + lime).

- Crop-soil management to make more efficient use of complexed P in manures (e.g. crop technologies to increase P acquisition under organic inputs).

- We are not aware of the current technologies for the processing of manure to improve handling (e.g. dewatering, drying) but such techniques would require energy input/ouput cost-benefits to be evaluated.

- Exploring flexibility in regulation such as closed periods for spreading based on appropriate live soil moisture and weather forecast live data and decision support systems.

Q10: What could be done to improve the recovery of phosphorus from food waste and other biodegradable waste?

There are many improvements to be made in driving down the amount of waste produced. These are complex socio-economic issues, but ones to which society is becoming more aware (e.g. supermarkets admitting how much of their products are thrown away, inappropriate sell-by dates and confusing best before dates, high expectations for product appearance and out of season goods). There is a need to intervene in many stages of waste recovery, which together add to substantial gains. In the developed world losses at present between farm to consumer appear to be 50/50 between the farming system losses (crop loss through pests, incomplete conversion of cereals fed to animals) and the consumer losses (wasted food). Key steps would be:

- Improved product labelling and supermarket actions to make consumers aware of food waste.

- Integrated pest and disease control for crops.

- Food waste collection and recovery via composting and anaerobic digestion.

- Better perceptions of recycled nutrient sources for consumers/buyers put off by human-derived waste streams being used as fertilisers for foods, where appropriate. Otherwise use of a risk based system to match certain waste stream products to different crops (high risk/perception to biofuels, low risk/perception to edible crops).

- The caveat to all these approaches is the requirement for new knowledge on the associated environmental risks and interactions (contamination, energy and water pollution life cycle analysis etc.).

Q11: Should some form of recovery of phosphorus from waste water treatment be made mandatory or encouraged? What could be done to make sewage sludge and biodegradable waste more available and acceptable to arable farming?

No, a mandatory approach initially would be wrong and market forces and associated environmental legislation (reducing water pollution, climate-carbon-energy resource efficient society obligations) should be allowed to gradually promote improved parts of the system. An appropriate timescale would allow an appropriate progression of the research and innovation delivery to ensure that the techniques are available and, importantly, the detrimental environmental effects and societal barriers are addressed. However, there should be some changes in nations' planning approaches that reinforce systems whereby the likely contamination and hence degree of processing of wastes is minimized, e.g. via tackling source separation issues and built infrastructure in municipal buildings, domestic buildings and waste distribution infrastructure.

To make such waste stream P products more acceptable requires evidence on risks of contamination (metals, organics and pathogens) and consideration of processing requirements to reduce such contamination. It is also important that the socio-economic strategies are in place so that the farmers/land managers have continued access to markets for products from the land bank used for application of these waste products. Improved understanding of the agronomic use efficiency of the products, tools and advice methods and structure on which to guide applications are necessary. Understanding of the benefits from waste-derived P fertilizers and assurance of management of the risks would reassure farmers in using such products, especially when balanced with understandable arguments as to the future issues with conventional chemical fertilizers (price and declining quality).