CREW CENTRE OF EXPERTISE FOR WATERS

Phosphorus recycling possibilities considering catchment and local agricultural system benefits: a review and regional Scottish case study

Marc Stutter, Ioanna Akoumianaki, Malcolm Coull, Richard Hewitt, Nazli Koseoglu

Executive Summary

Research questions

1. What are the key factors affecting Phosphorus (P) material flows and recycling potential?
2. Is it feasible to develop a P flow analysis for Scottish catchments to explore local P capture and reuse?

Background

It is important to understand national to regional mass balances for key resources being tackled for sustainability, such as P, to consider local spatial aspects affecting resource recycling and reuse. Phosphorus sustainability couples material recycling with the dominant use as agricultural fertilisers, in turn with potential pollution of soils and waters by excess fertiliser usage, then as part of the P 'circular system', with P pollution from wastewaters resulting from human food consumption. This strengthens the need for planning units such as waterbodies and how they overlay with other boundaries, for example road distances. This project was developed to downscale aspects of Scotland's country-scale P mass balance by looking at the background context of, and a worked example of, catchment-regional recycled P sources, usage opportunities and constraints against the context of offsetting the raw imported resource of chemical phosphate fertiliser.

Research undertaken

- A literature review evaluated current knowledge on recycled-P fertilisers, covering production methods, agronomic benefits, environmental risks and policy framework underpinning their use.
- A case study catchment was selected based on (i) need to address river P pollution, (ii) presence of key nodes of P bearing resources that were current being, or could be, recycled, (iii) had an appropriate agricultural land bank for potential offsetting of chemical fertiliser.
- A framework was developed to analyse scenarios of P capture and reuse and applied for the catchment case study giving consideration of opportunities, potential conflicts and constraints such as costs (e.g. transport, capture, and processing costs).
- Recommendations are given for future projects on catchment-regional P budgets including transferable approaches, novel learning, gaps in research and ability to model processes.

Key Findings

1. The evaluation of the characteristics and properties of recycled P fertilisers showed that:

- There are many alternatives to phosphate rock (PR) sourced fertilisers. Recycled-P approaches all have strengths as well as weaknesses such as soil pollution.
- The greatest sustainability, agronomic and environmental benefits can be achieved by rather simple approaches with high P recovery potential, such as manures, composts and biosolids. Material use as fertiliser replacement balances suitability in P supply against risks associated with the potential of soil contamination, losses to water, crop/food contamination and GhG emissions.

2. Scenario modelling results showed that:

- Selection of a failing waterbody for P concentrations gave a central Scotland case study where an established 40,000 kgP/year of commercial anaerobic digestate and 24,000 kgP/year in farm-produced manures competed with the ability to incentivise P recycling (14,000 and 4000 kgP/year, from biosolids and final effluent) from wastewater. The mass and form of available P-bearing resources was challenging to assemble.
- Potential agricultural usage was considered according to crop fertiliser requirements and regulatory constraints (determined by material compositions and processing level). Fertiliser P dosage levels were attained before soil metal pollution thresholds were exceeded.
- Fertiliser scenarios comprised: (i) chemical fertiliser (reference), (ii) accredited digestate use, (iii) wastewater sludge use, and (iv) struvite use, for (a) the waterbody only area (592 fields) and (b) by progressively using fields in successive 10 km road transport bands (to a subsidised transport distance of 60 km; 110K fields). Deficits and excesses of manures had a strong bearing on recycling opportunities in this mixed farming area. There was minimal potential for recycling in the waterbody area and the materials were usable within 20 km road distance (12K fields). A hypothetical processing scenario of struvite production from wastewater gave a 1600 kgP/year contribution, reducing effluent P concentrations and being cost effective as a fertiliser.
- A simple diffuse pollution risk framework was applied based on relative risks of riparian versus non-riparian fields and relative erosion risk of landscape-crop combinations. Few fields (~20%) were adjacent to watercourses and in high-risk classes for erosion (~10%).

Recommendations and policy implementation

- The large workload of identifying the available P resources showed a lack of coordination of inventories of waste-materials available to manage resources such as P sustainably.
- Despite a motivation to explore P recycling against water pollution benefits (wastewater P recovery) an excess of P bearing materials for the waterbody led to exploring wider farmed areas. Hence, effective P planning requires joining up planning scales and boundaries, not just those of catchments (e.g. road networks, fields-farms, local authorities and waterbodies).
- Urbanised areas have abundant P beyond local land bank requirements, with established industries (e.g. anaerobic digestion) subsidising P distribution to farmers in competition with incentivising wastewater P recovery. Hence, cross-sectoral coordination is required.
- Effective planning must ensure (i) recycled P-bearing materials offset chemical fertiliser at agronomic best practice constraints and remove excessive disposal onto 'sacrificial' and polluting localised areas and (ii) that farm manures are used effectively in priority.
- Advanced processing of P-bearing materials is scarcely practised in Scotland but some of these (e.g. struvite recovery from wastewater) have potential to maximise the ability to use recovered P over increased transport distances and over wider crop types (struvite is P dense for transport and sufficiently pure to remove crop restraints).
- Research is needed to develop models to understand the P diffuse pollution implications of changing chemical P fertiliser to partial or complete replacement with alternative materials. Simplistic assumptions (e.g. transferring manure-based mineralisation rates) are not robust to the growing diversity of potential soil amendments. New approaches can utilise existing approaches for model application (e.g. national soil-landscape risk maps, diffuse pollution approaches developed for waste licencing), but need new data on P solubility and leaching.