GWCT SUMMARY

Optimising phosphorus use in the Welland river basin

BACKGROUND

This is a summary of research on elemental phosphorus (P) inputs and outputs in the Welland catchment, and links to river water quality and the challenges of maintaining future food security in the region. The work was carried out as part of the RePhoKUs* project which investigated how P use in the UK food system could become more efficient, sustainable and resilient at catchment, regional and national scales.

Although an essential nutrient for crop and animal production, rock phosphate is a finite resource which should not be wasted, and leakage of P from the food system into water is causing widespread damage to the quality and biodiversity of inland and coastal waters in the UK and globally.

Based on Water Framework Directive criteria, the Upper Welland and its tributaries are currently classified as "Moderate status" for phosphate, and this is one of the principle causes of the Upper Welland not reaching the required "Good Overall Status". Three tributaries are at Good status for phosphate, ten are at Moderate status, four are at Poor status, and one is Bad. The Environment Agency's source apportionment modelling of the whole Upper Welland catchment indicates an annual TP load of 0.66 kg/ha with 74% in orthophosphate form due to the dominant contribution of sewage effluent discharge (62%) compared to a diffuse contribution from mainly agricultural sources of 38%.

NOTE ON TERMINOLOGY

RePhoKUs research uses elemental P (not phosphate P) for all food system stores and flows, and recognises three forms of river P concentrations: soluble reactive P (SRP), total dissolved P (TDP) and total P (TP). Regulatory agencies set river P concentrations as orthophosphate P and refer to phosphate-P. Elemental P is synonymous with TP, and SRP is considered synonymous with orthophosphate-P.

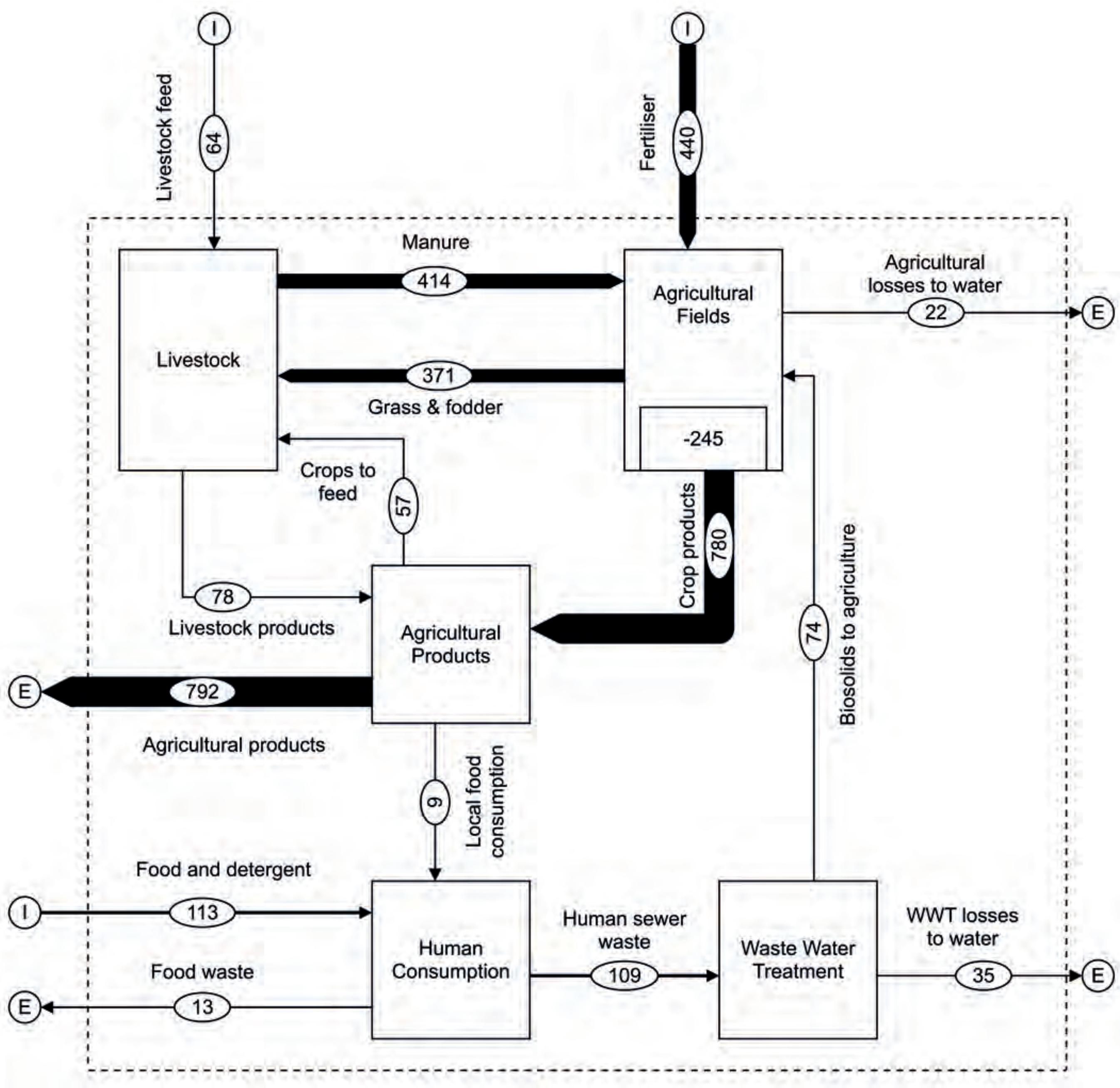
PHOSPHORUS FLOW THROUGH THE FOOD SYSTEM

A Substance Flow Analysis (SFA) was undertaken to quantify the stocks and flows of elemental P within the Welland catchment. The SFA maps all significant materials associated with different sectors of the food system and that are entering, leaving or circulating within the catchment, and is a useful mass balance model for identifying significant inefficiencies, losses and accumulations of P in the landscape. The model accounted for fertiliser use, crop yields and agricultural P offtake, livestock excretion, and human P use.

The model shows that the largest P import into the catchment is in fertiliser (~440 tonnes P) and manure P inputs to the soil are lower, at ~414 tonnes (**FIGURE 1**). Total offtake in crops and grass amounts to ~1150 tonnes P, meaning that the agricultural soil in the Welland catchment may be in P drawdown with an annual deficit of 245 tonnes P, equivalent to around -4 kg/ha. This represents a P use efficiency (defined as the ratio between P offtake and input) of 135%. For comparison, the UK national average P surplus was reported as 8 kg/ha with a P use efficiency of 66% in 2018. Losses to water in the Welland were estimated as 35 t P/yr from wastewater, and 22 t/yr from agriculture.

FIGURE 1

A P Substance Flow Analysis (SFA) for the Welland catchment. Values given are tonnes of elemental phosphorus per year.



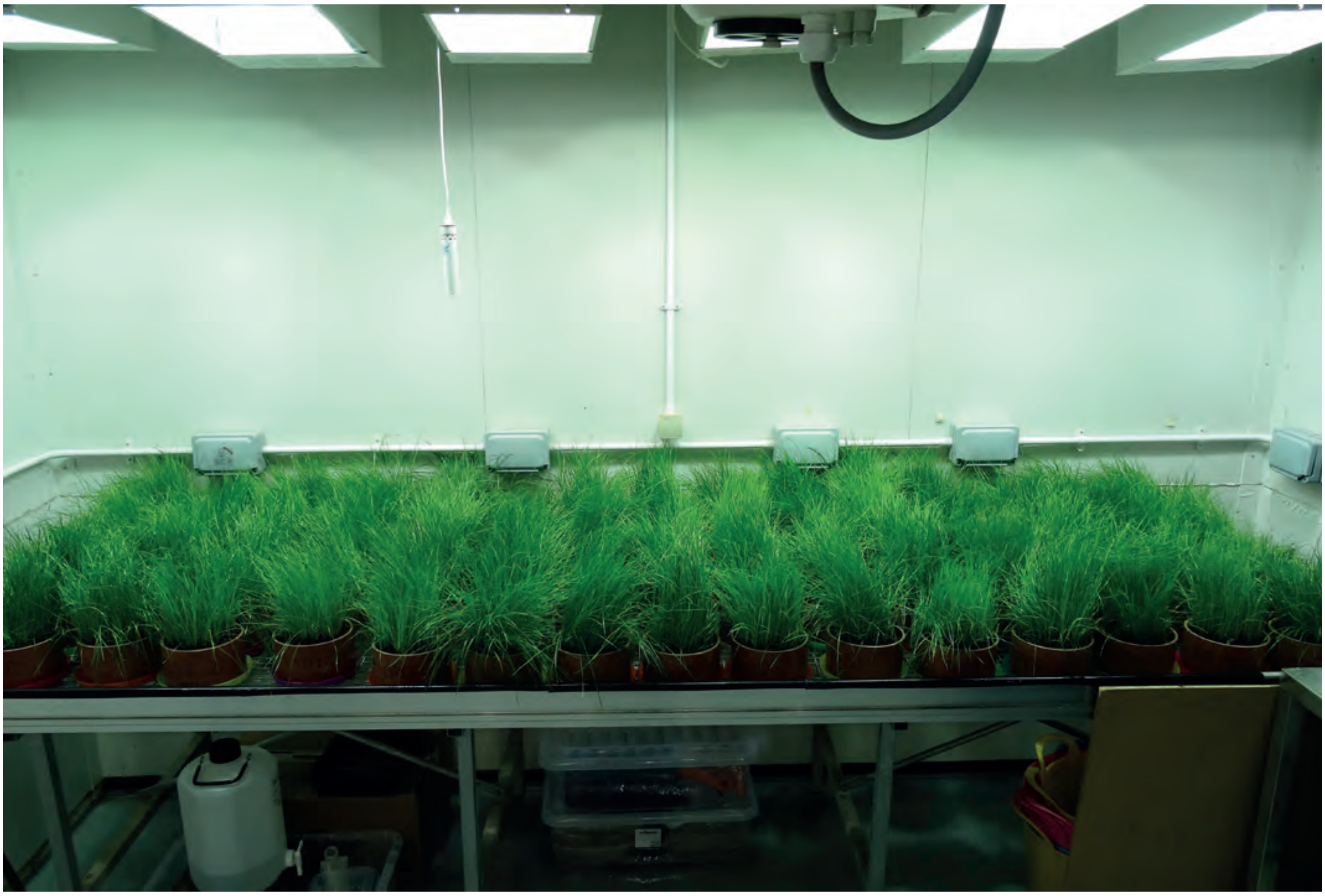


FIGURE 2
Legacy P trial conducted at Lancaster Environment Centre.

PHOSPHORUS LOCKED IN SOILS

Historically, there has been a national annual surplus application of P above actual crop offtake. This means that large amounts of historic P have accumulated in agricultural soils. There are two important questions about this legacy P. Firstly could it be agronomically important - could crops use this reservoir of P instead of applying fertilisers and manure? Secondly, does this reservoir of P pose a threat to water quality?

A trial was set up to try and answer these questions. Soils were collected from the Wye catchment, and from the Upper Bann in Northern Ireland, as well as from the Welland, and high yielding rye grass was grown continuously in pots under controlled environment conditions for two years (**FIGURE 2**). The pots received all required nutrients except P that was entirely excluded, meaning the grass only utilised P available from the soil. The grass was harvested monthly and biomass and P content monitored as well as periodic soil Olsen P measurements. Useful legacy P was assessed to be exhausted when either the soil reached Olsen P index 1 or the grass was deemed to be P deficient.

Based on this laboratory pot experiment, there appeared to be less legacy P in the Welland soils, potentially supplying between 0- and 5-years Legacy P across the fields on the farm. The period may be longer in some stable, biologically active soils. However, the Welland soils may have less legacy P because they generally had lower starting Olsen P status, and may have come from soils that are already experiencing P drawdown, as indicated by the SFA analysis.

We also monitored the concentration of porewater P during the pot P drawdown trial to help understand potential pollution risk from P loaded soils. The Wye soils were the only ones that showed increased P solubility at higher Olsen P status. The Welland soils showed no difference, suggesting that they have a high P buffering capacity (they can hold onto the P) which may also explain why they yielded less legacy P.

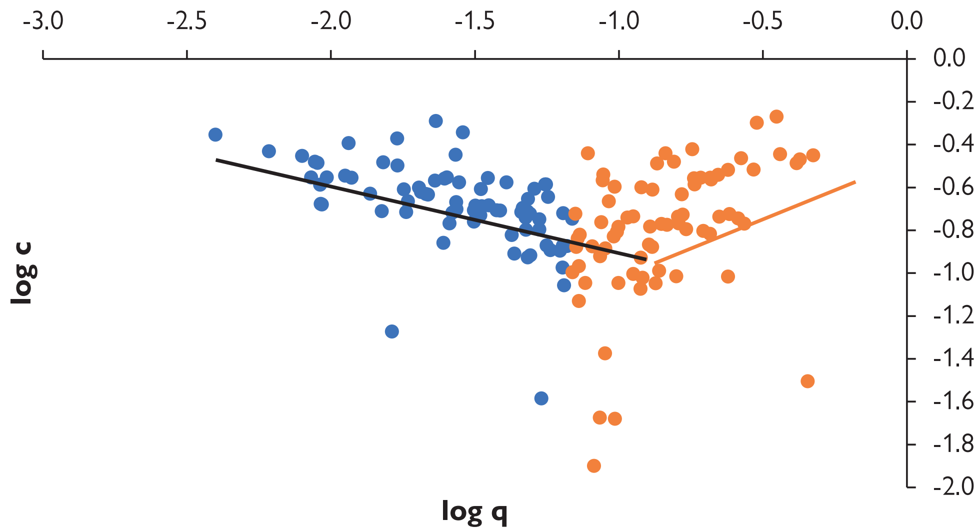


FIGURE 3

Relationship between flow (log q) and Total Phosphorus concentration (log c) in the upper Eye Brook catchment. Based on Freshwater Habitats Trust/Game & Wildlife Conservation Trust data from the Water Friendly Farming project in the upper Welland.

PHOSPHORUS IN WATER

The contributions of phosphorus from domestic and agricultural sources vary with flow. Our work showed that this relationship is not always consistent across catchments. However, a common occurrence is for domestic sources such as wastewater treatment plants to dominate at low flow, with concentrations decreasing with flow as these point sources are diluted. Phosphorus concentration increases at high flows as runoff from land becomes the dominant source of phosphorus (**FIGURE 3**).

It is important to address both agricultural and domestic sources of phosphorus to reduce impacts on water and to improve nutrient use efficiency within the food production and consumption system.

* The **RePhoKUs** project was a collaboration between Lancaster University; Agri-Food and Biosciences Institute, Belfast; University of Leeds; University of Technology, Sydney; and the UK Centre for Ecology and Hydrology and was funded by the Global Food Security's 'Resilience of the UK Food System Programme' with the UK's Biotechnology and Biological Science Research Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC) and the Scottish Government. It was hosted in the Welland by the Game & Wildlife Conservation Trust's Allerton Project as part of its role in the Welland Valley Partnership. More information at: **http://wp.lancs.ac.uk/rephokus/**.