An inventory of UK soil phosphorus and the implications for sustainable food production

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Due to inefficient use and dwindling reserves, inorganic phosphorus fertilizers will become decreasingly economically-viable. Without action this situation will lead to declining agricultural productivity. UK arable farmland occupies a diminishing, highly favorable ‘agricultural window of latitude’. This window is being squeezed by changing climate, and coupled with rising population, more food will need to be produced from a decreasing area. This likely intensification for agricultural areas such as the UK will need to be carefully balanced with negative ‘externalities’ such as pollution from nutrient runoff. Our research aims to investigate the utilization and sustainable use of the soil phosphorus resources and to minimize P losses that contribute to agronomic inefficiency and degradation of water quality. To date we have undertaken an inventory of the forms of P in a range of UK soils (n=32) including arable, extensive and intensive pasture and semi-natural. This has included conventional properties and P release indices, but most importantly quantitative ^{31}P NMR spectroscopy of forms of soil P. This has provided evidence of an appreciable ‘bank of residual P’ in UK soils that is currently unavailable to crops. Our limited knowledge of the extent to which we can better understand and utilize residual phosphorus pools to sustain crop production is surprising since (i) phosphorus limitation / co-limitation is the fundamental cap on world food production, and (ii) organically-complexed P can be a substantial soil P form (30-65% typically, but up to >90%). Our future goals are to explore a range of methods to make wider parts of this soil ‘P bank’ better available to crops, but less likely to be lost from the system. The possibilities for this range from ‘bio-technological’ solutions to simple ‘on farm’ management actions using readily-available materials: (i) plant physiology and manipulation – comparing crop types and examples of known efficient P ‘mining’ plants, (ii) manipulations of soil physico-chemical conditions - the effects of wetting and drying on the release of P from organic forms, and (iii) use of soil amendments. We also explore a concept of an ‘ideal soil P state’ of low potential for diffuse pollution losses to waters and highly available P for crop growth. Our results suggest that given an extreme hypothetical case of cessation of inorganic P fertilizer inputs the ‘P bank’ in UK arable and intensive grassland soils could only sustain productivity (current P uptake rates) for <50 years. This also assumes that we could overcome the technological barriers to making this P available. Hence, in a world where terms such as ‘peak P’ are becoming used, our message is for a combination of approaches: to work towards increasing the proportion of residual and added P that remains available for crop uptake, but also importantly to reduce system inefficiencies so that P losses are minimized using sustainable practices, nutrient trapping and recycling methods.