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Assessing phosphate rock depletion and phosphorus recycling options

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Abstract
We analyse global elemental phosphorus flows in 2009 for 1) mining to products, 2) animal and human manure flows, 3) crop harvests and animal production, 4) food production, 5) soil erosion, 6) and crop uptake. Informed by the flow assessment the potential and cost of phosphorus usage reduction and recycling measures are quantified, and fed into a constructed phosphorus supply-demand model with reserve assessment to assess the impact of these measures on phosphate rock resource availability. According to our results in 2009 globally 21.4 Mt elemental phosphorus from rock phosphate was consumed in products of which 17.6 Mt used as fertilizers, fully able to cover erosion losses and outputs in agriculture in aggregate, but insufficient from the perspective of bio-available phosphorus in soils. We find substantial scope for phosphorus use reduction, at potentially 6.9 Mt phosphorus, or 32% of 2009 phosphate rock supply. Another 6.1 Mt, or 28% can technologically be recycled from waterways and wastewater, but at a cost substantially above any foreseeable phosphate rock fertilizer price. The model results suggests phosphate rock reserves are sufficient to meet demand into the 22nd century, and can be extended well into the 23rd century with assessed use reduction and recycling measures.