Global phosphorus fluxes and the threat to food security

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Anthropogenic activities have greatly accelerated the cycling and fluxes of phosphorus (P) at global and regional scales in recent decades causing eutrophication of terrestrial and aquatic ecosystems and associated loss of biodiversity and increased human health risk. Widespread use of highly-soluble inorganic P in fertilizers and feeds, specialization and regionalization of farming systems, deforestation and increased urbanisation are key activities that have promoted greater losses of P in dissolved and particulate forms from land to rivers and the oceans. Current estimates suggest that fluvial transport of dissolved (ca. 5 Tg yr^{-1}) and particulate P (ca. 20 Tg yr^{-1}) to the oceans (i.e. a permanent sink over the human timescale) are at least double those in the pre-industrial era (Filippelli, 2008; Smit et al., 2009). Large (temporary) storage of P also occurs in soils (due to fixation, 45,000 Tg) and in the oceans (due to N limitation, 90, 000 Tg) because of inefficiencies in P use. Greater consumption of manufactured fertilizers and urbanisation in the future will further increase P storages and fluxes in line with world population growth, regional economic growth, higher yielding crops and more widespread production of bioenergy crops. Although clearly uncertain, P fluxes from agricultural land at regional scales can also be expected to increase under climate change due to the effect of higher temperatures on P mineralization rates and the effects of greater storm intensities on soil erosion rates and/or hydrological connectivity to watercourses. More severe eutrophication can be expected due to reduced river flows and increased residence time during summer.Phosphorus plays a central role in the functioning of biological systems and the manufacture of inorganic fertilizers has allowed rapid expansion of food production during the 20th century. However, Smit et al. (2009) calculate that current fertilizer consumption (18 Tg yr^{-1}) is over 5 times greater than the intake of P by the global population (i.e. <20% efficiency), yet is still lower than the estimated global losses of P to the oceans. This inefficiency and permanent loss of P to the oceans at such accelerated rates poses a real threat to the future food security because the reserves of rock phosphate (RP) used to manufacture P in fertilizers and feeds are becoming rapidly depleted. Recent estimates suggest that exploitable reserves of RP may last for only about 100 years (75-125 years depending on forecasts) with peak consumption occurring within the next few decades, (Cordell et al., 2009; Smit et al., 2009). Reserves are also concentrated in few and politically unstable regions suggesting supply routes may become more fragile raising concerns over pricing and availability. As there is no alternative source of P, protecting our future food security requires a radical re-think in how P is managed from field to global scales incorporating key concepts of valuing existing P stores (e.g. soils), and closing the P cycle by minimizing wastage and recovering nutrients for recycling. More effective utilization of P already in circulation will reduce society's dependence on inorganic fertilizers and the environmental footprint of their manufacture. Some options are discussed.

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