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Sustainable Global Phosphorous Inputs in View of Crop Yields and Water Quality

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Abstract

Sustainable management of phosphorus (P) requires inputs at such a level that the (soil) P supply does not limit the required food production for the growing global population (just boundaries) while keeping P losses by erosion and runoff within limits to avoid adverse impacts on water quality (safe boundaries). We developed and applied a method to assess the medium-term (period 2015-2050) and long-term (period after 2050) required amount of P fertilizer in view of a target crop P uptake for food production, in combination with acceptable P losses. The 'medium-term required' amount is defined as the amount that brings all cropland soils to a target soil P status that does not limit crop growth (build-up or mine) in addition to the target crop P uptake in view of global food P demand and acceptable P losses in view of water quality. The 'long-term required' amount is set equal to the target crop P uptake and acceptable P loss only, thereby maintaining the adequate soil P level that has been built-up or mined during the medium term period. The target crop P uptake was calculated as the P uptake at a target crop yield, defined as 80% of the crop yield potential, corrected for the global food P consumption demand. This demand was derived by multiplying the global population with an advised annual P intake, and dividing it by the share of crop uptake that is consumed by humans. The current (year 2015) global P budget includes a P input of 39.4 Tg P yr^{-1} of which 27.2 Tg P yr^{-1} is taken up, while the P surplus of 12.2 Tg P yr^{-1} is divided over a soil P accumulation rate of 10.9 Tg P $yr^{-1}$and a runoff rate of 1.3 Tg P yr^{-1}. Sustainable global P inputs imply that the world population can be fed while P losses to surface water stay below a critical limit. The required P uptake to feed a global population of 10 billon people is 32.5 Tg P yr^{-1}. In a situation in which the soil has attained a target P status, which does not limit the P uptake, the required P surplus to maintain that P status is equal to an estimated runoff of 1.1 Tg P yr^{-1}, thus implying a sustainable P input of 33.6 Tg P yr^{-1}. To avoid P losses that exceed water quality criteria, the current P erosion rate, however, needs to be reduced from a current 4.0 Tg P yr^{-1} to 1.6 Tg P yr^{-1} by erosion control. In addition, the gap between the current soil P status (base year 2015) and the target soil P status at global scale can be filled to ensure a crop yield increase while accounting for the P sorption capacity. The total global gap is estimated at 797 Tg P, implying a global annual P requirement of 22.7 Tg P yr^{-1} between 2015 and 2050 reach the target soil P status for all soils. However, the increase in soil P fertility can best be attained in soils with limited P sorption capacity to limit the soil P investment.

Keywords

Phosphorus Management, Sustainable Agriculture, Soil Phosphorus Fertility, Phosphorus Fertilization, Crop Nutrient Uptake, Water Quality Protection, Global Food Security, Nutrient Cycling