**Manuscript-style description of module**

**Phosphorus Uptake Model Description**

The “Kelley\_module” attempts to model phosphorus (P) uptake. Using estimates of annual plant P uptake from soil, considering plant demand, soil P pools, and soil pH and a “general P” modifier (climate). The model is divided into three submodules: Plant P demand, P availability, and P uptake.

**Submodule: Plant phosphorus demand**

The submodule calculates plant P demand based on the average net primary productivity (NPP) of leaves, stems, and roots, and considers the carbon phosphorus (C:P) stoichiometric ratios. The P demand (g P m⁻² y⁻¹) is for each organ is calculated by (**Equation 1**). Total P demand is summed across all organs (Mollier et al., 2008; Reichert et al., 2023; Wang et al., 2010).

|  |  |
| --- | --- |
| Pdemand, organ = NPPorgan / C:P ratioorgan | (**E1**) |

**Submodule: Soil phosphorus availability.**

Soil P availability is modeled by summing three P pools: soluble inorganic P (Pi), soluble organic P (Po), and insoluble Pi. Total P is adjusted by a pH modifier (ph\_mod) which reduces availability by 50% when pH falls outside the optimal P availability pH range of 4–6 (Taiz et al., 2015).

The climate modifier that modifies annual P availability is applied as fixed fraction. to the pH-modified P pool. To consider root access, the availability is further scaled by a root length modifier, determined by the ratio of average root length to a max exploration depth, capped at 1 (Reichert et al., 2023).

Conversion to carbon equivalents. Both P demand and P supply are converted to carbon-equivalent units (g C m⁻² y⁻¹) using the mean C:P ratio across organs.

**Submodule: Phosphorus uptake.**

Plant P uptake is set as the minimum of P demand and P availability in carbon-equivalent units (**Equation 2**).

|  |  |
| --- | --- |
| Puptake = min(Pdemand, C equivalent., Ppool, Cequivalent) | (**E2**) |

**Model outputs.**

The model returns a summary table including P demand by organ, total demand, soil pH effects, P pool sizes, P uptake (in both carbon and phosphorus units), and the remaining P pool.

**Manuscript-style description of module**

**References**

Mollier, A., De Willigen, P., Heinen, M., Morel, C., Schneider, A., & Pellerin, S. (2008). A two-dimensional simulation model of phosphorus uptake including crop growth and P-response. *Ecological Modelling*, *210*(4), 453–464. https://doi.org/10.1016/j.ecolmodel.2007.08.008

Reichert, T., Rammig, A., Papastefanou, P., Lugli, L. F., Darela Filho, J. P., Gregor, K., Fuchslueger, L., Quesada, C. A., & Fleischer, K. (2023). Modeling the carbon costs of plant phosphorus acquisition in Amazonian forests. *Ecological Modelling*, *485*. https://doi.org/10.1016/j.ecolmodel.2023.110491

Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. S. (2015). Chapter 5: Mineral Nutrition. In S. Smith & A. Bloom (Eds.), *Plant Physiology and Development* (6th ed., pp. 119–142). Sinauer Associates, Incorporated, Publishers. https://books.google.com/books?id=02TBoQEACAAJ

Wang, Y. P., Law, R. M., & Pak, B. (2010). A global model of carbon, nitrogen and phosphorus cycles for the terrestrial biosphere. *Biogeosciences*, *7*(7), 2261–2282. https://doi.org/10.5194/bg-7-2261-2010