Ecosystem Modeling Spring 2025 Monika Kelley
May 9, 2025

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).

$$P_{demand,\ organ} = NPP_{organ} / C{:}P\ ratio_{organ} \qquad (\mathbf{E1})$$

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**).

$$P_{uptake} = \min(P_{demand,\ C\ equivalent.},\ P_{pool,\ Cequivalent}) \qquad \textbf{(E2)}$$

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.

Description of module sensitivity and areas for improvement

Model sensitivity

The model sensitivity was tested on pH and average root length. As root length increases P uptake increases. When pH is within the optimum range of 4-6 P uptake increases.

Areas for improvement

Adding modifiers of P availability based on the P pool types (i.e. less available in the insoluble Pi pool). The model could also use more realistic and diverse climate modulators such as precipitation and temperature instead of a general "available P percentage".

References

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