Introduction of phosphorus dynamics and global-scale supporting datasets for CLM

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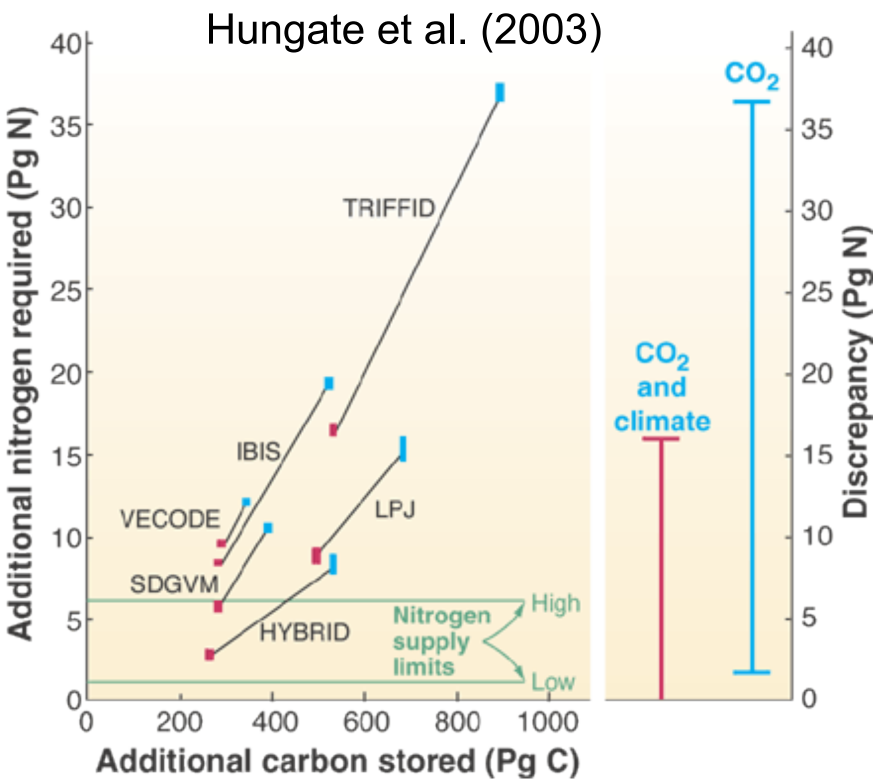
The introduction of C-N interactions has a direct effect on the estimate of carbon cycle-climate feedbacks



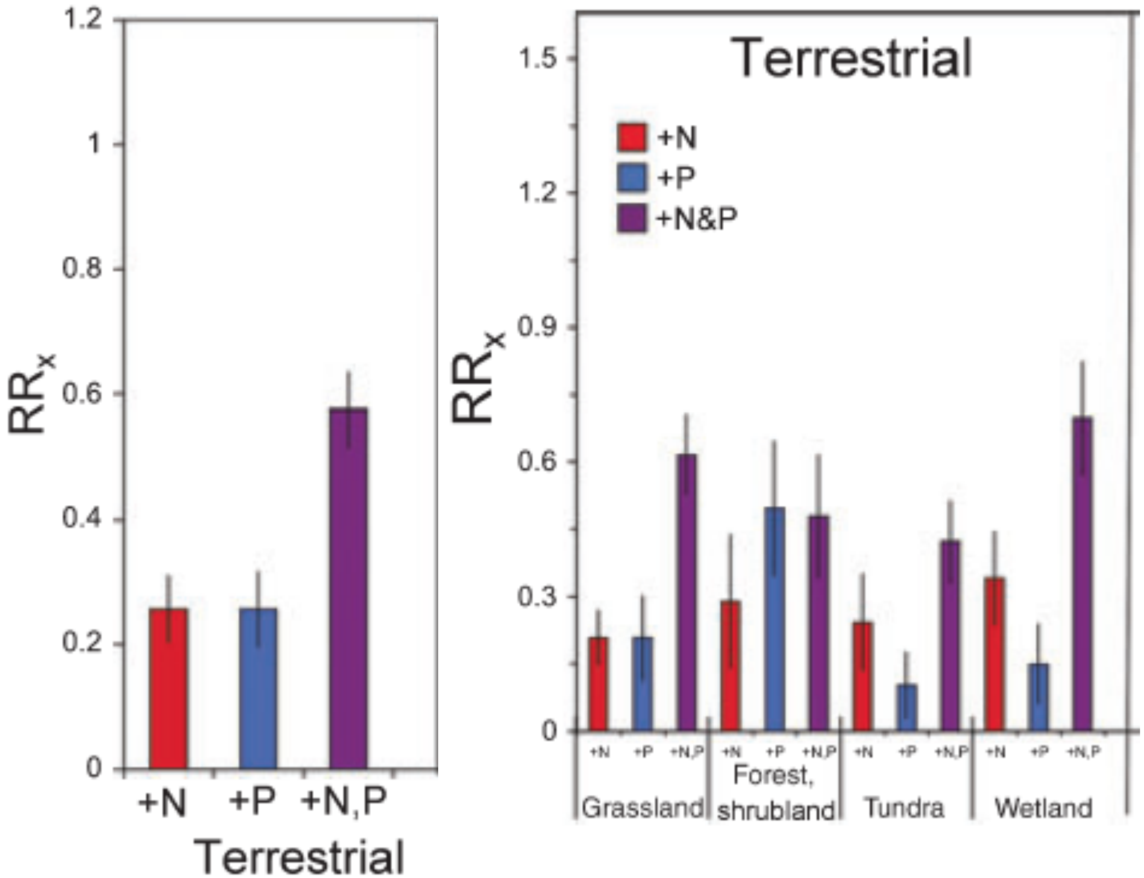
Sokolov et al., 2008
Xu-Ri and Prentice, 2008
Churkina et al., 2009
Thornton et al., 2007,2009
Houlton, 2009
Yang et al., 2009
Jain et al., 2009
Gerber et al., 2010
Zaehle et al. 2010

Disagreement among models with N dynamics comes principally in the tropics

- Little N limitation (Jain et al., 2009; Zaehle et al., 2010)
- Strong N limitation (Sokolov et al,, 2008; Thornton et al., 2009)
  - A proxy for combined nitrogen-phosphorus dynamics (Thornton et al., 2009)
- Inclusion of P dynamics in global biogeochemical-climate models is essential to reducing the uncertainty in C-climate feedbacks

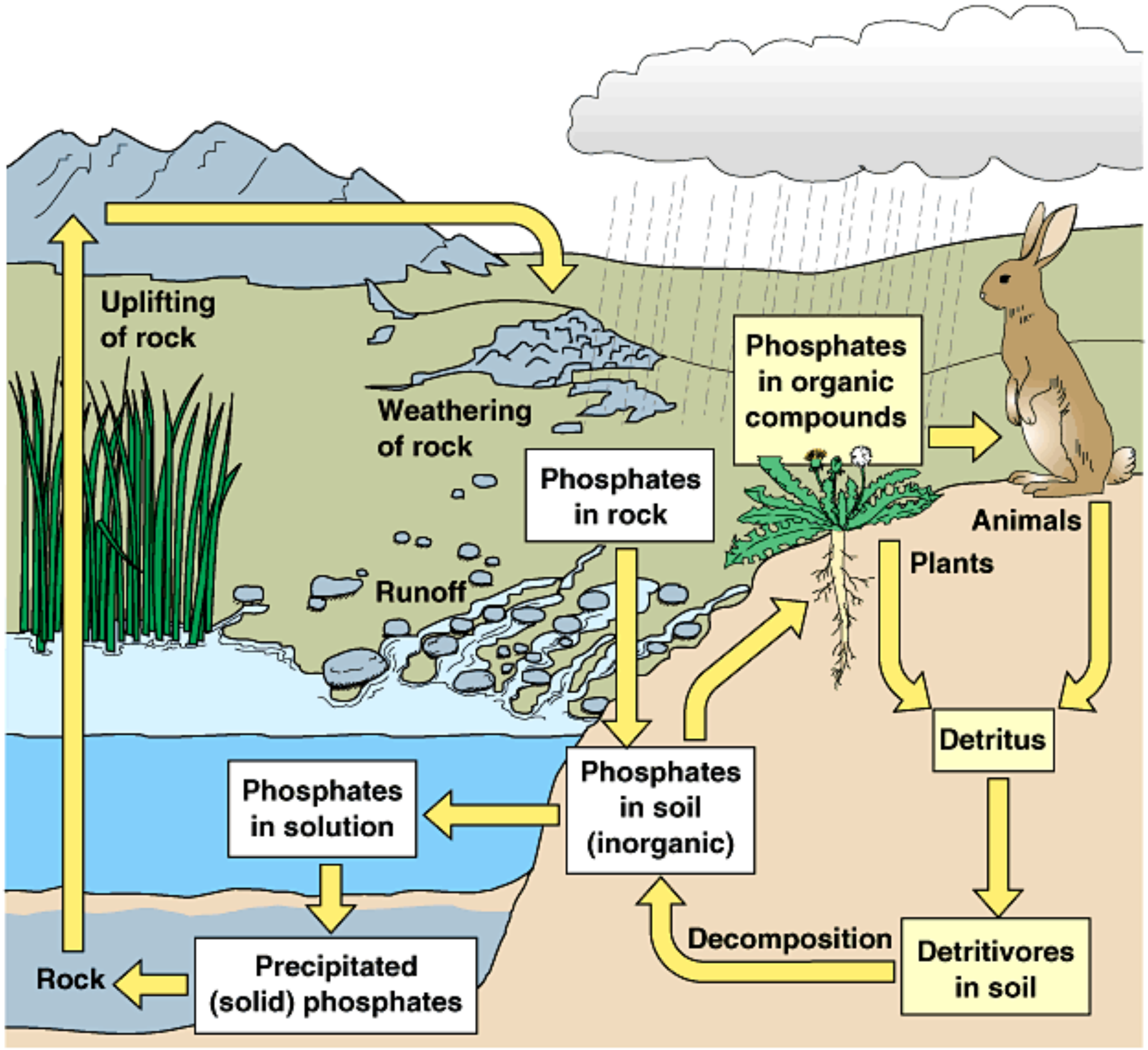
Widespread P limitation in terrestrial ecosystems, especially in lowland tropical forests

Elser et al., 2007

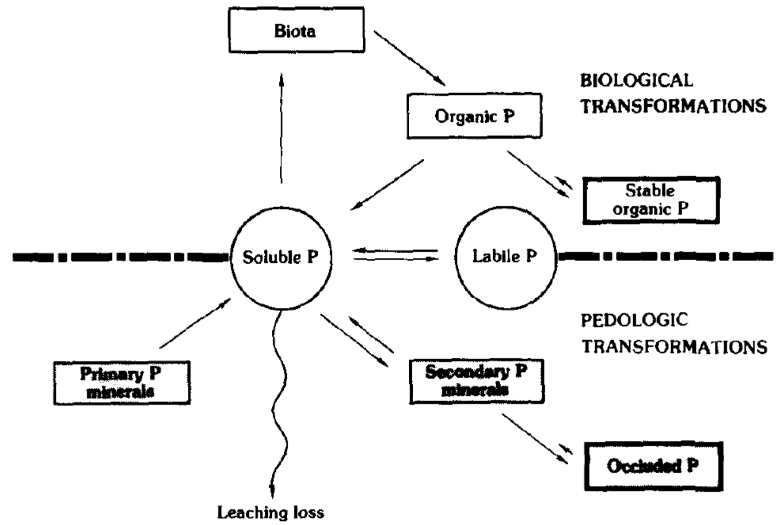


Elser et al., 2007

Global phosphorus cycle



Challenges for P modeling



From Smeck et al. (1985)

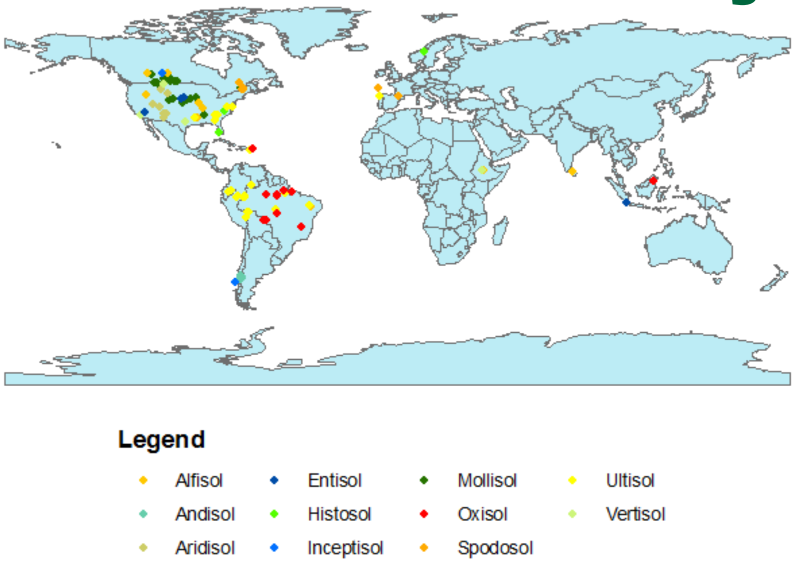
- Various forms of P in soils,
  - whose availability to plants varies greatly,
  - proportion of forms change with soil development
- Limited amounts of soil P measurements
- P cycle operates over geological time scales, it's not useful to incorporate all P processes in complex global C-N-P models running on fine time scales

I. Development of the global Hedley P database

Hedley P database

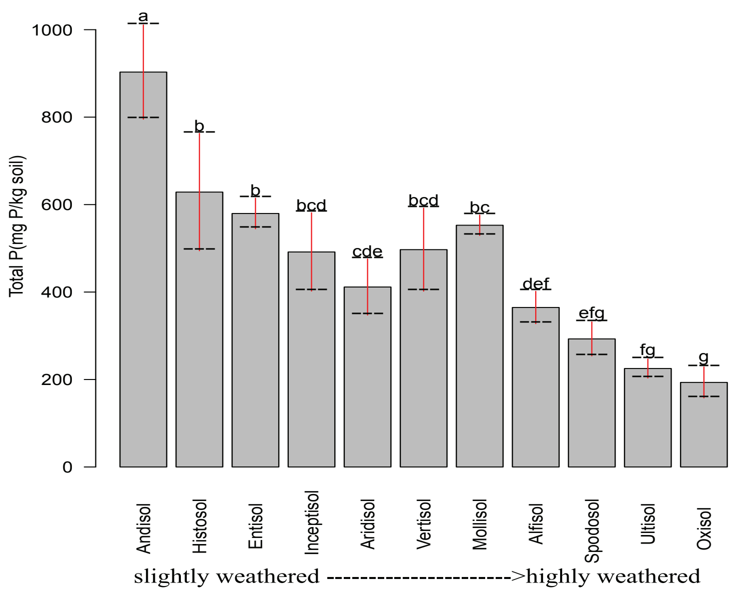
- Hedley sequential fractionation method- a useful tool to examine different forms of P in soils (Labile Pi, secondary mineral Pi, apatite P, occluded P, organic P)
- 178 soil measurements from literature
- Categorized by USDA soil order, useful for understanding of phosphorus transformations as a function of pedogenesis
- Useful for investigating C:N:P stoichimetry in soil organic matter by providing organic C,N,P measurements

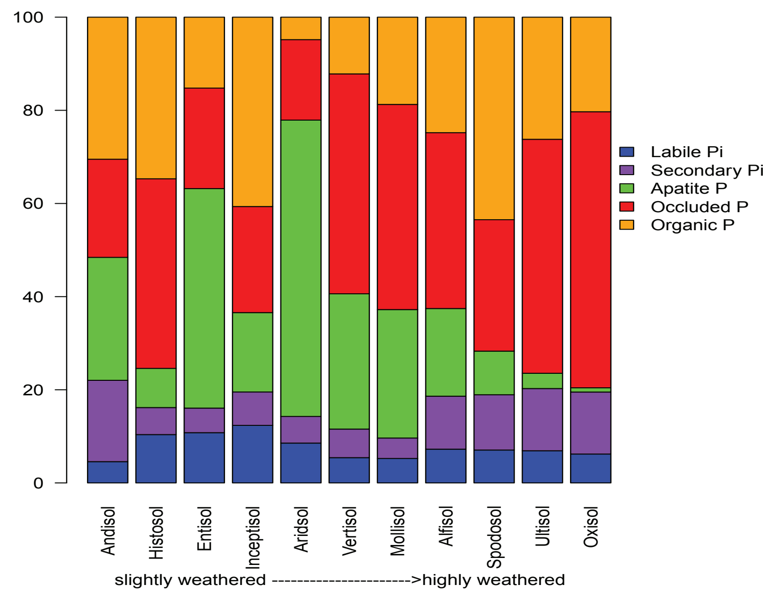
Hedley P database



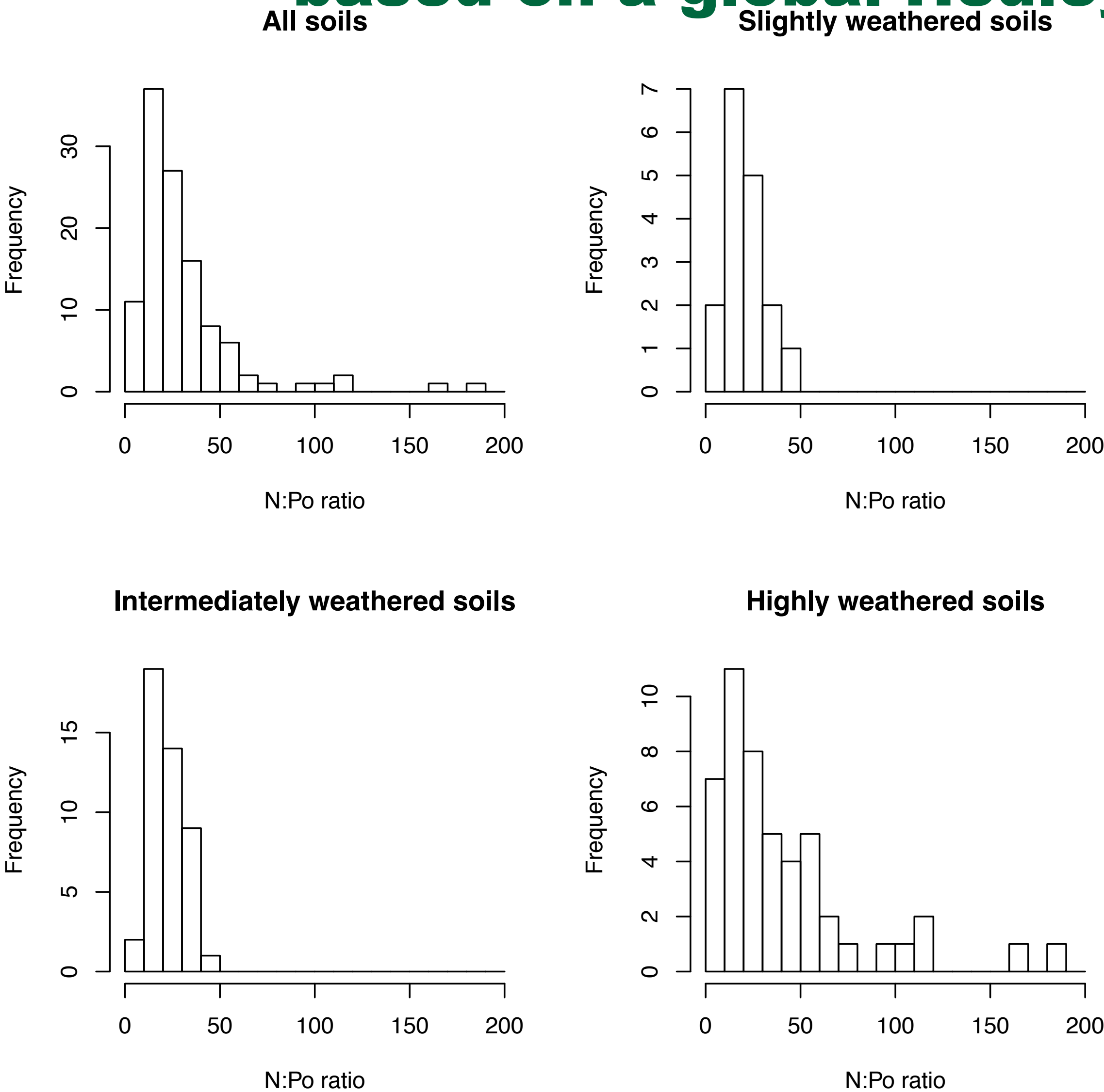
- **Supports the Walker and Syers(1976)' conceptual model for P transformation during pedogenesis:**
  - ➢The decrease of total P
  - ➢The continual increase and eventual dominance of occluded P fraction
  - ➢The first increase and then decrease of organic P fraction

- **But we found the persistence non-occluded P fraction (Labile Pi plus secondary Pi) – dust deposition and dissolution of occluded P?**





C:N:P stoichoimetry in soil organic matter
- based on a global Hedley P database



- **Carbon (C) and nitrogen (N) in soil organic matter are closely linked in all soils**

- **The decoupling of P from C and N in highly weathered soils**
    - Larger variation of N:Po
    - Higher mean values of N:Po

- **Biological and biochemical mineralization of organic P**

(Yang and Post, 2011)

II. Development of soil P maps for the initialization of the global scale biogeochemical models

A data based approach

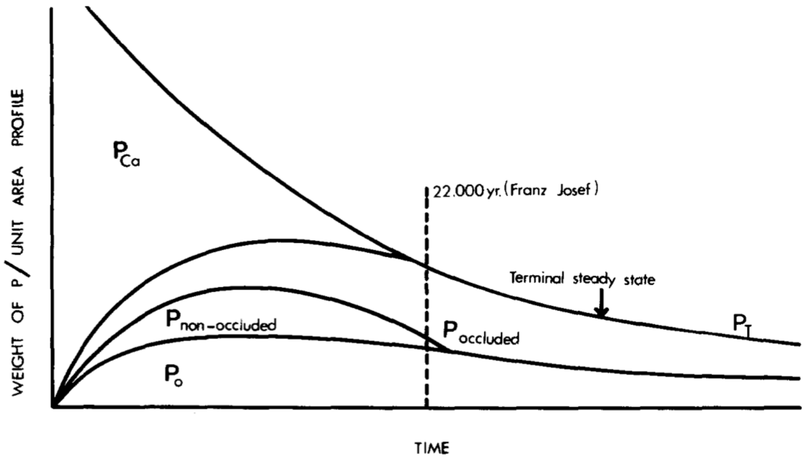
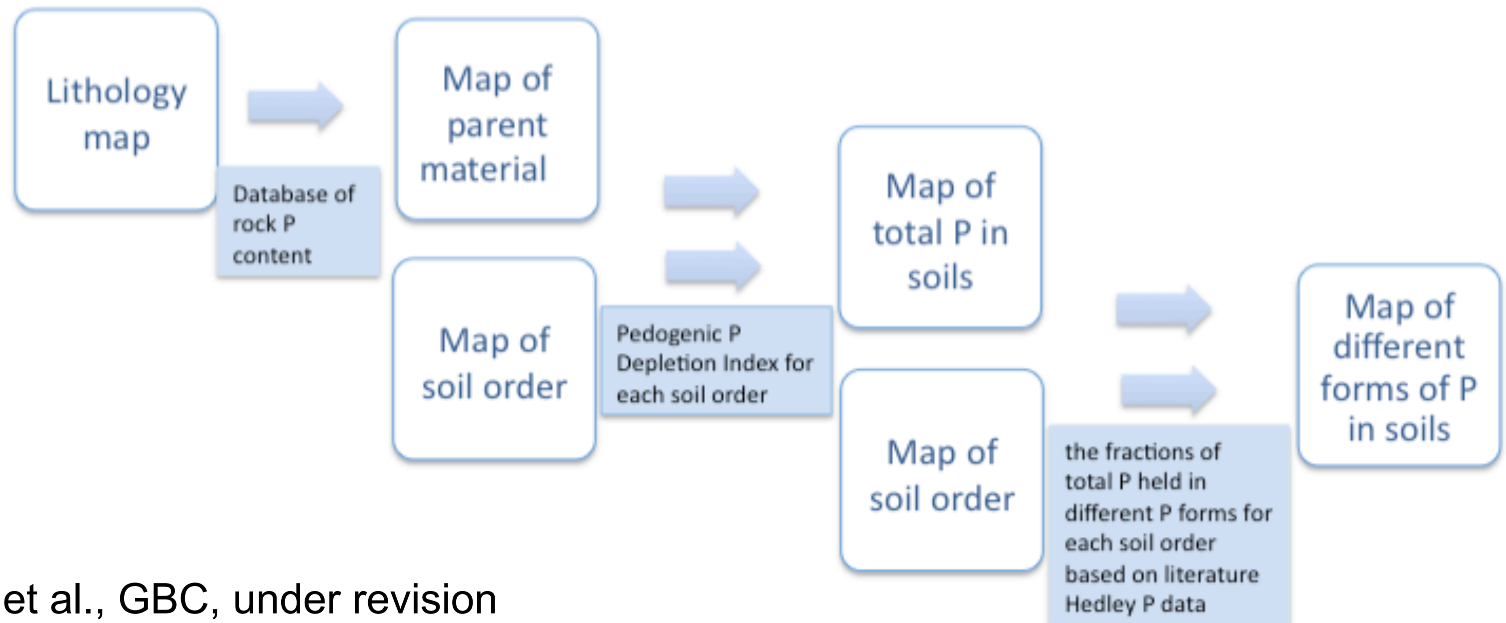


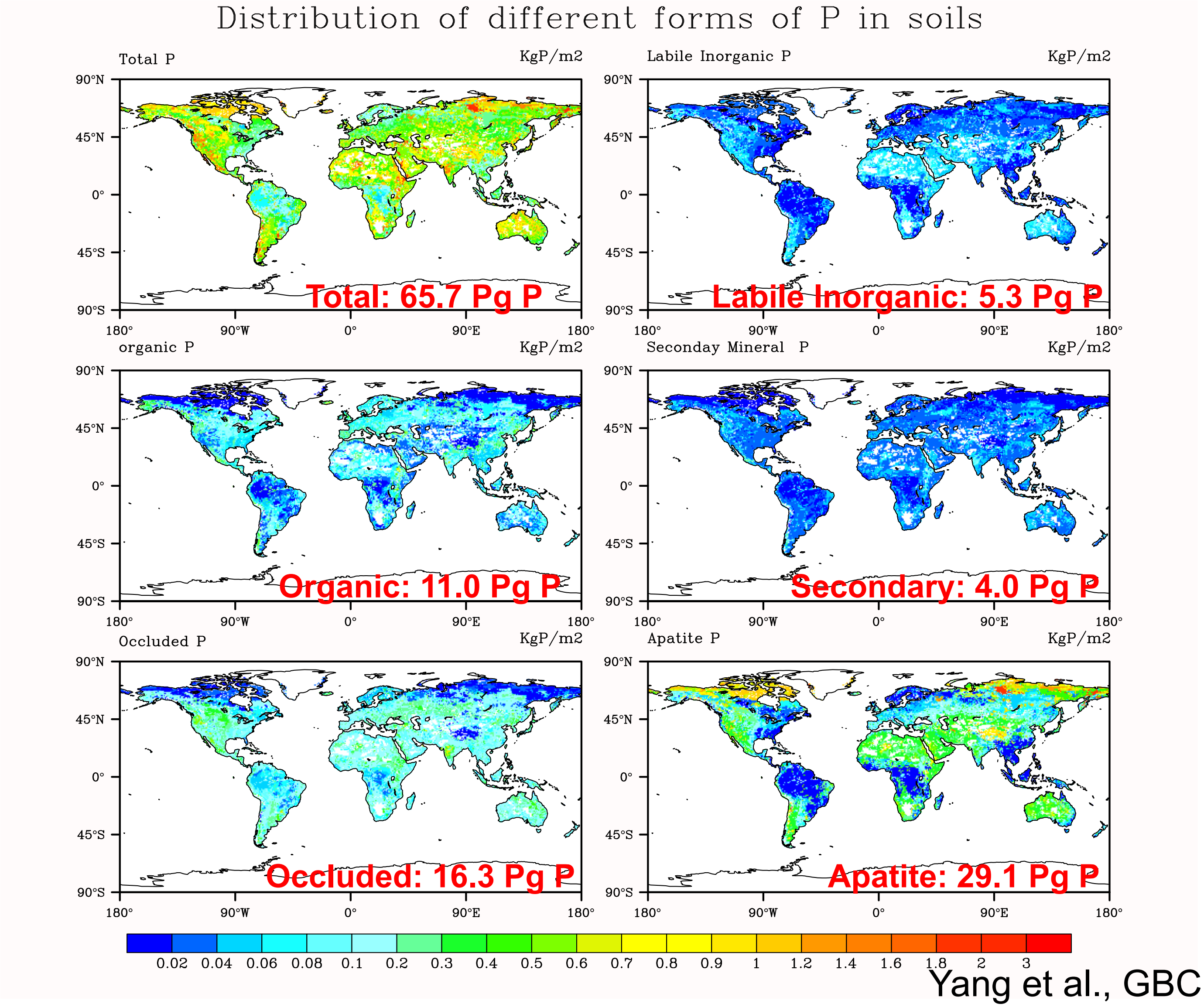
Fig. 1. Changes in forms and amounts of soil P with time.

- **Walker and Syers' conceptual model**
- **USDA soil order as an proxy for soil development stages**
- **Chronosequence studies and soil vertical profile P data used to quantify loss of total P for each soil order**
- **Hedley P database to provide the fractions of P in different forms for each soil order**



Yang et al., GBC, under revision

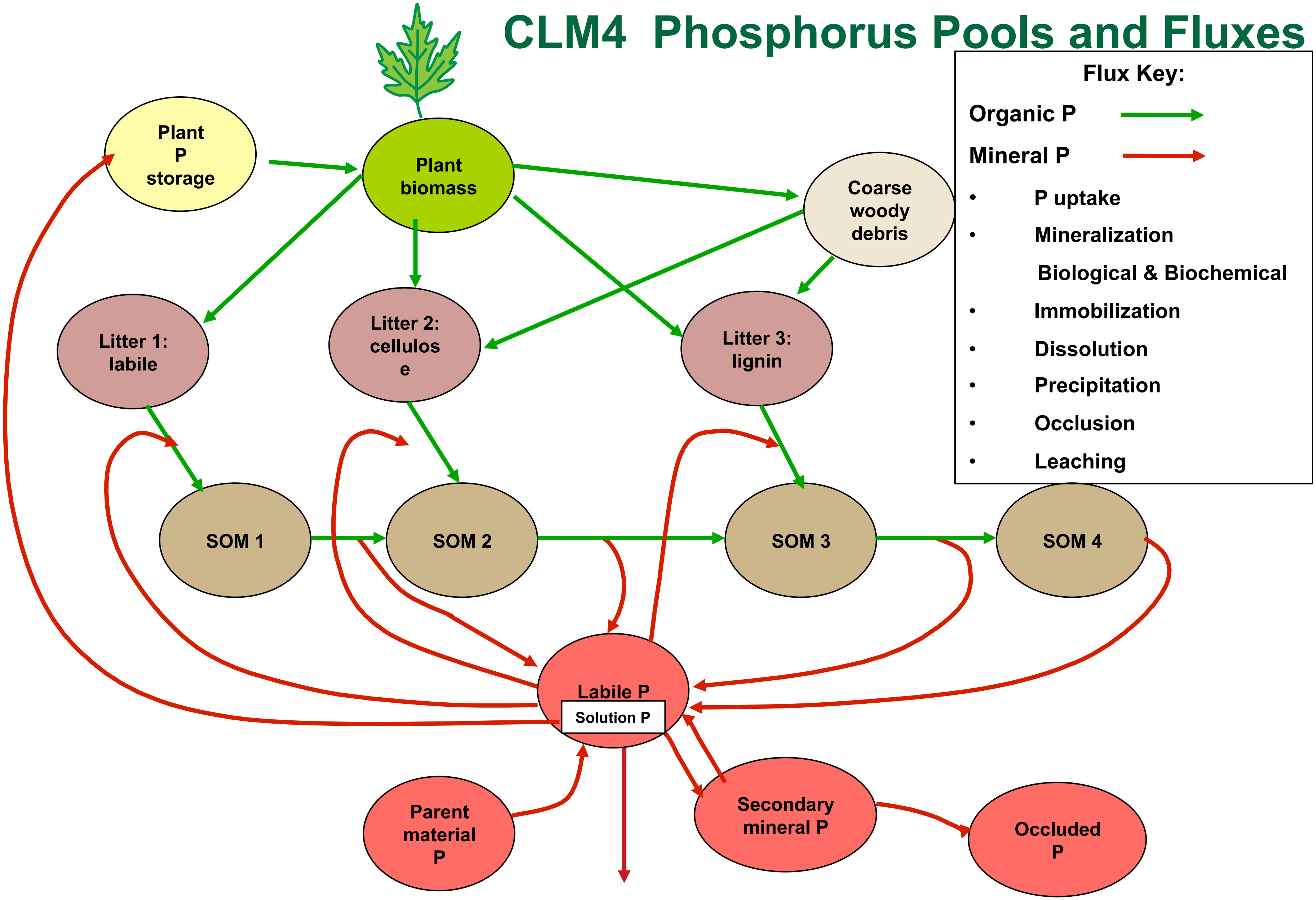
P maps for global model initialization



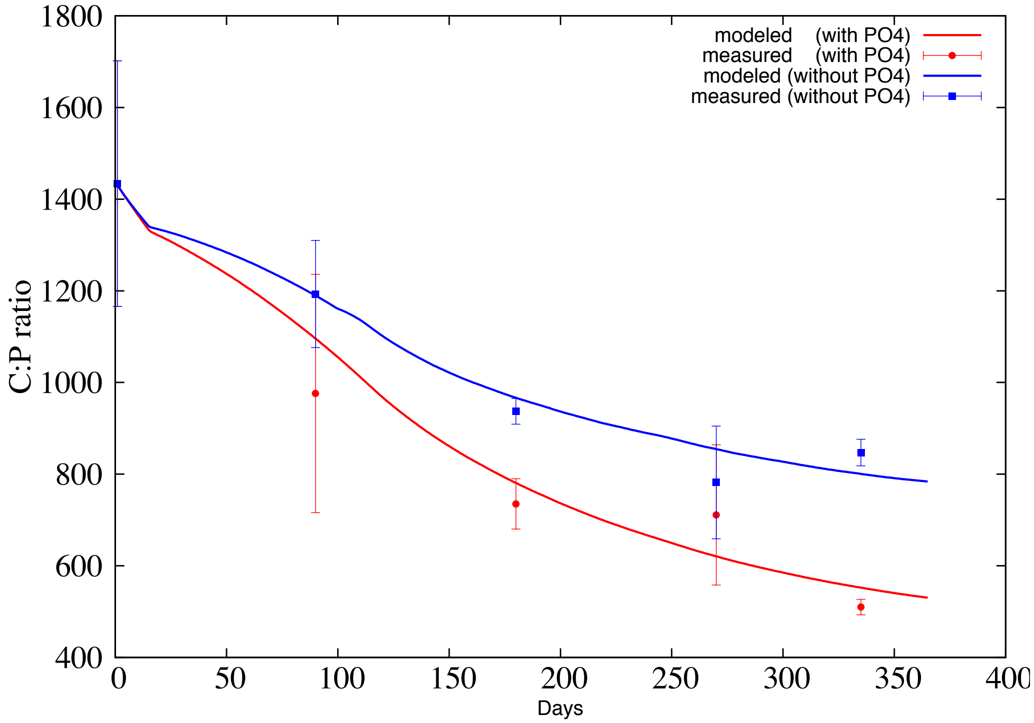
Yang et al., GBC, under revision

III. Incorporating P dynamics and C-N-P interactions into CLM

CLM4 Phosphorus Pools and Fluxes



Can stoichiometric constraints explain P dynamics during decomposition?



- P fertilization experiment showed that more P was accumulated in decomposing litter in the fertilized plots, although P fertilization did not affect decomposition rate.

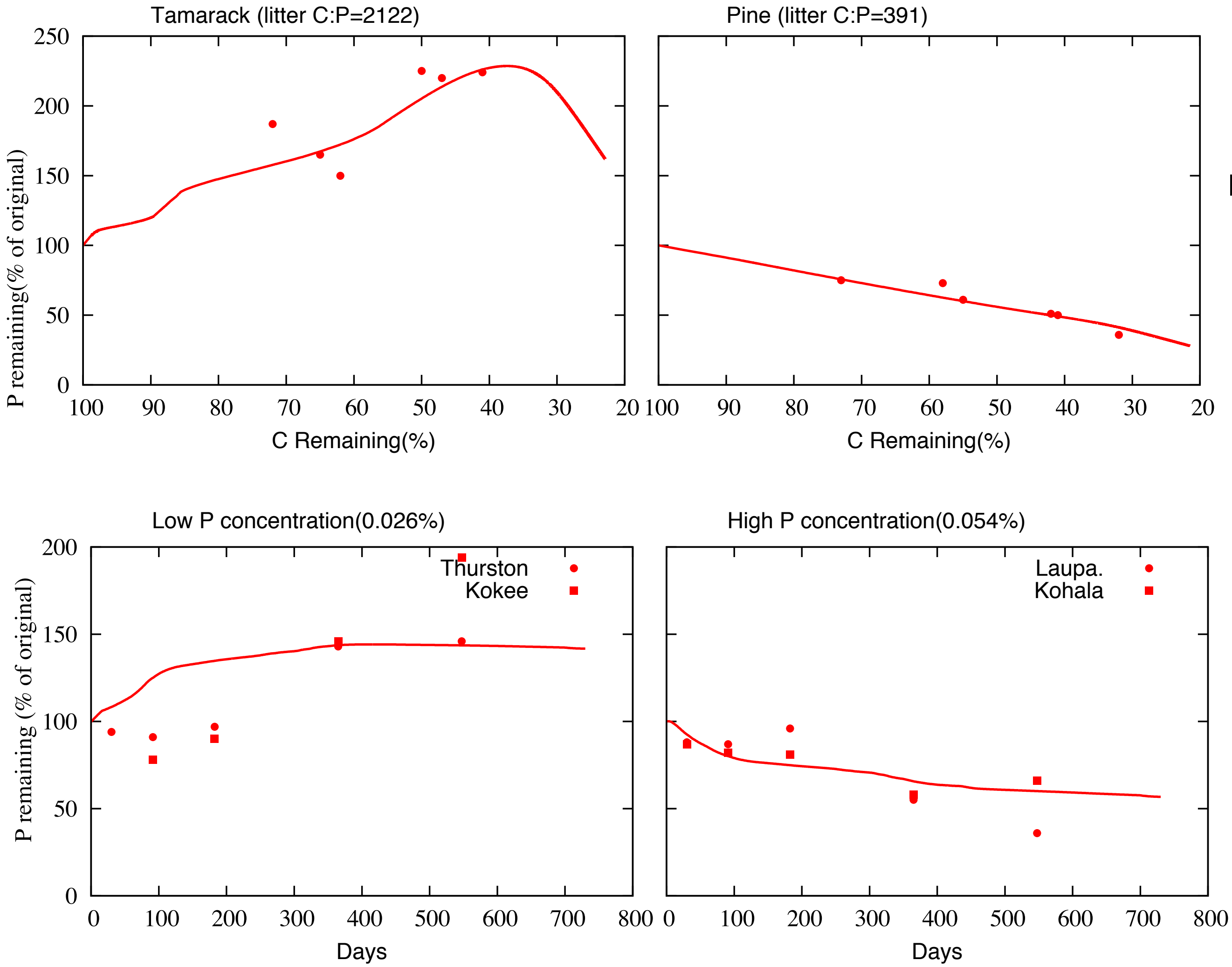
- Model simulations indicated that C:N:P stoichiometry can explain the changes of P content in decomposing litter when there is enough P in soils.

- Model simulations showed that biochemical mineralization is an important process when P is in short supply, consistent with the conceptual model proposed by McGill and Cole(1981).

- The decoupling of P from C and N in ecosystems with low soil available P provides an important mechanism for increasing P availability.

Measurement data from McGroddy et al.(2004)

Comparison between model simulations and empirical pattern from field studies



Data from CIDET(Moore et al. ,2006)

Data from a soil chronosequence in Hawaii (Crews et al., 1995)

Conclusions

- The new global Hedley P database provides quantitative foundation for the incorporation of P dynamics into models
  - ➢ Total P decreases as a function of soil development
  - ➢ Labile P decreases with the weathering stages of the soils, while the importance of organic P to soil labile P increases as soil development proceeds
  - ➢ C and N in SOM are closely linked in all soil orders, but P is decoupled from C and N in highly weathered soils
- We construct quantitative global maps of soil P, using P content of parent material and soil order as a proxy for soil development
  - ➢ Our estimate of soil P contents is consistent with other regional and global estimates.
  - ➢ The maps allow the appropriate initialization of available soil P for global terrestrial C-N-P biogeochemistry models
- Preliminary site level model-data comparisons show the ability of the CLM-CNP model to simulate P dynamics during decomposition
  - ➢ Stoichiometric relationship can explain P dynamics during decomposition when there is adequate available P in soils. However, P cycle can be decoupled from C and N during decomposition when soil available P is in short supply