Scenarios of future agricultural phosphorus stocks and flows

By coupling a phosphorus (P) stock and flow model to the integrated land-use model MAgPIE, we can derive scenarios for the future development of the agricultural P cycle.

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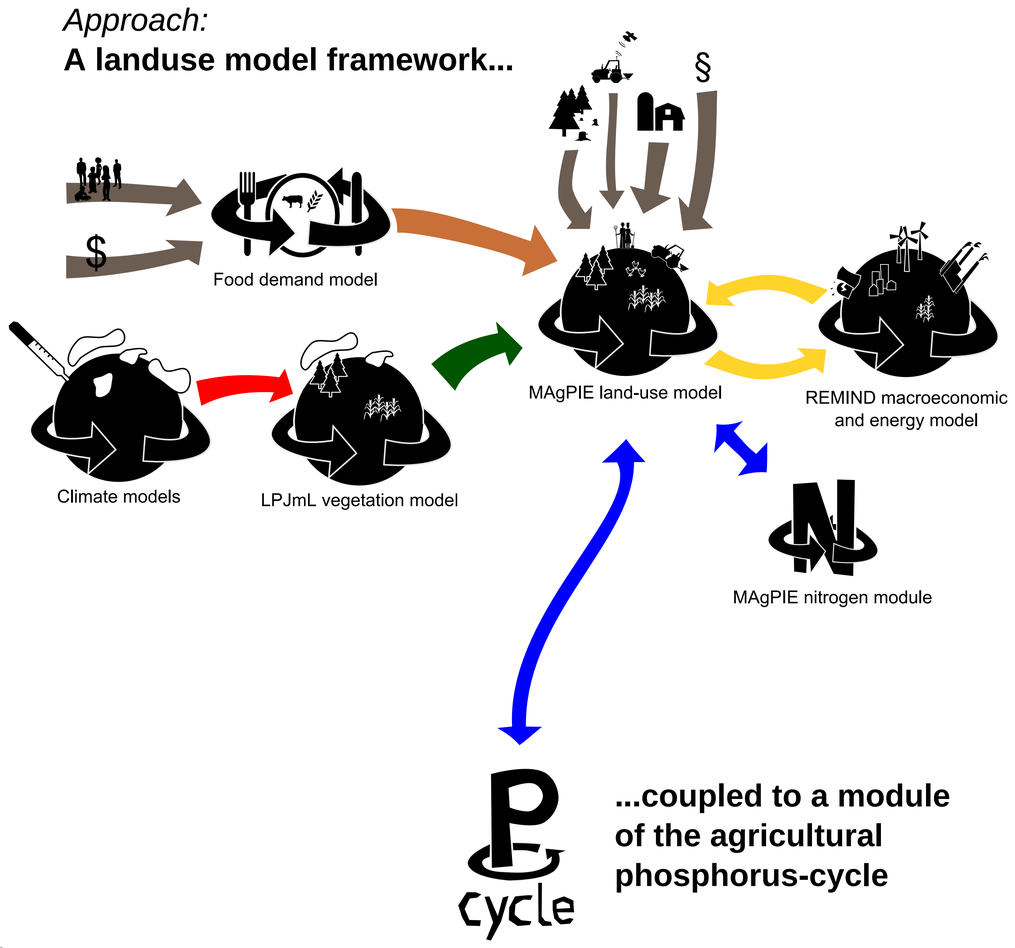
Research questions:

How will global phosphate extraction develop?

How will phosphate pollution develop?

Approach:

A landuse model framework...



...coupled to a module of the agricultural phosphorus-cycle

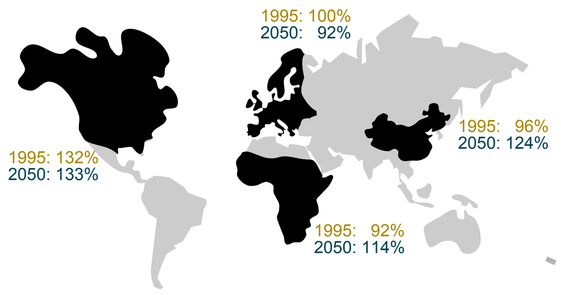
Methods:

How the P flows are estimated

- Crop and animal production, trade and food/feed/seed use:
  Activity based on MAgPIE outputs
  Crop and animal product specific P content based on literature
  Fritsch (2007), FAO (2004), Roy et al (2006), IFA et al (2007), ...
- Crop residues:
  Activity based on MAgPIE outputs (Bodirsky et al 2012)
  P-content of residues based on literature
  Fritsch et al (2007), FAO (2004), ...
- Weathering: 1kg/ha, similat to Smil (2000) and Liu et al. (2008)
- Leaching: Leaching rate of 3.5% Liu et al. (2008), but applied not only to inorganic fertilizer but to all Nr inputs, as manure is subject to substantial leaching, too (Macleod 2003, Hart 2004)
- Stable pool spin-up for starting values in 1995
  - organic P: organic soil carbon (LPJ output) multiplied with C:P ration of 180
  - inorganic P: topsoil (50cm) multiplied with average P content of 0.05%
  - fertilizer history: based on IFA(2010)
  - harvest (FAO), but only food and material use considered as feed is recycled to soils via manure
  - erosion: 15-35 t soil per ha depending on climate with average P content of 0.05% (Liu et al 2008)
- Labile pool: assuming a short-term P efficiency of 20% (Smil, 2000), labile pool has to be 5 times the P withdrawal through plant withdrawal and leaching
- Labile pool fixation to stable pool: 20% of labile pool remaining after harvest based on Wolf et al (1987)
- Stable pool mobilization to labile pool: calibrated to balance the budget with given fertilizer consumption in 1995, afterwards constant calibration factors range from 0.1-0.4% (realistic?)
- Fertilizer demand: endogenouns to fill up the labile pool under consideration of other P inputs like manure, residues, weathering, stable pool mobilization

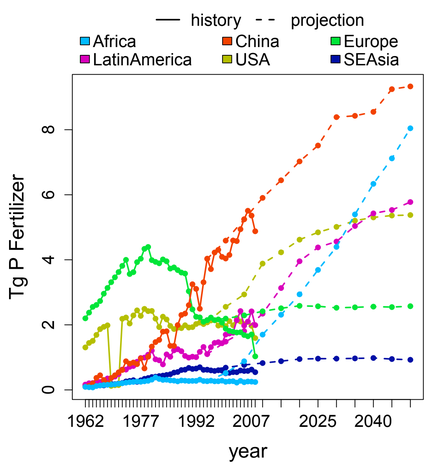
Result 2:

P trade in agricultural products
self-sufficiency of major regions



Result 3:

P fertilizer consumption
history and model projections

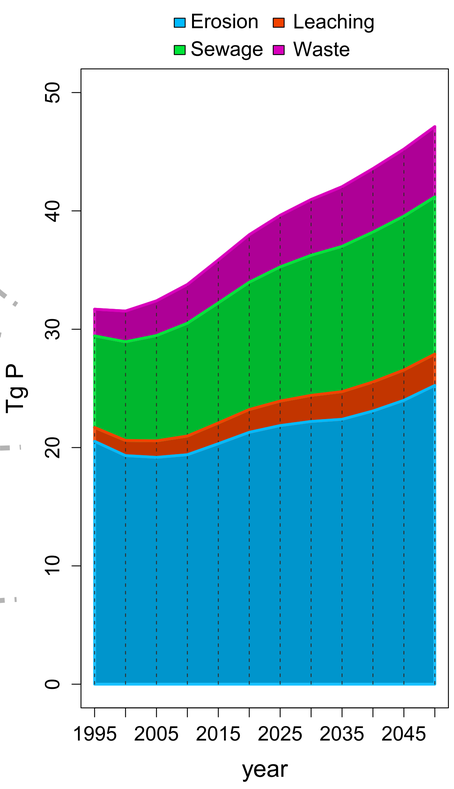


Result 1:

Model-estimates of global P flows
in a SSP2 scenario

Result 5:

Global P Losses



Result 4:

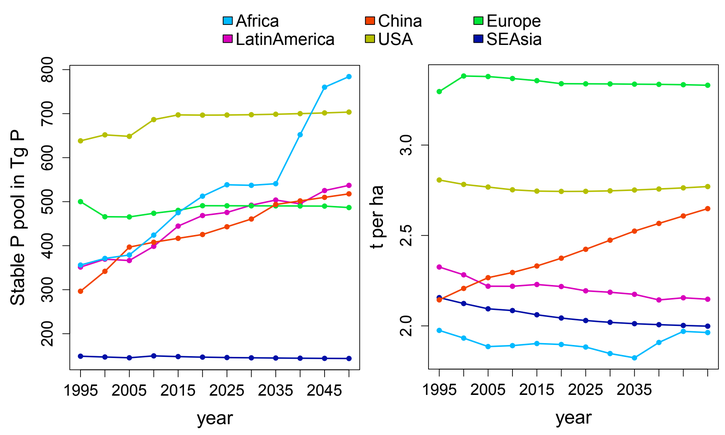
Development of stable P pool on agricultural soils

Cropland natural soil stocks 1995:
- Inorganic 3047 Tg
- Organic 818 Tg

Anthropogenic History 1962-1995:
- Fertilizer + 401 Tg
- Harvest removal - 111 Tg
- Erosion - 591 Tg

Total in 1995 3564 Tg

Model projections for 1995-2050:



Conclusions:

Preliminary findings

- Stable pool P accumulation only in few regions (Europe, USA), while declining in most world regions (sensitive to erosion assumptions)
- Rather low soil saturation effect
  -> conflicting finding with Sattari et al (2012) maybe because of assumption on erosion/initial pools
- Leaching losses in the future may rise due to strongly increasing production
- Erosion losses may rise due to land expansion and higher p-content of soils
- Sewage losses rise due to growing population
- Waste losses increase due to more prosperous lifestyles

Open Issues, please discuss with me!

- P losses during animal waste management have not been accounted for by any global study
- How can the modelling of erosion and leaching losses be refined?
- What are realistic mobilization rates of the aggregated stable P pool?
- Which soil types should I include to refine this simple model?
- Why does my model overestimate P consumption in Subsaharan Africa?