A research framework for phosphorus demand projections in China using Socioeconomic Shared Pathways

Jing-Yu Liu, Shanghai Jiao Tong University

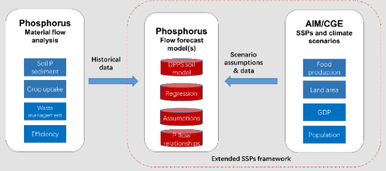
1. Introduction

- Phosphorus is a key element for life system. Over 80% of phosphorus use is for agriculture activities. Fast growing world population do put stress to the phosphorus resource security, which is mostly related to food security issue
- Food, energy crop and other agriculture products are produced on land with fertilizer input. Large scale of biomass will be needed to achieve the 2-degree climate goal. The production of biomass will require large amount of land, water and soil fertilizer, threatening global food security.
- Nitrogen and phosphorus fertilizer use, if not properly managed, can cause water pollution such as eutrophication. P security and environmental concern of P use were then added into the climate mitigation and negative emissions debate.
- This study will propose a research framework to project future phosphorus use in China through 2100. This study can shed lights on the food security in the context of climate change from the perspective of P fertilizer use.

2. Research framework

- A dynamic material flow analysis (MFA) model will be used to analyze the P flows between production and consumption.
- Future P flows will be projected by using historical data of P flows and scenario assumptions in SSPs scenarios.

- The framework can be extended to the world and used for assessing the impacts on planetary health of global climate policies.



3. Methods

- A dynamic material flow analysis (MFA) model scheme is shown in Figure 1. Data from 1970 to 2012 for 102 flows between nodes is from literature[2]. Projection methods see Table 1.

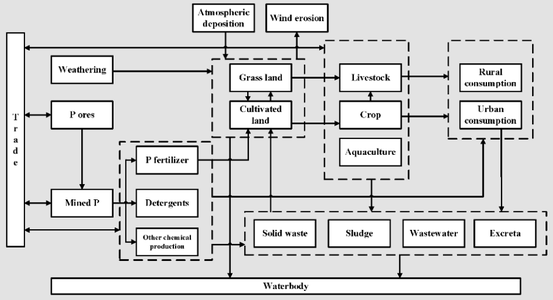


Figure 1 Material flow analysis scheme

Table 1 Projection methods

P flows/ parameters	Methods	Reference
P uptake in crops	Calculation using agricultural production from AIM/CGE and P content data of products.	[2]
P intake in crop land	DPPS model. It models labile and stable P in soil and thus relationship between P intake and uptake. Historical data used for parameter calibration and P uptake as exogenous variables.	[6]
P flow per capita in detergents and other chemical products	Regression using income level.	[7]
Sewage treatment	Historical trend is assumed to continue for treatment rate in SSP2. 25% difference for High and Low level	[7]
Wastewater treatment	Historical trend is assumed to continue for treatment rate in SSP2. 25% difference for High and Low level	[7]
Solid waste treatment	Historical trend is assumed to continue for treatment rate in SSP2. 25% difference for High and Low level	-
Manure management	Historical trend is assumed to continue for treatment rate in SSP2. 25% difference for High and Low level	-
Fertilizer Efficiency improvement	Historical trend is assumed to continue for Med level in SSP2. 25% difference for High and Low level	-
Wind erosion	Constant	-
Weathering	Proportional to land area	-
Atmospheric deposition	Proportional to land area	-

4. SSP assumptions

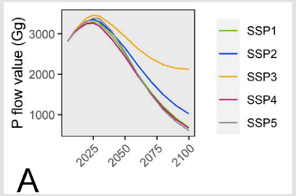
- Flows of P cycle in China are projected using SSP scenario assumptions and parameter settings derived from AIM/CGE model and regression predictions.
- Table 2 shows SSPs assumptions for scenario data input and P flow projections.

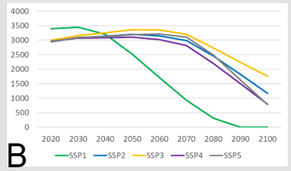
Table 2 SSPs assumptions

Key P flows	SSP1	SSP2	SSP3	SSP4	SSP5
GDP	Based on [3]				
Population	Based on [4]				
Urbanization	Based on [5]				
Agricultural products trade	High	High	Low	Low	High
Meat preference	Low	Med	High	High	Low
Yield	High	Med	Low	High	High
Fertilizer efficiency	High	Med	Low	Med	Med
Sewage treatment	High	Med	Low	Med	Med
Waste water treatment	High	Med	Low	Med	Med
Manure management	High	Med	Low	Med	Med

5. Results

- It is projected that SSP3 scenario will require the highest P uptake in crops due to large population and high agriculture output. Lack of P efficiency improvement, the required P intake is the highest in SSP3.
- Meanwhile, SSP1 will require the least P intake. After 2080 P intake will be zero but agricultural production will rely on P legacy stored in soil.
- Note that current results only consider the P uptake and intake in DPPS soil model. The other flows in P cycling have not been taken in consideration.
- Future work include closure of P forecast model, biomass treatment, and uncertainty analysis.





- Figure 2.A Crop uptake in BaU climate scenario for 5 SSPs;
- Figure 2.B Required P intake in BaU scenario for 5 SSPs (Unit: Gg). Including P fertilizer input, manure and human wastes input.
- Preliminary results. Please do not quote.

6. References

1. Cordell, D. and S. White, Life's bottleneck: Sustaining the world's phosphorus for a food secure future. Annu. Rev. Environ. Res., 2014. 39: p. 161.
2. Liu, X., et al., Intensification of phosphorus cycling in China since the 1600s. Proceedings of the National Academy of Sciences, 2016. 113(10): p. 2609-2614.
3. Dellink, R., et al., Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change, 2017. 42: p. 200-214.
4. Kc, S. and W. Lutz, The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. Global Environmental Change, 2017. 42: p. 181-192.
5. Jiang, L. and B.C. O'Neill, Global urbanization projections for the Shared Socioeconomic Pathways. Global Environmental Change, 2017. 42: p. 193-199.
6. Sattari, S.Z., et al., Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle. Proceedings of the National Academy of Sciences, 2012. 109(16): p. 6348-6353.
7. Van Drecht, G., et al., Global nitrogen and phosphate in urban wastewater for the period 1970 to 2050. Global Biogeochemical Cycles, 2009. 23(4).