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Global Phosphorus Fertilizer Supply Dependencies

Supply Chain, Percolation, Resilience, Trade Infrastructure, Multilayer Economic Networks

Extended Abstract

Global food security depends on the reliable and equitable availability of essential agricultural inputs. Phosphorus—an irreplaceable nutrient vital for plant development—is fundamental to agricultural productivity in all regions. Without it, sustainable food production is not possible.

However, phosphorus resources are highly unevenly distributed. The nutrient is extracted from phosphate rock and processed into fertilizers in only a handful of countries. Globally, just five major mining countries provide the vast majority of phosphate ore, and additional dependencies arise from a limited number of countries involved in transforming the mined ore into usable fertilizer products.

To analyze global phosphorus dependencies, we use publicly available data from the Harvard Growth Lab, the United States Geological Survey (USGS), and the Food and Agriculture Organization (FAO). These datasets are processed to extract mass flows of phosphorus-containing products (measured in Mt P_2O_5) and grouped into five product categories. Countries are assessed using quantitative indicators such as import dependency and supply diversity. Clustering techniques are applied to identify countries with similar trade characteristics. Dynamic analysis of import, export, and domestic consumption massflows enables the classification of countries by their functional roles in the phosphorus supply network—as miners, transformers, traders, and consumers.

Upstream trade structures are crucial to identify resilient alternative exporters and to assess similarities in trade patterns and risks of supply chain disruptions.

By mapping these functional interconnections, the study uncovers critical structural dependencies and supports strategies to enhance supply chain resilience and ensure equitable access to phosphorus-based fertilizers. **Converted trade data provides a viable approach to understanding the global phosphorus supply chain.** Many countries rely heavily on a small number of dominant suppliers who operate across multiple stages of the supply chain and have consistently served global markets from 2001 to 2024 (Tab. 1, Fig. 1).

The analysis identifies key actors in the global phosphorus network and classifies them by their functional roles—miners, transformers, traders, or consumers—making critical interdependencies and vulnerabilities visible. Our results show that countries with significant mining activity are mainly assigned the roles of transformers and traders. However, countries without domestic reserves—such as Germany and the Netherlands—also play essential roles across all product categories by acting as trading hubs with strong processing industries that upgrade phosphorus products along the value chain.

Countries like Turkey, Bangladesh, India, and Brazil are primarily identified as consumers (Fig. 2). Special emphasis is placed on the risks faced by import-dependent countries and the urgent need for fair and secure access to phosphorus fertilizers.

Highly dependent consumer countries can apply this methodology to identify more resilient alternative suppliers. Likewise, trader and transformer countries can use it to explore new markets and expand their strategic positions within the global supply network. By increasing transparency and revealing structural dependencies, the methodology supports fairer access to critical inputs—particularly for vulnerable importers.

Presenting this work at the conference—whether as an oral or lightning talk—would help raise awareness of the urgent need to secure global phosphorus supply chains as a foundation for food security.

This issue affects all regions and populations and requires the attention of researchers and policymakers alike. Ensuring fair and stable access to this non-substitutable resource is not only essential for sustainable agriculture but also for preventing conflict, instability, and displacement linked to food shortages.

References

[1] The Growth Lab at Harvard University. Int. Trade Data (HS, 92). Version V6. 2019.

Table 1: **Dependent countries.** Major supplier countries of category 4 products and the number of dependent countries relying on their supply.

Dominant supplier in category 4	Outflow share	Number of dependent countries
China	23 %	55
Morocco	21 %	25
Egypt	15 %	35
Israel	12 %	14
Tunisia	4 %	5
Netherlands	4 %	19
...	... %	...

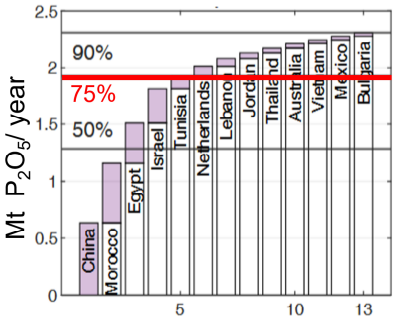

Figure 1: **Cumulative outflow.** The bars show the mean cumulative outflows per country, with threshold lines indicating 90%, 75%, and 50% of the total flow per category from 2019 to 2021.

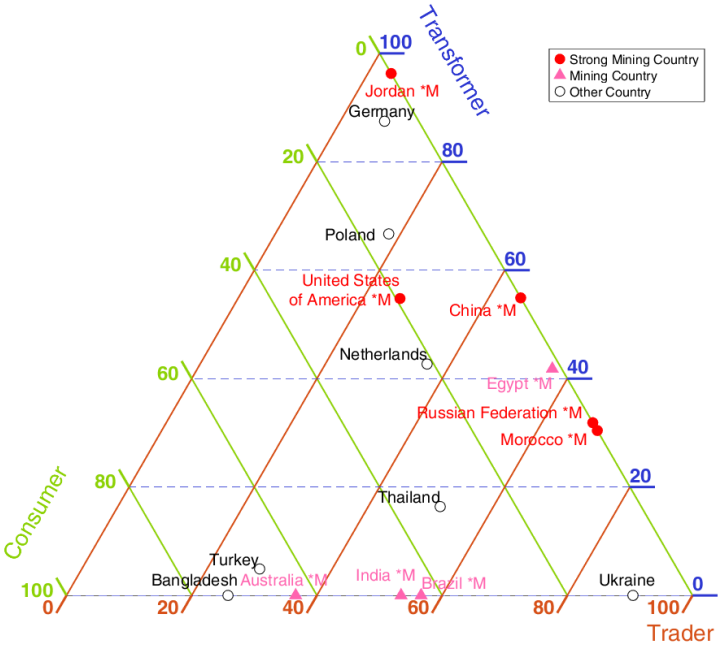

Figure 2: **Role shares across phosphorus product categories.** Shares of countries as Trader, Transformer, and Consumer (2019–2021), weighted by trade volume (P_2O_5 tonnes) across five product categories. "*M" marks countries with domestic mining, grouped as "strong mining", "mining", or "other" based on mining volume (0.5–2.0 Mt P_2O_5).