How do global protein supply chains affect the sustainability (*GHGE, land use, and nutrient concentration*) and nutritional adequacy (*meet nutritional requirements*) of diets in different countries?

**Import vs Export**

* Do countries that rely more heavily on imported protein sources have higher environmental impacts associated with their diets compared to countries that primarily consume domestically produced proteins, due to the added GHGE from transportation and processing?
* To what extent does reliance on imported protein sources, which do not return crop residues to the local soil, contribute to nutrient depletion and thus affect the long-term sustainability of domestic agricultural systems (more intensive use of fertilizers)?

**Plant-based/Future v Animal proteins**

* Can diversified protein supply chains, that include a higher proportion of plant-based proteins and future food proteins, lead to better nutritional outcomes and lower environmental impacts?
* Can diversified protein supply chains, that include foods with lower nutrient removal rates, improve long-term sustainability of agricultural systems and impact overall GHGE?

Data

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| --- | --- | --- | --- | --- |
| **Country** | **Protein Source**  (Plant v Animal based) | **Product** | **Element**  Production  Import Quantity, Export Quantity, Domestic supply quantity,  Feed,  Seed,  Losses,  Processing,  Food,  Protein supply quantity (g/capita/day) | **Year** |

|  |  |  |
| --- | --- | --- |
| **Country** | **Environmental Impact**  Land use & GHG emissions | **Product Group**  Beef  Pork  Eggs  Poultry  Animal protein  Dairy  Sheep/Goat Meat  Common wheat  Soy  Pulses  Nuts and trees  Maize  Rice |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Requirements**   |  | | --- | | Protein (g) | | Ca (mg) | | Fe (mg) | | Zn (mg) | | Vit. D (ug) | | Vit. A (ug) | | Vit. B12 (ug) | | EPA + DHA (g) | | Lysine (g) | | Methionine (g) | | Threonine (g) | | Tryptophan (g) | | **Value** |

Analyses:

* analyze the global protein supply chain, focusing on production, trade, and consumption patterns (over time?)
* evaluate environmental impact of different protein sources (animal v plant-based v future foods?) using GHGE and land use
* analyze nutritional adequacy of protein supply in different countries
* optimize protein distribution across countries for better nutritional outcomes and environmental outcomes

Step 1: Quantify Nutrient Removal

Use the nutrient concentration data (e.g., N\_kg\_per\_t\_fresh\_wt, P\_kg\_per\_t\_fresh\_wt, etc.) to calculate the total amount of each nutrient removed from the soil per metric ton of harvested crop.

Calculate the total nutrient removal for each crop in a country by multiplying the nutrient removal per ton by the total tonnage of the crop harvested.

Step 2: Establish Nutrient Replacement Needs

Use the harvest index (HI) to estimate the proportion of biomass that is removed as crop versus left as residue, which can also contribute to soil nutrient content.

Determine the nutrient replacement needs by considering the nutrient removal data and the natural soil replenishment rates (which can be minimal for intensive agriculture).

Step 3: Analyze Fertilizer Application Rates

Collect data on actual fertilizer application rates in the countries of interest, specifically for the crops you're studying.

Correlate these rates with your calculated nutrient removal rates to see if there's a pattern where higher nutrient removal corresponds to higher fertilizer applications.

Step 4: Consider Domestic vs. Imported Crops

Differentiate between domestically produced and imported crops. For domestic crops, there's a direct relationship between nutrient removal and the need for fertilizer application in the same country.

For imported crops, consider the nutrient depletion in the exporting country's soil and the impact of transport emissions.

Step 5: Statistical Analysis

Use regression analysis to statistically test the relationship between nutrient removal rates and fertilizer application rates. This can help establish causation and not just correlation.

Perform sensitivity analyses to account for variations in crop types, soil fertility, climate conditions, and farming practices.