Greenhouse Gas Emisssions Across the Supply Chain

Food production and agriculture accounts for over a quarter of global greenhouse gas (GHG) emission, representing a major contributor to climate change. However, impacts vary widely across different food groups and stages of production. To determine the highest-impact changes, we need an evidence and data on varying emission magnitude and distributions across different food groups and supply chain stages.

The analysis uses granular life cycle assessment (LCA) data on GHG emissions encompassing 43 key foods, from beef and dairy through plant-based staples. The data is from a study published by Joseph Poore and Thomas Nemeck (2018), which compiled a massive database of GHG emissions from about 38,700 commercial farms in 199 countries. Data was collected through a bottom-up life cycle assessment methodology. This involves quantifying resource use and environmental emissions at each stage of a product's supply chain - from inputs and land use changes through production, processing, transport and retail. By quantifying per-kilogram carbon dioxide emissions across the farm-to-retail supply chain, data provide a complete map of environmental hotspots across chains. Then, we can contrast distributions and magnitudes by food type provides robust evidence for high-impact mitigation points - insights more critical than "food miles" when determining leverage.

In this comparison, there are massive differences in terms of kilogram CO2-equivalent emissions between animal-based and plant-based foods. Of the five highest-emitting foods, four are meats and dairy: beef cattle, dairy cattle, lamb and sheep, and cheese all produce more than 20 kilograms CO2-equivalent per kilogram. In contrast, the highest plant food - chocolate - emits only 19 kilograms, and most plant foods generate less than 3 kilograms per kilogram. The highest emitter - beef from beef herds - results in 60 kilograms of GHG per kilogram - about 3 times the highest footprint of plant-based protein sources - chocolate. Additionally, the average emissions among animal-based foods is 16.39 kilograms of GHG per kilogram, compared to 2.82 kilograms of GHG per kilogram for the average emissions among plant-based foods.

If we examine emissions distribution across supply chain stages, we again see animal-based products are in a league of their own. For beef, lamb, cheese and other meats, agricultural production and land use conversion constitute the vast majority of emissions - over 80% for beef. The major sources are methane from livestock and carbon dioxide from converted lands. For beef, the farm stage emissions (shown in brown) from cattle methane and manure exceed two third alone. Land use change impacts (shown in green) account for another a quarter (Figure 1). Compared to farming's dominance, processing (shown in blue), transport (in read), retail (in yellow), and packaging (in grey) play minor roles, representing less than 10%. Across animal-based categories, farm, land use change and animal feed emissions for animal products account for about 80-90% of the total. The data exhibits a consistent trend: agricultural phases drive the substantial footprint, not food miles. Whether animal foods are raised locally or globally, it is the biological emissions inherent in livestock production that lead to outsized impacts, not geographic considerations.

For plant-based foods, emissions pale in comparison to animal products. The majority of impacts stem from agriculture itself through fertilizer usage, equipment operation, and yield variability between crops. Land use changes also play a moderate role. Transport accounts for the third highest share at approximately 10% across vegetables, fruits and grain categories – a significant portion. While farming methods and efficiency offer the greatest emission reduction potential, localizing production where feasible can provide meaningful impact reductions. Pursuing low emission agriculture techniques, optimizing crop yields, reducing food waste and reasonable transport minimization collectively present impactful climate solutions for the plant-based sector. Multi-pronged efforts combining agricultural development and localized distribution where viable are key.

In summary, massive differences exist in food's climate impact based on clear evidence - animal-based products result in exponentially higher greenhouse

emissions than plants. The supply chain analysis provides evidence that when it comes to food's climate impact, farming practices and efficiency dominate emissions for crop-based foods, while transport is largely negligible. The supply chain analysis highlights how curbing the climate impact of our diets fundamentally requires transitioning towards plant-based proteins, implementing low-carbon agricultural practices, and addressing emissions at their root source - on farms themselves.

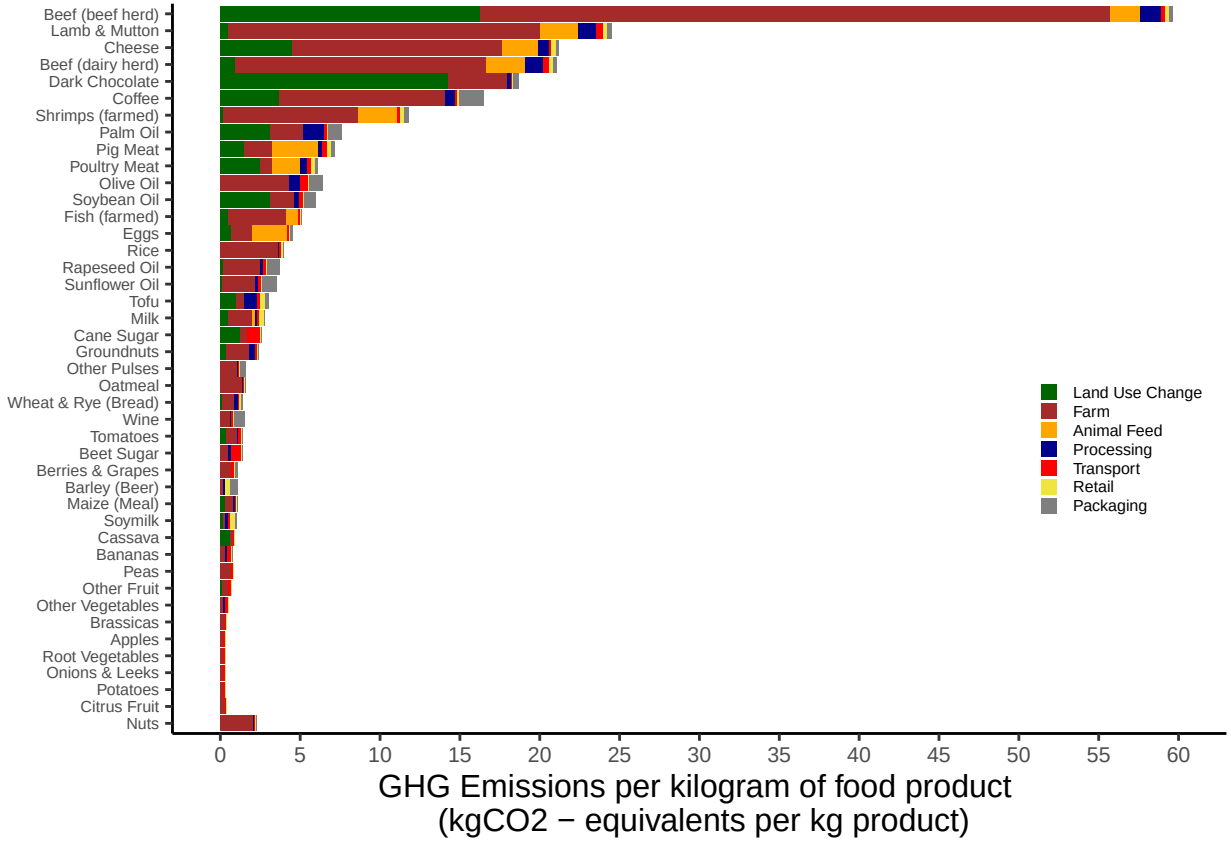

Figure 1: GHG emissions across the supply chain

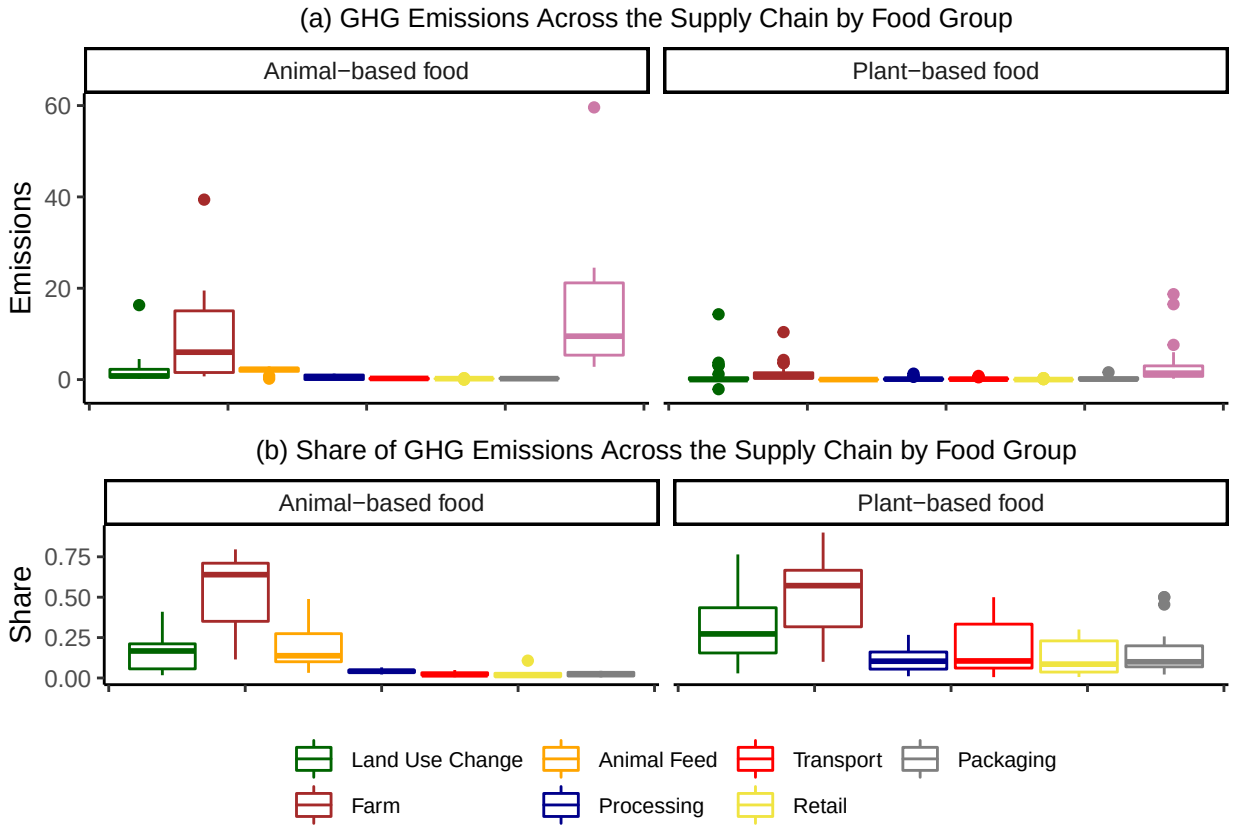

Figure 2: GHG Emissions Across the Supply Chain by Food Group

The data covers multiple environmental indicators beyond GHG emissions - including freshwater use, water scarcity, land usage, and eutrophication. Each category gets analyzed per functional unit - per calorie, protein content, and product weight. This multi-lens perspective reveals shifts in highest-impact foods. While apples rank low in land use, their water scarcity footprint per calorie raises concerns. For freshwater withdrawals, the leading products per kilocalorie (cheese, fish) differ from top contributors on a per protein basis (berries, apples). Comparing rankings, certain items like beef, cheese, rice, and tomatoes rank among top offenders across units, while relative impacts of nuts or fruit fluctuate. A complete picture necessitates evaluating both functional flow and environmental domain.

Land Use

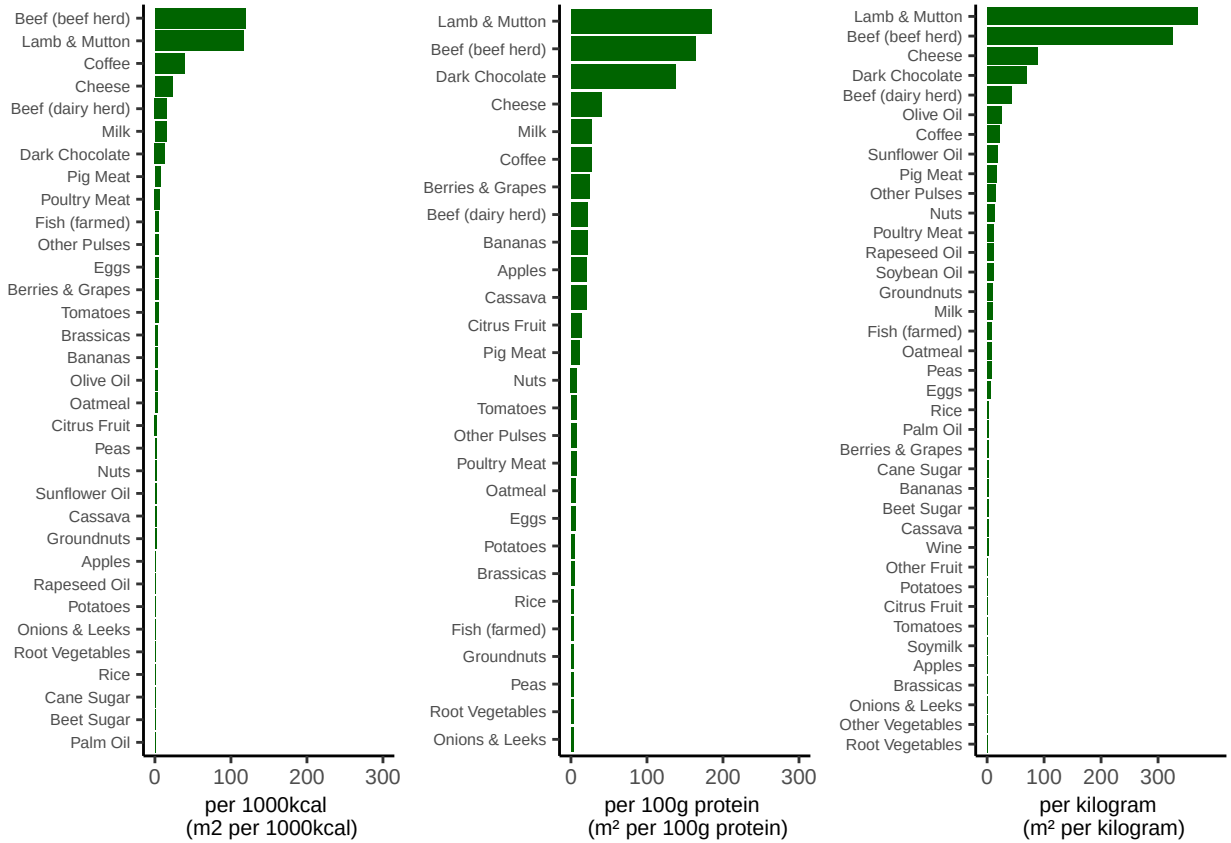

Figure 3: Land use across food products

Freshwater withdrawals

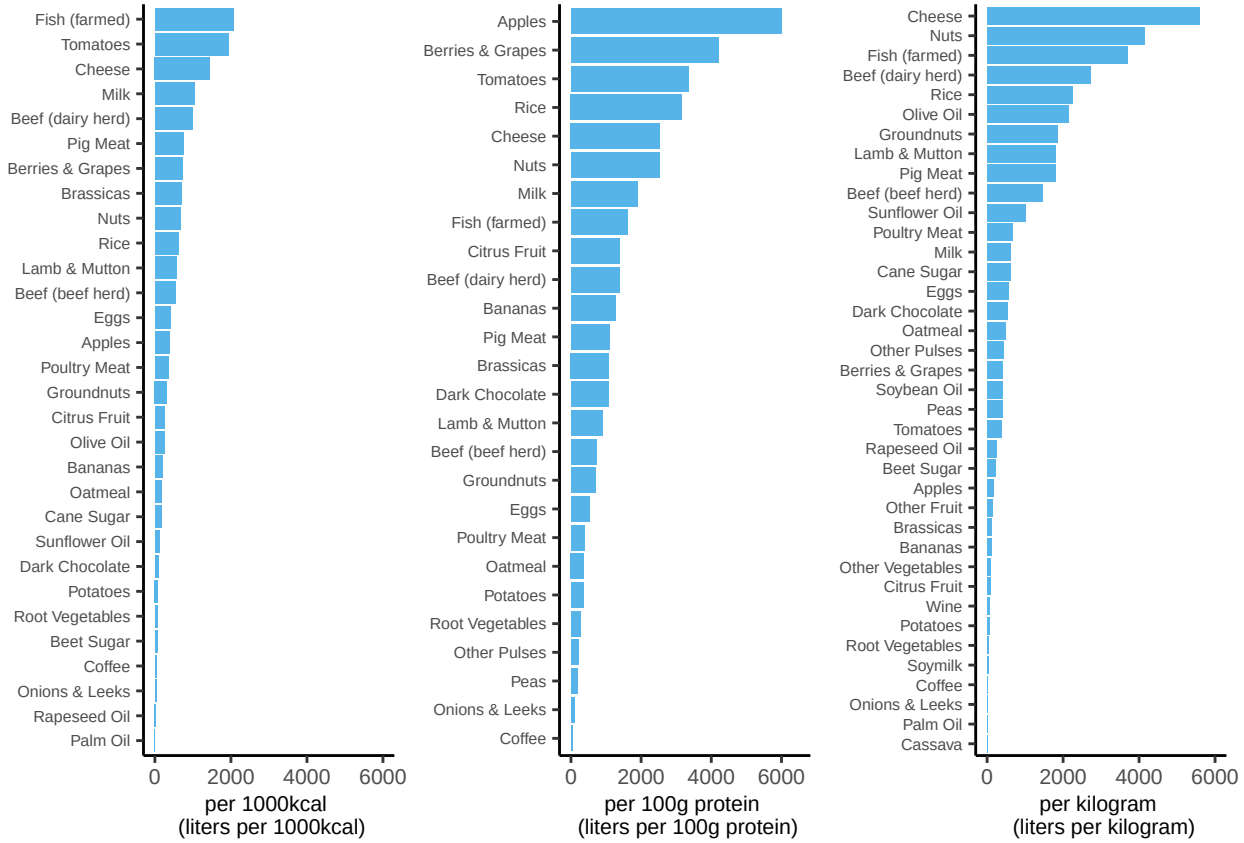

Figure 4: Freshwater withdrawals across food products

Scarcity-weighted water use

GHG emissions

Eutrophying emissions

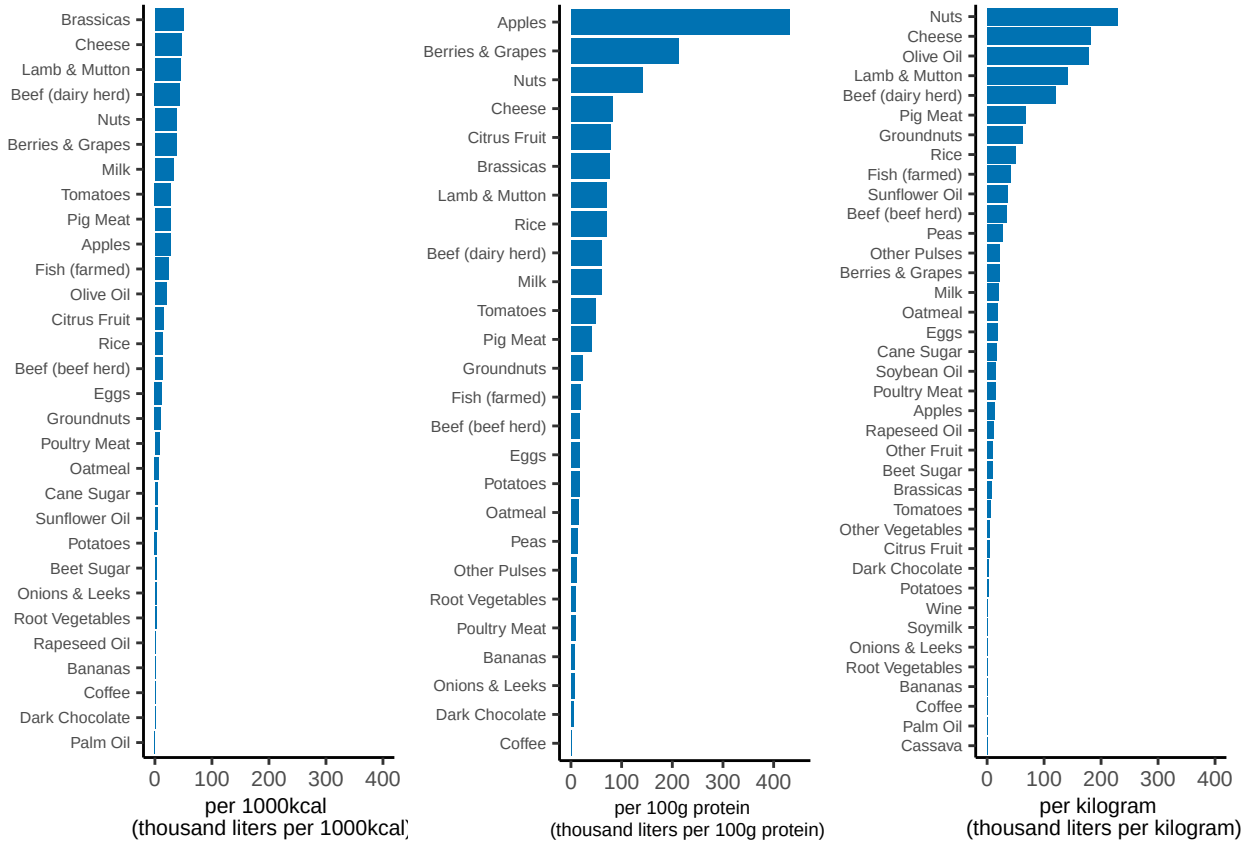

Figure 5: Scarcity-weighted water use across food products

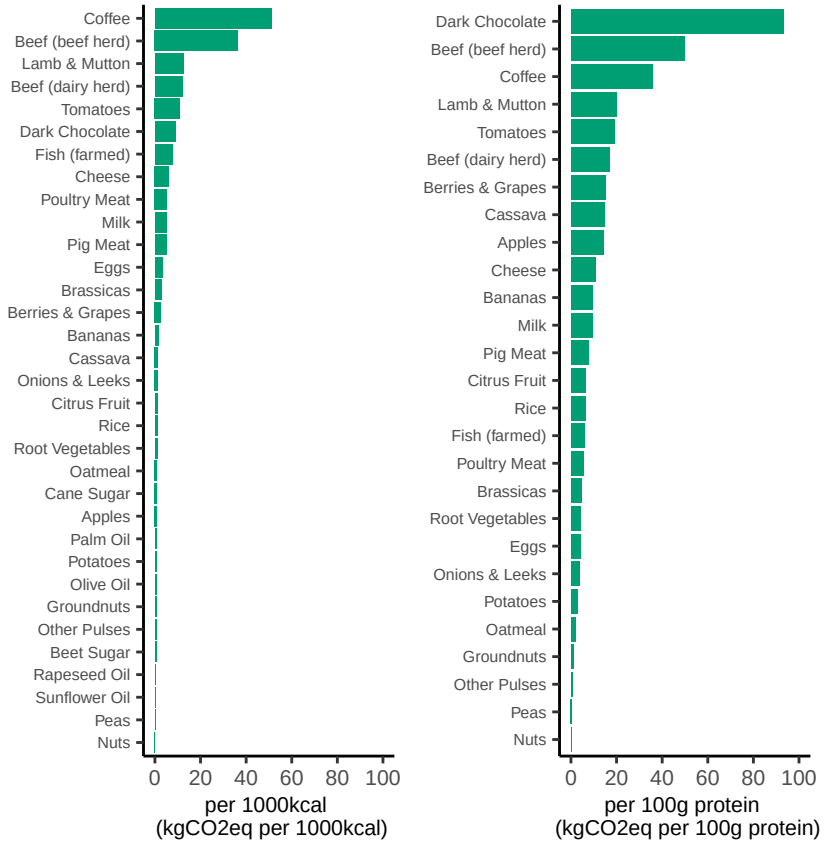

Figure 6: GHG emissions across food products

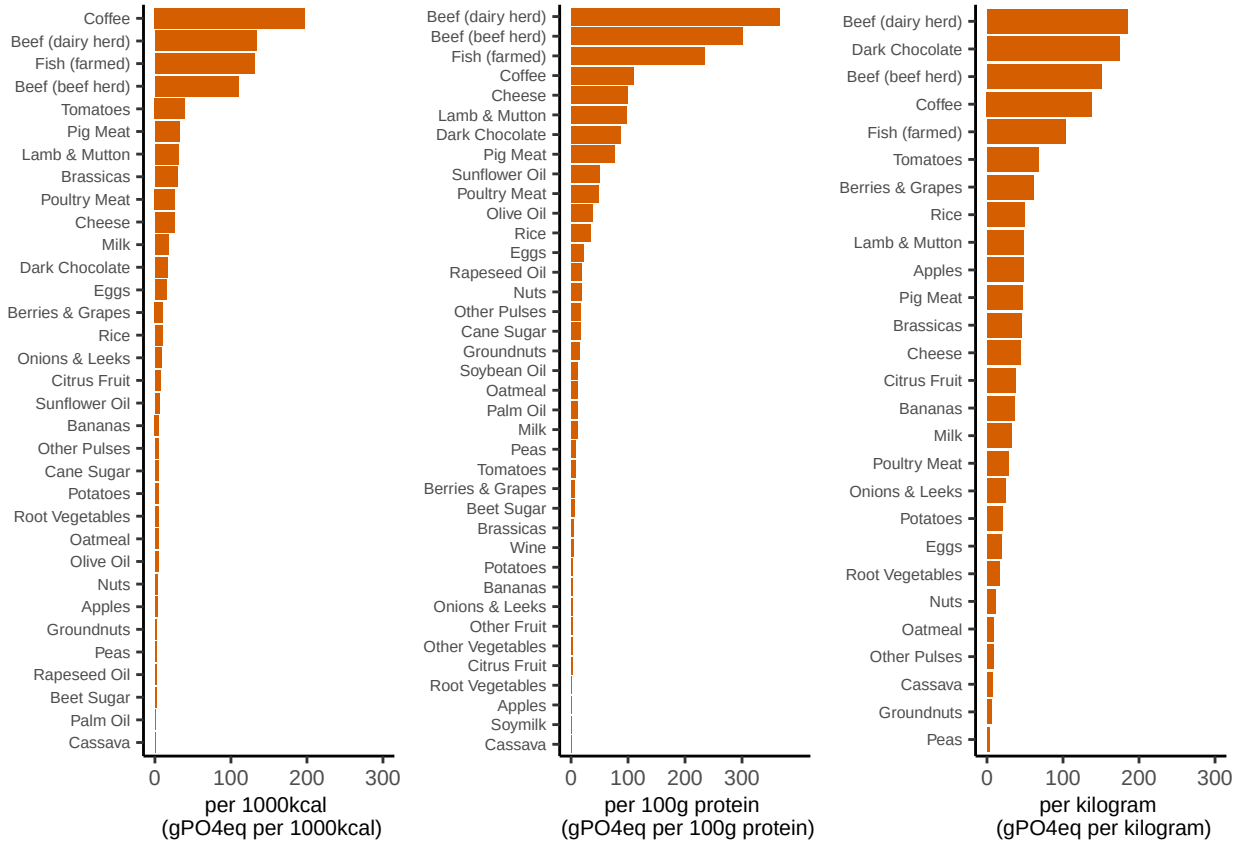

Figure 7: Eutrophying emissions across food products