Environmental impacts of food: variability and potentials for reduction through producers and consumers

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1. Introduction

The global food production is a major driver for environmental impacts [1]. Today's food system occupies 38% of the ice- and desert-free land, causes 26% of greenhouse gas (GHG) emissions, 32% of terrestrial acidification, 61% of freshwater withdrawals, and 78% of eutrophication [2] (these figures exclude agricultural production for non-food purposes).

The growing world population and changing eating habits, notably the increasing consumption of meat and other animal-based foods, lead to increased burden of food supply on the environment [3]. To keep environmental impacts within the platenary boundaries, drastic changes of food production and consumption are needed. To initiatite this process we need a solid decision support, as the knowledge of the environmental impacts of food production and consumption is currently too limited. The present study carries out a meta-analysis, established a harmonized database of environmental impacts of food and shows mitigation options for producers and consumers [2].

2. Materials and methods

Life cycle assessment (LCA) data were derived from 570 studies with a reference year around 2010 [2]. The consolidated database covers ca. 38,700 farms in 119 countries. Five indicators were analysed: land use (land occupation), freshwater withdrawals (and scarcity-weighted freshwater withdrawals), global warming, terrestrial acidification and eutrophication potentials. The data were standardised in several steps by correcting differences in functional units, emission factors, characterisation factors, allocation methods, and system boundaries. Missing life cycle phases were filled by standard data and emissions, and environmental impacts were recalculated, whenever needed. The global totals were validated by comparing with global yield data from FAOSTAT; the deviations were within ±10% for most crops [4]. We scaled the LCA data to the global level using weights. Estimated total arable land, freshwater withdrawals and GHG emissions were consistent with global estimates.

3. Results and discussion

We found a huge variability in impact between different ways of producing the same food [2]. The average ratio of the products with 90th percentile impacts to 10th percentile impacts are about a factor of 4 for global warming and acidification, 6 for land use, 11 for eutrophication and much higher for freshwater withdrawal and stress weighted water use (Table 1). This reveals tremendous differences between producers with high and those with low impacts. This range still covers only 80% of the production, meaning that 20% of producers have even higher or lower impacts. This effect can be seen, if we consider the 95th and 5th percentile (Table 1). These findings point to a large optimisation potential in food production. Even if part of the variability is determined by natural conditions, which cannot be changed easily, a large mitigation potential exists through improved management practices. The huge range of values for freshwater withdrawals is mainly due to the differences between rainfed and irrigated agriculture. The effects are even stronger for stress-weighted water use, since dry regions tend to have a high need for irrigation and simultaneously a high water stress.

The analysis showed that different producers require different ways to reduce their impacts; no universal solutions exist [2]. Low impact producers come from different countries, have different production systems and the sources of emissions and impacts differ as well. Nine mitigation strategies were explored using studies evaluation practice changes in the same location and year. Only two strategies, namely diversifying cropping systems and improving degraded pasture showed simultaneous improvements in both, land use and global warming. All other practices showed trade-offs. In general trade-offs between environmental impacts were frequent. To define a mitigation strategy, a detailed analysis of each production system in its context is therefore indispensable.

	Land Use	Global warming potential	Terrestrial Acidification potential	Eutrophi-cation potential	Freshwater withdrawals	Scarcity-Weighted Water Use
Ratio 90th to 10th percentile	6.0	4.3	4.0	11	840	5500
Ratio 95th to 5th percentile	12.9	7.8	5.5	15	280	8200

Table 1: Average range of environmental impacts of 40 food product groups. Negative and zero values were excluded.

A further observation is that the distributions of environmental impacts are highly skewed [2]. Between 40 and 50% of the impacts are caused by the 25% of the producers with highest impacts for land use, global warming, terrestrial acidification and eutrophication. This is even more pronounced for water use, where the the production of 5% of the food calories cause ~40% of scarcity-weighted water use. Improving the production of these producers or abandoning production methods and locations with the highest impacts is therefore a very effective mitigation strategy.

The challenge to reduce the environmental impacts of the food system is too big to be met by food producers alone, furthermore, there are natural limits in the production systems. Therefore, we need also to consider food consumption. As shown above, an effective strategy is to avoid products with high environmental impacts. The prerequisite is that the environmental impacts of individual food products are known, which is currently not the case.

The comparison between food groups shows that animal-based food products have higher environmental impacts compared to plant-based alternatives, considering the main nutritional role, namely the delivery of proteins [2]. Even producers of meat, dairy products, eggs and seafood with low impacts (10th percentile) have higher impacts that plant based alternatives, such as legumes or nuts. The potential mitigation effect of changing diets was assessed in two scenarios. In the first scenario, animal-based foods were completely replaced by plant-derived alternatives. This resulted in halved impacts for global warming, acidification and eutrophication from food, a ~75% reduction in land use and a ~25% reduction in food's water use. Higher mitigation effects could be achieved in countries with high meat consumption. In the second scenario, 50% of animal-based food products were replaced by plant-based alternatives by avoiding the producers with the highest impacts. This synergistic effect allowed to achieve about two-thirds of the mitigation potential of the first scenario. The various effects of such changes need further investigation, but it is clear that the mitigation potential in food consumption is large.

To improve production and consumption we need to evaluate the environmental impacts of production, to set impact targets and offer the producers diverse options to achieve these targets. The environmental impacts should then be communicated along the value chain to processors, retailers and finally to consumers, so that the different stakeholders can choose products with low environmental impacts.

4. Conclusions

This meta-analysis of food LCA studies showed that a large variability exists between producers of the same product indicating substantial mitigation opportunities. Different producers require different approaches to reduce their impacts; no universal solutions exist. Furthermore, trade-offs between different environmental impacts have to be taken into account. The impact distributions are hightly skewed, with 25% of the producers causing about half of the environmental impacts. Consumers can mitigate environmental impacts by reducing their consumption of animal-based food and by avoiding products with high environmental impacts. To achieve these improvements, better information on the environmental impacts must be made available and communicated along the value chain.

5. References

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