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LETTER

Environmental impacts of food trade via resource use and greenhouse gas emissions

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Abstract

Agriculture will need to significantly intensify in the next decades to continue providing essential nutritive food to a growing global population. However, it can have harmful environmental impacts, due to the use of natural and synthetic resources and the emission of greenhouse gases, which alter the water, carbon and nitrogen cycles, and threaten the fertility, health and biodiversity of landscapes. Because of the spatial heterogeneity of resource productivity, farming practices, climate, and land and water availability, the environmental impact of producing food is highly dependent on its origin. For this reason, food trade can either increase or reduce the overall environmental impacts of agriculture, depending on whether or not the impact is greater in the exporting region. Here, we review current scientific understanding of the environmental impacts of food trade, focusing on water and land use, pollution and greenhouse gas emissions. In the case of water, these impacts are mainly beneficial. However, in the cases of pollution and greenhouse gas emissions, this conclusion is not as clear. Overall, there is an urgent need for a more comprehensive, integrated approach to estimate the global impacts of food trade on the environment. Second, research is needed to improve the evaluation of some key aspects of the relative value of each resource depending on the local and regional biophysical and socio–economic context. Finally, to enhance the impact of such evaluations and their applicability in decision-making, scenario analyses and accounting of key issues like deforestation and groundwater exhaustion will be required.

Introduction

Agriculture—growing crops and raising livestock—provides essential nutritive food, as well as employment and economic return, in particular when commodities are traded domestically or internationally. However, it can negatively impact the environment through the use of natural (water, soil, land) and synthetic (fertilizer, pesticides, herbicides, etc.) resources, which alter the water, carbon and nitrogen cycles, and threaten the fertility, health and biodiversity of landscapes. Due to the spatial heterogeneity of resource productivity, farming practices, climate, and land and water availability, the environmental impact of producing food is highly dependent on the location of production. Trade can thus either increase or decrease the overall environmental impacts of agriculture, depending on the relative impacts in the importing and exporting region.

Because essential resources required for food production are largely immobile (e.g. water and land), agriculture is only possible in certain places. Trade thus allows people to live and access food in more places, and with greater diversity and quantity (Porkka *et al* 2013, D'Odorico *et al* 2014). The history of civilization and development shows the importance of trade in population and socio–economic growth. By moving food from its production to consumption places, trade facilitates growth but also distances consumers from the potentially damaging environmental impacts of agriculture (D'Odorico *et al* 2010). An economic solution to this problem would be to account for environmental damages in food prices (i.e. internalize externalities), but this is challenging due to equity issues across countries and groups with varying financial capacities, and tendency for unilateral, rather than multilateral policies. These economic and political considerations are the object of many studies (e.g. Barrett 1994, Esty 2001, Muradian and Martinez-Alier 2001) and will not be discussed here. Instead, we focus on work that has attempted to quantify the role of food trade in the environmental impacts of agriculture. Importantly, unlike the impact of food production, the overall impact of food trade is assessed by comparing relative impacts between trading partners. In the case of water, the impact of trade on global water use is considered beneficial if the exporter's water-productivity is higher than that of the importer, whereas the impact of both countries' production declines when any of the two countries' water productivity improves.

Food systems are becoming increasingly global, as trade is facilitated by better communication technology, global governance, trade agreements, etc. With the world population projected to reach 9 billion in this century, the challenge to feed the planet with already pressured natural resources is particularly difficult. Boosting agricultural production while minimizing environmental impact is indeed one of the major challenges of the 21st century (Global Food Security Programme 2015). As trade plays an increasingly important role in the world's food supply, and will be crucial for achieving global food security, it is essential to understand its effects on the environment and resource productivity, both key factors for sustainability.

A growing body of literature has been developed to answer the major research question of whether or not trade alleviates the environmental impacts of the global agricultural system. These impacts are multiple, such as resource depletion, pollution, climate disturbance, and biodiversity reduction. In this review paper, we highlight findings about the effects of food systems' globalization on agriculture's environmental impacts via resource use and greenhouse gas emissions. We present the current state of knowledge in the critical issue of the environmental impacts of food trade, and pinpoint key research directions ahead toward an improved understanding of this major global phenomenon.

Water resources

The agricultural sector is responsible for 70% of global freshwater withdrawals, with even larger shares in Asia and Africa (FAO 2011). In addition, irrigation drives 90% of global freshwater consumption (Hoekstra and Mekonnen 2012). This makes agriculture and food systems management crucial for water resources strategies. While mostly rainfed (80% of cultivated land in 2009, (FAO 2011)), global food production importantly relies on productive irrigated fields, with 40% of the global food supply produced with irrigation (WWAP 2014), and as much as 80% of food production in Pakistan, 70% in China and over 50% in India. Irrigation water sources, referred to as 'blue water', include surface and groundwater, from river flow to reservoirs and deep aquifers, each type presenting a different opportunity cost, availability over time and space, and renewal rate. In particular, non-renewable aquifers are increasingly overexploited in large food baskets of the world, like the California Central Valley, central USA, the North China Plain, Northern India and Pakistan (Wada *et al* 2010, Famiglietti 2014). As a highly significant issue for global, sustainable water and food security, the consumptive use of water resources for agriculture has been the focus of a vast array of research. This section focuses on the environmental impact of food trade on freshwater availability via agriculture's water resources use.

Water resources are unevenly distributed on the planet. In some regions, while population grows and diets shift toward water-intensive products like meat, water resources are placed under increased pressure, leading to water and food security issues (Dalin *et al* 2012, 2014). Besides, many areas of the world are expected to suffer increasingly frequent and intense droughts under climate change, which will strain water resource use in agriculture even more and potentially lead to crop failures (Field *et al* 2012). However, other regions have abundant water resources, prosperous agriculture and might slightly benefit from climate change in terms of crop yields (Parry *et al* 2007). Thus, among different strategies to increase agricultural water-use efficiency (e.g. mechanization, water-saving irrigation, fertilizers), trade of water-intensive food products, or virtual water trade, is a way to improve global and regional water-use efficiency by virtually transferring water resources from more to less water-productive areas.

In recent decades, the amount of water embedded in traded food has been modeled, estimated, quantified and analyzed, at different temporal and spatial scales. The water efficiency of trade, reflecting whether commodities flow from relatively more water productive areas to less productive ones, has been the main way to assess the impact of food trade on water resources use. The concept of global water savings has been defined, for a specific trade relationship, as the weight of commodity trade multiplied by the difference between the exporting country's water productivity and that of the importing country (Chapagain *et al* 2006). In other words, global water savings due to an international trade relationship represent the difference between the volume of water actually consumed by the exporter and the volume that the importer would consume if it produced the food domestically. The emerging conclusion from diverse papers is that much water resources are saved from trade, including irrigation water (de Fraiture *et al* 2004, Oki and Kanae 2004, Chapagain *et al* 2006,

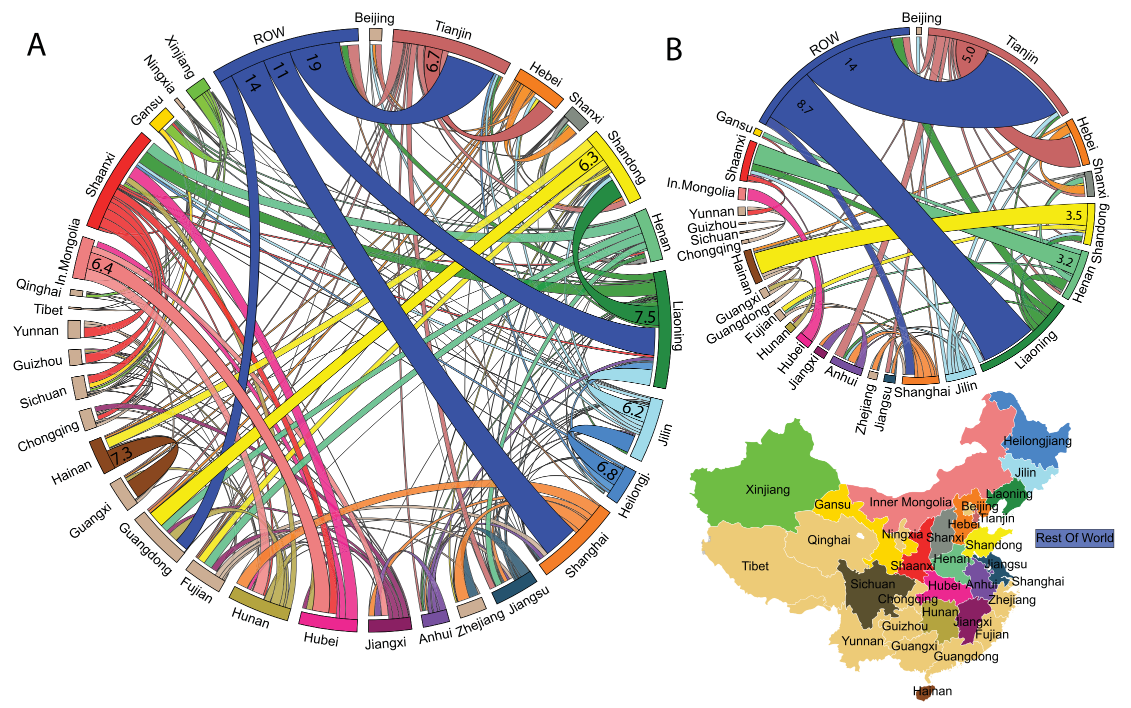

Figure 1. Virtual water trade between Chinese provinces and the rest of the world (ROW) (A), and associated positive global water savings (B). Numbers indicate the volume of water in cubic kilometers per year, and the link's color corresponds to the exporting province. The map at the bottom right provides a key to the color scheme. Note that the largest water saving links are foreign imports by Tianjin and Liaoning, and exports from Shandong to Hainan. Taken from Dalin *et al* (2014).

Yang *et al* 2006, Konar *et al* 2011, Dalin *et al* 2012, Konar *et al* 2012).

Chapagain *et al* (2006) estimated virtual water trade flows associated with 285 crop and 123 livestock commodities around the year 2000 and found they induced global water savings of 352 km^3 yr^{-1}. Dalin *et al* (2012) provided a temporal analysis of embedded water in trade of 58 staple crop and livestock commodities from 1986–2007, and found that the corresponding global water savings significantly increased over this period, from about 50 to 250 km^3 yr^{-1}. Most savings are induced by sizable and water-efficient trade of wheat and corn, while relatively more water-efficient but smaller trade of meat products contributed about a third of savings; similar contributions are found for year 2000 by Chapagain *et al* (2006). Dalin *et al* (2012) highlight that volume of trade significantly grew on existing water-efficient links, particularly on the importing link between China and its major soybean trade partners: Brazil, Argentina and the USA. Because of large differences in soy water productivity between China and its partners, Chinese soy imports were found to induce very large water savings. These findings led to a spatially detailed study of China's virtual water trade (figure 1(A), (Dalin *et al* 2014, 2015)), showing that most associated water savings are due to foreign imports (figure 1(B)). The lower number of commodities studied by Konar *et al* (2011) and Dalin *et al* (2012) explains the different overall volume of virtual water trade (i.e. 625 km^3 in Konar *et al* (2011) and about 1,250 km^3 in Chapagain *et al* (2006), with about 400 commodities) and corresponding savings between the studies. However, the proportions of water saved relative to water used in agriculture in both studies are comparable (i.e. 4% in 2000 in (Dalin *et al* 2012) and 6% in (Chapagain *et al* 2006)). These results imply that food trade favors efficient allocation of water resources, as places with higher productivity tend to produce and export to less productive ones, thus reducing overall water consumption.

While the aggregate water efficiency of international food trade is consistently shown across a number of studies, this pattern can shift when focusing on specific countries, trade links, commodities or types of water (Dalin *et al* 2012, Konar *et al* 2012, Konar and Caylor 2013). An important case is that of China, where Dalin *et al* (2014) highlight inefficient food trade links across Chinese provinces, originating from drier, less water-productive provinces like Inner Mongolia. Other authors also point out trade links that contribute to groundwater extraction, by analyzing food exports produced with water resources from threatened US aquifers (Marston *et al* 2015). Importantly, the water efficiency of trade as measured by savings is an informative, but not holistic measure of trade's impacts on water resources. Indeed, agricultural systems that are currently highly productive can also be unsustainable. For example, much irrigation is based on non-renewable sources (Wada *et al* 2012), including that in productive fields of the Western and Central USA. Notably, water resources can hardly be displaced across river basins, and thus water scarcity is a basin-level indicator. As a result, the 'value' of water varies across basins according to the local water scarcity. For this reason, indicators should account for these differences when comparing countries' productivity. Separating water by source is an initial step, but more needs to be done to assess the impacts of food trade on global water scarcity (Chapagain *et al* 2006). Some regions are productive but rely on the intensive use of scarce resources (e.g. South Africa, USA High Plains, etc.). In addition, some regions are cultivated unsustainably and with low productivity because of other concerns, like food self-sufficiency, employment, local and regional subsistence, political reasons and economic constraints. Recent work by Yano *et al* (2015) develops a water unavailability factor to inform on the local water resources context according to different types of water, based on their renewal rates. This allows not only for a consistent conversion across water sources (instead of summing all volumes), but also for an accounting of the local water scarcity.

Land and soil resources

As global demand for food rapidly increases due to population growth and changing diets, pressure for agricultural expansion leads to more land clearing and conversion to cropland or pasture, sometimes including deforestation of productive tropical areas. These land use changes can have important impacts on the environment, by releasing stored carbon, fragmenting species habitat, and altering the hydrological cycle, among others. Agricultural practices also impact ecosystems via the use of fertilizers, pesticides and other chemicals that can infiltrate soils and water streams, potentially leading to pollution or eutrophication. Here we will discuss work on land use and land use change for agriculture, and on the use of nitrogen (N) and phosphorus (P) fertilizers as potential pollutants around and downstream of fields. Emissions of greenhouse gases from agricultural activities, including nitrous oxide, are treated in the next section. Other environmental issues associated with using nutrients, such as depletion of phosphorus reserves (Cordell *et al* 2009) or impact of the N and P physically embedded in foods (Grote *et al* 2005), and soil salinization from irrigation in dry areas (Pitman and Läuchli 2002), are not discussed here. This section focuses on the environmental impact of food trade on land availability and environmental quality via agriculture's land use and N and P surplus.

In the past decade, deforestation rates have been slightly decreasing in Brazil, and have significantly increased in Indonesia, Malaysia, Paraguay, Bolivia, Zambia, Angola, Papua New Guinea and other tropical areas (Hansen *et al* 2013). In Indonesia and Malaysia, forests have been cleared mainly for palm oil production (Koh *et al* 2011, Carlson *et al* 2013), primarily destined to international markets. Important land clearings and conversions also occurred in the Brazilian Amazon, and deforestation in the early 2000s has been linked to export-oriented meat and livestock feed production, with much of the cleared forests used for pasture and soybean (Morton *et al* 2006). In these cases, access to global markets via trade evidently boosted forest clearings. However, tropical agriculture can be done in more sustainable ways. Export-oriented deforestation has been studied in Brazil and other tropical regions by De Fries *et al* (2013), highlighting the driving force of international food demand and analyzing how the relative success of Brazil at slowing down deforestation could be repeated in similar regions. This success was enabled by governance and technical monitoring capacity put in place to control deforestation in the mid 2000s. Hansen *et al* (2013) point out that although the short-term decline of Brazilian deforestation is well documented, changing legal frameworks governing Brazilian forests could reverse this trend. The effectiveness of Indonesia's recently instituted moratorium on new licensing of concessions in primary natural forest and peatlands, initiated in 2011, is yet to be determined. Lambin and Meyfroidt (2011) highlight the importance of understanding land change as part of global, open systems to design policies allowing both agricultural development and nature conservation in tropical regions.

The role of agricultural trade in the global area of land used for agriculture (or 'virtual land trade') has been analyzed by Meyfroidt *et al* (2010, 2013). Trade was found to transfer varying areas of cropland globally depending on estimation methods (Kastner *et al* 2014), which resulted in overall saving or losses of land area, depending on trade data used: either from multi-regional input–output (MRIO) methods or via bilateral trade datasets (e.g. FAOSTAT). The authors find these differences are most likely due to MRIO using aggregated products classes, and using land intensity per unit crop value, rather than per unit crop mass, as done by other accounts, while large price differences can exist for the same food commodity of varying quality. This suggests trade accounts based on mass are more appropriate to evaluate transfers of embedded land. Fader *et al* (2011) compared water and land transfers via agricultural trade and found that it has led to savings for both resources (i.e. 263 $km^3\ yr^{-1}$ and 41 Mha yr^{-1}, respectively). Soybean and maize contribute the most to land savings, suggesting trade of soy-based feed may be land efficient. They emphasize the fact that flows and savings of virtual water and land need to be analyzed together because they are intrinsically related. Indeed, water productivity correspond to a water flow per land area (evapotranspiration) divided by crop yield per land area. The crop yield per land area is exactly what could be called the 'land intensity' of agriculture. When comparing land intensity of crops, it is important to

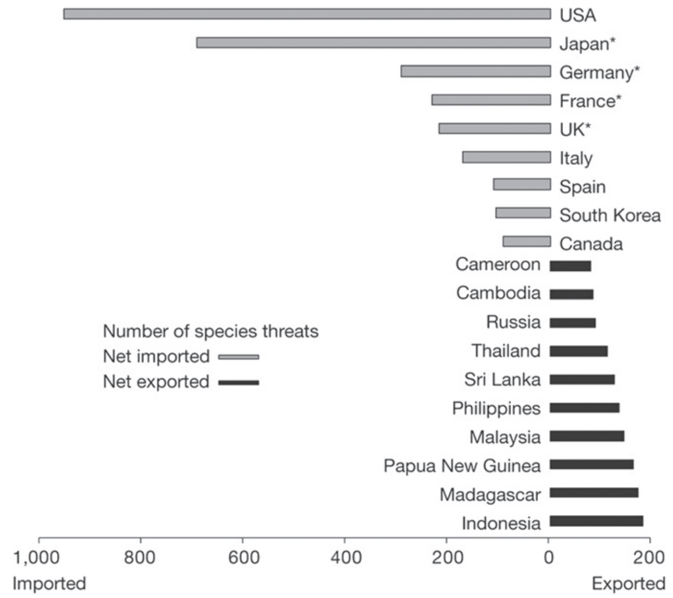

Figure 2. Top net importers and exporters of biodiversity threats. In importer countries marked with an asterisk, the biodiversity footprint rests more abroad then domestically; that is, more species are threatened by implicated imports than are threatened by domestic production. Taken from Lenzen *et al* (2012).

note that boosted yields have often come at the cost of more nutrient and chemical surplus (Drinkwater and Snapp 2007).

Land clearings and pollution from chemicals are also threatening biodiversity, due to habitat loss or fragmentation, and ecosystem disturbance. Lenzen *et al* (2012) have shown that trade contributes to biodiversity threats, especially in developing nations. Figure 2, from their study, highlights countries where more species are threatened by imports than by domestic production, including Japan, Germany, France and the UK. Similarly to tropical deforestation, biodiversity threats are often higher in mid latitudes, developing countries, where specific food commodities are produced for export to higher latitudes, more developed countries that do not have a suitable climate to make these commodities (e.g. palm, cocoa, bananas). Thus, even though overall land productivity seems higher in exporting nations than importing ones (Fader *et al* 2011), specific frameworks are required to mitigate biodiversity loss and forest threats due to commodity specific South–North trade. Some of such frameworks are currently in place, for example for soybean and palm oil.

Pollution from chemical application (nutrients, pesticides, herbicides, etc.) impacts soils, aquifers and rivers. The influence of agricultural trade and livestock production on the global phosphorus (Schipanski and Bennett 2012) and nitrogen (Lassaletta *et al* 2014) cycles are also of great importance. Lassaletta *et al* (2014) state that 'At the global scale the system is becoming less efficient because of the disconnection between crop and livestock production across specialized regions, increasing the environmental impacts'. Schipanski and Bennett (2012) found efficient trade in terms of phosphorous at the global scale but note a variety of issues related to the depletion of fertilizer resources and recycling difficulties. The authors note that trade of feed crops, particularly soybeans, increasingly contribute to global P transfers, but no conclusion is drawn on its effect on global P use. A model estimating the land, water and nitrogen inputs of meat and feed production was used to evaluate the virtual flows of these resources through trade (Galloway *et al* 2007). While pointing out important remaining improvements required in nitrogen use efficiencies, Galloway *et al* (2007) do not compare these values across trading partners. The agricultural pollution embedded in trade has been quantified by O'Bannon *et al* (2013), who highlight that increasing amounts of water pollution by nitrogen are traded globally, measured by the concept of 'gray water', i.e. volume of water needed to dilute river and aquifer pollutants to acceptable concentrations. However, conclusions are not clear regarding the efficiency of this process, i.e. whether or not pollution is avoided by trade. This important issue also needs to be studied and quantified at regional scales, as multiple studies point out that current trade contributes to concentrated N pollution impacts in exporting regions (Galloway *et al* 2007, Schipanski and Bennett 2012, O'Bannon *et al* 2013, Lassaletta *et al* 2014). Moreover, the estimation of local effects of N and P applications require to evaluate nutrient surplus, based on input and crop intake, as well as to improve the quantification of local rates of leaching to soil and streams.

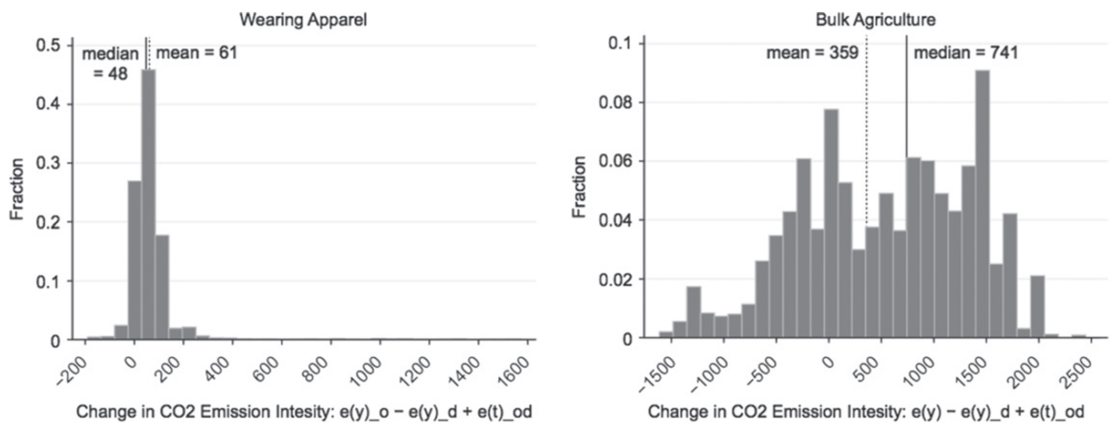

Figure 3. Net change in CO_2 emissions for trade in the wearing apparel (left) and bulk agriculture (right) sectors, i.e. emissions from transportation $(e(t)_{od})$ and difference between emission intensities of the origin $(e(y))$ and destination country $(e(y)_d)$, representing the increase or decrease of global emissions via a specific trade link. The units are in grams of CO_2 equivalent per dollar. The histogram weights each change in CO_2 emission intensity by the value of trade corresponding to that origin–destination–sector pair. Taken from Cristea *et al* (2013). Note that the carbon efficiency of agricultural trade significantly varies across trade links (i.e. country pairs).

Climate system

Fertilizer application, livestock management and land use change induce emissions of greenhouse gas, with varying intensities depending on the agricultural practices and types of land cleared. Land use change can also affect the hydrological cycle by modifying evapotranspiration, infiltration and discharge patterns. This section focuses on the potential environmental impact of food trade on the climate via agriculture's greenhouse gas emissions.

The major agricultural sources of greenhouse gas emissions are agricultural soils, agricultural waste burning, enteric fermentation and manure management. These processes mainly emit methane and nitrous oxide. Agriculture contributed 70% of global nitrous oxide emissions in 2010, mainly from synthetic fertilizers, animal waste dropped on soils (either as animal manure or by animals during grazing) and agricultural waste burning (IEA report http://edgar.jrc.ec.europa.eu/docs/IEA_PARTIII.pdf p 4). Studies of the impact of food production and trade on greenhouse gas emissions take a similar approach as studies on embedded water use, where water productivity (kg_{water}/kg_{food}) is replaced by carbon equivalent (CO_2^{eq}) intensity of products $(kg_{CO_2^{eq}}/kg_{food})$. But unlike water consumption, carbon emissions occurring during transportation can be significant and sometimes offset the emission avoided from trade due the carbon intensity differences between partners. Despite this, emissions from transportation have rarely been included. Davis and Caldeira (2015) quantified CO_2^{eq} emissions embedded in trade of goods and services and Caro *et al* (2014) calculated direct methane and nitrous oxide emissions (from enteric fermentation and manure) embedded in international trade of meat products. The latter do not provide a comprehensive assessment of the impact of meat trade on emissions for meat production (i.e. whether meat trade increases or decreases global emissions), but highlights some links where additional emissions occur with trade, due to different emission intensities of trade partners. Importantly, the authors note that carbon dioxide emissions associated with transport are not accounted for. In a study of world trade and its role on greenhouse gas emissions, Cristea *et al* (2013) account for emissions related to both food production and transportation. The authors note that agricultural products are often shipped with the least emission intensive transport mode (e.g. cargo) which makes transportation emissions very small relative to other modes. By adding on each trade link the transportation emissions (positive) and the difference in emission intensities between exporter and importer (positive or negative), Cristea *et al* (2013) find that trade of bulk agriculture (i.e. raw crops) reduces emissions in 41.6% of the trade flows (i.e. trade links from a specific country to another), in many cases substantially, due to a difference in emission intensities overcoming transportation emissions. However, the remaining links represent significant increases in emissions, so that the average effect of bulk agriculture trade is to increase emissions by 359 g of CO_2 per dollar of trade (figure 3). The effect of processed agriculture trade (including fruits, meats and dairy products) on global emissions is not provided, but the authors note that this type of trade is more likely to rely on carbon intensive air transport than that of raw crops, thus potentially increasing global emissions further.

Agricultural emissions due to land use change can also be significant, in particular when carbon rich tropical forests are cleared for pasture or cropland. Important contributors to these emissions include palm oil plantations in Indonesia (Carlson *et al* 2013), largely for foreign exports, and Brazilian export-oriented agriculture (Karstensen *et al* 2013). This trade likely contributes to important carbon emissions, given the difference in carbon stocks between tropical forests and most temperate lands. However, comparison of impacts is not obvious because, as previously mentioned, tropical commodities could not be produced domestically by most importers (e.g. Western Europe). Analyzing the differential effect of trade would need another counter-factual to imports than domestic production, e.g. domestic cultivation of substitute commodities, or imports from regions with different land use practices.

Final comments

A range of methods have been applied in the assessment of the environmental impacts of food production and trade, such as life cycle analysis (Roy *et al* 2009), material flow analysis (Kytzia *et al* 2004), mass balance, and systems models. We do not further develop here the methodological issues related to these assessments. However, it is important to point out the role of temporal, spatial and sectoral scales in the estimation of trade flows and resource consumption per unit commodity. A full range of spatial scales (regional, national, geological) play a role in the links between food trade and environmental issues. Aggregation and disaggregation across temporal, spatial and sectoral scales needs to be carried out in a consistent manner and accounting for scale-specific constraints. Importantly, comparison across existing studies of a specific environmental impact of trade (e.g. on water consumption) is limited by the different spatio-temporal scales and product aggregations used.

All the environmental impacts of agriculture reviewed here, in particular pollution, deforestation and biodiversity reduction, can be associated with equity issues. Indeed, Hoekstra and Mekonnen (2012) and O'Bannon *et al* (2013) found that water pollution often occurs in relatively less developed countries exporting to more developed ones. Similarly, biodiversity reduction (figure 2, (Lenzen *et al* 2012)) and deforestation (De Fries *et al* 2013, Karstensen *et al* 2013) are generally linked to South–North trade. Our review of quantitative estimates of the environmental impacts of food trade does not further address potential ethical and fairness questions (developed e.g in (Hornborg 1998)), but we highlight the importance of the perspective taken when estimating trade environmental impacts (e.g. global or regional). We suggest that quantitative estimates of impacts account for varying levels of exposure, such as local resource scarcity and ecosystem fragility.

Research directions

We have highlighted key issues on the environmental impacts of food trade, via land and water use and greenhouse gas emissions, discussing the complexity of these impacts and some difficulties in their estimation. We draw from this discussion three broad recommendations for future research aiming at improving the understanding, accounting and application of the environmental impacts of food trade.

First, the vast majority of studies focuses on one type of environmental effect, namely reduced water availability, global warming, biodiversity threat, etc. In the future, there is a clear need for more comprehensive approaches accounting for the multiple environmental effects of agriculture, and for the creation of consistent global indicators reflecting these effects. As part of such effort, understanding and accounting for the interactions within the water–food-trade-climate system is an important and challenging task going forward.

Second, the role of food trade in alleviating or worsening environmental impacts of agricultural production is often assessed by comparing relative impacts between importers and exporters. For this comparison to be useful and realistic, detailed contextual information, on issues like local resource scarcity, are required. Moreover, approaches to properly account for these contextual issues need to be further developed. In particular, for the impact of water use on water availability, the types of water resource and characteristics of the local hydrological cycle need to be included. For the effect of nutrient use on soil and water quality, the surplus amounts and the properties affecting their rate of transfers to soils, atmosphere and water should be measured and analyzed. To translate this accounting of spatially detailed resource scarcity or ecological vulnerability into trade analysis, it is important to consider subnational trade, especially in large, heterogeneous countries, to avoid loss of information by spatial averaging.

Third, as food production and consumption become increasingly global, accounting for trade linkages is key to track environmental and sustainability objectives in agricultural policy. The resource saving potential of trade is high, especially for water, even though careful attention to each specific trade relationship and local socio–economic context is required to avoid misinterpretations. Research is needed to provide relevant, multi-dimensional information to allow for the accounting of environmental impacts in decision-making. The applicability of research findings on the environmental impacts of food production and trade would be greatly facilitated by approaches focused on the future evolution of the food–environment trade system, such as scenario analyses informed by projected socio–economic and climate change. In addition, more research is needed to improve the accounting and inclusion of key environmental issues such as deforestation, loss of soil fertility and groundwater exhaustion.

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