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Commentary

Cropland area embodied in international trade: Contradictory results from different approaches

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ABSTRACT

With rapidly increasing trade volumes, resource use and environmental pressures related to traded products are high on research and policy agendas. Robust accounts of biophysical resources used in the production processes of traded goods are required to support sustainable consumption and to expose problem shifting related to environmental policies. In this context, multi-region input-output analysis (MRIO) is becoming a widely applied tool to establish consumption-based accounts and to analyse production-consumption links along complex international supply chains. Using the example of China's trade in cropland products and embodied cropland, we make the case for a re-evaluation of its application to land and other resources. While analyses based on physical trade matrices show that China is a major net importer of cropland products and embodied cropland, MRIO-based results suggest exactly the opposite. We do not find convincing arguments that could explain these large differences. Based on our knowledge of land systems and biomass metabolism and on the results from physical accounting, we question the plausibility of MRIO-derived results. We conclude by outlining next steps in research that are required to improve assessments of trade-related resource use in order to produce more robust results, a prerequisite for the formulation of policy recommendations.

1. Introduction: Why Robust Accounts of Resources Embodied in Trade Are Urgently Needed

Globalization and rapidly increasing international trade volumes motivate analysts to complement traditional production-based accounts with consumption-based accounting in order to comprehensively analyze the environmental pressures caused by national consumption (Peters et al., 2012), thereby contributing to a better understanding of teleconnections between producing and consuming regions mediated by trade (Seto et al., 2012). Consumption-based accounts quantify the amount of resource use or emissions associated with final consumption, ideally taking into account national differences in production technology. In contrast, production-based approaches measure resource use and emissions related to production processes on a given territory. At the national level, the difference between production and consumption stems from the resources/pressures associated with internationally traded products. Environmentally extended multi-region input–output analysis (MRIO) is presently considered the most promising tool for deriving consumption-based accounts, thought to be capable of comprehensively capturing upstream requirements and adequately taking regional differences in production structures into account. Wiedmann et al. (2011) provide a concise overview on the method, including recognized advantages and disadvantages. MRIO-based approaches have been widely used to quantify carbon emissions embodied in trade and produced crucial insights into global emission transfers (e.g., Davis and Caldeira, 2010; Hertwich and Peters, 2009; Peters et al., 2011). More recently, interest is growing in applying the method to quantify other resources embodied in international trade, for instance water, land, or materials (e.g., Bruckner et al., 2012; Chen and Chen, 2013; Weinzettel et al., 2013; Wiedmann et al., 2013; Yu et al., 2013).

Two recent global accounts of land embodied in international trade (Weinzettel et al., 2013; Yu et al., 2013), based on MRIO, caught our attention by producing counterintuitive findings, very different from those generated by physical accounts (Fig. 1). Puzzled by these results, we here make the case for a re-evaluation for the application of this method to account for embodied land and associated environmental impacts. We analyze differences in assessments of crop products and cropland embodied in international trade, using the case of China as an example, and discuss possible explanations for the diametrically opposed findings.

MRIO and physical accounting are two different approaches that necessarily yield different results, especially due to MRIO's capability of capturing indirect or upstream biomass flows embodied in the trade of non-biomass products (which are typically omitted in physical accounts). However, as we will argue below, the differences are so large that they do not only result in slight deviations, but result in values of opposite sign. Whereas one approach shows, for China, strong net-imports, the other shows strong net-exports. We do not find convincing arguments that could—conceptually—explain the large differences between

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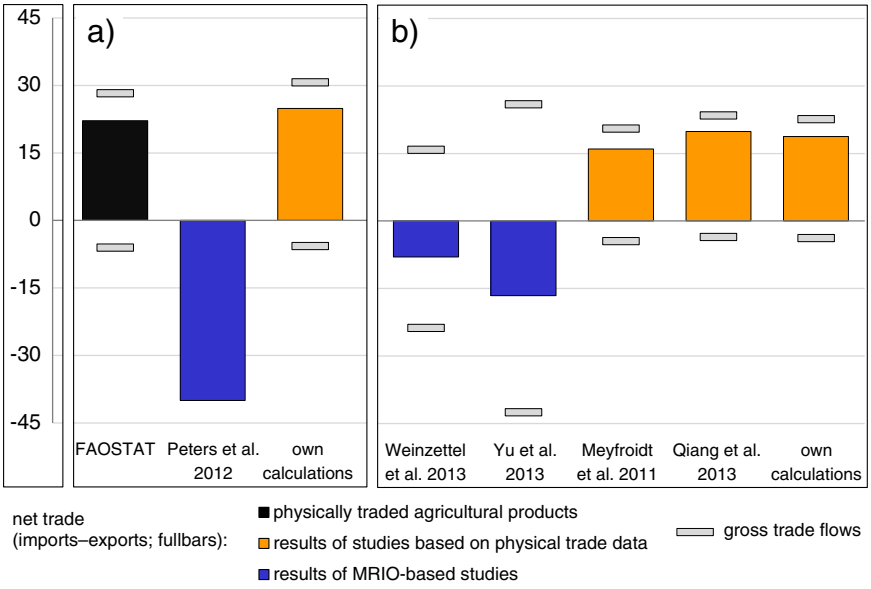

Fig. 1. Range of estimates of (a) crop products (unit: Mt C/yr) and (b) cropland (unit: Mha/yr) embodied in international trade for China in 2004. Production totals for China in 2004 were 275 Mt C/yr crop production and 160 Mha/yr cropland area harvested; all data refer to 2004 except where noted otherwise. Sources: FAO, 2012, converted from fresh weight to carbon; Peters et al., 2012 (GTAP MRIO value from Fig. 12; no gross trade data available); Weinzettel et al., 2013 (extracted from the data supplement and converted from gha into ha); Yu et al., 2013 (extracted from the data supplement, values for 2007); Meyfroidt et al., 2010 (value from Fig. S3); Qiang et al., 2013 (values from Figs. 1–3); own calculations: refer to main text for a short description.

results obtained by the different approaches. Based on our knowledge on land systems and biomass metabolism and on the results from physical accounting, we critically question the plausibility of MRIO-derived results. We call for further analyses (1) to rule out that methodological artifacts could strongly and perhaps systematically influence MRIO results and (2) to better understand and explain the reasons behind the observed differences.

China's foreign trade volumes have soared during recent decades and the country is increasingly seen as the world's production powerhouse. From a per capita perspective, China is poorly endowed with many natural resources, in particular cropland: In 2004, the country's cropland area was 160 million ha (Mha) (area harvested), which translates to a per capita average of 0.12 ha per capita (ha/cap), almost 40% below the global average of 0.19 ha/cap (FAO, 2012). In 2004, China produced crop products containing 275 million tons of carbon (Mt C) on these lands; here the difference to the global average is less pronounced (0.21 t C/cap and 0.26 t C/cap; FAO, 2012) indicating above-average land productivity. A number of published accounts of crop products and cropland linked to China's trade patterns exist, which, along with the nation's central role in the global trade structure, makes the country an excellent case for demonstrating the considerable differences in results obtained by different accounting approaches. We use the year 2004 as reference year, as most results were available for this year.[1]

2. MRIO-based Results vs. Results from Studies Based on Physical Trade Data: Net Trade Flows of Embodied Cropland Change Direction

We compare different estimates of crop products (converted into mass flows of tons of carbon per year) and cropland (hectares of cropland) embodied in China's international trade flows based on two different methodological approaches: MRIO approaches (blue bars in Fig. 1) are based on national input–output data in monetary units. These data depict, at the level of different sectors, direct inputs required (domestic and imports) in order to produce a given level and composition of final demand (domestic and exports). The so-called Leontief inverse, derived from these input–output data, produces coefficients for direct and indirect inputs required by a sector to produce one additional unit of output to final demand. This input–output system can be extended by a matrix of inputs into (e.g., material or land) or outputs from (e.g., emissions) sectors in physical units. This way the physical intensity of each unit of final consumption (e.g., in t/$ or ha/$) can be calculated. The biophysical trade data approach, in contrast, uses physical trade data (orange bars in Fig. 1) and relies on detailed bilateral trade flow matrices of agricultural products. Trade flows are converted into primary crop equivalents using country/region and product specific conversion coefficients (i.e. the amount of cereal used to produce 1 kg of bread or the crop-based feed used to produce 1 kg of pork), taking into account the use of by-products to avoid double counting. Land requirements are then calculated by using country and crop specific yields. It is important to note that both approaches typically use the same physical data for the studied environmental impact (e.g., data on harvested cropland areas from FAOSTAT) and that therefore the global totals should be the same. However, the allocation logic to consuming nations differs between the approaches (see below).

Fig. 1 compares the different estimates of crop products (left side) and cropland (right side) embodied in China's international trade in 2004. The bars represent net trade values, i.e. imports minus exports. The numbers originate from several independent studies and, where available, we include values for gross trade flows. As reference point, we calculated China's net trade balance of agricultural products based on FAO's physical trade statistics (FAO, 2012; converted into megatons (Mt) of carbon using factors from Krausmann et al., 2008, assuming a carbon content of 50% for dry matter biomass). In physical terms China imported 30 Mt C/yr and exported 7 Mt C/yr of agricultural products in 2004 and thus was a net-importer of 23 Mt C/yr of agricultural products.

Two recent studies on cropland linked to China's trade patterns, based on physical bilateral trade data and national crop yields (Meyfroidt et al., 2010; Qiang et al., 2013), concluded that Chinese agricultural trade was related to a substantial net import of embodied cropland (16–20 Mha/yr). The results of our own calculations are in line with these findings. Our results cover embodied crops and cropland associated with international trade flows of 450 agricultural products, including animal products (Kastner et al., 2013). This approach is similar to the two other studies, but the method takes longer transnational

[1] Many MRIO studies rely on version 7 of the GTAP (Global Trade Analysis Project) database (Narayanan and Walmsley, 2008) with the reference year 2004.