Methane emissions embodied in Mediterranean trade of cow's milk

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Countries around the world have experienced noticeable changes in both their economic and social conditions in the last few decades. While most of the economies have grown and socio-economic conditions improved, such improvements have been coupled with fundamental changes in the society–nature relationship, frequently leading to a worsening of the state of our ecosystems (UNEP, 2012).

Per capita food and services consumption has grown during the last four decades (Turner, 2008) and greenhouse gas (GHG) emissions have accumulated in the atmosphere (IPCC, 2013) causing climatic changes and potential negative feedback on the Earth system's health (Tittensor et al., 2014). International agreement is growing on the key role of climate change; moreover, food provision and food security are among the most important issues to be addressed in a planet with a 7 billion and growing population.

In this article we thus aim to debate how food consumption, and especially the consumption of milk throughout the Mediterranean region, influences this global picture.

The global methane issue: a focus on milk production and consumption

Previous studies have quantified carbon dioxide emissions embodied in products traded internationally; however, there has been limited attention to other greenhouse gases such as methane (CH_4). Global CH_4 emissions represent about 21% of total contribution of anthropogenic emissions of greenhouse gases to the enhanced greenhouse effect from pre-Industrial to present (EPA, 2012). Direct emissions of CH_4 from livestock worldwide represent approximately 6% of total anthropogenic GHG emissions (Caro et al., 2014a).

Methane emissions from livestock result primarily from the digestive processes of animals (enteric fermentation that only occurs in ruminants) and the anaerobic decomposition of manure (manure management). About 75% of total CH_4 emissions from livestock comes from cattle (with the remaining 25% coming from pork, buffalos, sheep, goat, camels, mules, asses and poultry) and are expected to increase in the next decades, especially in developing countries (Tubiello et al., 2013).

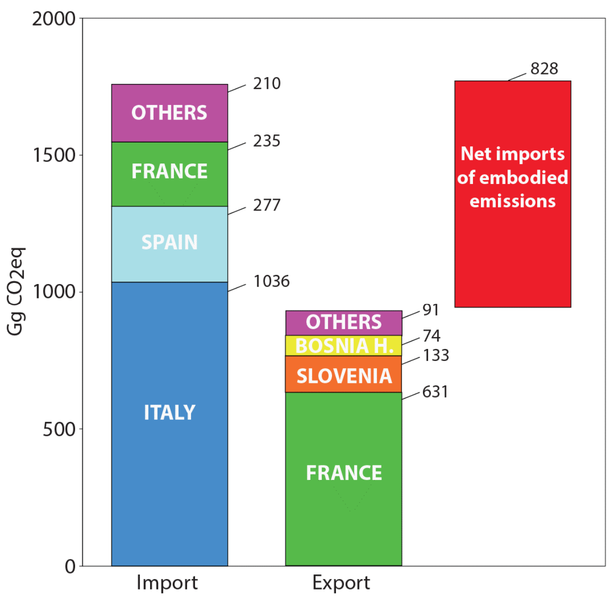
The Intergovernmental Panel on Climate Change (IPCC) has defined a comprehensive method for taking into account greenhouse gases (GHGs) emissions released from livestock sector at regional level (IPCC, 2006). However, the geographical or producer-based perspective currently used in the IPCC framework does not consider delocalization of production and the effect of international trade, thus allocating responsibility for emissions associated with livestock products consumed in one country but produced elsewhere, exclusively to the producing countries. For example, if milk is produced in France and then exported in Italy, how should emissions be allocated: to France as producer country or Italy as the consumer country? This crucial choice determines the results of the GHG inventory and the associated policy implications (Bastianoni et al., 2014).

The Mediterranean region has continuously represented an ideal setting for intricate patterns of trade, since historic times. Nowadays, trade in Mediterranean Sea is still of a strategic importance for maintaining economic and social equilibrium in this region. Recent studies have indicated that the Mediterranean's dependence on trade has continuously increased over the last three decades (e.g., Galli and Halle, 2014) and that by 2010 the Ecological Footprint embedded in net trade imports accounted for 30 percent of the region's Ecological Footprint (Galli et al., 2015).

Using an assessment framework presented in Caro et al., (2014b), here we estimate the total methane emissions embodied in the trade of cow milk across the Mediterranean region[1], for the year 2012. Cow milk is the primary product of dairy cattle: globally, 635 Mt of cow milk were produced in 2013, increasing by 102% with respect to 1961's levels (FAO, 2015). Moreover, according to Gerosa and Skoet, (2012), in the last two decades, increase in milk consumption in developing countries (2% growth per year), has significantly outpaced that of developed countries (0.1% growth per year), highlighting country-level differences. The emissions due to consumption are estimated by allocating emission embodied in trade to country on the basis of consumers' demand for milk. We use a bilateral trade approach to estimate emissions of CH_4 embodied in the international trade of cow milk. Quantities of imported and exported milk for each country are drawn from FAO trade data (FAO, 2015). Although this analysis focuses on the Mediterranean area, 177 countries are analyzed in our model to account for both interregional trade activities as well as trade with countries outside of the Mediterranean region. Methane emissions are expressed as carbon dioxide equivalent (CO_2-eq) emissions using IPCC global warming potential values (IPCC, 2013).

We found the Mediterranean region to be a net milk importer and emissions due to the import of milk (1758 Gg CO_2-eq) into the region to be higher than emissions due to milk export outside the region (930 Gg CO_2-eq) in 2012, resulting in 828 Gg CO2-eq of net imports of embodied emissions (see Fig. 1). Dairy cattle emissions represent a large share of anthropogenic GHG emissions in Mediterranean regions. The substantial milk-related methane emissions embodied in Mediterranean trade (Fig. 1) indicates that the emissions related to increasing consumption of milk are disconnected in space from the point of consumption. The largest Mediterranean importers of milk-embodied CO_2-eq were Italy (1036 Gg CO_2-eq), Spain (277 Gg CO_2-eq) and France (235 Gg CO_2-eq). These three countries represented about 88% of total milk-related emissions imported from Mediterranean countries. Figure 1 shows that, in the same year the largest Mediterranean exporters were France (631 Gg CO_2-eq), Slovenia (133 Gg CO_2-eq) and Bosnia Herzegovina (74 Gg CO_2-eq). This spatial disconnect between production and consumption represents a challenge for regional or national policies that regulate dairy cattle emissions in Mediterranean countries, because all existing policies neglect the role of emissions embodied in trade.

Figure 1
Total milk-related methane emissions imported and exported from/to the Mediterranean region, in 2012.



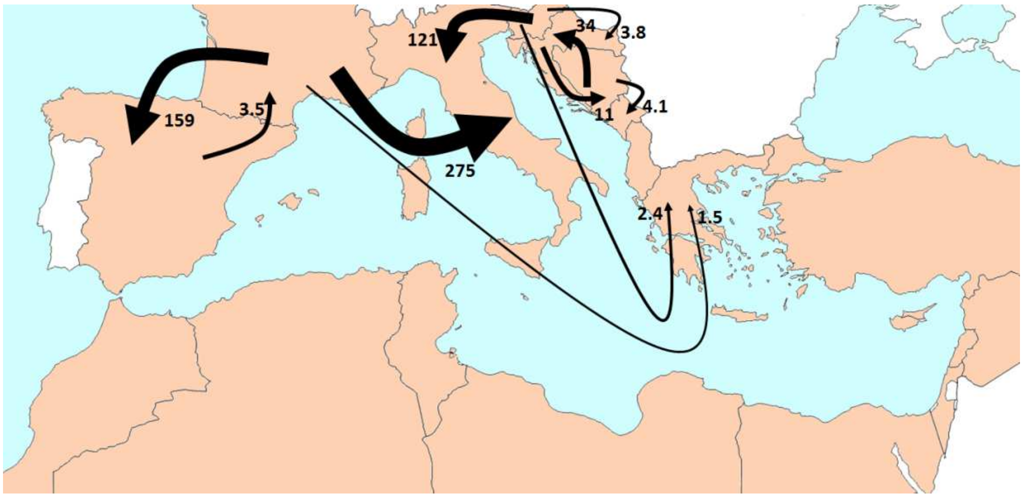
The total milk-related methane emissions embodied in Mediterranean trade is showed for comparison purposes

The main drivers of these amount of emissions embodied in the milk traded in and out of the Mediterranean region are i) the volume of milk traded and ii) the emission intensity associated with exporter/producer country. Emission intensities (dairy cattle emissions per ton of milk produced, see Caro et al. 2014b for more details) are dependent on where and how livestock is raised, produced and finally exported as milk. Figure 2 highlights the largest Mediterranean fluxes of milk-related methane emissions embodied in trade in 2012. The dominant global fluxes are the export of emissions embodied in milk from France to Italy and Spain, and from Slovenia to Italy. Milk exported to Italy embodied 396 Gg of CO_2-eq emissions, of which 275 Gg CO_2-eq were imported from France (70% of total emission imported from Italy) and 121 Gg CO_2-eq from Slovenia. In the same year, methane emissions embodied in the milk traded from France to Spain were also relevant (Fig. 2). Although they were less remarkable, we found significant fluxes among Balkan countries. Fluxes from and to North Africa and Middle East were found not significant.

[1] As Mediterranean countries, this study includes: Albania, Algeria, Bosnia H., Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, and Turkey.

Figure 2

Largest interregional fluxes of methane emissions (Gg of CO2eq) embodied in Mediterranean trade of milk between largest net exporting-importing countries in Mediterranean region, in 2012.



Maps show fluxes of emissions greater than 1.5 Gg of CO2eq.

From an environmental perspective, it is advantageous to have milk produced where they have the lowest emission intensities, because the intensity of production represents the GHG emissions released in atmosphere per quantity of milk produced. For example, according to Table 1, export of milk (and relative emissions) from Bosnia to Croatia (Fig. 2) is not advantageous from an emission point of view, as emission intensity of Croatia is lower than emission intensity of Bosnia. It means that domestic production in Croatia releases less emissions per ton of cow milk produced than domestic production in Bosnia. Therefore, in Croatia, consumption of cow milk imported from Bosnia is more emission intensive than consumption of cow milk domestically produced. Oppositely, in Italy, import of cow milk from France is less emission intensive than Italian domestic production (Table 1).

Table 1

Methane emission intensities of milk production (tCO2eq per t milk produced) in Mediterranean countries in 2012

Mediterranean country	Emission intensities
	tCO_2eq/t milk
Albania	1.17
Algeria	0.56
Bosnia H.	1.14
Croatia	0.70
Cyprus	0.37
Egypt	0.66
France	0.60
Greece	1.07
Israel	0.12
Italy	0.67
Lebanon	0.19
Libya	1.24

Malta	0.75
Montenegro	1.21
Morocco	0.82
Slovenia	0.54
Spain	0.54
Syria	0.52
Tunisia	0.75
Turkey	0.73

Figure 3 shows the percentage of methane emissions exported/imported to/from Mediterranean countries and rest of the world. We observe that import of France, Slovenia and Greece is higher from the rest of the world than from the Mediterranean area. In particular, France imported about 98% of emissions from countries not included in the Mediterranean region. Conversely, some Mediterranean countries strictly depend on other Mediterranean countries for their milk imports: Croatia and Spain import 63% and 58% respectively of their milk-embodied emissions, from the Mediterranean region. Regarding exported milk-embodied emissions, Slovenia and Croatia mostly trade with the Mediterranean region (96% and 86% respectively, exported to Mediterranean countries). France and Bosnia Herzegovina also follow this tendency (70% and 54% respectively, exported to Mediterranean countries), while Spain and Italy mostly export emissions to countries not included in Mediterranean area (92% and 65% exported to countries not included in Mediterranean area).

Figure 3
Percentage of methane emissions exported/imported to/from Mediterranean countries (MED) and rest of the world (ROW) for the largest importing/exporting Mediterranean countries in 2012

[1] MED = Mediterranean
[2] ROW = Rest of the World

Conclusion

Our analysis shows that in several countries a substantial percentage of milk-related emissions are traded internationally. Transitions in livestock systems are one of many complex and interlinked adjustments that occur in the global food system and help to achieve reductions in GHG emissions. In facts, trade liberalization may lead to higher livestock production in countries with lower input costs and more permissive environmental regulations, thus decreasing global food costs and incentivizing both global demand (Naylor, 2005) and international trade (Peters et al. 2012). Our analysis of dairy cattle emissions embodied in the Mediterranean trade of milk highlights the regional variation in emissions intensities and quantifies a significant barrier to effective regional and national policies regulating livestock emissions. For example the consumption-based accounting presented here can be used to define GHG-based border taxes (Atkinson et al. 2011). The effects of adopting a consumption-based accounting to estimate GHG emissions depend on how much consumers influence producer with their choices. Assuming a consumer perspective, consumers of milk should take responsibility for choosing the best strategies and policy by showing a preference for producers of milk who are attentive to GHG reductions. Therefore, an importer nation will be encouraged to find producers of milk with lower emission intensities (Table 1) whereas, exporter nations will be encouraged to reduce their emission intensity to meet the higher demand (Caro et al. 2014c).

While our study exclusively focuses on methane emissions released from live dairy cattle (such as CH_4 from enteric fermentation and manure management), other direct emissions of N_2O (such as manure management and manure left on pasture) and indirect CO_2 emissions embedded in the life cycle of meat products (such as animal transport, farm construction, feed production and desertification) occur and are not included in this analysis. Moreover, it should be noted that our analysis did not take into account issues such as animal health and its potential contribution to improving the milk sector. Future advancements should therefore focus on GHG emissions involved in the total production process of milk, including N_2O and CO_2 emissions as well as embodied land and water occurring elsewhere in the supply chain as animal health issues.

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